SUSTAINABLE WATER OPTIONS FOR SPORTSFIELDS

Final Report

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July 2011

Executive Summary

This document provides a summary of the work performed under the Smart Water Funded project, Sustainable Water Options for Sports Fields. This project was developed during a period of water restrictions and was tasked with:

- Identifying the socioeconomic impacts of water restrictions on sports fields, with a focus towards identifying a social value for sports fields.
- Providing a detailed information package to guide decision makers in the water industry and local government with respect to changes to fields and their irrigation that could improve their sustainability and ensure their continued use in periods of water shortage.
- Developing a model, packaged in a piece of software that can be used to identify water and nutrient demand and how these may change with irrigation using alternative water sources.

The project has resulted in the publication of three documents and one piece of software that are summarised by this report. Each of these, along with this report, should be available through the Smart Water Fund.

The socioeconomic impact study and contingent valuation ultimately found:

- Restrictions placed greater demands on local government, sporting clubs and volunteer groups.
- The redistribution of sporting allocations triggered by water restrictions systematically excluded less competitive individuals and less advantaged segments of the community.
- Restrictions compromised the capacity of clubs to contribute to building stronger communities
- The community supports sporting grounds as a core community asset and oppose their closure. A large number of people would be willing to pay a small levy to ensure that sports fields are maintained, but many would prefer that grounds be maintained with existing resources.

While it is only a rough guide, an estimate of social value of $500,000 annually for a sports field could be found based on a willingness-to-pay survey. This is based the average value chosen by more than 50% of survey respondents and multiplied by the average number of residents a sports field services.

The information package has provided information on different turf types (warm-season, cool-season and artificial), irrigation volume, delivery and storage, turf and soil health, human health, and community perception to alternative water sources as well as how alternative water sources may be used and their potential impacts in irrigation. The focus was on assessing the impacts of six water types: rainwater, stormwater, recycled grey water, recycled black water, ground water and desalinated water.

The software has been developed, trialled and reviewed as part of the project, and is now believed to be ready for general release. It will help councils when reviewing potential projects and current irrigation practices throughout Melbourne. It is in the process of being promoted for use by local councils and has seen a generally positive reception to date.

It is important that the results of this project continue to be promoted to ensure long-term uptake and continued future use.

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1. Introduction

This report represents the final report for the project Sustainable Water Options for Sportfields. It was developed as a Smart Water Fund project in Round 5, ultimately to help address the impact of water shortage and restrictions on sports fields and to help decision makers look to alternatives with regards to irrigation. The project began in a period of drought and water restrictions, and while these have been lifted for now, such conditions are common in Australia. This project can be considered useful for protecting against potential problems in the future. The project had three main objectives:

- To identify the socio-economic impacts of water restrictions on sportsfields and place a tentative “social value” on sportsfields to help decision makers when assessing project based on this value.
- To provide an information package to help decision makers when considering sustainable options for sportsfields. This would include information on water quality and alternative water types, turf types and their impacts to sport and ways of determining irrigation demand.
- To provide a model, in a piece of software, that would allow users to determine how water requirements would change with different soils and turfs and how nutrient demand can change with different water types.

The direction of the project was initially guided by a steering committee that consisted of representatives from:

- Yarra Valley Water
- City West Water
- South East Water
- Melbourne Water
- Manningham City Council
- Wyndham City Council
- Hume City Council

These organisations helped shape the direction of the project and provided feedback at relevant junctures throughout the project.

The report has led to the publication of three reports:

- S. Weller and A. English (2008), *Socioeconomic Impact Study of Water Restriction on Turf Sports Grounds in Metropolitan Melbourne*, Centre for Strategic Economic Studies, Victoria University: Melbourne, Australia.
- N. Milne and S. Gray (2010), *Sustainable Options for Sports Fields*, Institute for Sustainability and Innovation, Victoria University: Melbourne, Australia.
- N. Milne (2011), *Background to the Sports Field Irrigation Software, Version 4*, Institute for Sustainability and Innovation, Victoria University: Melbourne, Australia.

The project has also seen the development of a model/software to investigate sports field irrigation. The reports and the development of the model and software are detailed in the following sections.

