Eastern Golf Club Development
Tier 2 Pesticide Risk Assessment

Report Prepared for the Eastern Golf Club

By Ecos Environmental Consulting Pty Ltd, Atura Pty Ltd and Storm Consulting Pty Ltd

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Executive Summary

Background

The Eastern Golf Club (EGC) is proposing to relocate from its current location in Doncaster to larger premises at Yering. The new development includes a 27 hole golf course, a 9 hole par three course, a main club house and function centre, a turf farm providing turf sales wholesale to the public, a caretakers dwelling, water storage dams, and an extensive stormwater treatment wetland system.

During establishment and operation of the golf course, it is proposed to apply a range of pesticides to the course in a manner which balances course condition and the environmental sustainability of receiving environments.

Risk assessment

A review of environmental factors and the statutory framework in the Victorian State Environment Protection Policy (Waters of Victoria) identified the main risk associated with pesticide use on the Eastern Golf Club is that pesticide residues may be transported off the course during storm events and affect beneficial uses of the adjacent Yarra River, viz.:

1. *Natural aquatic ecosystems and associated wildlife*; specifically Macquarie Perch which is a protected fish under State and Commonwealth regulations. Fish life history stages such as eggs and larvae are most sensitive to residues of agricultural chemicals and therefore it is important to ensure runoff from the golf course does not contain chemical residue concentrations in excess of tolerable limits for these species.
2. *Potable water supply;* water is pumped from the river to Sugarloaf Reservoir to supply the Winneke Water Treatment Plant which supplies drinking water to Melbourne's northern and eastern suburbs.

Methods

Following on from an earlier first tier risk assessment, this second tier risk assessment focuses in more detail on the proposed pesticide usage at the Eastern Golf Club and makes use of hydrologically-based quantitative fate and transport pesticide models (STORM Pesticide Model) to predict likely concentrations of pesticide residues in stormwater runoff from the golf course.

The report identifies appropriate water quality objectives for the protection of the identified beneficial uses which are the protection of aquatic life in the river and the protection of potable water supply. A comparison is made between predicted environmental concentrations and the target water quality objectives (concentrations) to determine the extent of compliance with the target hazard quotients.

Key Model assumptions

The hydrological model assumes an initial and continuing loss of rainfall including dissolved pesticide residues to the soil. A mass balance calculates pesticide loads and resulting concentrations based on the hydrological model.

The core hydrological equations in the model have been verified with a commercially available hydrological model and are assumed to be reasonably representative of the catchment.

The 15 minute 5 year average recurrence interval rainfall event (5 year ARI) design storm was adopted. It is considered appropriate and conservative to assess pesticide residues in stormwater runoff discharged into the Yarra River. It was assumed that storm events occurred within 24 hours of pesticide application, although in practice, weather forecasts should allow a greater delay before such heavy rainfall events. Note that the effect of dilution in the Yarra River is not included in the modelling.

Pesticide wash-off is consistent with TurfPQ (a model that determines pesticide availability for wash-off). At the EGC, wash-off is influenced greatly by initial losses.

Mixing and dilution in the ponds is accounted for taking into consideration the pond geometry and location of inlets.

Compliance limits

Of the 36 pesticide (active ingredients) proposed for use, only 5 had ANZECC guidelines for the protection of freshwater ecosystems. In the absence of any Australian guidance, guidelines were derived for the remaining 31 pesticides using the Canadian Protocol for the Derivation of Guidelines for the Protection of Aquatic Life. The Australian Drinking Water Guidelines were used as guidance to determine appropriate water quality objectives for the protection of potable supplies. Where pesticides lacked a current Australian drinking water guideline, the World Health Organisation (WHO) Drinking Water Guidelines were used. If there was no WHO guideline, then European Union (EU) Drinking Water Guidelines were used. Since the EU guidelines contain a catch-all requirement of 0.1 µg/L for any pesticide, this was the default drinking water guideline level in the absence of Australian or WHO guidelines.

Results

Modelling indicated that under the proposed usage, no pesticide residues are predicted to occur in the outflows and therefore all pesticides readily comply with the target water quality objectives.

The most significant factors contributing to this result are:

- The water holding capacity (WHC) of the soil and the modelled initial losses
- limited concentrations are applied
- pesticide is applied to small areas only, e.g. greens
- the potential for wash-off is very low (due to chemical attributes or due to organic carbon source or runoff depth of that surface)

Sensitivity analyses showed that the factor of greatest importance in determining the predicted concentrations of pesticide residues that could be influenced by course management is the initial loss of rainfall as it percolates through the soil profile. Rainfall travelling by this mechanism is lost from the portion remaining for surface runoff. For the design rainfall event initial loss was markedly greater than the rainfall event, therefore surface flow and thus pesticide transport was predicted to be zero.

Recommendations

The STORM Pesticide Model developed from this study is a useful tool for assessing compliance with the guidelines (many of which were also developed through this study).

It is recommended that the application rates and locations of any additional pesticides proposed for use by the EGC in the future (i.e. new products available to the market or not tested as part of this assessment) be demonstrated to comply with the guidelines presented in the report using the STORM Pesticide Model.

More explicitly, as long as the predicted Hazard Quotient (HQ) does not exceed 0.5 for the protection of aquatic life for the design storm event, then the pesticide can be considered safe for use at the modelled application rates and locations. Similarly, if the drinking water HQ is predicted to be less than 0.1 for the same event the pesticide is safe for use.

Risk modelling focused on the routine use of pesticides for the management of the Eastern Golf Club. The risk from accidental spillages is not addressed by quantitative risk analysis, since such events are expected to be controlled by the Golf Club Management system. A brief outline of such a system is presented in the report discussion.

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Abbreviations and glossary

ADWG	Australian Drinking Water Guidelines
ANZECC	Australian and New Zealand Environment and Conservation Council
CAS No. or CASRN	Chemical Abstract Service Registry Number
EC_{50}	Half maximal effective concentration - refers to the concentration of a substance which induces a response halfway between the baseline and maximum after some specified exposure time
EGC	Eastern Golf Club
EU	European Union
HQ	Hazard Quotient = measured or predicted environmental value divided by guideline value
LC_{50}	Median lethal concentration. The concentration of a substance required to kill half the members of a tested population after a specified test duration.
p.a.	Per annum
PEC	Predicted Environmental Concentration
Phyto-toxic	Toxic to plants
PNEC	Predicted No-Effect Concentration
Poa	A genus of grasses. Some species are considered weeds.
QSAR	Quantitative Structure Activity Relationships
Salmonid	A member of the salmon and trout family of fishes
SEPP	State Environment Protection Policy
SOP	Standard Operating Procedure
T	Concentration of a toxicant (also known as an environmental quality objective) as specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)
WHO	World Health Organisation
WoV	Waters of Victoria SEPP
WTP	Water Treatment Plant

1 Introduction

The Eastern Golf Club (EGC) is proposing to relocate from its current location in Doncaster to larger premises at ‘Windsor Park’, an established equine centre in Yering. The proposed relocation includes a 27 hole golf course, a 9 hole par three course, a main club house and function centre, a turf farm providing turf sales wholesale to the public, a caretakers dwelling, water storage dams, and an extensive stormwater treatment wetland system (Weller 2010).

Stormwater runoff from the site is to be discharged into the Yarra River through an extensive stormwater treatment system at a similar location to an existing drainage line currently on site. A review of environmental factors and the statutory framework in the Victorian State Environment Protection Policy (Waters of Victoria) identified the aquatic ecosystems and associated aquatic fauna of the Yarra River and potable water supply as the key beneficial uses for the section of the River receiving stormwater runoff from the site. More specifically the presence of high conservation fish species in the river and the Yering Gorge Pumping Station, which pump water from the Yarra River into the Sugarloaf Water Supply Reservoir, indicated the need for a detailed water quality risk assessment.

Ecos *et al.* (2010) previously undertook a first tier screening level risk assessment of the proposed golf course pesticide usage in October 2010 for VCAT. This second tier risk assessment focuses in more detail on the proposed pesticide usage at the Eastern Golf Club and makes use of hydrologically-based quantitative fate and transport pesticide models to predict likely concentrations of pesticide residues in stormwater runoff from the golf course. The report identifies appropriate water quality objectives for the protection of the identified beneficial uses which are the protection of aquatic life in the river and the protection of potable water supply. A comparison is made between predicted environmental concentrations and the target water quality objectives (concentrations) to determine the extent of compliance with the target hazard quotients.

Background to the risk assessment

The Eastern Golf Club after taking specialist advice has prepared a list of pesticides (including insecticides, herbicides and fungicides) for effective long-term management of the site while providing maximum protection for the identified beneficial uses of the adjacent river. This risk assessment considers these pesticides and their modes, frequencies and quantities of usage and provides direction on additional controls where necessary to achieve compliance.

2 Risk assessment

2.1. Site description

The subject land is at 215 – 217 Victoria Road, Yering. The total site area is 240 ha, of which 180 ha will be developed and 60 ha will remain as remnant bushland. The total irrigated area will be approximately 54 ha. The site is bounded by the Yarra River to the west, Victoria Road to the east, Henley Road to the south and pasture land to the north (Figure 2-1).

The surrounding land uses comprise Yering Meadows Golf Course to the north east; Yarra Park Vineyard and Yering Grange Vineyard to the east; private property to the south, south east and north; and private property, the former Maroondah Aqueduct, and a Melbourne Water substation and pumping stations to the west and north west (Figure 2-1, Figure 2-2).

The point of runoff entry from the Eastern Golf Club site to the Yarra River is approximately 1.4 km upstream from the Yering Gorge Pump Station which supplies the Sugarloaf Reservoir (Figure 2-3).

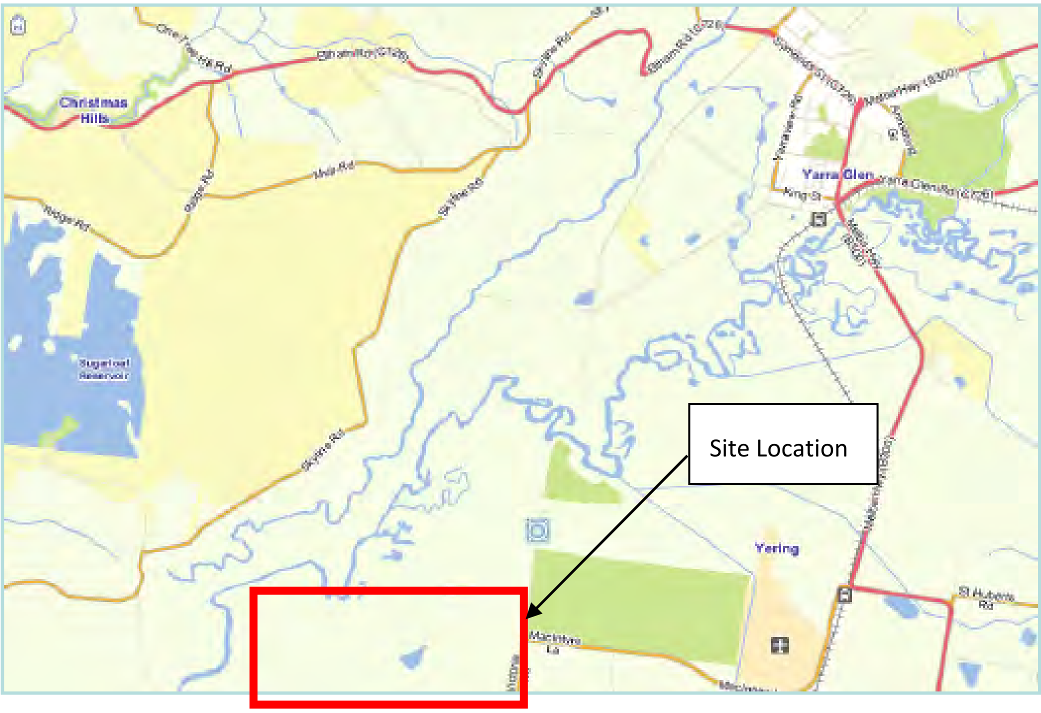

Figure 2-1. Overview of the site location

Figure 2-2. Eastern Golf Club Masterplan

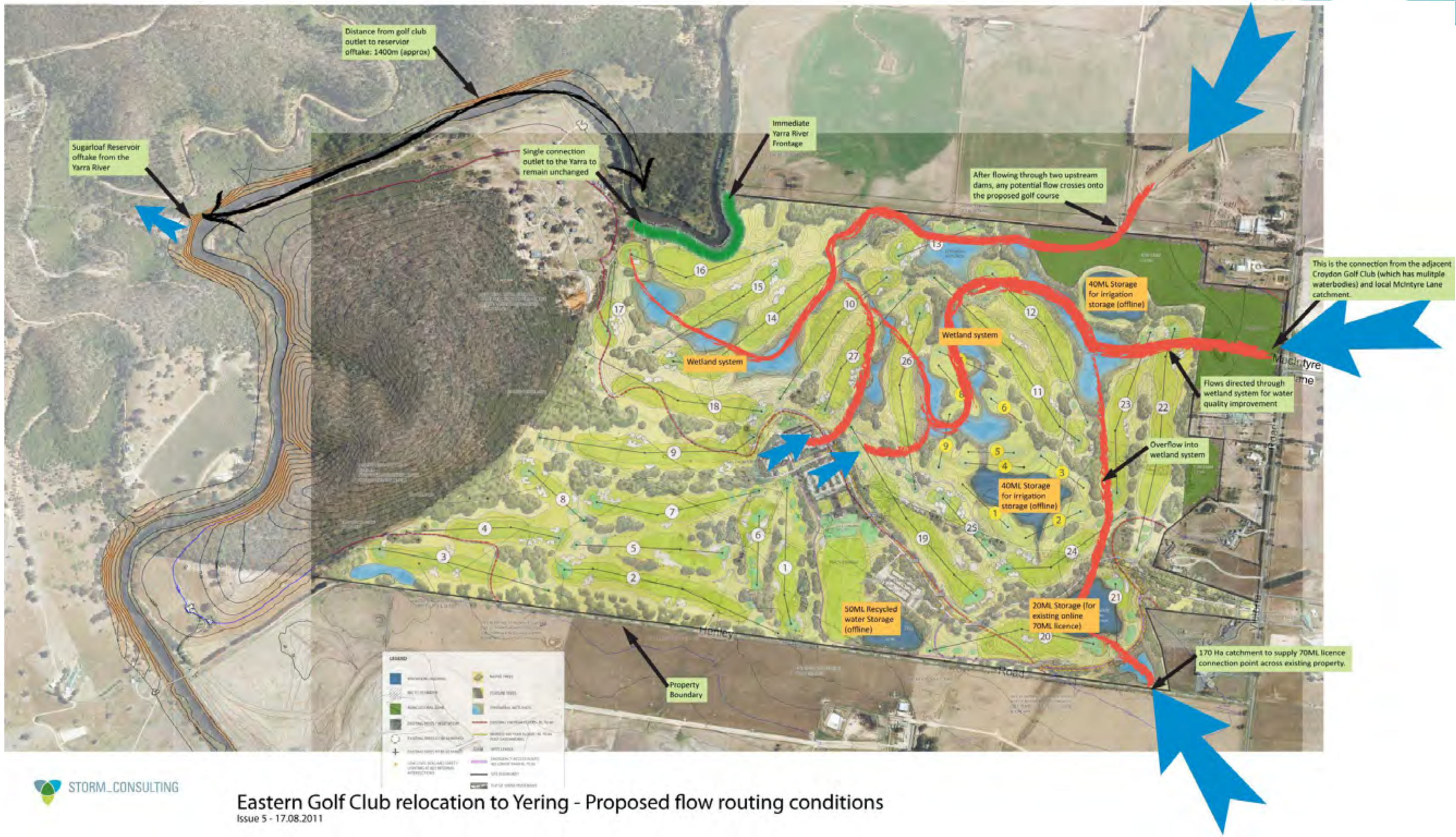

Figure 2-3. Detailed map of development site and relevant components related to assessing risks to drinking water and the environment.

2.2. Risk modelling overview

The main risk associated with pesticide use on the Eastern Golf Club is that pesticide residues may be transported off the course during storm events and affect beneficial uses of the adjacent Yarra River. A review of the statutory framework described in the Victorian State Environment Protection Policy (Waters of Victoria) identified two key beneficial uses:

1. *Natural aquatic ecosystems and associated wildlife*; In particular, the section of Yarra River downstream of the golf course supports populations of the threatened fish species Macquarie Perch, *Macquarie australasica* (Ecology Partners Pty Ltd 2010). Populations of Murray Cod, *Maccullochella peelii* peelii; and Australian Grayling, *Prototroctes maraena* also occur in the Yarra River but are considered to be unlikely to be present in the vicinity of the point of stormwater runoff from the golf course (Ecology Partners Pty Ltd 2010).

   Macquarie Perch is protected under State and Commonwealth regulations. Fish life history stages such as eggs and larvae are most sensitive to residues of agricultural chemicals and therefore it is important to ensure runoff from the golf course does not contain chemical residue concentrations in excess of tolerable limits for these species. Further details on the biology of Macquarie Perch are presented in Weller and Tomlinson (2009a); Ecos *et al.* (2010) and Ecology Partners (2010).

2. *Potable water supply;* water is pumped from the river to Sugarloaf Reservoir to supply the Winneke Water Treatment Plant which supplies drinking water to Melbourne's northern and eastern suburbs.

For the risk modelling, appropriate guidelines were identified or developed using international protocols for the protection of aquatic life and for drinking water supplies and these were compared to predicted environmental concentrations. The predicted environmental concentrations were determined using a pesticide runoff computer model which modelled rainfall runoff hydrology and pesticide fate and transport. Using the model, a number of different rainfall event and pesticide application scenarios could be modelled. Comparisons between predicted environmental concentrations and guideline values were made to determine the level of guideline compliance. The steps involved in guideline determination or development and in the modelling of predicted environmental concentrations are described in detail in the following sections.

2.3. Statutory framework for compliance assessment

2.3.1. State Environment Protection Policy (Waters of Victoria)

The statutory framework in Victoria for the protection of aquatic environments is described in the State Environment Protection Policy (Waters of Victoria)(Government of Victoria 2003) (abbreviated as SEPP(WoV). The SEPP (WoV) applies to all surface waters of Victoria and provides a legal framework for State and local government agencies, businesses and communities to work together to protect and, where necessary, rehabilitate Victoria's surface water environments. The policy protects the environmental values, beneficial uses and associated social and economic values of the water environment to ensure that the needs of current and future generations are met.

The SEPP (WoV) is an instrument of the *Environment Protection Act 1970* (Vic), and is administered by the Environment Protection Authority, which is responsible for ensuring its overall implementation. The policy has been developed with a number of intents (described on pages 8 and 9 of the policy). The two of most relevance to this study are numbers 1 and 2 which state that the policy:

(1) provides the framework to set beneficial uses and environmental values of surface waters that reflect our shared desire for sustainable surface water environments and that provide environmental, social and economic benefits to all communities; and

(2) recognises that, in achieving its purpose, action will need to be taken on a priority driven and progressive basis, taking into account environmental, social and economic considerations.

SEPP WoV Policy area and segments

The area to which the policy applies is all Victorian surface waters and the catchments that supply them. The policy describes a number of segments of the surface water environment including Aquatic Reserves, Wetlands and Lakes, Rivers and Streams and Marine and Estuarine segments. The policy segment of relevance to this study is the Rivers and Streams segment as this covers the waters of the Yarra River that receive runoff from the Eastern Golf Club.

Schedule F7 Waters of the Yarra Catchment

Schedule F7 of the SEPP (WoV) describes a variation that applies to the Waters of the Yarra Catchment. The variation pertains to a T value which is the concentration of a toxicant specified in the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000). The schedule varies the SEPP (WoV) by replacing 0.2T and 0.5T with T in Table 3.4.1 of the ANZECC Guidelines. In addition to replacing the objective, the decision and assessment process outlined in the Principle Policy is triggered if the T value is exceeded.

Where the Australian Water Quality Guidelines for Fresh and Marine Waters has been referenced, the 2000 version needs to be used. The level of ecosystem protection that needs to be used to determine the objective is:

(a) 99% for "largely unmodified", "natural" and "substantially natural" aquatic ecosystems;

(b) 95% for "modified" ecosystems;

(c) 90% for "highly" or "largely modified" aquatic ecosystems.

as defined in Table 3.4.1 of the guidelines and denoted as level of ecosystem protection (% species protected).

Schedule F7 further classifies the Yarra River Catchment into a number of segments. For the purposes of this study, the segment of interest is:

The *Rural Eastern Waterways Segment*, consisting of the surface waters of -

(i). Yarra River and its catchment upstream of the Sugarloaf Reservoir diversion at Yering Gorge, but not including Olinda Creek and its catchment downstream from York Road to Stringybark Creek;

(ii). the northern catchments of the Yarra River from the Sugarloaf Reservoir diversion at Yering Gorge to, and including, Watsons Creek; and

(iii). Diamond Creek and its catchment upstream of the junction of Diamond Creek and Arthurs Creek;

but not including any of the surface waters of the Aquatic Reserves Segment and the Parks and Forests Segment.

This segment incorporates the section of Yarra River upstream of the Sugarloaf Reservoir diversion at Yering Gorge to the point of runoff from the Eastern Golf Club which is 1.4 km upstream.

Table 2-1. Beneficial Uses to be protected in segments as set out in Schedule F7 of the State Environment Protection Policy Waters of Victoria (Government of Victoria 1999).

Beneficial Use	Segment						
	Aquatic Reserves	Parks and Forests	Rural and Eastern Water-ways	Rural Western Water-ways	Urban Water ways	Upper Estuary	Yarra Port
Maintenance of natural aquatic ecosystems and associated wildlife							
Natural ecosystems	✓						
Natural ecosystems with occasional disturbance due to human activity		✓					
Substantially natural ecosystems with some modification			✓				
Modified ecosystems				✓	✓		
Highly modified ecosystems with some habitat values						✓	✓
Passage of indigenous fish	✓[a]	✓	✓	✓	✓	✓	✓
Maintenance of indigenous riparian vegetation	✓	✓	✓	✓	✓	✓	
Water-based recreation							
Primary contact (e.g. swimming, water skiing)	✓[d]	✓	✓	✓	✓[b]	✓[c]	
Secondary contact (e.g. boating, fishing)	✓[d]	✓	✓	✓	✓	✓	✓
Aesthetic enjoyment (e.g. walking by the water)	✓[d]	✓	✓	✓	✓	✓	✓
Commercial and recreational use of edible fish & crustacea	✓[d]	✓	✓	✓	✓	✓	✓
Potable water supply							
Untreated	✓						
With treatment (disinfection only)		✓					
With treatment (disinfection & removal of suspended solids)			✓				
Agricultural water supply							
Stock water		✓	✓	✓	✓		
Irrigation (including watering parks and gardens)		✓	✓	✓	✓	✓	
Other commercial purposes							
Industrial water use			✓	✓	✓	✓	✓
Navigation and Shipping						✓	✓

For the purposes of Table 2-1 above, the letters super-scripted after the allocation of beneficial uses to segments have the following meanings -

"a" means that within the Aquatic Reserves Segment, "Passage of indigenous fish" past the Upper Yarra, Maroondah and Toorourong Reservoirs is not a protected beneficial use;

"b" means that within the Urban Waterways Segment -

(i) until and including 31 December 2002, "primary contact recreation" shall not be a protected beneficial use except in the waters of the Yarra River;

(ii) after 31 December 2002, "primary contact recreation" shall be a protected beneficial use during base flow periods and after a minimum period of five days has elapsed since the occurrence of a rainfall run-off event in those surface waters -

- where primary contact recreation is not prohibited by any law; and

- that are at least one metre in depth during base flow conditions and have at that depth, the shortest surface dimension of at least 6 metres and the longest surface dimension of at least 10 metres;

"c" means that within the Upper Estuary Segment "primary contact recreation" shall not be a protected beneficial use until and including 31 December 2002;

“d” means that within the Aquatic Reserves Segment, “Water based recreation” and “Commercial and recreational use of edible fish and crustacea” are not protected beneficial uses within the water supply areas with restricted public access identified in clauses 6(2)(a)(i) and 6(2)(a)(ii) of the SEPP(WoV).

According to SEPP (WoV) Schedule F7, the guideline value for Toxicants for the Rural Eastern Waterways Segment is < T, where T means:

(i) the national guideline concentration for toxicants in waters specified for the protection of aquatic ecosystems in the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000); or

(ii) other criteria specified by the Authority.

Beneficial Uses to be protected

The beneficial uses protected under Schedule F7 are the same as those applied throughout Victoria by the SEPP (Waters of Victoria), with adjustments to clarify their meaning or improve their appropriateness to catchment needs (Government of Victoria 1999).

Clause 7 lists the protected beneficial uses in each segment. These are set out in Table 1 of Schedule F7. The beneficial uses relevant to this study that are to be protected are:

1. *Maintenance of natural aquatic ecosystems and associated wildlife*, which includes the maintenance of stable and healthy animal and plant communities within the aquatic environment, as well as the terrestrial and arboreal life which depend upon these ecosystems. This beneficial use is divided into five categories which are applied to ecosystems of different types and condition. These categories are outlined in Table 2-2, below.