2. Socio-Economic Impacts – Milestone 2

The socio-economic impact study was performed to develop a better understanding of the social and economic effects of Stage 3a water restrictions that were in force when the project was developed. The scope of the project was limited to metropolitan public turf-based sports grounds such as Australian football and rugby grounds, soccer pitches and cricket ovals. The work undertaken and reported as part of the project included a review of previous research on social impacts of sport and sports grounds maintenance issues, a contingent valuation survey that aimed to quantify the value that the community places on sporting grounds, and a program of interviews that sought to assess the local scale impacts of Melbourne's water restrictions which limited the number of sporting grounds that local authorities were permitted to irrigate. At the time the study was undertaken, October 2008, councils were required to reduce their water allocation to less than 25% of pre-water restriction levels or to limit irrigating to one in four turf sporting grounds. As a result, many unwatered grounds were deteriorating and many sports and sporting clubs had been forced to alter their routines and game schedules.

The study has found that restrictions have in effect reduced the amount of usable turf-based sporting spaces available in metropolitan Melbourne. Yet demand for participation, from a wide variety of sports and activities, continues to increase. As a result, restrictions generated tensions over ground allocations and intensified the use of turf grounds. The study has found that:

- Water restrictions created new demands and costs for local government administration, forcing them to allocate additional staff and resources to manage access to sports grounds.
- Restrictions altered the relationship between sporting clubs and local government and increased the transparency of allocation of both clubs and water to grounds
- The redistribution processes triggered by water restrictions systematically excluded less competitive individuals from access to turf-based sport
- The redistribution processes triggered by water restrictions systematically excluded less advantaged segments of the community – children, women, migrants and the disabled – from access to turf-based sports.
- Restrictions imposed substantial and unsustainable costs on sporting clubs that rely on the goodwill of volunteers.
- Restrictions compromised the capacity of clubs to contribute to building stronger communities.
- These outcomes directly undermine the government's health, well-being and participation objectives.

The contingent evaluation study found that the community supports grounds as a core community asset and oppose their closure. A large number of people surveyed were willing to pay a small levy to ensure that sporting facilities were maintained, although there are also people that support maintaining grounds from existing resources, without the imposition of an additional tax or levy. Most people support using user fees and charges to help fund water saving measures. Based on the willingness-to-pay study a nominal social value of $500,000 can be placed on a sports ground, although it must be noted, that this is not a traditional way of estimating such a value and there would be a significant margin of error to such an estimation.

For more information on this component of the study please see the document "The Socio-economic Impacts of Water Restrictions on Turf Sports Grounds in Metropolitan Melbourne"

3. Information Package – Milestone 3

To assist councils and other authorities in understanding how different water sources, turf choices and irrigation systems can change the sustainability and usability of a turf, the project included the development of an information package aimed to address these issues and other questions that may arise. The result was the document titled “Sustainable Options for Sports Fields.” The aim of the document was to provide information that could help guide water authorities, local councils and ground managers in making decisions with regards to the sustainability of sports facilities. The following is a brief summary of the issues that are discussed in the document. For more information please refer to the document “Sustainable Options for Sports Fields.”

3.1 Turf Type

A range of different warm- and cool-season turf were presented and a summary of the tolerances were provided. Cool-season turfs have been typically associated with sports fields in Melbourne due to the general temperature conditions, however they are more water hungry. Typically they are more cold and frost tolerant than other turfs and more tolerant to close mowing and shade. Warm-season turfs, on the other hand, have been adapted for warmer environments and typically use less water. They are generally more heat resistant and drought tolerant, more salt tolerant and more wear tolerant. The main drawback is their poor cold tolerance and tendency to enter a dormant state in winter. This leads to a loss of colour (generally towards white or brown) and a loss of wear tolerance that is perceptually a negative for this class of turfs. Some species, particularly the hybrid couches, are able to overcome this however and other options such as overseeding, also provide potential solutions.

The effect of different natural turfs and soils on play properties such as ball bounce resilience and ball roll resistance were presented and generally showed little difference between warm- and cool-season turf (it must be noted that studies on warm-season turfs are rare). In terms of injury rates one Australian study suggested a slightly increased injury rate was expected on some warm-season turfs, although the increase was small [1].

Artificial turf is becoming more popular and, in its third generation, is considered aesthetically pleasing. Its main deficiencies come in its perception by players and other users, the heating of its surface and the chemicals that can be leached from it. Players generally perceive the turf to be more dangerous [2]. Studies have generally shown that injury rates do not increase in artificial turfs, but the injury types do [3]. Having said this, minor cuts and abrasions tend to be more common, but often go unreported [4]. It is these minor injuries that effect players perceptions and ultimately impacts on the way they play. Users have been shown to adapt to the new surface, though, and, over time, play is less affected [2]. More important was the impact on player endurance. To reduce major injuries, particularly concussions, artificial surfaces are generally less hard and more “springy” than natural surfaces. This leads to players tiring more quickly and potentially impacting the speed of the game [5].

The lack of evaporation from an artificial surface also gives rise to a difference in surface temperature. Surface temperatures on artificial turfs have been reported as high as 90 °C [6]. This has to be overcome by applying water to the surface prior to use to drive evaporative cooling.

Releases of chemical from artificial turfs have caused significant grass roots campaigns against them in some parts of the world. In particular the concern is with volatile organics that can be released from the turf and sporting infill. In general, no evidence has been found that these chemical affect players [7, 8], but community concern remains. Of greater importance is the need to capture stormwater from the field to prevent the leaching of these compounds and zinc into the environment.

3.2 Irrigation Volume, Delivery and Storage

The effective estimation of irrigation requirements is important to minimise the amount of water used. Unnecessary over-irrigation can lead to wasted water, increased loss of nutrients and pollution of waterways. Two weather-based models for irrigation requirements were presented in the report: Pan Evaporation and Penman-Monteith. The Pan Evaporation is the simpler of the two and, may be more accurate at times due to its more developed usage, particularly for turf irrigation. Having said this, the results from each study were generally proportional and either technique would ultimately be sufficient if employed on a long term basis and empirically modified. Techniques for measuring soil moisture content were also presented in the report. It was shown that, with the potential exception of heat capacity-based sensors, most are suitable for irrigation scheduling.

Irrigation delivery is one area where a significant amount of water can be wasted. The less expensive techniques are typically more prone to wastage and human error than more expensive technologies. In general, water savings have been seen for subsurface drip irrigation of up to 50%, while savings of up to 90% have been reported for subirrigation [9]. Both systems do however require significant capital expense and while in the long term maintenance requirements are generally lower, where they are required they can be quite expensive due to the systems underground location.

While the storage of irrigation water in tanks seems reasonable, many alternative sources are available in winter while water is needed in summer. Other water sources provide water regularly when it is not always needed. To optimize the efficiency of water provided to the field, large water storages may be required. Tanks are generally too expensive for this. Artificial lake storage and aquifer recharge are two other options that may prove appropriate for large storage where they can be made available. The both can lead to some decrease in the stored water quality however and this must be considered in case treatment is again necessary before use.

3.3 Turf and Soil Health

Impacts on turf and soil health from irrigation water come primarily from chemical sources. Salinity, boron, metals, oil and grease are four of the more significant ones. Salinity, in particular the ratio of sodium to magnesium and calcium, can bring about significant changes in soil chemistry ultimately leading it to structural collapse and preventing water penetrating into the soil. This ultimately leads to turf death. High salinity irrigation water should not be applied to clay soils and are best suited to soils classified as sandy loam or coarser [10].

Boron tolerance in turfs is quite high, however boron from desalinated seawater may still be significant. Where boron is a problem, the removal of clippings after mowing can reduce the impacts somewhat [10]. Some metals, particularly copper and zinc, are present in potentially toxic concentrations to turf in irrigation water. Avoidance of sources of these contaminants is important or else the soil will need to be monitored to ensure a build-up does not occur [11, 12]. Oil and grease can be particularly effective at decreasing the wettability of a soil and ultimately preventing irrigation. The use of surfactants can potentially overcome this problem where it is an issue [13].

3.4 Human and Animal Health

Human health concerns focus on microbiological considerations and treatment processes must be chosen with this in mind. While rainwater will probably not need treatment, other water sources will. It is best to work within the Australian Guidelines for Water Recycling [11, 12] as this document clearly outlines strategies for the reduction of potential health impacts. Along with treatment there are protocols that are likely to be required with some water use. The protocols are aimed at preventing staff, users and the general public from potential pathogenic threats.