Table 2-2. Levels of ecosystem protection. Source: Schedule F7 of the State Environment Protection Policy Waters of Victoria (Government of Victoria 1999)

Ecosystem	Description
Natural ecosystems	These are unmodified ecosystems, as found in areas where there is minimal human disturbance, such as closed water supply catchments.
Natural ecosystems with occasional disturbance due to human activities	These are ecosystems typical of forested land where there is some disturbance to the catchment. Disturbances must be temporary and minimised in time and area and the ecosystem should return to one typical of an undisturbed ecosystem within one year. The ecosystems therefore, must retain a high degree of resilience
Substantially natural ecosystems with some modification	While the surrounding catchment is modified, the stream itself should be capable of supporting a substantially natural community. These ecosystems will be expected in rural areas.
Modified ecosystems	These ecosystems occur in substantially modified catchments and are typical of urban areas. The stream ecosystems are highly disturbed, and, though still retaining native species, they are fewer in number and occur in different proportions than in less disturbed ecosystems
Highly modified ecosystems, with some habitat values	These are typical of the Yarra Port and Yarra Tidal Segments of the current Yarra Policy. Little is known of the ecological systems of these areas. However, native wildlife, such as birds, tortoises and fish, are known to be present

Based on the classification in Table 2-1, the section of the Yarra River between the Eastern Golf Club and the Yering Gorge Pump Station is classified as a “Substantially natural ecosystem with some modification”. The corresponding level of ecosystem protection in the ANZECC guidelines that needs to be used to determine the objective is 99%[1]. This is the level applied for “largely unmodified”, “natural” and “substantially natural” aquatic ecosystems - see Clause 6, (2), (a) on page 43 of SEPP (WoV) (Government of Victoria 2003).

2. *Potable water supply*, protecting water for human consumption. As stated earlier, the water is pumped from the river to Sugarloaf Reservoir to supply the Winneke Water Treatment Plant (WTP) which supplies drinking water to Melbourne’s northern and eastern suburbs. The Winneke WTP treatment process involves the filtration and disinfection. Treatment details and required drinking water standards are described in detail in Section 2.5.

Attainment programs

Clauses 12 to 58 of the SEPP (WoV) specify an Attainment Program which is a series of environment management practices and actions that protection agencies, businesses and communities need to implement to improve environmental quality and help protect beneficial uses. In addition to the attainment clauses listed in the SEPP (WoV), Schedule F7 specifies additional clauses (clauses 10 to 27). The principle clause of relevance to this study of pesticide usage at the Eastern Golf Club is *Clause 25: Run-off from non-urban land*. The clause states that:

> Protection agencies and occupiers of premises adjacent to waterways must ensure that non-urban land is managed to protect beneficial uses, and in particular that -
>
> (1) runoff from non-urban land is minimised in accordance with current best practice guidelines; and
>
> (2) best practice guidelines under sub-clause (1) are developed by protection agencies responsible for natural resource management in collaboration with rural land managers, primary industry and community representatives, and are targeted towards achievement of the objectives of this Schedule.

Schedule F7 further states that non-urban land in the Yarra catchment is used for a range of business, recreational and residential purposes including agriculture and horticulture, the grazing of horses and “hobby” farms and that Clause 25 requires that such land be managed according to best practice to minimise contaminated runoff containing nutrients, toxicants and suspended solids, entering waterways.

The Eastern Golf Club has developed an Environmental Improvement Plan for the course that sets out best practices to protect the quality of runoff leaving the golf course (see Storm Consulting 2011).

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[1] The 99% protection level signifies the percentage of species expected to be protected. The 99% protection level has been chosen as the default for ecosystems with high conservation value (ANZECC and ARMCANZ 2000).

2.4. Guidelines for the protection of natural aquatic ecosystems and associated wildlife

2.4.1. Pesticides proposed for use at the Eastern Golf Club

The Eastern Golf Club proposes to use a range of different pesticides including herbicides, insecticides and fungicides to manage pest organisms on the course. The list of pesticides below contains many redundancies to allow the course some flexibility in application rates and timings and product availability (*See Appendix 4 for a guide to general usage of the listed pesticides*). In addition, the same active ingredients are found in a number of commercial products with different formulations targeted at different modes of application or different pests. For the risk assessment, only active ingredients (i.e. the pesticide substances) are discussed since these are the substances for which environmental compliance is required. A total of 36 pesticides are listed of which 5 have ANZECC guidelines (namely 2,4-D, Bromoxynil, Glyphosate, MCPA, and Oryzalin). The remaining 31 pesticides do not currently have ANZECC guidelines.

Table 2-3. Pesticides proposed for use at the Eastern Golf Club and ANZECC guideline where available.

Pesticide	Type	ANZECC Guideline mg/L	CASRN
2,4-D	Herbicide	0.14	000094-75-7
Abamectin	Insecticide	n.g.	071751-41-2
Azoxystrobin	Fungicide	n.g.	131860-33-8
Bensulide	Herbicide	n.g.	000741-58-2
Bromoxynil	Herbicide	0.01	001689-99-2
Chlorantraniliprole	Insecticide	n.g.	500008-45-7
Chlorothalonil	Fungicide	n.g.	001897-45-6
Clopyralid	Herbicide	n.g.	001702-17-6
Dicamba	Herbicide	n.g.	001918-00-9
Dithiopyr	Herbicide	n.g.	097886-45-8
Endothal	Herbicide	n.g.	000145-73-3
Fosetyl-Aluminium	Fungicide	n.g.	039148-24-8
Glyphosate	Herbicide	0.37	001071-83-6
Iodosulfuron-Methyl-Sodium	Herbicide	n.g.	144550-36-7
Iprodione	Fungicide	n.g.	036734-19-7
Mancozeb	Fungicide	n.g.	008018-01-7
MCPA	Herbicide	0.0014	000094-74-6
Mecoprop	Herbicide	n.g.	007085-19-0
Metalaxyl-M	Fungicide	n.g.	070630-17-0
Oryzalin	Herbicide	0.4	019044-88-3
Oxadiazon	Herbicide	n.g.	019666-30-9
Paclobutrazol	Plant Growth Regulator	n.g.	076738-62-0
Pendimethalin	Herbicide	n.g.	040487-42-1
Propamocarb-Hydrochloride	Fungicide	n.g.	025606-41-1
Propiconazole	Fungicide	n.g.	060207-90-1
Propyzamide	Herbicide	n.g.	023950-58-5
Pyraclostrobin	Fungicide	n.g.	175013-18-0
Quinclorac	Herbicide	n.g.	084087-01-4

Pesticide	Type	ANZECC Guideline mg/L	CASRN
Rimsulfuron	Herbicide	n.g.	122931-48-0
Siduron	Herbicide	n.g.	001982-49-6
Tebuconazole	Fungicide	n.g.	107534-96-3
Thiamethoxam	Insecticide	n.g.	153719-23-4
Triadimenol	Fungicide	n.g.	055219-65-3
Trifloxystrobin	Fungicide	n.g.	141517-21-7
Trifloxysulfuron Sodium	Herbicide	n.g.	199119-58-9
Trinexapac-Ethyl	Plant Growth Regulator	n.g.	095266-40-3

Abbreviations: CASRN = Chemical Abstracts Services Registration Number, n.g. = no guideline.

2.4.2. Guideline development for pesticides not listed in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Since most of the pesticides proposed for use by the Eastern Golf Club do not currently have ANZECC guidelines, it was necessary to find other sources of guidance to determine safe concentrations for environmental protection. The ANZECC guidelines do not recommend other guidelines or a method for guideline development apart from suggesting a 1992 OECD approach for determination of Environmental Concern Levels (ECLs) (OECD 1992; 1995). ANZECC defines ECLs as working levels which are not meant as substitutes for water quality guidelines, but, if exceeded suggest the need for further data gathering.

ECLs are calculated from available toxicity data by applying various assessment factors (Table 2-4). The magnitude of the assessment factor or safety factor depends on the nature of available data. Where data is limited, higher assessment factors are applied. Although not stated, it is implicit that the ECL derivation method described in the ANZECC guidelines is focussed on chronic, long-term exposure assessment rather than assessment of short term exposure.

Table 2-4. ANZECC (ANZECC and ARMCANZ 2000) Assessment factors for deriving Environmental Concern Levels (after OECD 1992).

Assessment factor	Description
1000	Applied to the lowest acute LC_{50}, EC_{50} value or QSAR estimate within a dataset on only one or two aquatic species. The authors recommend a factor of 200 to limited chronic data;
100	Applied to the lowest acute LC_{50}, EC_{50} value or QSAR estimate within a dataset comprising, at a minimum, algae, crustaceans and fish; or
10	Applied to the lowest chronic NOEC value or QSAR estimate within a dataset comprising, at a minimum, algae, crustaceans and fish. The authors recommend applying a factor of 20.

2.4.2.1. Short-term versus long-term exposure

For the development of target water quality objectives it was necessary to to consider pesticide transport, however it is noted that modelling (described later in the report) indicates that no transport of pesticides will occur for the design storm event.

If pesticide residues arising from use on the Eastern Golf Club were to enter the Yarra River, the event would be infrequent and flora and fauna in the receiving waters would be exposed to the maximum residue concentration for a very short time (most likely < 1 to 2 hours) due to the short duration of the runoff event and due to rapid dilution in the Yarra River. Runoff from shorter duration and lower intensity rainfall events are largely intercepted by the golf course ponds. Only a small portion of rainfall events in a given year would be of sufficient magnitude to initiate flow to the Yarra River[2]. Furthermore, such events will not always coincide with a recent pesticide application. Consequently, an appropriate guideline would be risk-based and focussed on setting a safe limit for short-term exposure events rather than long-term exposure. While the current ANZECC guidelines do not distinguish between short term and long term exposure, the Canadian Water Quality Guidelines for the Protection of Aquatic Life do make such a distinction and also provide a protocol for the derivation of new guidelines (CCME 2007).

Consequently, the Canadian method for guideline derivation was used to develop short term exposure guidelines for freshwater environments where there were no current ANZECC guidelines (Table 2-5).

[2] For the event scenarios modelled later in the report, it was assumed that the golf course ponds were already full and would overflow with the additional rain. However, the ponds would unlikely to be always full, so this scenario is quite conservative

Table 2-5. Minimum data set requirements for the derivation of a short-term exposure guideline for freshwater environments (source: CCME 2007).

Group	Guideline Type A	 Type B1	 Type B2
Fish	Three species, including at least one salmonid and one non-salmonid.		Two species, including at least one salmonid and one non-salmonid.
Aquatic Invertebrates	Three aquatic or semi-aquatic invertebrates, at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic. It is desirable, but not necessary, that one of the aquatic invertebrate species be either a mayfly, caddisfly, or stonefly.		Two aquatic or semi-aquatic invertebrates, at least one of which must be a planktonic crustacean. For semi-aquatic invertebrates, the life stages tested must be aquatic. It is desirable, but not necessary, that one of the aquatic invertebrate species be either a mayfly, caddisfly, or stonefly.
Plants	Toxicity data for aquatic plants or algae are highly desirable, but not necessary. However, if a toxicity study indicates that a plant or algal species is among the most sensitive species in the data set, then this substance is considered to be phyto-toxic and two studies on nontarget freshwater plant or algal species are required.		
Amphibians	Toxicity data for amphibians are highly desirable, but not necessary. Data must represent fully aquatic stages.		
Preferred Endpoints	Acceptable LC_{50} or equivalent (e.g., EC_{50} for immobility in small invertebrates).		
Data Quality Requirement	Primary and secondary LC_{50} (or equivalents) data are acceptable to meet the minimum data set requirement. Both primary and secondary data will be plotted. A chosen model should sufficiently and adequately describe data and pass the appropriate goodness-of-fit test.	The minimum data requirement must be met with primary LC_{50} (or equivalents) data. The value used to set the guideline must be primary.	The minimum data requirement must be met with primary LC_{50} (or equivalents) data. Secondary data are acceptable. The value used to set the guideline may be secondary.

2.4.2.2. Definition of Short- and Long-Term Exposures

The Canadian Water Quality Guidelines for the Protection of Aquatic Life are set for both short-term and long-term exposures. Short-term exposure guidelines are meant to estimate severe effects and to protect most species against lethality during intermittent and transient events (e.g., spill events to aquatic-receiving environments, infrequent releases of shortlived/ nonpersistent substances.). In contrast, long-term exposure guidelines are meant to protect against all negative effects during indefinite exposures (CCME 2007).

2.4.2.3. Types of Guidelines

The Canadian Protocol for derivation of guidelines to protect aquatic life describes two approaches (Type A and B) for deriving water quality guidelines, depending on the availability and quality of data for the substance. Type A guidelines use a species sensitivity distribution (SSD) approach, making use of all the available and acceptable toxicity data, when there are adequate primary and secondary toxicity data (defined below) to satisfactorily fit a SSD curve. Type B Guidelines are based on the extrapolation from the lowest available and acceptable toxicity endpoint. Each approach requires a defined minimum amount of environmental and toxicological data.

Type B guidelines are derived for substances that either have inadequate or insufficient toxicity data for the Type A guideline, but for which enough toxicity data from a minimum number of primary and/or secondary studies are available. Type B guidelines are divided into Type B1 and Type B2 guidelines, based on the quantity and quality of available toxicity data. At present, there is no protocol for deriving guidelines when the minimum toxicity data requirement for a Type B guideline is not met (CCME 2007).

2.4.2.4. Method used for this study

For the present study, due to the large amount of work required to develop Type A guidelines where data is sufficient and the lack of data for many of the other pesticides, the Type B2 approach was used. The B2 approach is a modified version of the method traditionally used to derive Canadian Water Quality Guidelines for the Protection of Aquatic Life and other jurisdictions (CCME 2007). It is a generic method of wide applicability that can be used when data are inadequate to derive a Type A or Type B1 guidelines. In general, derivation of guidelines using the Type A or Type B1 approaches would be expected to yield slightly higher guideline concentrations (i.e. less conservative) since studies with lower reported effects levels that do not meet the more stringent requirements for Type A or Type B1 guidelines may not be included.

2.4.2.5. Canadian Type B2 Short-Term Exposure Guideline

The accepted endpoints for the development of Type B2 short-term exposure guidelines are LC_{50} or equivalent (i.e., EC_{50} for immobility) of a short-term exposure standard test (e.g., published by EC, OECD, USEPA, or ASTM), or another test otherwise deemed acceptable, where the LC_{50}/EC_{50} value has been derived by regression analysis of the toxicological data. The lowest scientifically defensible acceptable effects concentration from a short-term exposure study is the critical study for the derivation of the guideline. The endpoint concentration from the critical study is divided by a safety factor of 10 to derive the short-term exposure guideline value (CCME 2007). A 10-fold safety factor is considered appropriate since the exposure-response curve is typically sigmoidal meaning that toxicity declines exponentially as the concentration decreases from the median value.

2.4.2.6. Definition of primary and secondary data

Detailed definitions of primary and secondary data are presented in the Canadian Guidelines with the principal distinction being the level of detail reported and adherence to the highest standards of scientific technique and clarity of test results.

Secondary data are those that originate from studies where primary data cannot be generated, but are still of acceptable quality and level of documentation.

2.4.2.7. Ecotoxicological data sources used in the current study

As noted above, for this study, a detailed assessment of all published ecological toxicity data on each pesticide was not possible. However, the data used for guideline derivation has been obtained from three high quality databases:

1. The US EPA ECOTOX database (U.S. Environmental Protection Agency 2007). The U.S. EPA ECOTOXicology database (ECOTOX) is a source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife. ECOTOX was created and is maintained by the U.S.EPA, US Office of Research and Development (ORD), and the US National Health and Environmental Effects Research Laboratory's (NHEERL's) Mid-Continent Ecology Division (MED). The majority of literature reviewed for ECOTOX is from 1972 to the present. As data are entered and quality assured, the database system is updated; usually on a quarterly basis. The protocol for vetting toxicological data for inclusion on the database is listed in Appendix 1.
2. The University of Hertfordshire (UK) Pesticide Properties Database (PPDB) (PPDB 2009) is a comprehensive relational database of pesticide physicochemical, toxicological, ecotoxicological and other related data. The database has been developed by the Agriculture & Environment Research Unit (AERU) of the University of Hertfordshire with funding from the European Union.
3. The European Union Pesticides database (European Union 2011). This database has been prepared by the European Union to assist in determining regulatory compliance requirements for protection of the environment and food safety in relation to agricultural products. Detailed assessment reports for certain pesticides are included in the database. These are generally prepared by the European Union Standing Committee on the Food Chain and Animal Health.

Where possible, LC_{50} data was obtained from the above databases, or in the absence of LC_{50} data, EC_{50} data was used. For each pesticide that did not have an ANZECC guideline, the lowest LC_{50} or EC_{50} value was divided by a safety factor of 10 to determine the guideline value. Separate guidelines were derived for fish, invertebrates, amphibians and aquatic plants following the Canadian B2 guideline derivation approach (Table 2-5). The overall environmental guideline consisted of the most sensitive aquatic organism among fish, invertebrates, amphibians and aquatic plants.

2.4.2.8. Calculation of hazard quotients for protection of aquatic organisms

For effects on each major class of aquatic organism (i.e. fish, invertebrate, amphibian or aquatic plant), Predicted Environmental Concentrations (PECs) of each pesticide were calculated based on the modelled concentration of applied pesticides in stormwater (described in Section 2.7.4). Where possible PECs were compared to ANZECC Guideline values (where these existed) or in the case of no guideline being available, to a Predicted No-Effect Concentration (PNEC). The comparison involved the computation of a Hazard Quotient (HQ) using either the ANZECC guideline or the PNEC

The HQ was calculated as:

$$HQ = \frac{\text{PEC (mg/L)}}{\text{Guideline (GL)}}$$

or

$$HQ = \frac{\text{PEC (mg/L)}}{\text{PNEC (mg/L)}}$$

Where: HQ = hazard quotient; PEC = Predicted environmental concentration; PNEC = predicted no effect concentrations.

When PNEC is used in the hazard quotient computation, the quotient is sometimes then referred to as a risk quotient. However to avoid confusion, the term hazard quotient is used in this report in either case.

PNEC values were calculated from available ecotoxicological data using the Canadian Protocol for derivation of guidelines to protect aquatic life, consistent with approach B2 described above.

If HQ is < 1, then the risks are deemed acceptable, particularly since conservative assumptions have been used in the calculation of the HQ.

If HQ is > 1, then controls (e.g. reduced application rates, etc.) will be required to reduce the PEC so that the HQ is < 1 or alternative pesticides used which can achieve of a HQ of < 1.

An advantage of calculating the HQ is that it provides a measure of how much a compliant pesticide would need to increase in concentration to become non-compliant, or how much a non-compliant pesticide would need to decrease to become compliant. For example a HQ of 0.1 means that a pesticide PEC would need to increase 10-fold to become non-compliant. For such a pesticide, there is an additional safety factor of 10. Likewise, a non-compliant pesticide with a PEC of 15 would need to be reduced by a factor of 15 to become compliant.

Note that the above descriptions deal with a standard application of the HQ assessment approach where the guideline compliance target HQ = 1. Section 2.4 describes a reduction in target HQs used in this study to account for the existence of possible background concentrations of pesticide residues in the Yarra River and other factors.

2.4.3. Calculated short term exposure guidelines

In accordance with the Canadian B2 Guideline derivation protocol, separate guidelines were calculated for fish, invertebrates and aquatic plants. In some cases, the reference databases only contained the results for a single toxicity tests. The Ecotox database included a range of values when the substance was included and more than one test result was available. The PPDB database selectively included the result of sensitive species and did not report on the details of other tests. The PPDB states: "*Thresholds used have been selected to be consistent with industry guidelines, were developed, and are consistent with regulatory thresholds used in both the UK and EU*". The EU Pesticides database includes detailed assessment reports for certain pesticides from the European Union Standing Committee on the Food Chain and Animal Health. In some cases these reports contain detailed reviews of toxicological studies. Where this was the case, the lowest LC_{50} or EC_{50} result was used for the Guideline calculation in this report.

Where the number of toxicity studies used to determine the lowest acute toxicity value is:

- less than 2, or
- at least one of the fish species was not a salmonid, or
- one of the invertebrate species was not a planktonic crustacean,

then the guideline derivation method was not strictly compliant with the Canadian B2 guideline derivation protocol. However, in each instance where this was the case, there was a general lack of published ecotoxicological data and the data source was the PPDB database where the data used was selected to be consistent with industry guidelines and regulatory thresholds used in both the UK and EU. The calculated guidelines for fish, amphibians, aquatic invertebrates and aquatic plants are presented in Appendix 2. The overall environmental guidelines for all aquatic life are presented in Table 2-6. Typically, pesticides with little available toxicity data appeared less toxic or less likely to move off site than those have been studied more intensively. This is probably due to a research focus in the international literature on pesticides with possible environmental issues.

2.4.3.1. Macquarie Perch

As noted in Section 2.2 the threatened fish species Macquarie Perch, *Macquarie australasica*, is protected under State and Commonwealth regulations and requires special consideration. The guidelines developed here are derived from international toxicological databases that include Australian ecotoxicology data where this is published. While there are few Australian species with available toxicological data the modes of toxicity are usually universal and Australian species are expected to respond to pesticide residues in a similar fashion to species from the rest of the world. In relation to fish species, the Canadian Guideline Derivation Protocol specifically requires at least one set of ecotoxicological data to have been based on a member of the salmonid family (i.e. trout and salmon). The natural habitat of the immature stages of this family is usually high mountain streams with very high quality water. Consequently, salmonid egg, larvae and juvenile stages are particularly sensitive to toxicants and expected to be at least as sensitive as those of Macquarie Perch which has similar habitat requirements for its immature stages as those of trout.

Table 2-6. Short-term exposure guidelines for the protection of freshwater organisms for pesticides proposed for use at the Eastern Golf Club. Guidelines have been derived using the Canadian Protocol for Guideline Derivation. ANZECC guidelines are included for reference where available (note these are based on long-term exposure).

Pesticide	Type	Environmental Guideline (mg/L)	Most sensitive Organism (if not based on ANZECC)	Guideline Source	Fully compliant with Canadian environmental guideline derivation protocol B2?
2,4-D	Herbicide	0.14	ANZECC	ANZECC	n/a
Abamectin	Insecticide	0.000012	Invertebrates	PPDB	No
Azoxystrobin	Fungicide	0.0049	Aquatic Plants	Ecotox	Yes
Bensulide	Herbicide	0.0051	Invertebrates	PPDB	Yes
Bromoxynil	Herbicide	0.01	ANZECC	ANZECC	n/a
Chlorantraniliprole	Insecticide	0.00116	Invertebrates	PPDB	No
Chlorothalonil	Fungicide	0.00036	Invertebrates	Ecotox	Yes
Clopyralid	Herbicide	3.05	Aquatic Plants	PPDB	No
Dicamba	Herbicide	0.0061	Aquatic Plants	Ecotox	Yes
Dithiopyr	Herbicide	0.002	Aquatic Plants	Ecotox	No
Endothal	Herbicide	0.005	Invertebrates	Ecotox	Yes
Fosetyl-Aluminium	Fungicide	0.499	Aquatic Plants	Ecotox	Yes
Glyphosate	Herbicide	0.37	ANZECC	ANZECC	n/a
Iodosulfuron-Methyl-Sodium	Herbicide	0.000083	Aquatic Plants	PPDB	No
Iprodione	Fungicide	0.013	Aquatic Plants	Ecotox	Yes
Mancozeb	Fungicide	0.0023	Amphibians	Ecotox	Yes
MCPA	Herbicide	0.0014	ANZECC	ANZECC	n/a
Mecoprop	Herbicide	0.5147	Aquatic Plants	Ecotox	Yes
Metalaxyl-M	Fungicide	0.031	Fish	Ecotox	Yes
Oryzalin	Herbicide	0.4	ANZECC	ANZECC	n/a
Oxadiazon	Herbicide	0.00078	Aquatic Plants	Ecotox	Yes
Paclobutrazol	Plant Growth Regulator	0.273234	Aquatic Plants	PPDB	Yes
Pendimethalin	Herbicide	0.00054	Aquatic Plants	Ecotox	Yes
Propamocarb-Hydrochloride	Fungicide	9.9	Fish	PPDB	No
Propiconazole	Fungicide	0.00008	Aquatic Plants	Ecotox	Yes
Propyzamide	Herbicide	0.0287	Aquatic Plants	Ecotox	Yes
Pyraclostrobin	Fungicide	0.0006	Fish	PPDB	Yes
Quinclorac	Herbicide	0.05	Aquatic Plants	Ecotox	Yes
Rimsulfuron	Herbicide	0.00116	Aquatic Plants	PPDB	Yes
Siduron	Herbicide	0.013	Fish	Ecotox	Yes
Tebuconazole	Fungicide	0.01515	Aquatic Plants	PPDB	Yes
Thiamethoxam	Insecticide	0.0967	Invertebrates	Ecotox	No
Triadimenol	Fungicide	0.25	Invertebrates	Ecotox	No
Trifloxystrobin	Fungicide	0.0011	Invertebrates	PPDB	Yes
Trifloxysulfuron Sodium	Herbicide	0.000055	Aquatic Plants	PPDB	No
Trinexapac-Ethyl	Plant Growth Regulator	0.019	Aquatic Plants	Ecotox	Yes

2.5. Drinking water guidelines

For assessment of risks to drinking water supplies, a hierarchy of guidelines was used since the Australian Drinking Water Guidelines (ADWG) (NHMRC and NRMMC 2011) only contain guidance on a small number of pesticides. The guideline hierarchy used was:

1. ADWG 2011 guidelines
2. WHO (World Health Organisation (WHO 2004)) with updates
3. EU (European Union 1998) Directive on the quality of water intended for human consumption.