Animal and livestock health may also need to be considered where they may also utilize the ground. Importantly, pigs cannot be allowed on a field that is irrigated with recycled sewage due to the threat posed by *Taenia solium* or pig measles. Other significant risks include *Taenia saginata* in cattle, *Mycobacterium paratuberculosis* in cattle and sheep and *Giardia lamblia* in cats and dogs. Ultimately responsible risk assessment should be performed following the Australian Guidelines as a template where the protection of animals is required.

3.5 Community Perceptions

Perceptions of alternative water use are generally all favourable when it comes to sports field irrigation. Studies have placed acceptability of various water to be used in the order of stormwater (as most acceptable), recycled grey water, recycled black water and finally desalinated seawater [14, 15]. The reason for the low acceptability of desalinated seawater appears to be its energy consumption and associated greenhouse gas risk. Production of desalinated water using renewable energy sources may overcome some of this concern.

3.6 Alternative Water Sources

The six water sources investigated in detail were rain (roof) water, stormwater, grey water, black water, groundwater and desalinated water.

In general only desalinated seawater is rainfall independent with grey water and black water recycling being largely rainfall independent (although it is dependent on incoming volumes that often decrease during water storage) when compared to the other three sources. Groundwater is highly dependent on the natural recharge rates often making it unsustainable; however, it can be particularly efficient when combined with aquifer recharge of another water source for longer term water storage. The volumes of water generated by rainwater may be too low for use as an independent source, but would be suitable when supplemented by another water source.

In terms of contamination, salinity is a major issue in recycled grey and black waters, some groundwaters and desalinated seawater. In these instances, calcium additions may be required. These saline water sources should not be used on clay soils. Salinity can be reduced by treatment such as reverse osmosis; however these will be high in energy costs.

Metal contaminations are generally a problem in rain and stormwater treatment. They are a function of the catchment and avoidance of copper or galvanised metals, particularly roofing, can help to reduce the impact [12]. While treatment may not be necessary, monitoring the soil may be required where these compounds are present in relatively high concentrations [12].

Desalinated seawater may be potentially harmful in terms of its boron content, depending on the desalination technique used. Where this is a concern, clippings should be removed after mowing to ensure no build up of boron can occur [10].

The provision of nutrients is an important aspect of grey and black water recycling. A number of researchers have shown that recycled black water will provide all of a turf's phosphorus and potassium requirement and go a long way to meeting the nitrogen requirements [10]. Grey water will perform similarly.

Finally, any consideration of alternative water must consider all local requirements and guidelines. The report is aimed at a Melbourne audience and therefore makes reference to various Victorian and Australian guidelines. It is important that any planning be considered from the point of view of the most current version of these guidelines that can be typically found online.

4. Software/Model – Milestone 3

The Sportsfield Irrigation Software was developed as a part of the project aimed at more accurately estimating water requirements, identifying how different water sources may change demand for different nutrients as well as estimating the volume of water supplied from various water sources. While the mathematics is similar for many sources, storm water and decentralized water sources can significantly complicate the models. The model itself was developed to calculate:

- The volume of water required for irrigation – Two models were assessed the Pan Evaporation model and the Penman-Monteith model. Ultimately, with more mature factors for turf evapotranspiration requirements, the Pan Evaporation model was chosen to represent this. This also allowed users to determine determine different demands based on the amount of growth required from the field (and therefore its importance). Three levels of growth were defined: Strong, Average and Just Acceptable. These ultimately influence the irrigation requirements for the field through the average soil moisture content and the daily value for evapotranspiration. That is to say a turf with a lower growth requirement can survive using less water in a soil with a lower moisture availability.
- The volume of water supplied from various water sources after treatment – This model caters for rainwater, stormwater, grey water, recycled water (both decentralized and centralized), brackish/ground water, desalinated sea water and a custom water that can be defined by the user. Treatment options are numerous and depend on the water source. For more details on the various models, please refer to the associated document "Background to the Sports Field Irrigation Software".
- The nutrient requirements of the turf – This is calculated based on the assumption of Beard [16] that only the nutrients removed from a turf should be replaced and focuses on the macronutrients: potassium, nitrogen and phosphorus.
- The quality of water supplied from various water sources after treatment – While users can define water qualities, in may cases this will be unknown or assumptions will need to be made. An investigation of the literature provided a range of estimates for various water qualities in Melbourne as well as the reduction factors for different treatment processes.
- The cost offset from reducing fertilizer demand when using nutrient rich water sources
- The quantity of calcium that may be required to avoided sodicity issues – This was performed using the sodium adsorption ratio (SAR), the conductivity and the guidelines outlined by Harivandi [10]. Ultimately, the aim was to add enough calcium to keep an irrigation water in the negligible range for sensitive soils and slight to moderate for sandy soils.
- The capital and operational costs of water treatment – This was done using a series of cost models from literature and unpublished sources. Ultimately it links the capital and operational costs to flow rate (or area in the case of wetlands and rain gardens). It should be kept in mind that cost estimates such as these are generally accurate only to within 33% and should not be used as a substitute to detailed planning.

- The greenhouse gas generation as a CO_2 equivalent of water treatment – The boundary for this determination was placed so as only to include direct greenhouse gas emissions and the emissions associated with electricity usage. The determinations have come from the averages of literature values. It should be kept in mind that there are significant variations in these values depending on how a project is implemented and users must keep this in mind.
- Optimized storage volume for a specified volumetric reliability
- Optimized decentralized catchment sizes for a specified volumetric reliability – This was requested by water authorities to assist when developing decentralized recycled water schemes.

The software itself has been programmed using Visual Basic. NET and utilizes access to the 2007 or 2010 version of Microsoft Excel. As a result, the minimum requirement for the software is access to Microsoft Office 2007 or 2010.

The software was developed based on the initial recommendations of the steering committee and later input from potential users as part of a trial. In the process the software has gone through some changes and there have been two updates to the software since it was first made available to Smart Water and the steering committee. The initial version of the software was v. 1.004. The version put to trial was one updated with some feedback from the Steering Committee members (v 1.005). After trial v 1.006 has been prepared and this version will be made generally available for use. Appendix A contains information of changes to the software in the various updates.

For more detailed information on the models used and the inputs and outputs of the software, please refer to the document “Background to the Sports Field Irrigation Software.”

5. Trial – Milestone 4

Milestone 4 of the project Sustainable Water Options for Sports Fields was to trial the sports field irrigation software developed in Milestone 3. The trial used version 1.005 of the software, a slight update from the software initially provided to Smart Water. A list of changes to the software in version 1.005 is given in Appendix A. Seven councils were invited to participate in the study:

- Moonee Valley City Council
- Hobson Bay City Council
- Maribyrnong City Council
- Brimbank City Council
- Nillumbik City Council
- Knox City Council
- Kingston City Council

Of these councils five agreed to participate. The participants came from two main positions within the councils: sustainability or water officer/planner and sports field irrigation manager. The users were provided a copy of the software, the literature review and the document explaining the software. Each user was also asked to use the software in the presence of the interviewer for half an hour to one hour to allow for observations to be made before being asked for their impressions of the software in terms of usability, usefulness and content.

The following is a discussion of the main findings of the trial. It is split into three sections: general comments on water use and the direction of local councils with respect to sports field irrigation, technical or logical issues in the software and general issues or comments with respect to the software. Also included were the initial observations and proposed solutions outlined in the Milestone 4 report.

5.1 General Comments

- At least two councils identified that the irrigation and fertilization of fields were performed or under the purview of different people. While the interviewer may have been talking to the irrigation manager, they would not know when or how much fertilizer was applied.
- One council representative did not believe that any fertilizer was applied to their playing surfaces.
- The issue of clippings removal was raised by one council as being impossible. They felt that no council could possibly be performing this. It should be noted that during trials all other councils claimed that clippings were removed when they used the software.
- Councils were at different levels with respect to planning alternative water sources. One council had highlighted potential sources for all sports fields under their purview, while one had plans for only one site. Most however fell between the two.
- The main alternative water source being investigated by councils was stormwater recycling. There were a number of schemes highlighted by the interviews, generally one in each council area. One of the main issues raised here was the amount of time required for planning and particularly funding of such projects with one interviewee saying that seven or eight years for a project to move from planning to fruition was short when compared to other projects they were aware of.
- Another issue raised with alternative water sources concerned the guarantees on water quality and quality management issues. This was a significant concern to all councils and was highlighted by at least one as an issue when working on an alternative plan with the local water authority. This was also raised as an issue with tinkered recylced water. One user felt when the water was being used not enough information was available with regards to the salinity or sodium concentration in the water.
- The salinity issues associated with Western Treatment Plant were raised on a number of occasions and most councils were aware of anecdotes concerning use of the water on some sports fields in the western suburbs. One council in the western suburbs stated they had stopped supplies from Western Treatment Plant and were now tankering water from one of Yarra Valley Water's plants. Another council highlighted that they had stopped using recycled water entirely.
- All councils felt that roofwater/rainwater as an irrigation source is not a solution.
- All councils identified soil as an issue, in terms of knowledge, testing and how it was dealt with by the software. Some councils were unaware of the soil profile their playing fields were on. Other councils understood they had not performed enough testing on their fields. In general only one council felt that the soil type was accounted for well in terms of their fertilization application rate and irrigation estimates. A final important point was that one user felt that the interaction between nutrients and soil should be better explored. This is mentioned here as the project team felt that the software in its current form would not be able to do this as it is only a measure of irrigation requirement throughout a year and does not really account for application rate. This makes it impossible to monitor the nutrient interactions with soils. There are also a range of other factors that contribute to this that, given many council's knowledge and understanding of soil quality could unnecessarily complicate the model as it stands.