The EU guidelines have a default value[3] for pesticides of 0.1 µg/L and thus provide a guideline value for all pesticides that are not listed in the ADWG or WHO guidelines. Drinking water guidelines for all pesticides are shown in Table 2-7.

Table 2-7. Drinking Water Guidelines and their source used in this risk assessment

Pesticide	Type	Human health Drinking Water Guideline mg/L	DW Guideline Source
2,4-D	Herbicide	0.03	ADWG 2011
Abamectin	Insecticide	0.0001	EU 1998
Azoxystrobin	Fungicide	0.0001	EU 1998
Bensulide	Herbicide	0.0001	EU 1998
Bromoxynil	Herbicide	0.01	ADWG 2011
Chlorantraniliprole	Insecticide	6	ADWG 2011
Chlorothalonil	Fungicide	0.05	ADWG 2011
Clopyralid	Herbicide	1.8	ADWG 2011
Dicamba	Herbicide	0.1	ADWG 2011
Dithiopyr	Herbicide	0.0001	EU 1998
Endothal	Herbicide	0.13	ADWG 2011
Fosetyl-Aluminium	Fungicide	0.0001	EU 1998
Glyphosate	Herbicide	1	ADWG 2011
Iodosulfuron-Methyl-Sodium	Herbicide	0.0001	EU 1998
Iprodione	Fungicide	0.1	ADWG 2011
Mancozeb	Fungicide	0.009	ADWG 2011
MCPA	Herbicide	0.04	ADWG 2011
Mecoprop	Herbicide	0.01	WHO 2006
Metalaxyl-M	Fungicide	0.0001	EU 1998
Oryzalin	Herbicide	0.4	ADWG 2011
Oxadiazon	Herbicide	0.0001	EU 1998
Paclobutrazol	Plant Growth Regulator	0.0001	EU 1998
Pendimethalin	Herbicide	0.4	ADWG 2011
Propamocarb-Hydrochloride	Fungicide	0.0001	EU 1998
Propiconazole	Fungicide	0.1	ADWG 2011
Propyzamide	Herbicide	0.03	ADWG 2011
Pyraclostrobin	Fungicide	0.0001	EU 1998
Quinclorac	Herbicide	0.0001	EU 1998
Rimsulfuron	Herbicide	0.0001	EU 1998
Siduron	Herbicide	0.0001	EU 1998
Tebuconazole	Fungicide	0.0001	EU 1998
Thiamethoxam	Insecticide	0.0001	EU 1998
Triadimenol	Fungicide	0.0001	EU 1998
Trifloxystrobin	Fungicide	0.0001	EU 1998
Trifloxysulfuron Sodium	Herbicide	0.0001	EU 1998
Trinexapac-Ethyl	Plant Growth Regulator	0.0001	EU 1998

[3] Certain organochlorine pesticides listed in the EU guidelines have a lower guideline value, however none of these are among the list of pesticides proposed for use at the Eastern Golf Club.

Total pesticide concentrations

An additional requirement for the EU Drinking Water Guidelines is that total pesticides should be less than 0.5 µg/L. This is difficult to model accurately, but a review of PECs and commercial products suggests that only the broad application mixture herbicides need to be considered here. The commercial formulation: Methar Tri-Kombi contains 2,4-D, Dicamba and Mecoprop and was considered the highest risk in this regard. However since modelling described later in this report indicated that combined PEC's for this product was still less than 0.00 ug/L (see Section 2.7.9) the issue of pesticide combinations is not discussed further[4].

2.6. Hazard Quotient Revisions

As a guide to the initial modelling effort and to ensure that such modelling was conservative, it was necessary to make revisions to the target water quality objectives to account for:

(i). possible existence of pesticides residues in the Yarra River arising from other sources;

(ii). the use of some pesticides that have relatively low toxicity to human health so that the setting of target water quality objectives for the protection of potable supply on the basis of HQ alone could lead to analytical detections even though such detections would be at safe levels.

To account for point (i) the target HQ for the protection of environmental and potable supply beneficial uses was reduced from 1.0 to an HQ of 0.5.

To account for point (ii) the target HQ for the protection of potable supply (only) was reduced from a HQ_{DW} of 0.5 (see section 2.6 above) to a HQ_{DW} of 0.1. This gave a 5-fold relative Margin of Safety (as measured by the inverse of HQ_{DW} (i.e. 1/ HQ_{DW}).

Subsequent modelling results described later in this report indicated that the concentration of pesticides in the water discharged to the Yarra River under the design storm event would not contain detectable concentrations of pesticides. Considering these findings revisions to the HQ targets are less important, however, they have been retained in the report to provide a basis for assessment of the modelling results.

[4] The Australian Drinking Water Guidelines (2011) point out (page 6-10) that the large margin of safety incorporated in the majority of the guideline values is considered to be sufficient to account for potential interactions with other substances.

2.7. Hydrological modelling – solute transport

2.7.1. General description of hydrological modelling

The STORM Pesticide model is an MS Excel based program that integrates hydrology with pesticide mass balance in a continuous simulation at 6 minute increments. It has been created for the purpose of assessing the potential pesticide concentrations in runoff from the proposed Eastern Golf Club.

The model combines hydrologic catchment characteristics and surface areas with significant discrete rainfall events to generate runoff flows that are based on standard industry algorithms to estimate runoff flow rates and volumes. The storage ponds are also embedded in the model that defines the mixing characteristics for dilution, the ponds' connections with catchments and also upstream ponds sequence of drainage (Figure 2-4). The hydrology engine[5] drives the mass balance of pollutants that are washed off the catchment according to the pesticide application (rate and area). Degradation characteristics produce final pond concentrations and outflow concentrations for various pesticides.

The STORM Pesticide model is flexible allowing different application zones and catchment combinations to be explored. Each model variable is described in further detail through this chapter in the report.

2.7.2. Hydrology Engine

2.7.2.1. Rainfall data

The 1, 5 and 10 year ARI rainfall events were theoretically derived from Bureau of Meteorology (BoM) data for this site and converted to 6 minute increments for the purposes of validating the hydrology engine. This is further described 2.7.2.4 Validation.

2.7.2.2. Catchment Nodes

The golf course and contributing external local catchments were split into a total of 24 sub-catchments (Figure 2-5). Identification of catchments was conducted from design surface data provided by Greg Norman Golf Course Design (GNGDC). Attempts were made to keep entire fairways in each catchment, however, this was not possible in every case. The sub-catchment definitions were checked by WBCM Consultants for validity.

Within each catchment, the contributing areas of the following various potential surfaces were determined:

i. Greens
ii. Tees
iii. Fairways
iv. Rough
v. Turf farm

[5] *i.e.* the hydrology engine means to the hydrological equations at the core of the model

vi. Impervious; and
vii. Pervious

Initial loss and continuing loss

Associated with each of these surfaces is an initial and continuing loss which is commonly used in hydrology models. These variables enable estimation of runoff from each surface within the catchments. The loss which occurs at the beginning of the storm before run-off is generated is known as the initial loss. The continuing loss represents the average loss over the remaining storm duration.

The initial and continuing losses of these surfaces are assumed constant across all catchments. However, the combination of contributing surfaces, catchment shape and size ultimately influences the catchment's hydrologic response. The hydrological characteristics of each surface type are summarised in Table 2-8. The breakdown of these surfaces within the catchments is illustrated in Table 2-9.

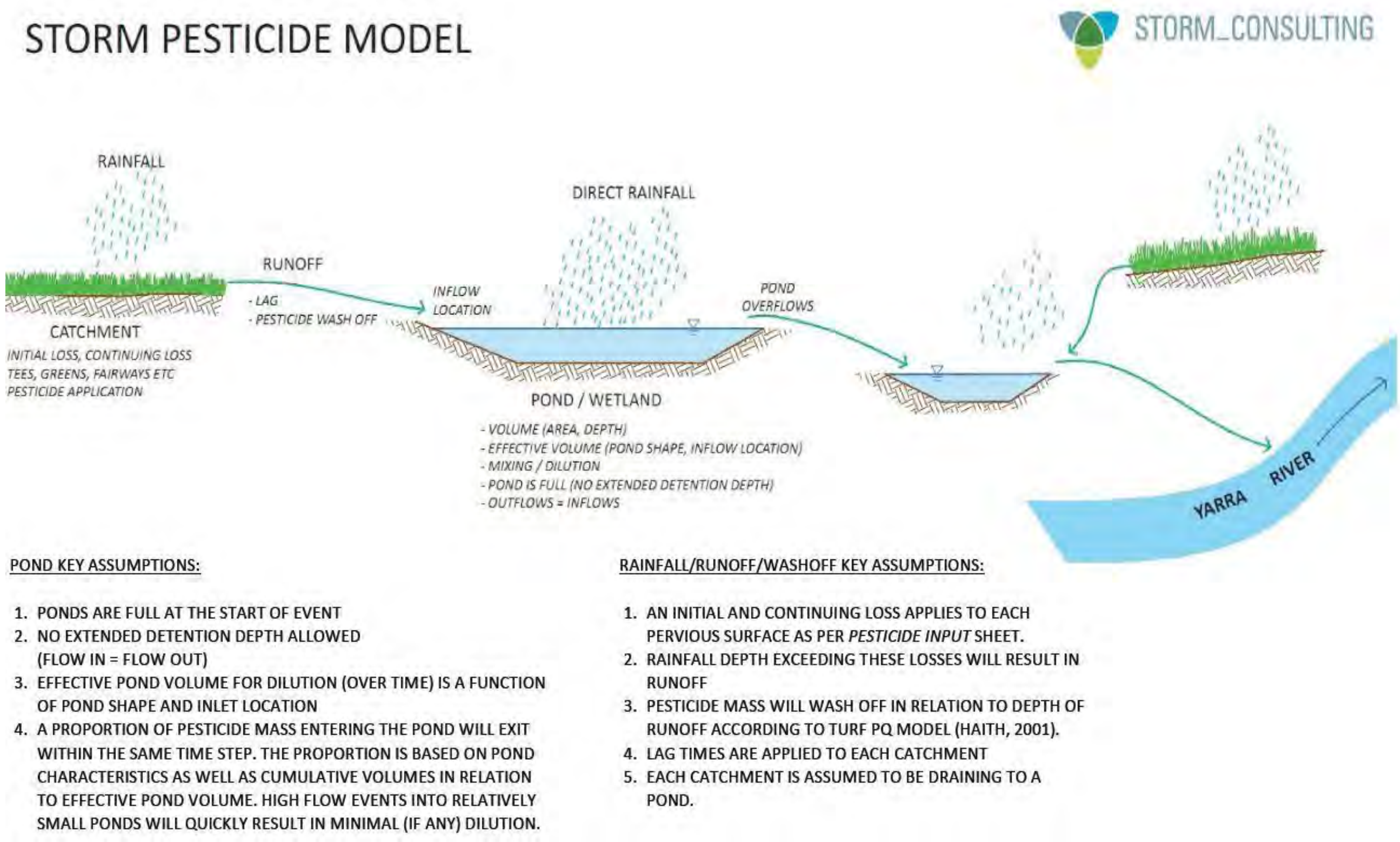

Figure 2-4. STORM Pesticide model schematic

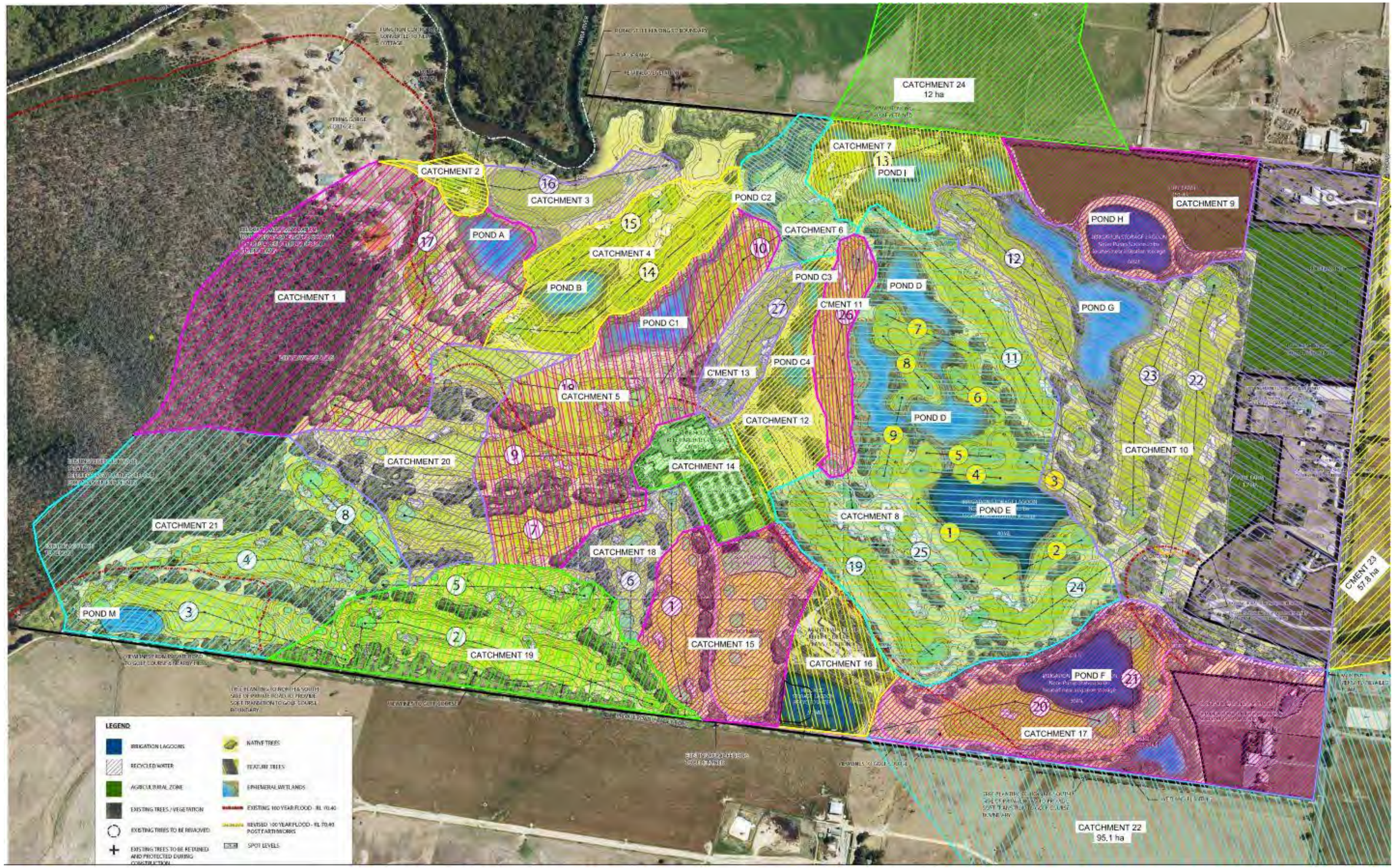

Figure 2-5. Golf course sub-catchments

Table 2-8. Hydrologic characteristics adopted for various surfaces

Surface Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Tees	25	4
Fairways	25	4
Greens	35	0
Rough	17	4
Turf Farm	25	6
Impervious	1	0
Pervious	17	6

Table 2-9. Catchment surface breakdown

Catchment	Total Area (m^2)	Drains to Pond	Tee (m^2)	Fairway (m^2)	Green (m^2)	Rough (m^2)	Turf Farm (m^2)	Impervious (m^2)	Pervious (m^2)
1	185258	A	2185	2884	778	1363	0	5600	172448.5
2	8842	A	0	1690	681	0	0		6471.6
3	28060	A	468	10142	0	4990	0		12459.5
4	56672	B	180	27541	1275	22881	0		4795
5	120806	C1	1379	34902	2531	14484	0		67509.08
6	26954	C2	1371	2225	587	1576	0		21194.8
7	31233	I	1396	1852	526	1412	0		26047.5
8	219975	D	2625	62561	3681	22460	0	17598	111050.6
9	46200	H	0	0	0	316	40000		5884.7
10	350687	G	2525	54030	8350	10899	60000	11128	203755.2
11	23563	D	237	708	820	4917	0		16880.2
12	30304	C4	800	0	0	0	0	1515	27988.8
13	23568	C1	0	10451	529	3588	0		9000.3
14	30246	D	0	0	0	0	0	24197	6049.2
15	74850	D	3901	27844	1848	11977	0		29280.1
16	12880	D	0	0	0	0	0	9016	3864
17	136497	F	1690	15531	1981	4952	0	5539	106803.7
18	28348	C4	1437	2823	1140	4130	0		18818.5
19	103228	M	1056	26299	1383	27851	0		46639.9
20	71356	B	694	17013	615	7669	0	8028	37337.3
21	175073	M	2097	15926	2285	23859	0		130906.1
22	951000	F	0	0	0	0	0	47550	903450
23	578400	G	0	0	0	0	0	28920	549480
24	120000	I	0	0	0	0	0	6000	114000

The time of travel and time of concentration incorporates the spatial characteristics of the catchment using fundamental hydrological principles. This is a common concept in hydrology which influences the catchment response and outflow hydrograph for given rainfall events.

The receiving pond was defined for each catchment, providing the hydraulic relationship between catchment and pond nodes. The catchment inlet effectiveness (entered as a percentage) enabled an ordinal description of the pond inlet location with respect to the outlet. An effectiveness of 0% corresponds to a catchment inlet located at the point of the outlet. A value of 100% means that the inlet is at the very opposite end of the pond creating the longest possible flowpath. Similarly a value of 50% translates to an inlet location half-way along the longest flowpath.

2.7.2.3. Pond Nodes

There are a number of ponds proposed for the Eastern Golf Club development. These ponds will provide mixing and dilution opportunity for pesticides in inflows. Small events will be significantly diluted depending on the physical characteristics of the pond including:

i. Volume
ii. Aspect ratio (the ratio of pond length to width)
iii. Location of catchment inlets

These characteristics determined the volume of pond that was discounted as ineffective volume. The remaining effective volume was used in the calculations of mass pesticide balance. Mixing patterns were also considered to incorporate the relationship between inflow and outflow concentrations. It is assumed that a proportion of pollutants entering the pond will exit the pond in the same time interval. This relationship is based on the cumulative inflows in relation to the effective pond volume. For a relatively small inflow into larger ponds, the outflow concentration is expected to be relatively low due to dilution. However, large inflows into a relatively small pond would have little dilution.

The ponds are conservatively assumed to be 100% full prior to a rainfall event. It is also assumed that there is no flow routing through the ponds i.e. the ouflows for each time interval equal the inflows.

Another key assumption is that the pesticides remain in solution for the duration of the rainfall event and that no reduction of pesticide mass occurs by photolysis, adsorption or any other process.

From information provided by Greg Norman Golf Course Design, the physical attributes of each pond were derived. Pond area at normal water level (NWL), average depth, maximum depth and volume at NWL were estimated. Pond shape and inlet locations were combined to provide a parameter for effective pond volume. In order to represent pond shape, a percentage value was assigned for a pond aspect parameter. Short and wide ponds would be reflected by a low aspect ratio. The inlet location was derived from the values assigned for each contributing catchment. For ponds with only one contributing catchment, the inlet effectiveness was equal to that of the catchment. However, where multiple catchments drained to the one pond, an area-weighted inlet effectiveness value was calculated. The product of the aspect and inlet location provided the total effective pond volume (expressed as a percentage). These characteristics are summarised in Table 2-10.

The STORM Pesticide Model enabled incorporation of drainage links by appointing contributing catchments as well as contributing ponds immediately upstream of each pond. The drainage links assumed in the modelling are described in Table 2-14.

Table 2-10. Pond characteristics

POND	Surface Area at NWL (m^2)	Average Depth (m)	Maximum Depth (m)	Volume at NWL (m^3)	Aspect (%)	Inlet Location (%)	Effective Pond Volume (%)	Drains to
A	8,897	0.8	1	7,118	70	78	54	Yarra River
B	5,476	0.8	1	4,381	90	93	84	A
C1	9,479	0.8	1	7,583	80	80	64	B
C2	890	0.6	1	534	60	80	48	C1
C3	1,580	1	1.2	1,580	90	60	54	C2
C4	2,837	1	1.2	2837	90	66	60	C3
D	23,538	0.8	1	18,830	80	69	59	C4
F	17,373	1.8	3	31,271	60	94	56	G
G	22,899	0.9	1.2	20,609	90	75	68	D
I	14,225	0.7	1.2	9,958	90	60	54	C2
M	4,322	1	1.4	4,322	90	95	86	-

2.7.2.4. Validation

To validate the hydrology engine, an XP-RAFTS hydrologic model and a MUSIC v5.16 model were built using the same catchment and rainfall data. The peak flow and volume outputs were then compared to those generated in the STORM Pesticide model. The results (Table 2-11 and 2-12) highlight a strong correlation with the STORM Pesticide model.

Table 2-11. Peak flow comparison of STORM Pesticide with XP-RAFTS 15 minute storm.

Storm ARI	XP-RAFTS peak flow (m^3/s)	STORM Pesticide peak flow (m^3/s)	Rational Method (m^3/s) (Peak for rural catchments)
1 year	1.81	1.40	1.17 (2 yr ARI)
5 year	3.94	2.57	1.85
10 year	4.83	3.03	2.37

Note that it is recommended that MUSIC v5.16 and earlier should not be used for peak flow analysis and has therefore been excluded. The peak flows for the STORM Pesticide model are lower than those reported by XP-Rafts. The output time step for XP-Rafts is 1 min whereas the output time step for the STORM Pesticide model is 6 min. Therefore the reported peak in XP-Rafts is expected to be higher as there is less averaging occurring. The peak flows for the Rational Method are also reported for reference however this is more appropriate for rural catchments. Therefore we are satisfied that the STORM Pesticide Model is reasonably consistent.

A further check of validity, and probably more critical, is the flow volume. A comparison is detailed below (Table 2-12).

Table 2-12. Event volume comparison of STORM Pesticide with XP-RAFTS and MUSIC v5.16

Storm ARI	Duration	XP-RAFTS (m^3)	MUSIC v5.16 (m^3)	STORM Pesticide (m^3)
1 year	15 minute	1820	1150	1983
5 year		3480	1730	3685
10 year		4110	1950	4358
1 year	30 minute	2650	1450	2852
5 year		6860	2230	8675
10 year		13280	3710	16282
1 year	60 minute	3760	1800	3853
5 year		16880	7090	18164
10 year		26340	11600	30320

The flow volumes are reasonably consistent with the STORM Pesticide model yielding a higher runoff. The STORM Pesticide model is considered valid as it is reasonably consistent with proprietary models for peak flow and volume, particularly with XP-RAFTS.

2.7.3. Pesticide Mass Balance

2.7.3.1. Pesticide list

A list of assessed pesticides belonging to the following pesticide groups is provided in Table 2-13:

i. Herbicides
ii. Fungicides
iii. Insecticides; and
iv. Growth inhibitors

Application rates, timings and surfaces, as well as degradation characteristics were provided by EGC, specific to each pesticide. These attributes are discussed further below.

2.7.3.2. Application surfaces

Pesticides are applied to the following surfaces:

i. Greens
ii. Tees
iii. Fairways
iv. Rough
v. Turf farm

The management purpose will dictate which surface each pesticide will be applied to. Certain pesticides will be applied only to new golf course elements upon installation. Others are a preventative measure, used as part of the regular maintenance regime, applied once a month or year, or during a particular season. Many pesticides are applied to only one surface. The STORM Pesticide model allows for multiple application sites to be considered and modelled. Furthermore, this allows both spatial and temporal restrictions to be placed on application as a method of managing risks associated with pesticide concentrations in runoff.

2.7.3.3. Pesticide Application

The application rates have been provided by EGC and reflect the label specifications. However, due to an improved application technique, some pesticides are expected to be applied below stipulated label rates and in some cases at a lower frequency. The pesticides assessed are listed in Table 2-13.

Table 2-13. Pesticides, proposed application mode, rate and purpose.

Pesticide	Application Rate (g/ha)	Proposed Application
2,4-D	1,575	2 x p.a., all fairways + tees in 1 week (Twice per annum, fairways, tees and roughs)
Abamectin	20	Fairway establishment. Applied once to 1-2 fairways at a time.
Azoxystrobin	570	Preventative. Applied to all greens at once, up to once per month
Bensulide	1,500	*Poa* control, all greens over a 2-3 week window as required
Bromoxynil	1,200	Fairways and roughs once in Autumn and Spring
Chlorantraniliprole	300	Preventative. Applied to all fairways and tees at once, once per year
Chlorothalonil	18,000	Preventative. Applied to all greens at once, up to once per month
Clopyralid	202	Fairways and roughs once per year.
Dicamba	168	2 x p.a., all fairways + tees in 1 week
Dithiopyr	840	2 x p.a., all fairways + tees in 1 week
Endothal	263	All greens in 1 day
Fosetyl-Aluminium	10,000	Preventative. Applied to all greens at once, up to once per month
Glyphosate	3,240	Course establishment – used in this manner once to remove existing ground cover prior to major works (also spot applications as required on established course – note: this latter usage involves irregular very small scale applications and therefore is not modelled in this report).
Iodosulfuron-Methyl-Sodium	15	Fairways and roughs, once in Autumn
Iprodione	4,500	Preventative. Applied to all greens at once, up to once per month
Mancozeb	18,250	Preventative. Applied to all greens at once, up to once per month
MCPA	1,500	Fairways and roughs, once in Autumn and Spring
Mecoprop	1,411	2 x p.a., all fairways + tees in 1 week
Metalaxyl-M	840	Preventative. Applied to all greens at once, up to once per month
Oryzalin	2,000	2xpa, all fairways + tees in 1 week
Oxadiazon	3,990	Once per fairway at establishment only
Paclobutrazol	560	Growth inhibitor for *Poa*. Mature greens where observed. Twice Per annum (all greens)
Pendimethalin	1,485	Fairways and tees once per year, Applied all at once
Propamocarb-Hydrochloride	3,900	Preventative. Applied to all greens at once, up to once per month
Propiconazole	1,550	Preventative. Applied to all greens at once, up to once per month
Propyzamide	600	2 x p.a., all fairways + tees in 1 week
Pyraclostrobin	612	Preventative. Applied to all greens at once, up to once per month
Quinclorac	825	Fairways and Tees once per year in Summer
Rimsulfuron	30	Autumn or Spring, Once per year, Fairways and tees
Siduron	50,000	Autumn or Spring, Half Total Area of green, Up to twice per year.
Tebuconazole	600	Preventative. Applied to all greens at once, up to once per month
Thiamethoxam	300	Fairways and tees at once, once per year
Triadimenol	1,500	Preventative. Applied to all greens at once, up to once per month
Trifloxystrobin	300	Preventative. Applied to all greens at once, up to once per month
Trifloxysulfuron Sodium	30	Fairways and Tees, Applied all at once, Once a year - Autumn or Spring
Trinexapac-Ethyl	1,000	Fairways in summer

EGC does not expect to use all of the pesticides listed above. The schedule of typical pesticides expected to be used in a preventative manner are listed in Table 2-14. Others may be required from time to time as required to address a specific pest.

Table 2-14. Expected Annual Schedule of Preventative Use Pesticides (half-life days)

Month	Week	Greens	Fairways	Tees
Jan	1	*EN's*		
	2	Iprodione (84) + Fosetyl (0.1)		
	3			
	4			
Feb	5	*EN's*		
	6	Tebuconazole (62) + Trifloxystrobin (7)		
	7			
	8			
Mar	9			
	10	Chlorothalonil (22)		
	11			
	12			
Apr	13		2,4-D (10) + Dicamba (8) + Mecoprop (8.2)	2,4-D (10) + Dicamba (8) + Mecoprop (8.2)
	14	Propiconazole (214)		
	15			
	16			
May	17			
	18	Triadimenol (250)		
	19			
	20			
	21			
Jun	22	Pyraclostrobin (32)	Propyzamide (47)	Propyzamide (47)
	23			
	24			
	25			
Jul	26	Mancozeb (0.1)		
	27			
	28			
	29			
	30	Chlorothalonil (22)		
Aug	31			
	32			
	33			
	34		Trifloxysulfuron (63)	Trifloxysulfuron (63)
Sep	35			
	36			
	37		Dithiopyr (39)	Dithiopyr (39)
	38			
Oct	39			
	40			
	41			
	42			
	43			
Nov	44			
	45	*EN's*		
	46	Azoxystrobin (70) + Propamocarb (39.3)		
	47			
Dec	48			
	49	*EN's*		
	50	Iprodione (84) + Fosetyl (0.1)		
	51		Trinexapac-ethyl (0.33)	
	52			

Note: EN's are Entomopathogenic nematodes

2.7.3.4. Entomopathogenic Nematodes

Entomopathogenic (i.e. insect killing) nematodes (or ENs) are soil-inhabiting, lethal insect parasitoids that belong to the phylum Nematoda, commonly called roundworms. In the turf industry in Australia, ENs are used as a biological control agent for turf insect pests. Use of biological control agents in preference to pesticides or in conjunction with reduced pesticide usage is referred to as Integrated Pest Management (IPM). The use of ENs means that overall pesticide usage at the course can be reduced. Since EN's die off quickly in the absence of insect larvae, they need to be applied monthly to greens and normally only during the November to February period.

Based on OECD expert group evaluations ENs are not considered to pose a health risk to humans nor a risk to the environment. Long-term effects on non-target organisms (NTOs) or other environmental impacts following the application of indigenous or exotic EPN have not been reported (Ehlers 2011).

2.7.4. EGC Pesticide export offsite

The export of pesticides is expected to be primarily by rainfall and associated runoff from the areas that pesticide is applied. The STORM Pesticide model uses algorithms from Haith's TurfPQ model (Haith 2001) to generate the potential pesticide wash-off in a soluble form. A conservative estimate of particulate transport has also been undertaken although there is little sediment expected to be eroded off the golf course elements and into the ponds.

2.7.4.1. Potential pesticide export

As noted above pesticide movement off the site was modelled using equations from TurfPQ, a model developed by Haith (2001). TurfPQ is a pesticide runoff model developed exclusively for turf. The model is based on a number of calculations for runoff volume and linear partitioning of pesticide into adsorbed and dissolved components during a precipitation or irrigation event. TurfPQ was tested with default parameters for 52 pesticide runoff events involving six pesticides in measured plot studies in four US states. The model typically produced conservative over-predictions of pesticide runoff, particularly with strongly adsorbing pesticides. TurfPQ captured the dynamics of the pesticide runoff events well, with $R^2 = 0.65$. Sensitivity analyses indicated that prediction errors could be reduced by better estimates of adsorption parameters and runoff curve numbers. However, even with default parameters, TurfPQ predictions are at least as accurate as those produced by more complex models.

Validation of model

The TurfPQ model equations used (Equation 11 and 13 cited in Haith (2001)) were validated against data from Rice *et al.*, (2010). The experiments of Rice *et al.*, (2010) were designed to measure the quantity of pesticides in runoff from creeping bentgrass (*Agrostis palustris*) turf managed as golf course fairway to gain a better understanding of factors that influence chemical availability and mass transport. Less than 1 to 23%

of applied pesticides (Chloropyrifos, Flutolanil, Mecoprop-p (MCPP), dimethylamine salt of 2,4-dichlorophenoxyacetic acid (2,4-D), or Dicamba) was measured in edge-of-plot runoff when commercially available pesticide formulations were applied at label rates 23±9 h prior to simulated precipitation (62±3 mm at an intensity of 0.44 to 0.73 mm/min). The plots were saturated the day before application so that soil moistures were consistent across plots and the plots would produce runoff in the early stages of the precipitation. This produces conservative results as pesticides would not normally be applied to saturated catchments as there is less opportunity to bind in the profile. With the exception of Chlorpyrifos, all chemicals of interest were detected in the initial runoff samples and throughout the runoff events. Chemographs of the five pesticides followed trends in agreement with mobility classifications associated with their soil organic carbon partition coefficient (K_{OC}).

The TurfPQ model used the following variables to estimate % of applied pesticide moving off-site:

- K_{OC}= Soil organic carbon-water partitioning coefficient
- Pt = Pesticide applied (g/ha)
- Rt = Rainfall (mm)
- Qt = Runoff (mm)
- OC = Organic carbon (kg/ha)

K_{OC} values used were as reported in Table 2-17 and pesticide applied as reported in Table 2-13. The organic carbon mass adopted in the STORM pesticide model was dependent on the application surface and the state of maturity of the turf thatch. Haith (2001) adopted a figure 1,120 kg/ha organic carbon per mm of thatch depth for modelling with TurfPQ. Based on this figure and the expected thatch depths to be maintained at the golf course, Table 2-15 gives the organic carbon values used in the modelling for this study.

Table 2-15. Organic carbon versus turf thatch depth for different golf course land uses

Thatch (mm)	Organic Carbon kg/ha	Golf course land use
5	5,600	Installation
15	16,800	Greens
25	28,000	Fairways, Tees and Roughs

Kramer *et al.* (2009) indicated that turf with a thick thatch had an organic carbon amount of approximately 37,767 kg/ha and moderate thatch had 10,235 kg/ha. The turf used by Rice *et al.* (2010) was 14 months old when their experiments were started and the five pesticides used in their experiments were modelled using the TurfPQ equations and results (% of applied pesticide that run off-site) compared with experimental data (Figure 2-6). This comparison indicated that for turf fairway areas typical of many golf courses, the equations used from TurfPQ gave a good estimate of pesticide movement off-site compared with measured values (Figure 2-6). The experimental conditions (Rice *et al.* 2010) were as follows:

- A soil characterized as Waukegan silt loam texture (3% organic carbon, 29% sand, 55% silt, and 16% clay). *Soils at the EGC are predominantly alluvial in* *origin and are dominated by a silty clay texture, varying from very stiff to stiff silts and silty clays* (Storm Consulting 2011). *The minor differences in soil characteristics here are unlikely to affect model accuracy, particularly since the pesticide model makes greater use of the turf thatch organic carbon content than the soil carbon which ranges from <2 to 12% at the site prior to development averaging approximately 3 to 5%* (Douglas Partners 2009)*. In fact the silt clay texture found predominantly on site has a greater water holding capacity (estimated to be 200 mm/m available water) than the soils used to develop TurfPQ (estimated to be 150 mm/m available water)* (Tanji *et al.* 2007)*. This difference in water holding capacity should decrease runoff volumes predicted by TurfPQ and therefore be conservative for the modelling in this report.*

- The experimental plots were pre-wetted beyond the soil saturation (volumetric water content: 68±3%) approximately 48 h prior to initiation of simulated precipitation
- A rainfall event that was relatively intense over a relatively long duration (60 mm total at 34 mm/h). *This rainfall event is considerably greater than those typically experienced at Eastern Golf Club.*

The half-life component of TurfPQ was not used as this was already considered in the hydrologic model, and the worst case would be application and rainfall soon after, minimising any time for degradation. TurfPQ assumes that all pesticide runoff is in the dissolved form as the dense vegetation of turf-grasses and associated organic matter strongly favours water retention on site and sediment/suspended solid losses are relatively small (Haith 2001, 2003). The potential load of total organic carbon (TOC) in water leaving the wetlands was determined to be relatively small compared with guideline values.

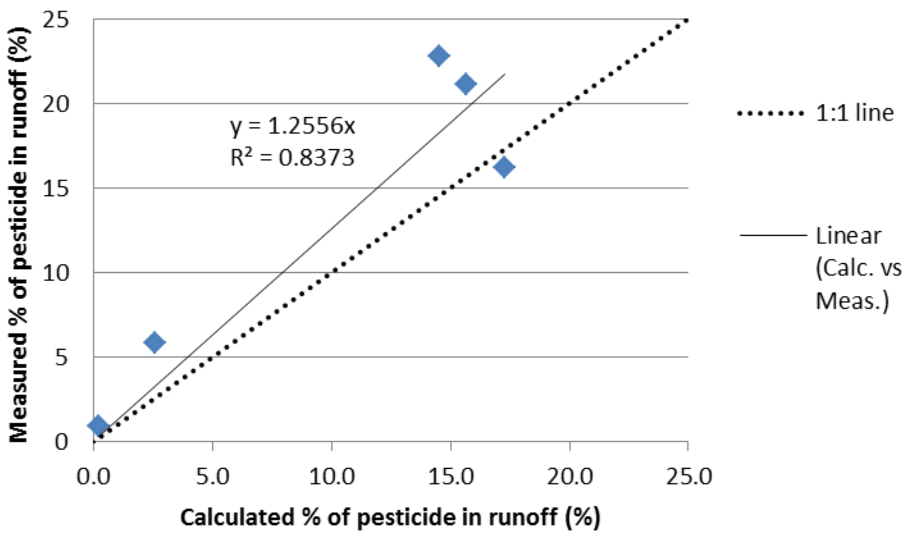

Figure 2-6. Model validation: Comparison of calculated and measured percent (%) of applied pesticide in runoff.

Particulate transport

TurfPQ deals only with dissolved substances and does not address substances that could be bound to suspended solids (SS). For example, pesticides such as Pendimethalin which is hydrophobic would bind largely to soil and turf organic matter and thus could really only be transported attached to SS. Due to the high density of turf on golf courses, suspended solids and turbidity of runoff is generally low in relation to other types of land uses. Consequently, transport of pesticide residues in golf course runoff is expected to be dominated by soluble pesticides rather than those bound to particulates.

A situation in which transport of particulate-bound pesticides could be significant could occur when the pesticide transported is very persistent and applied at a high rate and thus may build up in sediments over repeated usage. Such pesticides (e.g. Bifenthrin) have been excluded from use at the EGC.

A simple model of particulate transport was developed for the EGC to determine if any of the applied pesticides could exceed environmental and drinking water guidelines via this route of transport. The model was very conservative and is based on assumptions derived from the US EPA and published literature. It does not involve use of the STORM Pesticide Model.

Table 2-16. Particulate pesticide transport model parameters and source of information

Parameter	Value and units	Source, description
Soil Depth	0.05 (m)	Estimate – standard soil depth used in such risk assessments. On a mature course it is assumed that mobilisation of deeper soils cannot occur under normal operation
Greens Organic Carbon (OC)	16,800 (kg/ha)	Haith (2001)
Fairways OC	28,000 (kg/ha)	Haith (2001)
Soil Density	1,300 (kg/m3)	Estimate based on review by Higginson and McMaugh (2009)
Soil OC percentage	6%	Estimated based on review by Higginson and McMaugh (2009)
SS conc in runoff	30 (mg/L)	1). Australian Stormwater Recycling Guidelines (NRMMC *et al.* 2009) gives values for Urban stormwater. As this is from all sources, the lower percentiles were used here as a guide as golf course turf is known to provide a higher quality runoff than most urban catchment surfaces (5^{th} percentile = 19.01, 25^{th} = percentile 45.41) 2). US EPA Office of Pesticide Programs suggest the use of 30 mg/L SS for wetland ponds in drinking water risk assessments (cited by Haith 2010)
SS OC percentage	4.00%	US EPA Office of Pesticide Programs suggest the use of 4.00% OC for SS for wetland ponds in drinking water risk assessments (cited by Haith 2010)
Application rate (g/ha or equiv)	Substance specific	See Table 2-13.
Golf course land use	Greens, Fairways, Tees and Rough	Most pesticides are applied only to greens or only to the remaining categories listed at left
% contribution to SS	Calculation	The proportion of the course to which the pesticide is applied
Adjustment factor	Calculation	As the particulate model does not account for initial loss (see Table 2-8) an adjustment factor was used to limit the particulate model to predict zero particulate pesticide transport when the Storm Model (which deals with soluble pesticide transport) also predicts zero transport. This adjustment recognises the greater accuracy of the Storm Model.

Special properties

The chemistry of some pesticides means they have certain properties that need special consideration for using the K_{OC} in Turf PQ. This is because their soil sorption behaviour changes, e.g. they could:

- ionise at a certain pH;
- be hydrophobic;
- form metal ligands.

These factors have been considered for the all pesticides proposed to be used at the EGC and corrections made to consider the characteristics when modelling with Turf PQ (Detailed in Appendix 3).

Table 2-17. *Soil Half-life and Soil organic carbon-water partitioning coefficients for each pesticide. Data source = PPDB (2009).*

Label active ingredient name	Half-life (DT_{50}) soil typical, days	K_{OC}	Label active ingredient name	Half-life (DT_{50}) soil typical, days	K_{OC}
2,4-D	10	88.4	Metalaxyl-M	39	660
Abamectin	30	6631	Oryzalin	20	949
Azoxystrobin	70	589	Oxadiazon	502	3200
Bensulide	90	3900	Paclobutrazol	112	210
Bromoxynil	8	30.2	Pendimethalin	90	15744
Chlorantraniliprole	210	328	Propamocarb-Hydrochloride	39.3	706
Chlorothalonil	22	850	Propiconazole	214	1221
Clopyralid	34	5	Propyzamide	47	840
Dicamba	8	12.36	Pyraclostrobin	32	9304
Dithiopyr	39	801	Quinclorac	450	50
Endothal	5	8.5	Rimsulfuron	24.3	47
Fosetyl-Aluminium	0.1	221.7	Siduron	135	420
Glyphosate	12	1435	Tebuconazole	62	769
Iodosulfuron-Methyl-Sodium	8	45	Thiamethoxam	50	70
Iprodione	84	700	Triadimenol	250	273
Mancozeb	0.1	998	Trifloxystrobin	7	2377
MCPA	15	7.4	Trifloxysulfuron Sodium	63.5	30.6
Mecoprop	8.2	47	Trinexapac-Ethyl	0.33	28

Pesticide decay

Soil and water half-lives of each pesticide were specified by data extracted from the University of Hertfordshire Pesticide Properties database (PPDB 2009). From this information, a decay curve was derived to account for pesticide degradation over time in soil prior to the design rainfall event and in water during the rainfall event for the mass that is transported by runoff. For correlation to the rainfall data, the decayed concentrations were assessed in 6 minute increments. The half-life of each pesticide determines its longevity within the system. Pesticides with a long half-lives exhibit minimal decay over the modelled timescales (Figure 2-7).

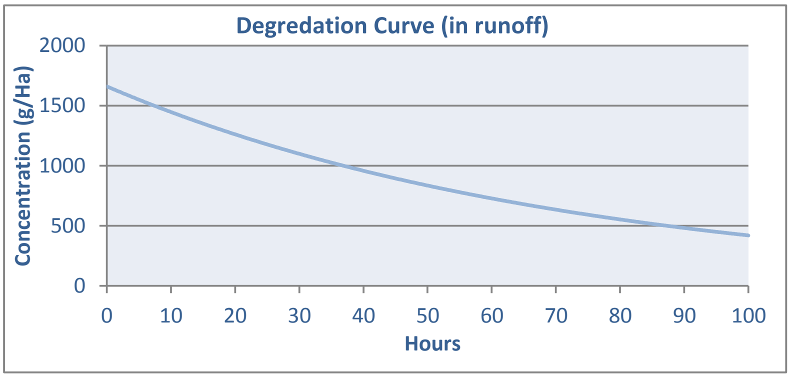

Figure 2-7. Typical pesticide degradation curve.

It is acknowledged that half-life data can be quite variable and are highly dependent on the environmental conditions experienced at a particular site. The half-life data used were classed as typical values in the Pesticide Properties database and are those given in the general literature. They are often a mean of all field and laboratory studies. The Pesticide Properties database notes that the typical value is the value normally used in regulatory modelling studies and is for aerobic conditions.

Pesticide wash-off by Yarra River inundation

There is a possibility of applying pesticide to some golf course elements that are subject to inundation by Yarra River flooding. Most of the floodplain is expected to be inundated in river flooding levels equating to recurrence intervals of 5 years or greater and typically take days to reach peak heights.

The transportable fraction of pesticide (i.e. that portion available for wash-off) is likely to be washed off the inundated margins of the course as the river level rises. The large volumes associated with river flooding would provide considerable dilution as the golf course is incrementally inundated. Further dilution is expected with local rainfall and dilution in the ponds.

2.7.5. Form of Model Output

The STORM Pesticide model reports the modelling results for each pesticide application with respect to the application surface, catchment and application rate. A storm event is applied to the catchment 24 hours after application of each pesticide and the results are reported in the form of outflow concentration from Pond A which flows into the Yarra River.

The predicted environmental concentration (PEC) is in the form of a peak outflow concentration which is then compared with the environmental limits of concentration or an average outflow concentration which is used for assessing compliance with drinking water guidelines described in Section 2.7.9 below.

2.7.6. Modelling Strategy

2.7.6.1. Selection of design storm

Storm duration

Work by Rice *et al.* (2010) indicates that the majority of pesticide wash-off occurs over 1 to 2 hours. A long wash-off time allows dilution to have a greater affect which lowers spike concentrations. A shorter duration was adopted which results in wash-off occurring within minutes rather than hours.

A 15 minute design storm was adopted in the modelling and the wash-off was driven by depth of runoff rather than a time function. This results in a sharper peak of pesticide concentration and also less runoff volume generated in this shorter event to provide dilution.

It should be noted that the environmental guidelines are largely based on 48 hour to 96 hour LC_{50} ecotoxicology tests whereas the STORM pesticide model reports the peak concentration of the pesticide which occurs for minutes only.

Recurrence interval

The nominated design storm event must be one that is realistic and but conservative. For this study the 5 year ARI was considered appropriate as higher ARI events generally involved inundation of the golf course by the Yarra River. Using MUSIC v5.11 an analysis was untaken on the 46.25 years of pluvial data and noted that the design rainfall depth occurred 18 times within a 30 minute block. This translates to a probability of exceedence of 1 in 836. There are 5 proposed applications of pesticides on fairways per year. If there was no consideration given to weather forecasting, the probability of exceeding the design storm within a day of applying the pesticide is 1 in 61,061 or once in every 167 years.

This design storm event is a conservative scenario. The following scenarios can occur post application:

- A rainfall event smaller than the design storm event;
- Irrigation (reducing the wash-off potential significantly);
- A significant decay of most pesticides over time;
- Further bonding to the soil.

2.7.6.2. Modelling approach for pesticide solutes

The process of assessment firstly considered application to all catchments 24 hours before the design storm event. HQs (hazard quotients) were then calculated based on the PEC exiting the final pond. Note that although subsequent modelling results indicated that no pesticide is transported for the design storm event, HQs are still calculated by the model. However, since the PECs are zero, then the HQs are also calculated to be zero. By altering certain model settings it is possible to generate non-zero HQs (see Section 2.7.9).

For environmental assessment HQs were calculated based on the peak concentration discharged to the Yarra River as this accounts for the situation were biota in the river may encounter the discharge plume. For assessment of risks to potable supplies, HQs were calculated from the average concentration discharged to the Yarra River since the peak concentration only lasts for a few minutes and the passage of the plume through the river and into the storage would necessarily involve some mixing within the plume. Further mixing with Yarra River water also occurs but dilution via this mechanism was not considered in the modelling.

2.7.7. Determination of steady-state background pesticide concentrations

Since the pesticides proposed for use at the Eastern Golf Course are re-applied at certain frequencies, it is possible that residual or background amounts of pesticide may remain on the golf course turfs and in the golf course wetlands after an application and following rainfall events. After several re-applications an equilibrium arises between the amount of pesticide applied, the frequency of application and the rate of removal through environmental processes. The equilibrium value is known as the steady-state background concentration. As long as the pesticide is re-applied at the particular frequency and rate, then an average, steady state, residual concentration of pesticide may be present. The more persistent the pesticide the longer the time taken to reach steady state.

Factors that determine the rate of removal of pesticides from the golf course turfs and wetlands include:

- *Photolysis* – the breakdown of the pesticide molecule by light, particularly UV light;
- *Hydrolysis* – the dissociation of the pesticide molecule in reaction with water molecules;
- *Flushing* – the flushing of golf course wetlands due to successive rainfall events;
- *Biodegradation* – the breakdown of pesticides by microorganisms (mainly bacteria) in the soil and in water;
- *Volatilisation* – the loss of pesticide molecules as vapour to the atmosphere; and
- *Leaching* – loss of pesticide residues to groundwater

It is often difficult to obtain reliable data on the rates of all the above phenomena and for the purposes of determining environmental compliance sometimes only two or three factors are assessed. If these factors on their own can be used to demonstrate compliance with environmental guidelines, then it is not necessary to include detailed assessments of the remaining factors.

To determine steady state background concentrations of pesticides at the Eastern Golf Course, for this assessment we have focussed on:

- Biodegradation in soil;
- Photolysis and hydrolysis in water; and
- Flushing.

Our primary source of data for soil biodegradation, and aqueous photolysis and hydrolysis was the University of Hertfordshire Pesticide Properties Data Base (PPDB) (PPDB 2009). The PPDB was described in Section 2.4.2.7. It presents estimates for such functions as used in regulatory assessments in the European Union. For the pesticides proposed for use at the EGC, PPDB information coverage on pesticide soil biodegradation half-lives is complete, while information on photolysis half-lives is generally available for most of the pesticides. Coverage for hydrolysis is less quantitative. Availability of relevant half-life data for the processes considered is discussed later in this document.

To calculate steady-state concentrations on the course and in the wetlands we calculated the percentage removal between applications for each process and added successive values of this figure until an asymptote was reached. For example if 50% of a compound was remaining between applications, at the time of the third application there would be 50% remaining of the second application and 50% x 50% = 25% from the first application. The total remaining would then be 50% + 25% = 75%. A third application would require 50% of 25% = 12.5% to be added (i.e. 75% + 12.5% = 87.5%, *etc*.).

2.7.7.1. Determination of steady state concentrations on soil at the Eastern Golf Course

The DT_{50} or half-life is the time required for the pesticide concentration to decline to 50% of the amount at application. The Pesticide Properties Data Base (PPDB 2009) which was the source of the data used in the current assessment states that the DT_{50} is calculated from a field or laboratory soil sample as follows:

> *"Typically data is derived from laboratory studies, but where the substance is persistent in soil under laboratory conditions, field studies may be carried out. 'Typical values' quoted are those given in the general literature and are often a mean of all studies field and laboratory. This is the value normally used in the regulatory modelling studies and is for aerobic conditions."*

Using the PPDB half-life and the expected duration between pesticide applications, we calculated the percentage of pesticide remaining on the soil from the previous application. However before doing this, we carried out a preliminary step: since most transportable pesticide washes off with the first rainfall event, the amount available for wash off in subsequent events is much less than in the first event (see Rice et al. (2010) figure 3). Reliable quantitative statistics on this figure are difficult to find, so it was conservatively estimated to be 50% of the material available for wash off in the first event.