5.2 Technical/Logical Issues

1. In the period just before the trial began one water authority provided feedback that the data entered into a window doesn't "save". *[SOLUTION: The data is saved but is not recalled when a window is reopened. This will be corrected.]*
2. In one instance potable water was initially selected to perform the modelling. All subsequent scenarios used potable water whether it had been selected or not. *[SOLUTION: The code that selects potable water will be investigated to see where the bug lies. It seems that when the option is selected it is permanently selected]*
3. Under greywater and stormwater use, phosphorus and potassium demand registered zero in the excel spreadsheet. *[SOLUTION: It was noted in the Milsetone 3 report that a bug in the nutrient demand calculations had been identified and corrected. It is believed this bug could be the result of the original correction. It will be fixed for the next release]*
4. In the stormwater catchment window when no bushland or gardens are selected as part of the catchment, the window will not move on without extra data on soil moisture capacity and evapotranspiration are provided. *[SOLUTION: Prefill these four textboxes with data assuming a poorly structured clay soil. This will allow the window to move on while leaving the ability to change in the hands of the user.]*
5. No user was interested in the stormwater catchment subsurface parameters. This made the window that pops up when a user is finished defining the catchment confusing *[SOLUTION: The window will be removed]*

5.3 General Issues/Comments

1. In general all users felt the software would be useful, but some more guidance was required in terms of its use. *[SOLUTION: Firstly, the load page will be altered to more clearly define the steps that need to be followed. The sportsfield details menu item will be moved to a button with a description that this is Step 1. A description will be added to the water sources explaining that this is Step 2. The calculate menu item will be changed to a large button at the bottom of the page and be given a description as Step 3. Each of the windows will now have a help button added to the menu that will provide users with information of the type of data that needs to be entered into the various text boxes and a brief description of what they will mean.]*

   More specific points include:

   a) There was some confusion over the terms "optimize" and "reliability" *[SOLUTION: Add a tool tip to these terms to assist in understanding, descriptions will also be added to the relevant help pages]*
   b) The definitions of "class" for the playing/usage level of the sports fields were confusing to all users. It wasn't clear from the original description what the highest and lowest levels applied to or where each one should be used *[SOLUTION: These definitions were changed from classes of fields (Classes 3 to 5) to brief descriptions of the growth required of the turf: strong, average, just acceptable. An example of where each level of growth was also included, e.g. "Just Acceptable" is given for fields that are used for training or recreational purposes. The five classes have been refined to three after feedback described in point 3]*
   c) A definition of rainwater is required as the difference between rainwater and stormwater is not clear. *[SOLUTION: Add a description to the new help button]*
   d) It wasn't clear whether to perform the simulation over one field or all. *[SOLUTION: a description will be added to the load page explaining this]*
   e) When selecting soil type it wasn't clear what part of the profile was of importance *[SOLUTION: It will be clarified that the soil type is important only for the root zone or top layer of the soil]*