The % of pesticide remaining on the soil from the previous application was then used to calculate a steady state background concentration by adding successive half-live values until equilibrium was reached (Figure 2-8).

Soil degradation steady-state values for each pesticide are shown in Table 2-21.

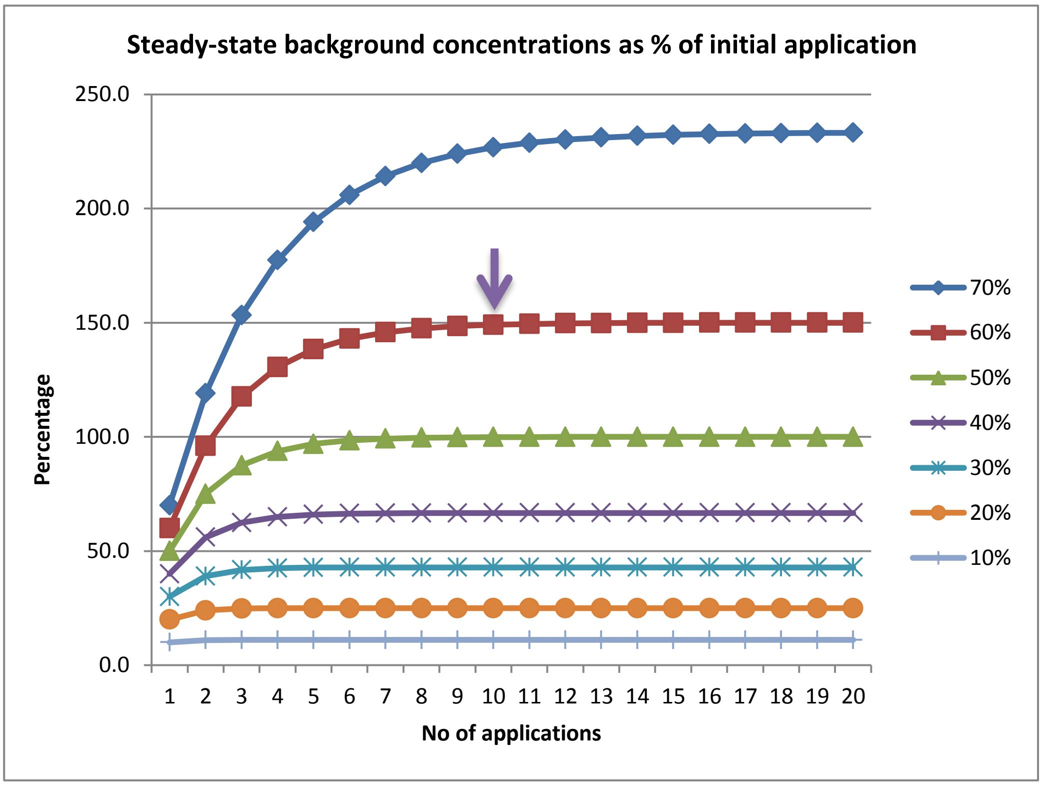

Figure 2-8. Example steady state calculations for successive applications of golf-course pesticides. For example, when the residual pesticide concentration at the time of re-application is 60% of the initial application, the residual pesticide concentration will reach steady-state equilibrium at around 10 applications (= 150% of the initial concentration – see arrow).

2.7.7.2. Determination of steady state concentrations in Pond systems at the Eastern Golf Course

Photolysis: UV Attenuation rates

Many studies have shown that ultraviolet light, particularly UV-B light in the wavelength range from 280 to 315 nm is responsible for the bulk of photodegradation of organic compounds in water. UV-A radiation (315 to 400 nm) may also induce some photochemical reactions (Doll and Frimmel 2003). The depth at which UV-B penetrates water will to a large extent control the rate of photochemical reactions in a waterbody. UV extinction rates with depth are typically reported as $z_{1\%}$ or the depth at which the amount of UV light present is 1% of the value at the water surface. This value varies according to the amount of dissolved and suspended material in the water and the chromophoric (light-absorbing) properties of that material.

Morris *et al.* (1995) provide UV-B depth-irradiance data for several lakes in the US and Argentina. Maximum depths for $z_{1\%}$ were over 10 m while minimum depths were less than 1 m.

For water bodies with high suspended solids and high dissolved organic carbon (DOC) $z_{1\%}$ may be limited to the top 10 to 30 cm. In a study of UV and visible light attenuation in Dutch inland waters, De Lange (2000) reported that in most systems $z_{1\%}$ was less than 0.3 m. However, DeLange does not provide descriptions of the nature of the waterbodies and it appears many are turbid ditches. The clearest waterbody measured was the Dutch Lake Maarsseveen with a $z_{1\%}$ depth of 50 cm. In humic lakes of Central Finland, Huovinen *et al.* (2003) showed that UV-B radiation was attenuated in approximately 50 cm in a lake with a DOC of 4.9 mg/L.

The attenuation of irradiance with depth in optically homogenous water follows the Beer-Lambert equation:

Eq 1. $$E_d = E_d(0)e^{-K_d z}$$

where K_d is the vertical attenuation coefficient for downward irradiance, $E_d(z)$ the irradiance at depth z, and $E_d(0)$ the irradiance just below the surface (Kirk 1994 cited in Huovinen *et al.* 2003).

K_d values are influenced by a several factors including the absorption coefficient, dissolved organic carbon (DOC) and the type of DOC present. These factors are not yet known for the EGC wetlands as they are yet to be constructed, however it is possible to come up with reasonable estimates of DOC (see below). Huovinen *et al.* (2003) provide formulas for predicting the UV-B attenuation coefficient K_d based on the DOC. While Huovinen *et al.* present several different formulas based on their research and that of others, we focussed on three formulas that covered the width of the UV-B waveband (280 to 320 nm) (Table 2-18). Since we have no reason to choose one formula over the other, we took the average result of the three formulas as our input K_d value.

Table 2-18. Formulas for calculation of UV-B (280-320 nm) attenuation coefficient Kd

Symbol	Formula	Values	Units	Source
$z_{1\%}$	n/a	0.147	m	Calculation
DOC	n/a	15	mg/L	Estimate
$E_d(0)$	n/a	1	Unitless	Assume unit irradiance at surface
$E_d(z)$	$E_d(z) = E_d(0)e^{-Kdz}$	1.005E-02	Unitless	Calculation
K_d	$K_d = 0.6(DOC)^{1.29}$ ($r^2 = 0.76$)	19.738	Unitless	Arts *et al.* (2000) cited in Huovinen *et al.* (2003)
K_d	$K_d = 4.14(DOC)-17.70$ ($r^2 = 0.98$)	44.400	Unitless	Graneli *et al.* (1996) Huovinen *et al.* (2003)
K_d	$K_d = 0.71(DOC)^{1.25}$ ($r^2 = 0.84$)	29.539	Unitless	Arts *et al.* (2000) Huovinen *et al.* (2003)
K_d	n/a	31.226	Unitless	Calculation of average

DOC estimates

Briggs *et al.* (1993) reported values of DOC for floodplain billabongs on the Murrumbidgee River of between 27 to 36 mg/L and considered these to be high by world standards. These billabongs are surrounded by dense stands of River Red Gum (*Eucalyptus camaldulensis*) which shed large amounts of leaf and bark litter. The EGC wetlands are expected to have a lower density of fringing trees and large areas of turf so it is anticipated that DOC values would be much lower in the EGC wetlands as inputs of leaf litter would be much less. Furthermore the EGC wetlands are planned to have significant areas of emergent vegetation (Table 3). Rose *et al.* (2008) used modelling and field measurements to argue that photolysis was enhanced in vegetated wetlands compared to unvegetated wetlands due to faster sedimentation and increased light penetration despite shading. Based on the above analysis, for assessment purposes a reasonable, but conservative DOC value of 15 mg/l was chosen for modelling photolysis in the EGC wetlands.

The average K_d value (Table 2-19) gave a z1% of around 15 cm. The average UV-B radiation as a % of the surface radiation in the top 15 cm is 26.25%. This value was used to calculate a revised photolysis half-life (DT_{50}) in the EGC wetlands for each pesticide proposed for use.

Table 2-19. Calculation of $z_{1\%}$*.(see Equation 1).*

E_d as % of surface	$E_d(z)$	z (m)
100.00%	1	0
45.81%	0.4581	0.025
20.99%	0.2099	0.05
9.61%	0.0961	0.075
4.40%	0.0440	0.1
2.02%	0.0202	0.125
0.92%	0.0092	0.15
Average E_d for top 15 cm as % of surface = 26.25%		

Photolysis depths for EGC wetlands

There are 11 wetlands proposed for the EGC (Table 2-20). Based on area and volume data for the wetlands, the proportion of volume of each wetland that lay within the z1% layer was calculated. For each wetland and each pesticide a revised photolysis half-life was calculated as in the following example:

- Photolysis DT_{50} (from PPDB) = 5 days
- DT_{50} adjusted for average within z1% layer = 5 days/26.25% = 19.0 days
- Proportion of volume in z1% layer, say 19%
- Proportion of unshaded volume in z1% layer, say 13%
- DT_{50} adjusted for average of whole wetland = 19.0 days/13% = 146.15 days

The above calculations assume that the wetlands are vertically well-mixed which given their shallow depths is reasonable.

To calculate the average photolysis rate for each pesticide across all wetlands, each wetland DT_{50} was multiplied by its proportion of the total wetland volume and the values summed to provide a weighted average DT_{50} (Table 2-21).

Table 2-20. Eastern Golf Course Wetland areas, depths and volumes and proportion of volume in the top 50 cm.

Pond	Area (NWL) (m^2)	Ave. Depth (m)	Max depth (m)	Volume at NWL (m^3)	Reedbed area % of total (approx)	Volume in $z_{1\%}$ layer (m^3)	Unshaded volume in $z_{1\%}$ layer	Proportion of volume in $z_{1\%}$ layer
A	8,897	0.8	1.0	7,118	33	1,334.5	894.1	19%
B	5,476	0.8	1.0	4,381	33	821.4	550.3	19%
C1	9,479	0.8	1.0	7,583	33	1,421.8	952.6	19%
C2	890	0.6	1.0	534	67	133.5	44.1	25%
C3	1,580	1.0	1.2	1,580	25	237	177.8	15%
C4	2,837	1.0	1.2	2,837	25	425.5	319.2	15%
D	23,538	0.8	1.0	18,830	33	3,530.7	2,365.6	19%
F	17,373	1.8	3.0	31,271	19	2,605.9	2,110.8	8%
G	22,899	0.9	1.2	20,609	38	3,434.8	2,129.6	17%
I	14,225	0.7	1.2	9,958	63	2,133.7	789.5	21%
M	4,322	1.0	1.4	4,322	40	648.3	389.0	15%

Hydrolysis

Most pesticides have very low hydrolysis rates, most probably for commercial reasons since such compounds have a longer shelf-life when stored in aqueous solution. Consequently for most pesticides the hydrolysis half-lives were given a text classification (e.g. persistent). For steady-state calculations of such cases, the hydrolysis rates were recoded at a numerical value zero to allow numerical calculation of overall removal rates (Table 2-22). Where a particular pesticide did have a quantified hydrolysis half-life in the PPDB (e.g. Rimsulfuron, DT_{50} = 7.2 days), this rate was used.

Flushing

In addition to pesticide decay processes, rainfall-driven dilution and flushing processes will occur with a regular frequency throughout the year. Catchment calculations were used to derive an average turnover frequency of golf course ponds. The estimated number of times the ponds volume will be replenished by catchment runoff is estimated to be 11.6 times per annum. This value was used to calculate the average number of turnovers of the wetlands between applications.

In practice, flushing efficiency may not be 100% and some portion of the original water may remain after each event. Since flushing is expected to be reasonably efficient, flushing efficiency was set at 90%. This means that 10% of the original water may remain per event. Given regular flushing and regular pesticide application, a steady state of pesticide residues due to flushing can be assumed (Table 2-22).

Although 90% flushing efficiency has been adopted in the calculations, a sensitivity check was undertaken using Chlorothalonil to see how a lower efficiency could affect the results. Chlorothalonil is not well removed due to soil degradation, photolysis or hydrolysis and so is particularly sensitive to flushing efficiency. At 90% flushing efficiency, Chlorothalonil had a HQ_E of 0.00. If an extremely low flushing efficiency of 50% is adopted, Chlorothalonil's HQ_E is still 0.00, still well below the threshold environmental HQ of 0.5. This observation highlights the fact that even for pesticides sensitive to flushing efficiency there is still a considerable margin of safety even when flushing efficiencies are modelled a very low rates.

2.7.7.3. Steady state calculations due to soil degradation, photolysis, hydrolysis and flushing

The total net removal of pesticide residues from the golf course is the product of the steady state removals for each process. This was calculated as the Log_{10} value of the product of soil degradation photolysis, hydrolysis and flushing (Table 2-23). This log reduction value for each pesticide was applied to the modelled maximum outflow predicted environmental concentration (PEC) for the rainfall event scenarios described in Section 2.7.9. The resultant number provided a background concentration to be added to the PEC of the most recent event. In other words, for any modelled event the PEC = the modelled concentration due to the recent pesticide application (soluble and particulate) *plus* the background concentration from previous applications.

The resultant steady-state PECs were used to recalculate the Hazard Quotients (HQs) for protection of the environment and potable water supplies for each scenario.

Although some pesticides had persistent characteristics for some processes and/or were applied frequently, this was usually counterbalanced by limited areas of application (e.g. greens only) or by high removal rates due to other processes. The result was that revision of the HQ calculations to consider steady state background levels (using conservative assumptions) resulted in little change to the HQ values. All predicted HQs are within HQ targets as described elsewhere in this report.

Table 2-21. Expected duration between pesticide applications and soil degradation and photolysis rates

Label active ingredient name	Expected duration between applications (days)	Half life (DT_{50}) soil typical, days	% remaining after soil decay	Soil degradation steady state	Aqueous photolysis DT_{50} (days) at pH 7	Photolysis DT_{50} (days) revised for UV-B Penetration	% remaining after photolysis decay
2,4-D	182	10	0.0%	0.0%	13	351.69	69.9%
Abamectin	365	30	0.0%	0.0%	1.5	40.58	0.2%
Azoxystrobin	30.5	70	73.9%	141.8%	8.7	235.36	91.4%
Bensulide	365	90	6.0%	3.2%	n.d.	n.d.	100.0%
Bromoxynil	182	8	0.0%	0.0%	0.5	13.53	0.0%
Chlorantraniliprole	365	210	30.0%	21.4%	0.31	8.39	0.0%
Chlorothalonil	30.5	22	38.3%	31.0%	65	1758.47	98.8%
Clopyralid	365	34	0.1%	0.0%	271	7331.48	96.6%
Dicamba	182	8	0.0%	0.0%	50.3	1360.79	91.1%
Dithiopyr	182	39	3.9%	2.0%	19.1	516.72	78.3%
Endothal	365	5	0.0%	0.0%	n.d.	n.d.	100.0%
Fosetyl-Aluminium	30.5	0.1	0.0%	0.0%	n.d.	n.d.	100.0%
Glyphosate*	182	12	0.0%	0.0%	69	1866.69	87.3%
Iodosulfuron-Methyl-Sodium	365	8	0.0%	0.0%	50	1352.67	82.9%
Iprodione	30.5	84	77.7%	174.6%	67	1812.58	98.8%
Mancozeb	30.5	0.1	0.0%	0.0%	n.d.	n.d.	100.0%
MCPA	182	15	0.0%	0.0%	0.05	1.35	0.0%
Mecoprop	182	8.2	0.0%	0.0%	44	1190.35	89.9%
Metalaxyl-M	30.5	39	58.2%	69.5%	n.d.	n.d.	100.0%
Oryzalin	182	20	0.2%	0.1%	0.08	2.16	0.0%
Oxadiazon#	n.a.	502	n.a.	n.a.	5.9	159.62	n.a.
Paclobutrazol	182	112	32.4%	24.0%	n.d.	n.d.	100.0%
Pendimethalin	365	90	6.0%	3.2%	21	568.12	64.1%
Propamocarb-Hydrochloride	30.5	39.3	58.4%	70.2%	n.d.	n.d.	100.0%
Propiconazole	30.5	214	90.6%	456.7%	n.d.	n.d.	100.0%
Propyzamide	182	47	6.8%	3.7%	41	1109.19	89.2%
Pyraclostrobin	30.5	32	51.7%	53.4%	1.7	45.99	63.1%
Quinclorac	365	450	57.0%	66.3%	n.d.	n.d.	100.0%
Rimsulfuron	365	24.3	0.0%	0.0%	11.7	316.53	45.0%
Siduron	182	135	39.3%	32.3%	290	7845.50	98.4%
Tebuconazole	30.5	62	71.1%	123.0%	n.d.	n.d.	100.0%
Thiamethoxam	365	50	0.6%	0.3%	2.7	73.04	3.1%
Triadimenol	30.5	250	91.9%	521.8%	9	243.48	91.7%
Trifloxystrobin	30.5	7	4.9%	2.6%	2.7	73.04	74.9%
Trifloxysulfuron Sodium	365	63.5	1.9%	0.9%	18	486.96	59.5%
Trinexapac-Ethyl	365	0.33	0.0%	0.0%	21	568.12	64.1%

*Glyphosate is to be used only for irregular very small scale spot applications as required. For ease of assessment it is modelled at the label application rate assuming use on fairways only. #Oxadiazon is used once at establishment only

Table 2-22. Hydrolysis rates, average no. of turnovers between applications and flushing steady state values

Label active ingredient name	Aqueous hydrolysis DT_{50} (days) at 20°C and pH 7	% remaining after hydrolysis decay	Steady state due to hydrolysis and photolysis	Average no. of turnovers between applications	Flushing steady state
2,4-D	Stable - v. persistent	100.0%	275.0%	5.8	0.00%
Abamectin	Stable - v. persistent	100.0%	0.5%	11.6	0.00%
Azoxystrobin	Stable - v. persistent	100.0%	1126.9%	1.0	10.73%
Bensulide	Persistent	100.0%	3100.0%	11.6	0.00%
Bromoxynil	Stable - persistent	100.0%	0.0%	5.8	0.00%
Chlorantraniliprole	n.d.	100.0%	0.0%	11.6	0.00%
Chlorothalonil	Stable - v. persistent	100.0%	2636.4%	1.0	10.73%
Clopyralid	Stable - v. persistent	100.0%	1992.6%	11.6	0.00%
Dicamba	Stable - v. persistent	100.0%	1098.5%	5.8	0.00%
Dithiopyr	Stable - v. persistent	100.0%	424.9%	5.8	0.00%
Endothal	n.d.	100.0%	3100.0%	11.6	0.00%
Fosetyl-Aluminium	Stable - v. persistent	100.0%	3100.0%	1.0	10.73%
Glyphosate	Stable - v. persistent	100.0%	783.2%	11.6	0.00%
Iodosulfuron-Methyl-Sodium	Stable - v. persistent	100.0%	566.0%	11.6	0.00%
Iprodione	3	0.1%	0.1%	1.0	10.73%
Mancozeb	2.3	0.0%	0.0%	1.0	10.73%
MCPA	Stable - v. persistent	100.0%	0.0%	5.8	0.00%
Mecoprop	Stable - v. persistent	100.0%	981.4%	5.8	0.00%
Metalaxyl-M	Stable - v. persistent	100.0%	3100.0%	1.0	10.73%
Oryzalin	Stable - v. persistent	100.0%	0.0%	5.8	0.00%
Oxadiazon	31	n.a.	n.d.	n.a.	n.a.
Paclobutrazol	Stable - v. persistent	100.0%	3100.0%	5.8	0.00%
Pendimethalin	Stable - v. persistent	100.0%	212.9%	11.6	0.00%
Propamocarb-Hydrochloride	Stable - v. persistent	100.0%	3100.0%	1.0	10.73%
Propiconazole	53.5	67.4%	206.3%	1.0	10.73%
Propyzamide	Stable - v. persistent	100.0%	921.9%	5.8	0.00%
Pyraclostrobin	Stable - v. persistent	100.0%	204.9%	1.0	10.73%
Quinclorac	n.d.	100.0%	3100.0%	11.6	0.00%
Rimsulfuron	7.2	0.0%	0.0%	11.6	0.00%
Siduron	Stable - v. persistent	100.0%	2501.0%	5.8	0.00%
Tebuconazole	Stable - v. persistent	100.0%	3100.0%	1.0	10.73%
Thiamethoxam	Stable - v. persistent	100.0%	5.3%	11.6	0.00%
Triadimenol	Stable - v. persistent	100.0%	1157.6%	1.0	10.73%
Trifloxystrobin	40	58.9%	84.8%	1.0	10.73%
Trifloxysulfuron Sodium	20	0.0%	0.0%	11.6	0.00%
Trinexapac-Ethyl	Stable - v. persistent	100.0%	212.9%	11.6	0.00%

Note for Aqueous hydrolysis DT_{50} PPDB database often only provides a text classification (e.g. Stable, very persistent). Where a numerical DT_{50} is provided by PPDB, it is shown in the table. Text classifications for pesticides identified as stable in aqueous solution were accorded a DT_{50} of 100%.

Table 2-23. Net adjustment factor for steady state calculation.

Label active ingredient name	Net adjustments (-ve Log10) due to pesticide degradation in soil, photolysis, hydrolysis and flushing
2,4-D	11.1
Abamectin	17.9
Azoxystrobin	-0.3
Bensulide	11.6
Bromoxynil	64.4
Chlorantraniliprole	23.6
Chlorothalonil	0.1
Clopyralid	13.8
Dicamba	18.7
Dithiopyr	6.8
Endothal	32.4
Fosetyl-Aluminium	91.6
Glyphosate	20.2
Iodosulfuron-Methyl-Sodium	24.9
Iprodione	3.8
Mancozeb	97.1
MCPA	43.4
Mecoprop	11.8
Metalaxyl-M	-0.4
Oryzalin	30.7
Oxadiazon*	1.0
Paclobutrazol	4.9
Pendimethalin	12.8
Propamocarb-Hydrochloride	-0.4
Propiconazole	0.0
Propyzamide	6.3
Pyraclostrobin	0.9
Quinclorac	10.3
Rimsulfuron	32.0
Siduron	4.9
Tebuconazole	-0.6
Thiamethoxam	15.4
Triadimenol	-0.8
Trifloxystrobin	2.6
Trifloxysulfuron Sodium	19.3
Trinexapac-Ethyl	124.8

*Oxadiazon is used only at the start of course construction and the maximum outflow concentration is the same as for the single use. A net adjustment factor of 1.0 signals no change.

2.7.7.4. Quinclorac

No environmental fate data could be located for the pesticide Quinclorac. The BIOWIN4 Primary Biodegradation model contained in the US EPA EPI Suite package(US EPA 2011) predicted a primary biodegradation rate of “weeks” while the Ultimate Biodegradation model BIOWIN3 gave a period of “weeks to months” for 6 half-lives. This suggests that the proposed 12 month duration between applications would not give rise to a detectable residue in the golf course ponds.

2.7.8. Particulate transport

Estimated PECs and HQs for pesticides transported bound to SS are shown in Table 2-24. As noted earlier this analysis does not make use of the STORM Pesticide Model. Although the model is very conservative, it shows that the prior to the implementation of the adjustment factor (described in Table 2-16) predicted HQs comply with the targets with significant margins of safety. In no case did the addition of PECs from soluble and suspended solids transported fractions have a significant effect on HQ values. Since the soluble transport model (Storm Pesticide Model) predicted zero pesticide transport, the adjustment factor is triggered and this sets all particulate transport to zero as well. As discussed in Table 2-16, the adjustment recognises the greater accuracy of the Storm Model which has a superior hydrological engine and includes the effects of initial loss. Given these attributes, if the Storm Model predicts zero transport of the soluble fraction of pesticide (which is the major transport pathway) it is realistic to assume that particulate transport is also zero. Due to the difference in the way the soluble and particulate transport models were constructed it was not possible to further calibrate the particulate transport model against the Storm module to any greater degree.

Table 2-24. Particulate transport pesticide modelling scenarios with catchments applied, flow event, predicted environmental concentration in runoff (PEC) and Hazard Quotients where HQ_{ENV} = environmental hazard quotient, HQ_{DW} = drinking water hazard quotient. The HQ targets for this study is HQ_{ENV} <= 0.5 and HQ_{DW} <= 0.1. The adjusted values account for the zero transport predicted by the soluble transport model (Storm Model).

Pesticide	Type	Environ -mental Guideline (mg/L)	Drinking Water Guideline (mg/L)	Pre-adjusted PEC (mg/L)	HQ_{ENV}	HQ_{DW}	Adjusted PEC (mg/L)	Adjusted HQ_{ENV}	Adjusted HQ_{DW}
2,4-D	Herbicide	0.14	0.03	9.54E-06	0.000	0.000	0E.00	0.000	0.000
Abamectin	Insecticide	0.000012	0.0001	8.87E-08	0.007	0.001	0E.00	0.000	0.000
Azoxystrobin	Fungicide	0.0049	0.0001	2.11E-07	0.000	0.002	0E.00	0.000	0.000
Bensulide	Herbicide	0.0051	0.0001	5.56E-07	0.000	0.006	0E.00	0.000	0.000
Bromoxynil	Herbicide	0.01	0.01	6.97E-06	0.001	0.001	0E.00	0.000	0.000
Chlorantraniliprole	Insecticide	0.00116	6	1.41E-06	0.001	0.000	0E.00	0.000	0.000
Chlorothalonil	Fungicide	0.00036	0.05	6.67E-06	0.019	0.000	0E.00	0.000	0.000
Clopyralid	Herbicide	3.05	1.8	1.17E-06	0.000	0.000	0E.00	0.000	0.000
Dicamba	Herbicide	0.0061	0.1	7.87E-07	0.000	0.000	0E.00	0.000	0.000
Dithiopyr	Herbicide	0.002	0.0001	3.94E-06	0.002	0.039	0E.00	0.000	0.000
Endothal	Herbicide	0.005	0.13	9.75E-08	0.000	0.000	0E.00	0.000	0.000
Fosetyl-Aluminium	Fungicide	0.499	0.0001	3.71E-06	0.000	0.037	0E.00	0.000	0.000
Glyphosate	Herbicide	0.37	1	2.06E-05	0.000	0.000	0E.00	0.000	0.000
Iodosulfuron-Methyl-Sodium	Herbicide	0.000083	0.0001	8.71E-08	0.001	0.001	0E.00	0.000	0.000
Iprodione	Fungicide	0.013	0.1	1.67E-06	0.000	0.000	0E.00	0.000	0.000
Mancozeb	Fungicide	0.0023	0.009	6.76E-06	0.003	0.001	0E.00	0.000	0.000
MCPA	Herbicide	0.0014	0.04	8.71E-06	0.006	0.000	0E.00	0.000	0.000
Mecoprop	Herbicide	0.5147	0.01	6.61E-06	0.000	0.001	0E.00	0.000	0.000
Metalaxyl-M	Fungicide	0.031	0.0001	3.11E-07	0.000	0.003	0E.00	0.000	0.000
Oryzalin	Herbicide	0.4	0.4	9.37E-06	0.000	0.000	0E.00	0.000	0.000
Oxadiazon	Herbicide	0.00078	0.0001	1.23E-06	0.002	0.012	0E.00	0.000	0.000
Paclobutrazol	Plant Growth Regulator	0.273234	0.0001	2.08E-07	0.000	0.002	0E.00	0.000	0.000
Pendimethalin	Herbicide	0.00054	0.4	6.96E-06	0.013	0.000	0E.00	0.000	0.000
Propamocarb-Hydrochloride	Fungicide	9.9	0.0001	1.45E-06	0.000	0.014	0E.00	0.000	0.000
Propiconazole	Fungicide	0.00008	0.1	5.74E-07	0.007	0.000	0E.00	0.000	0.000
Propyzamide	Herbicide	0.0287	0.03	2.81E-06	0.000	0.000	0E.00	0.000	0.000
Pyraclostrobin	Fungicide	0.0006	0.0001	2.27E-07	0.000	0.002	0E.00	0.000	0.000
Quinclorac	Herbicide	0.05	0.0001	3.87E-06	0.000	0.039	0E.00	0.000	0.000
Rimsulfuron	Herbicide	0.00116	0.0001	1.41E-07	0.000	0.001	0E.00	0.000	0.000
Siduron	Herbicide	0.013	0.0001	9.26E-06	0.001	0.093	0E.00	0.000	0.000
Tebuconazole	Fungicide	0.01515	0.0001	2.22E-07	0.000	0.002	0E.00	0.000	0.000
Thiamethoxam	Insecticide	0.0967	0.0001	9.26E-08	0.000	0.001	0E.00	0.000	0.000
Triadimenol	Fungicide	0.25	0.0001	5.56E-07	0.000	0.006	0E.00	0.000	0.000
Trifloxystrobin	Fungicide	0.0011	0.0001	1.11E-07	0.000	0.001	0E.00	0.000	0.000
Trifloxysulfuron Sodium	Herbicide	0.000055	0.0001	1.41E-07	0.003	0.001	0E.00	0.000	0.000
Trinexapac-Ethyl	Plant Growth Regulator	0.019	0.0001	4.43E-06	0.000	0.044	0E.00	0.000	0.000

2.7.9. Solute transport

Modelling indicates that based on the assumed initial losses (as specified in Table 2-8) no pesticide residues are predicted to occur in the outflows (Table 2-25, Table 2-26). The most significant factors contributing to this result are:

- The water holding capacity (WHC) of the soil and the modelled initial losses
- limited concentrations are applied
- pesticide is applied to small areas only, e.g. greens
- the potential for wash-off is very low (due to chemical attributes or due to organic carbon source or runoff depth of that surface)

Sensitivity analyses showed that the factor of greatest importance in determining the PECs that could be influenced by course management is the initial loss. When initial losses were reduced to 80% of the values shown in Table 2-8, PECs were still zero, but when this factor was reduced to 60% some PECs exceeded the adopted targets. Consequently, it is important that the EGC Operations Management Plan specifies an appropriate withholding period of no rainfall prior to pesticide applications. This will ensure initial losses are always consistent with their modelled level as listed in Table 2-8 (i.e. at 100%). A method for determining the appropriate holding period is given in Appendix 5 of this report.

2.7.9.1. Wetland buffers and treatments

As a further management control, the Eastern Golf Course will institute buffers with an average width of 15 m around the wetlands draining through to Pond A and ultimately to the Yarra River (see Appendix 6). There will be no pesticide usage within these buffer areas except for limited spot use of herbicides to control excessive weed growth. In addition, where topography requires some reduction of the 15 m buffer width, additional controls are planned that will direct surface drainage away from the wetlands to holding areas that allow treatment, or through swales that will slow the runoff down by holding as it slowly permeates through the ephemeral plantings into the wetland, thus providing additional filtering.

2.7.9.2. Oxadiazon

Oxadiazon is only used during turf establishment and therefore the risk of wash-off is far less than other pesticides. However, weather forecasting prior to application is warranted for the sensitive catchments. Due to long half-life of Oxadiazon, as an extra precaution, the three holes closest to the Yarra River, holes 14, 15, 16, 17, are to be excluded from application of the herbicide. For these holes different (and more expensive) physical disruption technique (“sodding”) that does not involve the use of Oxadiazon will be used to control the target weeds.

Table 2-25. PECs for Pond A for the modelled 5 yr 15 minute (13.72 mm) rainfall event for three scenarios of initial losses. 100% initial losses shows the PEC assuming initial loss as in Table 2-8. Subsequent scenarios assume these initial losses are reduced by 80% and 60% respectively. Values other than zero are underlined for ease of reference. Max and Ave PEC = maximum and average PEC respectively. PECs shown consist of soluble + particulate + steady state background (of soluble + particulate) transport pathways.

Label active ingredient name	100% Initial losses		80% Initial losses		60% Initial losses	
	Max PEC mg/L	Ave PEC mg/L	Max PEC mg/L	Ave PEC mg/L	Max PEC mg/L	Ave PEC mg/L
2,4-D	0.0000	0.0000	0.0000	0.0000	0.0035	0.0023
Abamectin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Azoxystrobin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bensulide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bromoxynil	0.0000	0.0000	0.0000	0.0000	0.0032	0.0021
Chlorantraniliprole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chlorothalonil	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clopyralid	0.0000	0.0000	0.0000	0.0000	0.0041	0.0027
Dicamba	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dithiopyr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Endothal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fosetyl-Aluminium	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Glyphosate	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Iodosulfuron-Methyl-Sodium	0.0000	0.0000	0.0000	0.0000	0.00006	0.000040
Iprodione	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mancozeb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MCPA (500g/ha)	0.0000	0.0000	0.0000	0.0000	0.0084	0.0055
MCPA (1500g/ha)	0.0000	0.0000	0.0000	0.0000	0.0253	0.0169
Mecoprop	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Metalaxyl-M	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oryzalin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxadiazon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Paclobutrazol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pendimethalin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propamocarb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propiconazole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propyzamide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pyraclostrobin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Quinclorac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rimsulfuron	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Siduron	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Tebuconazole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Thiamethoxam	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Triadimenol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Trifloxystrobin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Trifloxysulfuron sodium	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Trinexapac-Ethyl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2-26. Hazard Quotients for Pond A for the modelled 5 yr 15 minute (13.72 mm) rainfall event for three scenarios of initial losses. 100% initial losses shows the PEC assuming initial loss as in Table 2 8. Subsequent scenarios assume these initial losses are reduced by 80% and 60% respectively. Max and Ave PEC = maximum and average PEC use for environmental and drinking water compliance assessment respectively. HQ_{ENV} *= environmental hazard quotient,* HQ_{DW} *= drinking water hazard quotient. The target HQs for this study are* $HQ_{ENV} <= 0.5$ *and* $HQ_{DW} <= 0.1$*. Green cells = HQ < target, yellow cells > 10% and < 100% of target, red cells = HQ > target.*

Label active ingredient name	100% Initial losses		80% Initial losses		60% Initial losses	
	HQ_E	HQ_{DW}	HQ_E	HQ_{DW}	HQ_E	HQ_{DW}
2,4-D	0.00	0.00	0.00	0.00	0.025	0.017
Abamectin	0.00	0.00	0.00	0.00	0.00	0.00
Azoxystrobin	0.00	0.00	0.00	0.00	0.00	0.00
Bensulide	0.00	0.00	0.00	0.00	0.00	0.00
Bromoxynil	0.00	0.00	0.00	0.00	0.32	0.21
Chlorantraniliprole	0.00	0.00	0.00	0.00	0.00	0.00
Chlorothalonil	0.00	0.00	0.00	0.00	0.00	0.00
Clopyralid	0.00	0.00	0.00	0.00	0.0014	0.0009
Dicamba	0.00	0.00	0.00	0.00	0.00	0.00
Dithiopyr	0.00	0.00	0.00	0.00	0.00	0.00
Endothal	0.00	0.00	0.00	0.00	0.00	0.00
Fosetyl-Aluminium	0.00	0.00	0.00	0.00	0.00	0.00
Glyphosate	0.00	0.00	0.00	0.00	0.00	0.00
Iodosulfuron-Methyl-Sodium	0.00	0.00	0.00	0.00	0.74	0.48
Iprodione	0.00	0.00	0.00	0.00	0.00	0.00
Mancozeb	0.00	0.00	0.00	0.00	0.00	0.00
MCPA (500g/ha)	0.00	0.00	0.00	0.00	6.0	3.9
MCPA (1500g/ha)	0.00	0.00	0.00	0.00	18.1	12.1
Mecoprop	0.00	0.00	0.00	0.00	0.00	0.00
Metalaxyl-M	0.00	0.00	0.00	0.00	0.00	0.00
Oryzalin	0.00	0.00	0.00	0.00	0.00	0.00
Oxadiazon	0.00	0.00	0.00	0.00	0.00	0.00
Paclobutrazol	0.00	0.00	0.00	0.00	0.00	0.00
Pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00
Propamocarb	0.00	0.00	0.00	0.00	0.00	0.00
Propiconazole	0.00	0.00	0.00	0.00	0.00	0.00
Propyzamide	0.00	0.00	0.00	0.00	0.00	0.00
Pyraclostrobin	0.00	0.00	0.00	0.00	0.00	0.00
Quinclorac	0.00	0.00	0.00	0.00	0.00	0.00
Rimsulfuron	0.00	0.00	0.00	0.00	0.00	0.00
Siduron	0.00	0.00	0.00	0.00	0.00	0.00
Tebuconazole	0.00	0.00	0.00	0.00	0.00	0.00
Thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00
Triadimenol	0.00	0.00	0.00	0.00	0.00	0.00
Trifloxystrobin	0.00	0.00	0.00	0.00	0.00	0.00
Trifloxysulfuron sodium	0.00	0.00	0.00	0.00	0.00	0.00
Trinexapac-Ethyl	0.00	0.00	0.00	0.00	0.00	0.00

2.8. Groundwater

2.8.1. Assessment of likely fate of pesticide residues in groundwater

2.8.1.1. Overview

Pesticides entering groundwater may be transported eventually to the Yarra River consistent with the general groundwater flows in the area. The groundwater flows are very low compared to surface water. It is also a more consistent flow rather lacking the peaks and troughs that occur in surface water flows. The pesticide risk assessment predicted peak and average concentrations in the stormwater outflows to the river during a high rainfall event. This load is expected to be orders of magnitude higher than potential groundwater sources.

The vertical depth of the unsaturated zone is generally > 3 m in the golf course region and the average horizontal distance to water is 100s of metres. The subsurface is mostly fine-grained silts and clays (Douglas Partners 2009) so very slow flow rates can be expected. Flow rates are explored further below.

2.8.1.2. Analysis of groundwater flow rates and effects of irrigation

The groundwater contour plan indicates that groundwater flow beneath the site is from the southeast and flows in a north-westerly direction towards the flood plain area in the northern portion of the site and also in a westerly direction towards the Yarra River (Douglas Partners 2009). Groundwater appears to be at a consistent level of approximately 60 m AHD for wells GW1, GW2, GW4 and GW5 located within the flood plain. From the flood plain, groundwater appears to be flowing in a westerly direction towards the Yarra River (Douglas Partners 2009).

The bores closest to the river are GW5, GW8 and GW10. Douglas Partners found GW10 to be dry due to the presence of a siltstone layer suggesting there is little if any groundwater flow to the river in this area. Therefore the bores in the areas of highest risk for contaminant transport are bores GW5 and GW8. The golf course holes nearest these bores are 14, 15, 16 and 17 (GW5) and 3, 4 and 8 (GW8). The course fairways are generally located at an angle of 45° degrees or less to the river. In fact most are perpendicular to the direction of river flow so that one end is perhaps within 50 m of the river the other end some 100s of metres away.

Groundwater flow rates can be estimated from Darcy's Law. Since Darcy's Law includes the parameter Δh (= depth to groundwater) which could conceivably be influenced by leaching from irrigation, then it is possible for irrigation to change the flow rate. Darcy's law is:

$$V = \frac{K_{sat}\left(\Delta h/_{L}\right)}{\eta}$$

The Darcy's Law parameters and their values for the EGC are V = water flow velocity in m/s, K_{sat} = hydraulic conductivity in m/s (10^{-6} m/s), Δh = depth to groundwater (1.48 m), L = distance travelled (100 m) and η = porosity (0.1). Values for K_{sat} for silts and clays were obtained from Freeze and Cherry (1979) as was η.

Bores GW5 and GW8 are about equal distance to the river and bore GW5 was selected to determine flow times. In considering irrigation effects from the whole of the course, it is important to consider the flow gradient to GW% and to the river beyond and then to consider the effects on such gradients caused by irrigation leaching (Figure 2-9).

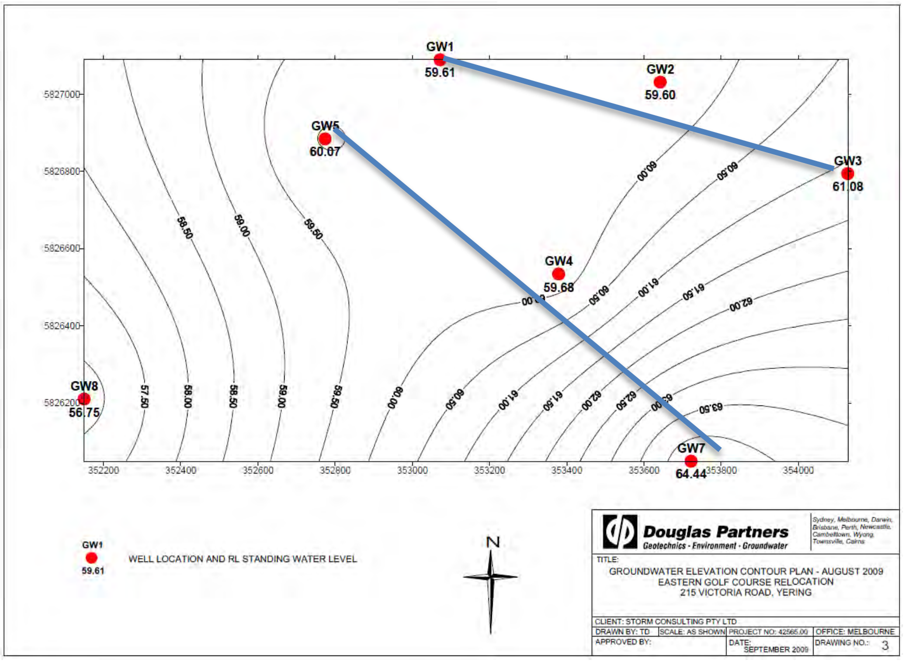

Figure 2-9. Groundwater elevation contour plan (Douglas Partners 2009) and gradient measurement lines

Calculations for the groundwater gradients shown in Figure 2-9 above are:

> *Distance: GW5 – GW7 = 1300 m*
>
> *Head: 60.07 – 64.44 = 4.37*
>
> *Gradient = 0.003361*
>
> *From Darcy's Law, Flow velocity = (10^{-6} x 0.003361)/0.1= 3.361 x 10^{-8}m/s = 2.90 mm/day*
>
> *Distance: GW1 – GW3 = 1200 m*
>
> *Head: 59.61 – 61.08 = 1.47*
>
> *Gradient = 0.001225*
>
> *From Darcy's Law, Flow velocity = (10^{-6} x 0.001225)/0.1 = 1.225 x 10^{-8} m/s = 1.06 mm/day*

Using these flow rate and gradient calculations to assess the time taken for groundwater to travel 100 m to the Yarra River from the vicinity of GW5 gives a range of 94.3 to 258.8 years. These flow rates are very slow and the effect of leaching from irrigation (see following section) would need to be quite strong to increase the hydraulic head enough to significantly increase the flow velocities.

Furthermore, such long flow times are much greater than 10 half-lives for all the pesticides proposed for use at the course. Although pesticide biodegradation in the saturated zones may be reduced as these areas may be anaerobic, the long travel times are expected to still provide a significant opportunity for anaerobic biodegradation to achieve satisfactory removal rates.

3 Discussion

The pesticide modelling described in this report has identified appropriate guidelines for protection of aquatic life in the Yarra River and drinking water customers supplied by water drawn from river. Using a quantitative model of pesticide behaviour when applied to golf course turfs combined with stormwater hydrology, the modelling has provided predictions of environmental concentrations of pesticides dissolved in stormwater runoff from the course. In addition, simple and conservative modelling of pesticides transported bound to particulate organic matter has provided predictions of environmental concentrations of pesticides occurring via this pathway.

The modelling has shown that under proposed usage, the pesticides readily comply with the guidelines (either ANZECC guidelines, derived environmental guidelines using the Canadian approach, or Australian, WHO or EU drinking water guidelines). The pesticides proposed for use and the application controls described can be considered for inclusion on planning controls for the golf course. However, in each case and in the case of new pesticide products, it is recommended that the application of such products be demonstrated to comply with the guidelines using the modelling approaches described in the study.

More explicitly, as long as the predicted Hazard Quotient does not exceed 0.5 for the protection of aquatic life for the design storm event, then the pesticide can be considered safe for use at the modelled application rates and locations. Similarly, if the drinking water HQ is predicted to be less than 0.1 for the same event, the pesticide is safe for use (note that the modelling undertaken for this study predicts zero transport). As a further assurance, monitoring of stormwater quality entering and discharging from the golf course (described below) can be used to refine and further calibrate the model in the future.

3.1. Risk management at the EGC

This risk assessment has focussed on the routine use of pesticides for the management of the Eastern Golf Club. The risk from accidental spillages is not addressed by quantitative risk analysis, since such events are expected to be controlled by the Golf Course Management system. A brief outline of such a system is described below.

3.1.1. Best practice management of pesticides on golf courses

The EGC will develop a Course Maintenance Environmental Management System which will implement best practices to ensure course maintenance activities achieve the following goals:

- Minimisation of the risk to human health and the environment;
- Utilisation of site specific information to determine appropriate pest management decisions;
- Control under documented Standards of Procedure; and
- Monitoring for continual performance improvement.

Risk management framework

The EGC Environmental Management System will include a register of hazardous events with scores for each event for likelihood and consequence (likelihood x consequence = risk). This could be done as raw risk and residual risk after the application of an appropriate control measure. Application of control measures should ensure that the residual risk is in the low category. This approach would also accord with the Australian Drinking Water Guidelines risk management framework and is similar to the Hazard Analysis at Critical Control Points (HACCP) plans that many Victorian water authorities use for water safety management for drinking water and recycled water.

Risk management methods and practices

In controlling weeds, insect pests and disease, and maintaining turf surfaces, the EGC will make use of management practices incorporating biological, behavioural, chemical, manual and mechanical methods. Under such programs, chemicals will represent one of a range of tools to be used to prevent or remedy unacceptable pest damage.

As part of Eastern Golf Club's overall risk management, risks associated with chemical use will be identified at each stage of the pesticide management process from ordering through to disposal of residual material and record keeping. Management strategies including Standard Operating Procedures (SOPs) will be set in place for:

- Ordering
- Delivery
- Storage
- Inventory
- Mixing
- Dispensing and spray drift management
- Spill management and response
- Equipment management
- Pesticide use record keeping
- Equipment management

Supporting each component involved with the use of pesticides there will be:

(i). Materials Safety Data Sheets (MSDS) records available to all staff and visitors to the site;

(ii). A high level of training and competence of staff; and

(iii). Integrated Pest Management strategies used to minimise pesticide use.

The EGC acknowledge that when managing spills and storage issues and infrastructure environmental legislation, the dangerous goods legislation and the OHS legislation must be considered. This involves issues like separation distances, segregation, ventilation, ignition sources, on site protected works, primary and secondary containment, spill recovery, security, warning systems, ingress and egress, vapour zones. These issues are spread across more than just the environmental legislation. Therefore, EGC will seek to appoint an accredited dangerous goods officer with appropriate experience dealing with the above issues and developing infrastructure solutions that comply fully with the environmental legislation, the dangerous goods legislation and OHS legislation.

Through its Course Maintenance Environmental Management System the EGC will also minimise pesticide use and continually improve management of rates and frequencies of application, and ensure environmentally hazardous and persistent pesticides are avoided as specified in the Victorian Government Guidelines for Planning permit applications in open, potable water supply catchment areas (Victorian Government Department of Planning and Community Development Melbourne 2009). As part of the process EGC will identify the objectives for chemical use at the golf course, be specific about typical issues that can require pesticide application and corresponding best management practices (BMPs). If BMPs exist that avoid pesticide application in the first place, then they will be adopted.

Auditing

The Course Maintenance Environmental Management System Specify will include an Auditing Schedule for audits of the system and the EGC's compliance with environmental requirements including pesticide risk management. Copies of audit reports would be supplied to relevant referral authorities on request.

Pesticide monitoring and management details

The recommendations of the EGC Environmental Improvement Plan (Storm Consulting 2011) will be revised in the Course Maintenance Management System to cover each of the management strategies described above. With respect to pesticide use record keeping, monitoring of stormwater discharge quality entering and leaving the course should be conducted during the establishment and normal operations phase of the golf course. Monitoring should be conducted for all pesticides used on the course in the prior 3 month period (grab samples of peak flows should be sufficient). Monitoring data can be used to further calibrate the STORM Pesticide Model described earlier in this report. Once compliance can be demonstrated by monitoring under a particular pesticide application regime, no further monitoring should be required unless a different regime involving application of greater quantities of a particular pesticide (i.e. higher application rates, wider application or both) is proposed.

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Appendix 1 US EPA ECOTOX database

US EPA Ecotox database Data Limitations

Table A1: Restrictions placed on ECOTOX data. Data not satisfying these requirements are excluded from the ECOTOX databases:

Criteria	Requirement/Inclusions	Limitations/Exclusions
Chemical	• Single chemicals relevant to environmental exposure are included. • Verifiable Chemical Abstract Services (CAS) number	• Mixtures (petroleum fuels) • Air pollution (CO_2, ozone)
Species	• Ecologically relevant species • Priority species are wild (test results for terrestrial domestic and laboratory species are used to fill data gaps when needed) • Organism taxonomic information verifiable against standard taxonomic sources	• Human, monkey, bacteria, viral and yeast
Effect/ Response	• Biological effect on live, whole organisms • Adverse effects are priority (beneficial, nutritional effects are lower priority)	• Dead organisms • In Vitro
Concentration/ Dose	• Concurrent environmental chemical concentration/dose reported as concentration, dose or application rate • Sediment studies must have a water concentration reported to be included	• Inhalation studies route (including intratracheal instillation) • Sediment only concentration • Lead shot • Unverified measurement unit • Log values
Exposure Duration	• Duration reports an associated concurrent with a biological effect	• Unverifiable duration
Publication /Data Format	• Primary data source • Full text English (some Non-English papers are encoded that have an English abstracts)	• Reviews • Full text foreign language • Abstract only format

Appendix 2. Derived short-term exposure guidelines for fish, amphibians, aquatic invertebrates and aquatic plants

Table 4-1. Short-term exposure guidelines for the protection of freshwater fish for pesticides proposed for use at the Eastern Golf Club. Guidelines have been derived using the Canadian Protocol for Guideline Derivation. n.g. = no guideline. ANZECC guidelines are included for reference where available (note these are based on long-term exposure).