2. One button to select average water quality values was deemed of more use than multiple check boxes. *[SOLUTION: While a single button will be added to check all boxes, the individual check boxes will remain for those who have some water qualities but not all. The button to check the boxes will be made more prominent in the window]*
3. While irrigation at Class 3 was deemed a “normal” level for irrigation requirement, Classes 1 and 2 seemed excessive to most users. *[SOLUTION: Classes 1 and 2 will be eliminated. It was always felt by the project team that this seemed an excessive level of irrigation. Combined with the feedback contained in Point 1b this means that three levels of growth will now be used to differentiate fields: Class 3 becomes strong growth, Class 4 becomes average growth and Class 5 becomes just acceptable growth]*
4. In stormwater treatment it was felt that more treatment options were required, in particular rain gardens should be added *[SOLUTION: Find relevant data on rain gardens for inclusion in model]*
5. One user felt the graphs of nutrient supply were confusing and should be reduced to one year rather than ten *[SOLUTION: Remove the daily accumulation of nutrients from the graph and replace with a single point for each year]*
6. Nutrient data should be given in total application per year rather than application per square metre per year *[SOLUTION: Change the definition of this within the software]*
7. The x-axis on the graphs was too busy, the days should be replaced by years *[SOLUTION: Redefine the x-axis parameters in the software]*
8. The cost of potable water and recycled water should be included *[SOLUTION: This data will need to be requested from the water authorities and average values used]*
9. The greenhouse gas emissions associated with potable water production should be incorporated. The same would likely apply to centralized recycled water production *[SOLUTION: This data will need to be requested from the water authorities and average values applied]*
10. One user was interested in being able to generate a graph showing the different demand of warm-season versus cool-season turf for a specific site. While this could be done by extracting the data from the produced Excel file, the user felt that the software would be strengthened by the inclusion of this option. *[SOLUTION: This can be accounted for in the sportsfield details window by allowing a third option “Comparison” under turf type. At this stage the water options would then be limited to potable only as a full comparison should be performed by selecting first one and then the other for other water sources.]*
11. The users liked that multiple sources could be selected for a field and one highlighted that the hierarchy used aligned well with their own hierarchy.
12. One user felt the software was too scientific *[SOLUTION: With the addition of further explanation it is hoped that this will at least improve users understanding and ability to use the software where the user has come from a non-scientific background]*

6. Review – Milestone 4/5

The review of the software was focused on the feedback obtained as part of the trial and some further feedback from water authorities. This ultimately resulted in the development of version 1.006 of the software. The main changes for this version are outlined in Appendix A. In general all of the suggestions outlined in the Milestone 4 report were adopted. There are some caveats to this however due to other changes made to the software and in defining some boundaries for the project. The following discussion will explain what changes were made to the software and the reasoning that was part of the review to this. It is divided into similar sections as reported in Section 5 and includes a section on water authority changes.

6.1 Technical/Logical Issues from Trial

1. The initial concern with "saving" data was addressed through changes to the programming ensuring that data was recalled by all windows when they were reopened. The data had always been saved, just not recalled. This does make multiple simulations easier to run.
2. An investigation of the software revealed that on multiple runs water options selected in the first simulation weren't deselected on subsequent runs. This required a small change to the coding to correct.
3. Investigation of the issue with regards to nutrient demand revealed it was not associated with the water type or earlier correction, but was actually a mistake associated with clipping removal. When clippings are removed it is assumed that the nutrient demand is largely met. In the case of what occurred during trial, the user had selected that clippings were not removed. Consequently, the P and K requirements should read zero.
4. The issue surrounding the stormwater catchment window was corrected by prefilling most boxes. This means that users unfamiliar with how such systems and modelling works will not be required to make any changes, but users with a greater knowledge of this field can make the changes to more adequately represent their own areas.
5. The concern with subsurface parameters in stormwater modelling is that while they are important and can significantly impact the results, they are often not understood by many users. The values all came pre-filled and do not necessarily require input from the user. Subsequently, the software code was changed slightly to no longer prompt the user to look at this tab.