Pesticide	Type	ANZECC Guideline mg/L	Lowest value LC_{50} mg/L	Source	Most sensitive fish species	No of observations in data-bases	Compliant with Canadian protocol B2 for fish?	Guideline value for Fish mg/L *
2,4-D	Herbicide	0.14	0.014	Ecotox	Nile Tilapia	197	n/a	0.14
Abamectin	Insecticide	n.g.	0.0036	PPDB	Rainbow Trout	1	No	0.00036
Azoxystrobin	Fungicide	n.g.	0.47	Ecotox	Rainbow Trout	3	Yes	0.047
Bensulide	Herbicide	n.g.	0.379	Ecotox	Channel Catfish	11	Yes	0.0379
Bromoxynil	Herbicide	0.01	0.042	Ecotox	Brown Bullhead	5	n/a	0.01
Chlorantraniliprole	Insecticide	n.g.	13.8	PPDB	Rainbow Trout	2	Yes	1.38
Chlorothalonil	Fungicide	n.g.	0.0082	Ecotox	Common Jollytail	63	Yes	0.00082
Clopyralid	Herbicide	n.g.	99.9	PPDB	Rainbow Trout	2	Yes	9.99
Dicamba	Herbicide	n.g.	20	Ecotox	Bluegill	23	Yes	2
Dithiopyr	Herbicide	n.g.	0.36	PPDB	Rainbow Trout	2	Yes	0.036
Endothal	Herbicide	n.g.	0.18	Ecotox	Cutthroat Trout	48	Yes	0.018
Fosetyl-Aluminium	Fungicide	n.g.	75.8	Ecotox	Rainbow Trout	4	Yes	7.58
Glyphosate	Herbicide	0.37	1.3	Ecotox	Rainbow Trout	203	n/a	0.37
Iodosulfuron-Methyl-Sodium	Herbicide	n.g.	100	PPDB	Bluegill	2	Yes	10
Iprodione	Fungicide	n.g.	3.06	Ecotox	Channel Catfish	6	Yes	0.306
Mancozeb	Fungicide	n.g.	0.074	PPDB	Rainbow Trout	29	Yes	0.0074
MCPA	Herbicide	0.0014	0.022	Ecotox	Nile Tilapia	22	n/a	0.0014
Mecoprop	Herbicide	n.g.	10	Ecotox	Rainbow Trout	8	Yes	1
Metalaxyl-M	Fungicide	n.g.	0.31	Ecotox	Bluegill	2	Yes	0.031
Oryzalin	Herbicide	0.4	2.46	PPDB	Rainbow Trout	3	n/a	0.4
Oxadiazon	Herbicide	n.g.	0.086	Ecotox	Mozambique Tilapia	14	Yes	0.0086
Paclobutrazol	Plant Growth Regulator	n.g.	16.2	Ecotox	Grass Carp, White Amur	5	Yes	1.62
Pendimethalin	Herbicide	n.g.	0.05	Ecotox	Rainbow Trout	12	Yes	0.005
Propamocarb-Hydrochloride	Fungicide	n.g.	99	PPDB	Rainbow Trout	1	No	9.9
Propiconazole	Fungicide	n.g.	0.83	Ecotox	Rainbow Trout	20	Yes	0.083
Propyzamide	Herbicide	n.g.	4.7	PPDB	Rainbow Trout	5	Yes	0.47
Pyraclostrobin	Fungicide	n.g.	0.006	PPDB	Rainbow Trout	2	Yes	0.0006
Quinclorac	Herbicide	n.g.	31.6	Ecotox	Bluegill	5	Yes	3.16
Rimsulfuron	Herbicide	n.g.	390	Ecotox	Bluegill	3	Yes	39
Siduron	Herbicide	n.g.	0.13	Ecotox	Bluegill	4	Yes	0.013
Tebuconazole	Fungicide	n.g.	4.4	Ecotox	Rainbow Trout	2	Yes	0.44
Thiamethoxam	Insecticide	n.g.	125	PPDB	Rainbow Trout	1	No	12.5
Triadimenol	Fungicide	n.g.	14	Ecotox	Rainbow Trout	5	Yes	1.4
Trifloxystrobin	Fungicide	n.g.	0.014	Ecotox	Rainbow Trout	3	Yes	0.0014

Pesticide	Type	ANZECC Guideline mg/L	Lowest value LC_{50} mg/L	Source	Most sensitive fish species	No of observa tions in data-bases	Compliant with Canadian protocol B2 for fish?	Guideline value for Fish mg/L *
Trifloxysulfuron Sodium	Herbicide	n.g.	103	PPDB	Rainbow Trout	2	Yes	10.3
Trinexapac-Ethyl	Plant Growth Regulator	n.g.	35	Ecotox	Channel Catfish	4	Yes	3.5

Table 4-2. Short-term exposure guidelines for the protection of freshwater invertebrates for pesticides proposed for use at the Eastern Golf Club. Guidelines have been derived using the Canadian Protocol for Guideline Derivation. n.g. = no guideline. ANZECC guidelines are included for reference where available (note these are based on long-term exposure)

Pesticide	Type	ANZECC Guideline mg/L	Lowest value LC_{50} or EC_{50} mg/L	Type	Source	Most sensitive Invertebrate species	No of observations in data-bases	Compliant with Canadian protocol B2 for Invertebrates?	Guideline value for Invertebrates mg/L *
2,4-D	Herbicide	0.14	1	LC_{50}	Ecotox	Water Flea	78	n/a	0.14
Abamectin	Insecticide	n.g.	0.00012	EC_{50}	PPDB	Common Water Flea	1	No	0.000012
Azoxystrobin	Fungicide	n.g.	0.055	LC_{50}	PPDB	Mysid shrimp	8	Yes	0.0055
Bensulide	Herbicide	n.g.	0.051	LC_{50}	PPDB	Mysid shrimp	4	Yes	0.0051
Bromoxynil	Herbicide	0.01	0.032	EC_{50}	Ecotox	Water Flea	2	n/a	0.01
Chlorantraniliprole	Insecticide	n.g.	0.0116	EC_{50}	PPDB	Large Water Flea	1	No	0.00116
Chlorothalonil	Fungicide	n.g.	0.0036	LC_{50}	Ecotox	Giant Tasmanian F/water Crayfish	26	Yes	0.00036
Clopyralid	Herbicide	n.g.	99	EC_{50}	PPDB	Large Water Flea	3	Yes	9.9
Dicamba	Herbicide	n.g.	3.9	LC_{50}	Ecotox	Scud Order	24	Yes	0.39
Dithiopyr	Herbicide	n.g.	0.47	LC_{50}	PPDB	Mysid shrimp	2	Yes	0.047
Endothal	Herbicide	n.g.	0.05	LC_{50}	Ecotox	Grass Shrimp, Freshwater Prawn	20	Yes	0.005
Fosetyl-Aluminium	Fungicide	n.g.	100	EC_{50}	PPDB	Large Water Flea	2	Yes	10
Glyphosate	Herbicide	0.37	2.95	EC_{50}	Ecotox	Water Flea	26	n/a	0.37
Iodosulfuron-Methyl-Sodium	Herbicide	n.g.	100	EC_{50}	PPDB	Large Water Flea	1	No	10
Iprodione	Fungicide	n.g.	0.36	EC_{50}	Ecotox	Water Flea	6	Yes	0.036
Mancozeb	Fungicide	n.g.	0.073	EC_{50}	PPDB	Large Water Flea	7	Yes	0.0073
MCPA	Herbicide	0.0014	11	LC_{50}	Ecotox	Water Flea	10	n/a	0.0014
Mecoprop	Herbicide	n.g.	100	EC_{50}	Ecotox	Water Flea	1	No	10
Metalaxyl-M	Fungicide	n.g.	41.9	LC_{50}	Ecotox	Water Flea	2	Yes	4.19
Oryzalin	Herbicide	0.4	0.19	LC_{50}	Ecotox	Scud	5	n/a	0.4
Oxadiazon	Herbicide	n.g.	0.23	LC_{50}	PPDB	Mysid shrimp	9	Yes	0.023
Paclobutrazol	Plant Growth Regulator	n.g.	12.8	LC_{50}	Ecotox	Oriental Mystery Snail	10	Yes	1.28
Pendimethalin	Herbicide	n.g.	0.28	EC_{50}	Ecotox	Water Flea	4	Yes	0.028
Propamocarb-Hydrochloride	Fungicide	n.g.	100	EC_{50}	PPDB	Large Water Flea	1	No	10
Propiconazole	Fungicide	n.g.	0.37	LC_{50}	PPDB	Mysid shrimp	12	Yes	0.037
Propyzamide	Herbicide	n.g.	3.9	LC_{50}	PPDB	Mysid shrimp	1	No	0.39
Pyraclostrobin	Fungicide	n.g.	0.016	EC_{50}	PPDB	Large Water Flea	1	No	0.0016
Quinclorac	Herbicide	n.g.	29.8	EC_{50}	Ecotox	Water Flea	1	No	2.98
Rimsulfuron	Herbicide	n.g.	110	LC_{50}	PPDB	Mysid shrimp	2	Yes	11
Siduron	Herbicide	n.g.	18	EC_{50}	PPDB	Large Water Flea	1	No	1.8
Tebuconazole	Fungicide	n.g.	0.46	LC_{50}	PPDB	Mysid shrimp	1	No	0.046
Thiamethoxam	Insecticide	n.g.	0.967	LC_{50}	Ecotox	Red Swamp Crayfish	1	No	0.0967
Triadimenol	Fungicide	n.g.	2.5	EC_{50}	Ecotox	Water Flea	1	No	0.25
Trifloxystrobin	Fungicide	n.g.	0.011	EC_{50}	PPDB	Large Water Flea	2	Yes	0.0011
Trifloxysulfuron Sodium	Herbicide	n.g.	108	EC_{50}	PPDB	Large Water Flea	1	No	10.8
Trinexapac-Ethyl	Plant Growth Regulator	n.g.	5.8	LC_{50}	PPDB	Mysid shrimp	1	No	0.58

Table 4-3. Short-term exposure guidelines for the protection of amphibians for pesticides proposed for use at the Eastern Golf Club. Guidelines have been derived using the Canadian Protocol for Guideline Derivation. n.g. = no guideline. ANZECC guidelines are included for reference where available (note these are based on long-term exposure). NIDB = not in database.

Pesticide	Type	ANZECC Guideline mg/L	Lowest value LC_{50} mg/L	Source	Most sensitive amphibian species	No of observations in databases	Compliant with Canadian protocol B2 for amphibians?	Factor of Safety - 1=ANZECC, 10 = amphibians LC50	Guideline value for Amphibians mg/L *
2,4-D	Herbicide	0.14	181	Ecotox	Leopard Frog	6	n/a	1	0.14
Abamectin	Insecticide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Azoxystrobin	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Bensulide	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Bromoxynil	Herbicide	0.01	NIDB	NIDB	NIDB	NIDB	n/a	1	0.01
Chlorantraniliprole	Insecticide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Chlorothalonil	Fungicide	n.g.	0.245	Ecotox	Bog Frog	1	No	10	0.0245
Clopyralid	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Dicamba	Herbicide	n.g.	106	Ecotox	Brown Striped Marsh Frog	6	Yes	10	10.6
Dithiopyr	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Endothal	Herbicide	n.g.	1.2	Ecotox	Fowler'S Toad	2	Yes	10	0.12
Fosetyl-Aluminium	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Glyphosate	Herbicide	0.37	38.9	Ecotox	Green Frog	10	n/a	1	0.37
Iodosulfuron-Methyl-Sodium	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Iprodione	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Mancozeb	Fungicide	n.g.	0.023	Ecotox	Green Frog	9	Yes	10	0.0023
MCPA	Herbicide	0.0014	10	Ecotox	Toad	1	n/a	1	0.0014
Mecoprop	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Metalaxyl-M	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Oryzalin	Herbicide	0.4	NIDB	NIDB	NIDB	NIDB	n/a	1	0.4
Oxadiazon	Herbicide	n.g.	1.3	Ecotox	Toad	4	Yes	10	0.13
Paclobutrazol	Plant Growth Regulator	n.g.	9.1	Ecotox	Common Or European Toad	8	Yes	10	0.91
Pendimethalin	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Propamocarb-Hydrochloride	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Propiconazole	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Propyzamide	Herbicide	n.g.	40	Ecotox	Toad	4	Yes	10	4
Pyraclostrobin	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Quinclorac	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Rimsulfuron	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Siduron	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Tebuconazole	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Thiamethoxam	Insecticide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Triadimenol	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Trifloxystrobin	Fungicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Trifloxysulfuron Sodium	Herbicide	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.
Trinexapac-Ethyl	Plant Growth Regulator	n.g.	NIDB	NIDB	NIDB	NIDB	No	10	n.g.

Table 4-4. Short-term exposure guidelines for the protection of freshwater aquatic plants for pesticides proposed for use at the Eastern Golf Club. Guidelines have been derived using the Canadian Protocol for Guideline Derivation. n.g. = no guideline. ANZECC guidelines are included for reference where available (note these are based on long-term exposure).

Pesticide	Type	ANZECC Guideline mg/L	Lowest value EC_{50} mg/L	Source	Most sensitive plant species	No of observations in databases	Compliant with Canadian protocol B2 for aquatic plants?	Factor of Safety - 1=ANZECC, 10 = plants	Guideline value for Aquatic Plants mg/L *
2,4-D	Herbicide	0.14	0.04	Ecotox	Eurasian Watermilfoil	61	n/a	1	0.14
Abamectin	Insecticide	n.g.	7.3096	PPDB	Inflated Duckweed	2	Yes	10	0.73096
Azoxystrobin	Fungicide	n.g.	0.049	Ecotox	Diatom	4	Yes	10	0.0049
Bensulide	Herbicide	n.g.	0.14	PPDB	Inflated Duckweed	11	Yes	10	0.014
Bromoxynil	Herbicide	0.01	0.051	PPDB	Inflated Duckweed	8	n/a	1	0.01
Chlorantraniliprole	Insecticide	n.g.	2	PPDB	Inflated Duckweed	1	No	10	0.2
Chlorothalonil	Fungicide	n.g.	0.0068	Ecotox	Green Algae	38	Yes	10	0.00068
Clopyralid	Herbicide	n.g.	30.5	PPDB	Green Algae	1	No	10	3.05
Dicamba	Herbicide	n.g.	0.061	Ecotox	Blue-Green Algae	7	Yes	10	0.0061
Dithiopyr	Herbicide	n.g.	0.02	Ecotox	Green Algae	1	No	10	0.002
Endothal	Herbicide	n.g.	50	PPDB	Green Algae	1	No	10	5
Fosetyl-Aluminium	Fungicide	n.g.	4.99	Ecotox	Green Algae	6	Yes	10	0.499
Glyphosate	Herbicide	0.37	1.6	Ecotox	Eurasian Watermilfoil	18	n/a	1	0.37
Iodosulfuron-Methyl-Sodium	Herbicide	n.g.	0.00083	PPDB	Inflated Duckweed	1	No	10	0.000083
Iprodione	Fungicide	n.g.	0.13	Ecotox	Green Algae	5	Yes	10	0.013
Mancozeb	Fungicide	n.g.	0.047	PPDB	Green Algae	9	Yes	10	0.0047
MCPA	Herbicide	0.0014	0.17	PPDB	Inflated Duckweed	8	n/a	1	0.0014
Mecoprop	Herbicide	n.g.	5.147	Ecotox	Duckweed	9	Yes	10	0.5147
Metalaxyl-M	Fungicide	n.g.	77.01	PPDB	Inflated Duckweed	1	No	10	7.701
Oryzalin	Herbicide	0.4	0.0154	Ecotox	Inflated Duckweed	4	n/a	1	0.4
Oxadiazon	Herbicide	n.g.	0.0078	Ecotox	Green Algae	4	Yes	10	0.00078
Paclobutrazol	Plant Growth Regulator	n.g.	2.73234	PPDB	Inflated Duckweed	8	Yes	10	0.273234
Pendimethalin	Herbicide	n.g.	0.0054	Ecotox	Green Algae	27	Yes	10	0.00054
Propamocarb-Hydrochloride	Fungicide	n.g.	301	PPDB	Inflated Duckweed	1	No	10	30.1
Propiconazole	Fungicide	n.g.	0.0008	Ecotox	Green Algae	18	Yes	10	0.00008
Propyzamide	Herbicide	n.g.	0.287	Ecotox	Green Algae	9	Yes	10	0.0287
Pyraclostrobin	Fungicide	n.g.	1.72	PPDB	Inflated Duckweed	1	No	10	0.172
Quinclorac	Herbicide	n.g.	0.5	Ecotox	Blue-Green Algae	9	Yes	10	0.05
Rimsulfuron	Herbicide	n.g.	0.0116	PPDB	Inflated Duckweed	4	Yes	10	0.00116
Siduron	Herbicide	n.g.	0.21	Ecotox	Green Algae	1	No	10	0.021
Tebuconazole	Fungicide	n.g.	0.1515	PPDB	Inflated Duckweed	4	Yes	10	0.01515
Thiamethoxam	Insecticide	n.g.	90	PPDB	Inflated Duckweed	1	No	10	9
Triadimenol	Fungicide	n.g.	3.2	Ecotox	Green Algae	1	No	10	0.32
Trifloxystrobin	Fungicide	n.g.	0.037	Ecotox	Green Algae	3	Yes	10	0.0037
Trifloxysulfuron Sodium	Herbicide	n.g.	0.00055	PPDB	Inflated Duckweed	1	No	10	0.000055
Trinexapac-Ethyl	Plant Growth Regulator	n.g.	0.19	Ecotox	Inflated Duckweed	4	Yes	10	0.019

Appendix 3 – Additional pesticide properties considered for Turf PQ.

Ionisable pesticides

Based on the acidity or basicity, the mobility of ionisable pesticides can be significantly affected by the pH of soil or thatch in a turf. TurfPQ does not discriminate between ionic or ionisable pesticides and therefore the effect of pH of the turf in not considered. The only way the user can potentially incorporate this aspect is by providing a locally measured K_{oc} value or at least database values adjusted based on pH of the system being assessed. This is important for two reasons: (i) the values of K_{oc} in literature are based on soil rather than turf and (ii) these values are not universal as they depend of pH of the soil and turf. However, it should be noted that not all ionisable pesticides are equally sensitive or need to be assessed this way. Only some of the commonly used pesticides in turf management have the pKa in the relevant pH range. Those among the 36 pesticides selected by Eastern Golf Course (EGC) are listed in Table 4-5 below. Other compounds have pKa values that are unlikely to be markedly influenced in the common pH range. In these cases (indicated with U in Table 4-5) an order of magnitude reduction in the K_{oc} was used to be precautionary. Golf course soil pH will be maintained between 6 and 7 and this should also minimise any ionisation of the pesticide identified.

Hydrophobic pesticides

Kramer *et al.* (2009) found that TurfPQ also underestimates the runoff of hydrophobic pesticides such as chlorpyrifos. This was in contrast to the observations by Haith (2001). Most hydrophobic pesticides are expected to have high sorption (K_{oc}) values in the database used in the model. Several compounds of the 36 commonly used pesticides in turf fall in the highly or moderately hydrophobic category (as listed in Table 4-5 below). The sorption K_{oc} value for most of these compounds is high enough in the databases and even if the sorption is somewhat adjusted, it is unlikely that prediction would be much different. However, for moderately and highly hydrophobic pesticides the transport pathway through colloids (pesticide attached to colloids) rather than dissolved phase is likely to be the main mechanism of runoff. This pathway is not taken into consideration in TurfPQ and is considered relatively low for golf course with effective water management strategies. The other reason for any underestimation of transport of such pesticides is through inaccurate estimation of amount of water running off (as discussed above) by choosing inappropriate curve number. The Eastern Golf Course Risk Assessment use pesticide sorption components of Turf PQ only and did not use the curve number components of Turf PQ as the hydrology of the proposed site was modelled by Storm Consulting.

Importance of metal ligands

Metal ligands are relevant to only very few pesticides and the role of such interactions for pesticide runoff is not well understood in literature. It is likely of minor importance only. Furthermore, this level of refinement in an assessment such as this based on TurfPQ is not warranted. There are other more important aspects (as mentioned above) that may be of greater significance (e.g. Organic Matter content, amount of runoff water, and ionisation in the range of soil or organic matter pH).

Table 4-5 Estimation of mobility of relevant pesticides from 36 selected for use by Eastern Golf Course Difference classes of compounds their potential responsiveness to changed prediction in TurfPQ.

Ionisable				Moderately hydrophobic		Highly hydrophobic	
Pesticides	Susceptibility to change in sorption	pKa	K_{OC}	Pesticide	Susceptibility to change in sorption	Pesticide	Susceptibility to change in sorption
Bromoxynil	Moderate (U)	3.86	302	Azoxystrobin	Moderate (O)	Abamectin	Low
Endothal	Moderate (U)	3.4,6.7	85	Chlorothalonil	Moderate (O)	Bensulide	Low
Iodosulfuron-methyl-sodium	Low	3.2	45	Iprodione	Moderate (O)	Chlorantranilipole	Moderate (O)
MCPA	Moderate (U)	3.7	257	Mancozeb	Low	Dithiopyr	High (O)
Mecoprop	Low	3.11	47	Oryzalin	Low	Oxidizon	Moderate (O)
Quinclorac	Low	4.34	50	Paclobutrazole	Moderate (O)	Pyclostrobin	Low
Rimsulfuron	Low	4.0	47	Propiconazole	Low	Pendimethalin	Low
Trifloxysulfuron sodium	High (U)	4.76	306	Propyazamide	Low	Tebuconzole	Low
Trinexapac-Ethyl	High (U)	4.57	280	Siduron	Low	Trifloxystrobin	Moderate (O)
Fosetyl aluminium	Moderate (U) – half-life of 0.1d negates this.	4.7	2217				

U – Sorption related underestimation (K_{oc} was adjusted by an order of magnitude – divided by 10 as a safety measure for these pesticides when modelled in TurfPQ), O- Sorption related overestimation

Appendix 4 – Guide and context to pesticide use at the Eastern Golf Course

Guide and context of pesticide use (illustration purposes only):

⇒ Different Actives have different chemical groupings thus their inclusion. Selection also depends on IPM strategy (i.e. purpose for use in the first place)

⇒ As a practical example of control, if DITHOPYR is used (pre-emergent herbicide for stopping Poa in Couch fairways), then RIMSULFURON would likely not be required (post-emergent herbicide for removing poa in couch fairways if it exists. Alternative, ORYZALIN would not be used and RIMSULFURON instead applied if Poa starts to show.

Broad Spectrum Fungicide (Greens)
Pyraclostrobin / Iprodione / Chlorathalonil / Propiconazole / Triadimenol
Azoxystrobin / Tebuconazole / Triloxystrobin / Mancozeb
Metalaxyl-M / Fosetyl

Insecticide (Fairways)
USED ONLY IF THERE IS MITES
Abamectin

Broadleaf Herbicide (Fairways)
2,4-D / Dicamba / Mecoprop / Clopyralid / MCPA / Bromoxynil

Pre-Emergent Herbicide (Fairways)
USE: Preventative meaning it can reduce or eliminate need for post-emergent herbicide use
Dithopyr / Pendimethalin / Oryzalin / Propyzamide

Insecticide (Greens)
USED ONLY IF EN's ARE NOT USED/AVAILABLE
Thiamethoxam / Chlorantraniliprole

Pre-Emergent Herbicide (Greens)
USE: Preventative meaning it can reduce or eliminate need for post-emergent herbicide use
Bensulide

Post-Emergent Herbicide (Fairways)
USE: Only if required (i.e. pre-emergent not effective)
Rimsulfuron / Trifloxysulfuron

Post-Emergent Fungicide (Greens)
USE: Only if Pythium (disease) exists
Propomocarb

Post-Emergent Herbicide (Greens)
USE: For removing Poa in Greens however we are proposing bent grass so this product would unlikely be required unless poa was evident.
Endothal

OTHER Actives and their particular use:

⇒ **OXADIAZON** is a one-off use Active and only on areas where solid turfing does not take place. It is proposed to solid turf the holes near the Yarra.

⇒ **GLYPHOSATE** is used broadly only prior to golf course being constructed. Once constructed it is only used for spot applications.

⇒ **QUINCLORAC** is only required to eradicate Kikuyu. We do not propose to have ANY Kikuyu on the golf course, but reality is if it exists on the land now, it may grow through over time in small areas. Thus it would never be broadly applied and if ever requiring use in the future would be spot applications.

⇒ **SIDURON** is only used for removing couch/kikuyu out of the bent grass greens. It is quite possible that we will sod these areas (cut solid turf out and replace with solid turf) if this ever occurred to minimise impact on golfers.

⇒ **IDOSULFURON METHYL SODIUM** is only used if Onion Grass exists. Again it would only be used where it exists not broadly sprayed over the site.

⇒ **TRINEXAPAC ETHYL** is a turf growth regulator for fairways and may not even need to be used. Similarly, **PACLOBUTRAZOL** is used to regulate Poa in Greens but we are proposing pure bent grass greens so again this would unlikely need to be used unless poa was evident.

Appendix 5 – Soil water holding capacities and infiltration rates

Infiltration rates of water into soil

The infiltration rate of water into soil is the velocity or speed at which water enters into the soil. It is usually measured by the depth (mm) of the water layer that can enter the soil in one hour. In dry soil, water infiltrates rapidly. This is called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate where saturated hydraulic conductivity can be measured. The initial infiltration rate is usually much greater than the steady state infiltration rate. The saturated hydraulic conductivity or steady state infiltration rate depends on soil texture (the size of the soil particles) and soil structure (the arrangement of the soil particles) and is a useful way of categorizing soils from an irrigation point of view. Soil saturated hydraulic conductivity varies between soil type, soil texture and soil structure. Soils can range between 1 to 150 mm/h (Brady and Weil 1999), however, agricultural soils usually range between 1 and 30 mm depending on the soil texture and soil structure (Table 1).

Table 1. Basic steady state infiltration rates for various soil types

Soil type	Basic steady state infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10-20
clay loam	5-10
clay	1-5

Source (Brouwer et al. 2008)

Soil water holding capacity

Soil water holding capacity can be used to describe several types of water held:

- Soil Water Holding Capacity (WHC) or field capacity is the total amount of water that the soil will hold after it has been saturated and allowed to drain by gravity, leaving a mix of organic material, mineral, water and air (Figure 1). Some of this water can be extracted by plants and some cannot due to tight physico-chemical binding to soil particles.
- Soil Available Water (SAW) is the water easily available for the plants to use.
- Saturated water content (SWC) occurs when all the air pores within soil are filled with water.
- Total porosity of the soil (Pore Volume or PV) is all the airspace within a soil, which usually ranges from 30 to 55% (Peverill et al. 1999; Hazelton and Murphy 2007). This is also very dependent of soil texture, clay type, bulk density and soil structure (Cotching 2011) (Figure 1). .
- Free draining pore volume (PVFD) is the pore space filled with air after removing the volume of water held (WHC) and the minerals in the total soil volume. This should be within the total porosity of the soil.

The WHC and SAW can be estimated by knowing the soil texture (Table 2). The pore volume can then be calculated and soil WHC volume calculated to estimate PVFD. The actual PVFD available for water to access when the soil is saturated will always be lower than the theoretical PVFD as some air will trapped in the soil and due to the variability in soil structure, organic matter and soil texture. Therefore, to be precautionary, 50% of the theoretical PVFD was used to estimate the volume that might be filled with rainfall or irrigation to saturate the soil profile. When the soil profile is completely saturated (all PV filled with water) surface runoff will occur.

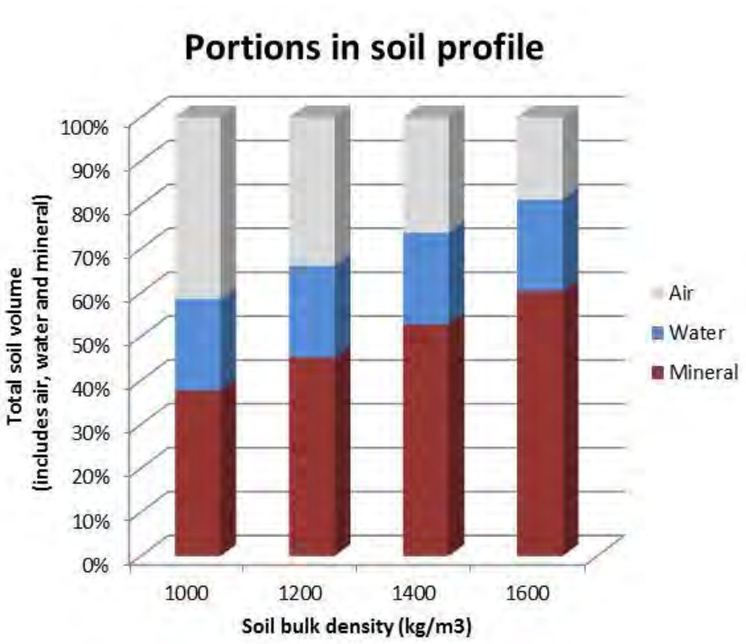


Figure 1. Comparison of soil bulk densities on mineral and air volumes in soil (note soil WHC is maintained at 63mm in 30 cm depth of soil)

It should also be noted that as soon as the WHC of the soil is exceeded in the root zone (30cm in this case) and water starts to fill the PVFD there is a possibility of vertical flow (deep-leaching) of water or horizontal flow (through-flow, e.g. sloped ground – Stevens *et al.,* 1999). Any deeper percolation down the soil profile (vertical flow) is usually governed by the saturated hydraulic conductivity of the most restrictive soil layer (this can range from 0.1 to to 150 mm/h depending on the soil/mineral material). Any through-flow (horizontally flow) is governed by the slope of the land and transmissivity of the soil horizons above the soil horizon that retards vertical flows.

Table 2. Estimates of soil water holding capacity and soil available water from soil texture

Soil texture	Field capacity or water holding capacity (WHC) (mm of water/30cm of soil depth)	Soil Available Water (SAW) (mm of water/30cm of soil depth)
Sand	30	18
Loamy sand	48	28
Sandy loam	**63**	**35**
Loam	80	45
Silt loam	90	45
Sandy clay loam	88	33
Sandy clay	85	40
Clay loam	95	43
Silty clay loam	108	48
Silty clay	120	60
Clay	120	55

Source (Handreck and Black 2002; Tanji et al. 2007)

Logic for rainfall that initially infiltrates

When completed, if the soils at the proposed EGC are a sandy loam for 30 cm, then there is approximately 35 mm (bolded in Table 2) of rain or irrigation that can be applied that will infiltrate into the soil before the free draining pore volume (PVFD) starts to fill. Filling of the PVFD leads to deep drainage or ultimately runoff. Irrigation practice usually operates within this range to ensure turfs have adequate supply of water for at least the next hot day (5-12 mm). If rainfall is forecast a good management practice would seek to deplete the SAW as low as possible without stressing the plant, or keeping a safety buffer to cover a day (i.e. 5-12mm) and allow the rainfall to replenish the soil store of SAW. This would be 23 to 30 mm rainfall as initial infiltration rate (>30mm/hr Hazelton and Murphy, 2007) soaking into the turfed area, prior to runoff commencing. Runoff will occur if the intensity of rainfall is greater than the saturated hydraulic conductivity rate (Table 1) or if very dry the rapid infiltration rate.

The above suggests that runoff from golf courses would be limited, other data supports this (Haith and Duffany 2007).

Volume of water held by the soil

This section provides the logic for estimating:

- the volume of water held in soil; and
- time post rainfall or irrigation, that provides a soil buffer that will have a relatively high chance of capturing a typical rainfall event and minimise runoff from that event (safe period before applying pesticides).

The volume of water infiltrated before runoff should consider the WHC and PVFD. The PVFD will usually drain vertically (deep drainage) and influence losses of SAW and the WHC for plant use much more quickly than evapotranspiration. Soil permeability usually ranges from 2.5 mm/h (poorly structure clay loam) to 150 mm/h or higher with some sands (Sand), unless there is a fairly impermeable subsurface layer (light, medium or heavy clay with sodic or poor structure). The subsoil at the proposed EGC site (potentially the most restrictive layer in terms of water permeability) is probably similar to reasonably structured light clay (Neylan 2010) which should have a permeability of 2.5 to 10 mm/h (Hazelton and Murphy, 2007 p. 13). On site measurement should confirm this when the EGC is constructed.

If a bulk density of 1.4 g/cm^3 is assumed (typical for most soils) and the WHC of a sandy loam assumed (63 mm in 30 cm soil – Table 2) then the available pore space (PVFD) is equivalent to 79 mm of rain in the top 30 cm of soil (47%). The critical rainfall event for pesticide runoff is 13.7 mm (as modelled for this study – see Section 2.7.6.1) and vertical water flow (deep drainage) has been assumed to be 4 mm/h. Therefore, it is estimated that it will take only 3.4 hours (13.7mm/4mm) to drain enough PVFD to allow the critical rainfall event with minimal runoff. However, in practice and to be conservative the following modification of the theoretical values were used to estimate the days from an irrigation event or rainfall required to ensure there was sufficient PVFD and/or SAW capacity available to store 13.7 mm of rainfall in the soil:

- 50% of PVFD was used, *i.e.* 39 mm of rainfall equivalent storage in PVFD
- 1 mm/h deep drainage was used (rather than the 4 mm/h shown in Table 2-8) for two reasons:
    - Free drainage from the soil does not have a constant hydraulic head like that that usually considered for rainfall. Darcy's Law indicates that over the 30 cm of soil depth the changes in hydraulic conductivity would be approximately 50% of the constant head hydraulic conductivity (Oosterbaan and Nijland 1994);
    - Information on measured deep drainage is limited at this stage and should be confirmed once the EGC is constructed.

It should be noted that the above assumptions are conservative.

The PVFD indicated there was sufficient PV to receive more the 13.7mm (39 mm equivalent). When the revised deep drainage rates (1.0 mm/h) and evapotranspiration rates from the Bureau of Meteorology are considered, the days required between a period of heavy rainfall or irrigation (assuming soils are saturated completely) before pesticides could be used are estimated to be approximately 0.5 days with no water applied to the soil. If soils are not saturated with the rain event these time frames could be less than this, especially in summer where the daily evaporation rates are higher (Table 3).

Table 3. Monthly variation in water loss from soil post saturation and days to achieve sufficient soil storage for a critical rainfall event[A]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evapotranspiration (ETo) (mm/day monthly average)											
4.8	4.5	3.3	2.1	1.3	0.9	1.0	1.4	2.1	3.0	3.9	4.5
Deep drainage (mm/day) at 1mm/h											
24											
Days to achieve 13.7 mm of storage in soil pore volume											
0.48	0.48	0.50	0.53	0.54	0.55	0.55	0.54	0.53	0.51	0.49	0.48

[A]A critical rainfall event with respect to pesticide runoff is 13.7 mm (Section 2.7.6.1)

Restricted Application Control

In Section 2.7.9, it is stated that

> *"sensitivity analyses showed that the factor of greatest importance in determining the PECs that could be influenced by course management is the initial loss. When initial losses were reduced to 80% of the values shown in Table 2-8, PECs were still zero, but when this factor was reduced to 60% some PECs exceeded the adopted targets. Consequently, it is important that the EGC Operations Management Plan specifies an appropriate withholding period of no rainfall prior to pesticide applications. This will ensure initial losses are always consistent with their modelled level as listed in Table 2-8 (i.e. at 100%)".*

To ensure chemicals used at the proposed EGC site are applied when the initial loss of soil water is greater than at least 80% of the value specified a period of time post rain/irrigation event is considered the best management approach. Instituting an appropriate holding period post rainfall will ensure the majority of rapidly available water storage space in the soil after a rainfall or irrigation event comes from deep drainage. Deep drainage makes soil water storage available rapidly from the soil free draining pore volume (PVFD), rather than the soil WHC and SAW. Soil moisture sensors are designed to monitor the SAW to indicate when irrigation is required and will probably be inadequate for assessing PVFD.

To consider water lost from both free draining rates and evapotranspiration rates separate equations were developed. These two equations were then combined into the one single model (equation) to be used as a management tool to determine the time required post rainfall before pesticides could be applied.

Two rainfall events (RF) were considered:

- Previous rainfall (PRF) which was assumed to saturate the soil (conservative in many cases) (mm)
- Recent rainfall (RRF) (mm)

Variables considered were:

- Evapotranspiration rates (ETo) (mm/hr – determined from average monthly evaporation rates divided by days in a month and hours in a day).
- Deep drainage (vertical) rates (mm/hr)
- Time from PRF (PRFh)

- Depth of PRF and RRF (mm)
- Hours of sunlight (SLh)
- Month of the year (1 to 12, starting at January =1)

By combining the two equations derived from Figure 2 and Figure 3 the final model was derived:

$$BPAh = 15 + (1 * PRFh) + \left\{1 * \left(RRF - \left(\left((0.0054 * mth^2) - (0.0713 * mth) + 0.2869\right) * SLh\right)\right)\right\}$$

Inputs required can be accessed easily from a weather station on site at the EGC and the inputs required are:

PRFh – time from previous rainfall (hr)
RRF – recent rainfall (mm)
mth - Month of the years (Jan =1)
SLh – Sunlight hours since the PRF event and prior to the RRF (hr)

Where:

BPAh = Hours Before Pesticide Application after a rainfall event. A minimum of 2 hours or as described on the pesticide application directions from manufacturer (if higher) should take priority on the BPAh.

The calculation considers the ETo on average in any month but only gives credit to the sunlight hours of ETo with the average daily ETo being distributed evenly across the 24 hours. This will therefore be a conservative estimate as ETo is much higher with heat via direct sunlight. The ET is the least variable of most climatic data and monthly averages were considered appropriate.

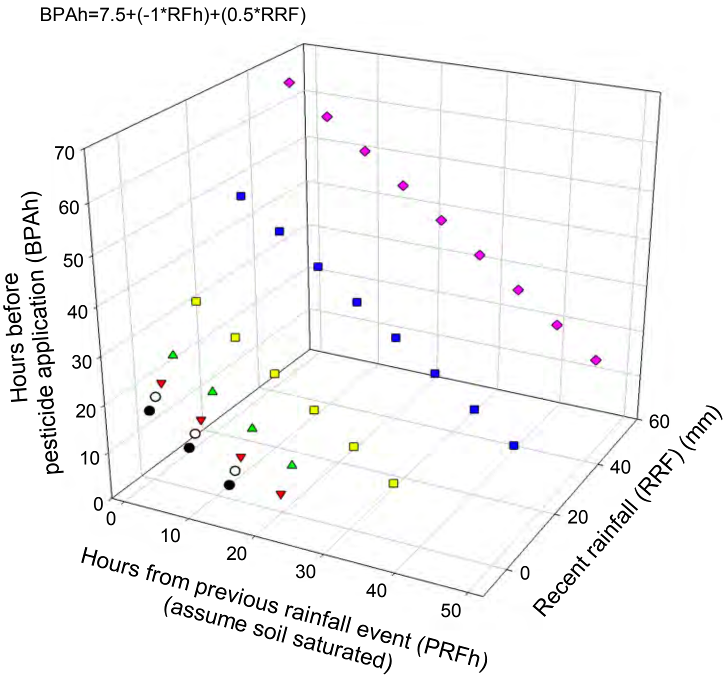


Figure 2. Impact of the time from previous rainfall event and previous rainfall on the time required before pesticide application for a critical rainfall event of 13.7 mm. This equation does not consider ETo.

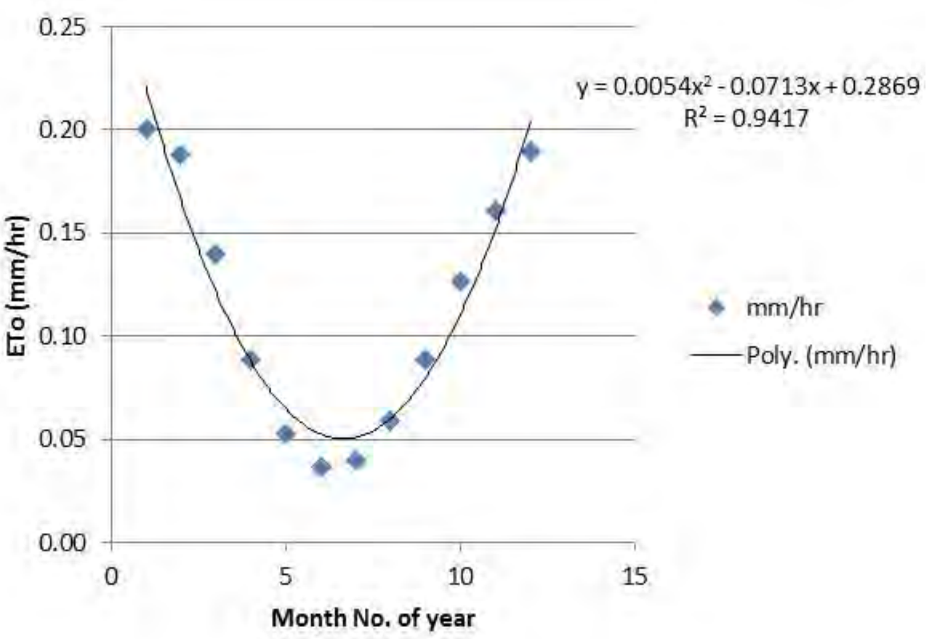


Figure 3. Relationship between the month number of the year (1 = January, 6 = June) and the average ETo for each month (x equals month of year and y = ETo). Poly = polynomial line fitted using the equation in the figure.

Appendix 6 – Wetland Buffer Planting and Treatment Types

The Eastern Golf Club
Wetland Buffer Planting

As a result of the Melbourne Water requiring buffer planting to all live wetlands within The Eastern Golf Club the project team analysed the design in detail and as a result set a goal of achieving an average of a 15m buffer planting to all live wetlands through the golf course. The area of this is in the vicinity of 115,500m2 and is based on the current design. It is highly likely that during detailed design of the golf course and wetlands that this buffer zone will be increased.

It must be noted that we have set the goal as an *average* of 15m. There are areas within the golf course where 15m is not achievable and would have major implications on the functionality of the golf course. We understand the importance of mitigating any adverse effects that fertilisers and pesticides would have on the wetlands, and would like to indicate that there are treatments to deal with these scenarios.

The golf course on a whole will be comprised of two main zones, In-Play – which is the maintained area of the golf course where there will be regular mowing and watering. The golf course will be implementing sound environmental practices which will include keeping the use of fertiliser and pesticides to a minimum. The Out of Play areas will be an unmaintained area of the golf course, save for weeding and other practical requirements. These areas will be comprised of indigenous vegetation mixes which will provide habitat for the native animals, birds and reptiles. These areas will significantly reduce the use of fertilisers and pesticides within the golf course, setting a benchmark for golf courses management within Australia.

The wetlands have been designed to include aquatic planting of appropriate native and indigenous species. These plant profiles will be informed by Melbourne Water guidelines.

The wetland buffer areas will be comprised of the 'Out of Play' grassland mix as well as ephemeral planting within the appropriate vicinity to the wetlands (as per Melbourne Water guidelines).

In summary, the project team are commited to achieving a minimum of 115,500m2 of buffer planting to all live wetlands within the Eastern Golf Course. The style of golf course we are proposing will significantly improve water quality and bio-diversity within the area.

Treatment Types

There are several proposed treatment / buffer areas between the *'In Play'* turf managed golf course and the wetland (NWL) edge.

Typical Treatment: 15m+ vegetated buffer planting
Where there is sufficient space there will be at least a 15m buffer zone to all wetland areas. In some cases this will be up to and above 30m. As mentioned earlier these will be comprised of indigenous vegetation species and ephemeral plants.

Typical Treatment: Vegetated swale
Where there is not sufficient space for the 15m we will investigate bio-retention swales. The swales will catch any runoff from the 'In Play' areas of the golf course and slow it down by holding as it slowly permeates through the ephemeral planting into the wetland, thus providing additional filtering of the runoff.

Typical Treatment: Hard Edge
There will be the rare occasion where we are proposing a hard edge to a wetland (less than 5% of interface) where an additional treatment is required. In this instance runoff from the 'In Play' area of the golf course and the water's edge will drain towards a small grassed swale (with drainage) that will direct it into a buffer area for treatment before it drains into a wetland.

Typical Treatment: Collection between holes
An additional treatment which will be implemented throughout the golf course is incorporated into the 'Out of Play' areas of the golf course. This treatment take the runoff from the 'In Play' areas of the golf course into the 'Out of Play' areas which act as large vegetated swales filtering out any contaminants before reaching the wetland.

'Out of Play' treatment at The Vintage, Hunter Valley, NSW
This type of 'non-turf managed' edge is proposed as a wetland buffer in some areas.

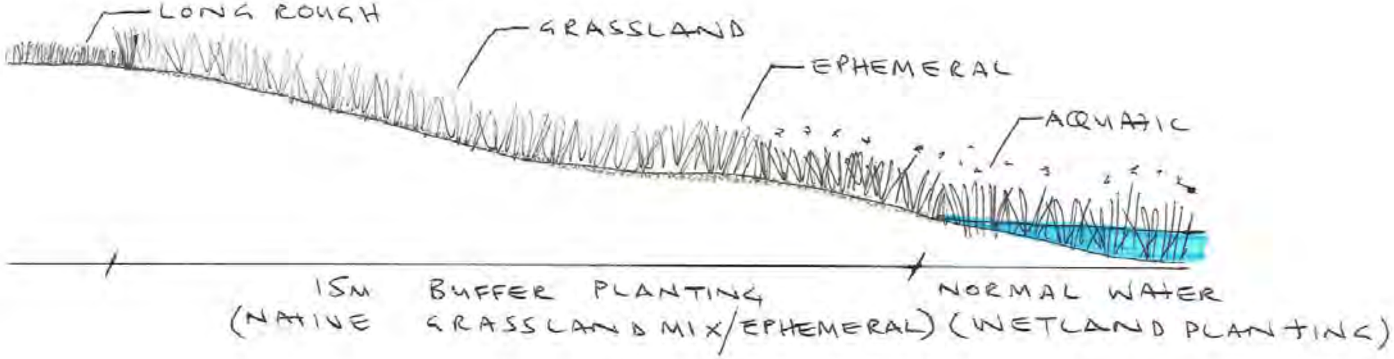
'Out of Play' treatment at Henley Golf Course, Yarra Valley, Victoria
Non-turf managed areas

The Eastern Golf Club

Wetland Buffer Planting: Treatment Types

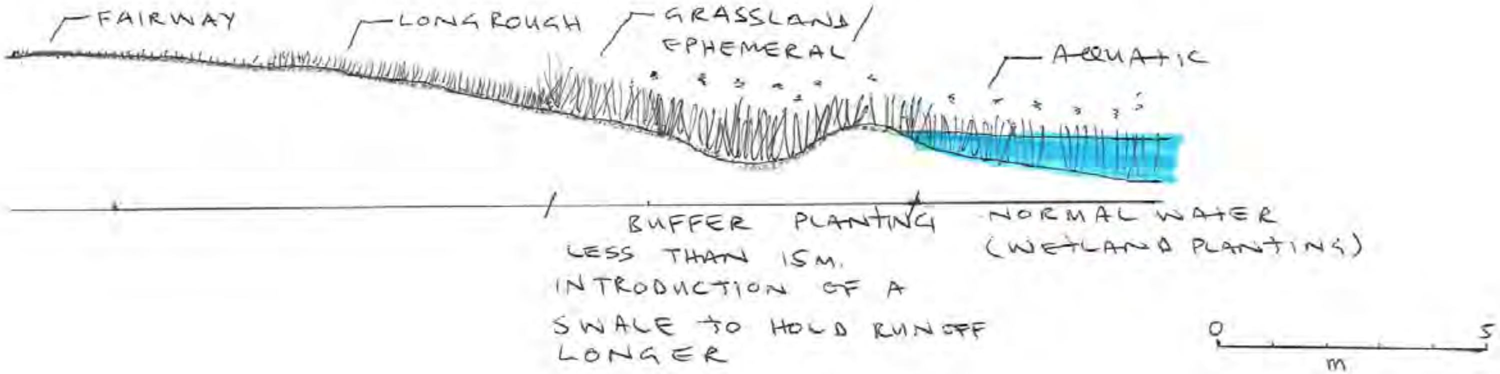
Typical Treatment: 15m+ vegetated buffer planting

Where there is sufficient space there will be at least a 15m buffer zone to all wetland areas. A mentioned earlier these will be comprised of indigenous grass species and ephemeral plants.



Typical Treatment: Vegetated swale

Where there is not sufficient space for the 15m we will be implementing bio-retention swales. The swales will catch any runoff from the 'In Play' areas of the golf course and slow it down by holding as it slowly permeates through the ephemeral planting into the wetland, thus providing additional filtering of the runoff.



town planners, urban designers & landscape architects

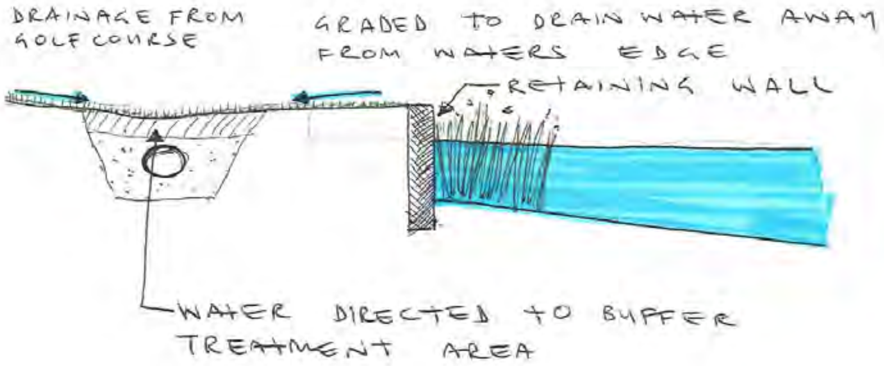
Tract

The Eastern Golf Club

Wetland Buffer Planting: Treatment Types

Typical Treatment: Hard Edge

There will be the rare occasion where we are proposing a hard edge to a wetland (for a very limited area) where an additional treatment is required. In this instance runoff from the 'In Play' area of the golf course and the water's edge will drain towards a small grassed swale (with drainage) that will direct it into a buffer area for treatment before it drains into a wetland.



Typical Treatment: Collection between holes

An additional treatment which will be implemented throughout the golf course is incorporated into the 'Out of Play' areas of the golf course. This treatment take the runoff from the 'In Play' areas of the golf course into the 'Out of Play' areas which act as large vegetated swales filtering out any contaminants before reaching the wetland.

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Current Wetland Buffer Diagram