6.2 General Issues/Comments from Trial

1. The major concern raised during trial was the ability to follow the software. This has been improved by changes to the main window of the programme, via the addition of tooltips to all windows to give explanations of terms and requirements (this takes the place of the help button planned in Milestone 4), and through the addition of two help windows specifically giving information of definitions of water types. These changes are outlined in details in Appendix A. The important changes were to the main window where the menu bar was removed and the menu items transferred to buttons on the screen. This was combined with clearly defined steps for the user followed by a large "Calculate" button. Other changes:
    a. Optimize and reliability were defined using tooltips.
    b. As described in the Milestone 4 report, the concept of "classes" of field were removed and replaced by three levels of growth required. These were: Strong, Average and Just Acceptable. The definitions replaced the previous Classes 3, 4 and 5 (see Point 3).
    c. In the main programme a "?" button was added along with tooltips directing users to this button with more useful definitions of rainwater and stormwater. Specifically rainwater is defined as "Rain falling on and collected from a roof only" while

    stormwater is defined as “Rain collected from an area (catchment), that includes anything on the ground, e.g. roads, footpaths, gardens”
    d. To assist users in understanding that the simulation is for one field the following was added to the main window: “The software was designed to model irrigation and fertilizer demand for one field. All data should be entered for this field.”
    e. A tooltip was added to give a description of soil type as “ The soil for the root zone or top few cm only”
2. A button was added to “Select all Estimates” in the water quality windows. However, the individual check boxes were retained in order to ensure that users could add an estimate for any parameter if it was unknown.
3. The original Class 1 and Class 2 were removed as the irrigation at these levels seemed excessive. As a consequence only three levels of growth were retained in the final software: Strong, Average and Acceptable representing the old Classes 3, 4 and 5 respectively.
4. Rain gardens were added to the model in order to give a more likely option. Other techniques were considered, however their addition became more complicated due to the nature of stormwater project having multiple potential objectives. Consequently only rain gardens and wetlands were retained as treatment options.
5. For ease of reference, accumulation of nutrients in the reported graphs was removed and replaced with annual totals.
6. The way in which the nutrient demand and supply was presented was altered to be more relevant to potential users, in that it gave values only in $kg.y^{-1}$ rather than $g.m^{-2}.y^{-1}$.
7. In order to reduce the number of points listed on the x-axis in plots, it was necessary to change the nature of the plots to X-Y Scatter graphs. This had the added impact of removing the ability to use stacked graphs although ultimately this is probably not necessary to understanding how different water sources are provided.
8. The cost of potable and recycled water was added to the programme (and can be adjusted along with the water quality parameters). Ultimately this adds to the operating costs of using purchased waters. The default values for these waters were obtained using averages of the data obtained from the Essential Services Commission and were relevant for non-residential water use from July 2011. The values were $2.01.kL^{-1} for potable water, 95% this value (or $1.90.kL^{-1}) for RO-treated recycled water (estimate only as no data currently exists) and $1.67.kL^{-1} for tertiary and secondary recycled water (from City West Water and South East Water data).
9. As part of the review process, the potential to include greenhouse gas (GHG) emissions associated with potable water production was considered. However, the issue ultimately comes in where to draw the boundary for the tool as a number of possible questions are raised. By including the GHG emissions associated with treating and transporting potable water would that then mean that similar options for recycled water would need to be considered? Should the GHG emissions associated with water storage in dams also be included? Would the GHG emissions associated with stormwater collection need to be considered within the boundaries of the model? Importantly, could there be some double accounting as a result of a carbon tax or emissions trading scheme. If the price of water reflects the price of carbon then it was ultimately decided this would be a better way of representing the potential for a project. Consequently, the boundaries for GHG production in this model were framed only around direct emissions and emissions as a result of electricity usage (the electricity usage is calculated separately and can be easily removed, or can be eliminated if alternative energy supplies are utilized). As a result, no changes were made to the current GHG emissions model.
10. While the interest in comparing warm- and cool-season demand was already possible by extracting the data from two simulations, the ability to comparison of water demand for the two was provided. It was added, however, under the condition that only potable water can

be used to meet the demand of the field. This was done to simplify the software and calculations which may have become too bulky to be used otherwise.

11. This was a general comment in agreement with the programme.
12. This point was dealt with as reasonably as possible by adding more default data and decreasing the requirements placed upon the user. Further explanations were also added to assist users in understanding the software more thoroughly.

6.3 Other Changes from Review

One of the most significant changes came as a result of a review into the stormwater treatment costs. The issue ultimately stemmed from an error in the calculation of wetland areas, ultimately leading to significant overestimation wetland area and subsequently of the capital and operating costs. As a result, the model was completely replaced with a focus on costing from the size of the treatment area as opposed to flow rates. This resulted in the equation for capital costs of:

$$\$ \quad = \quad \times$$

Where k is the cost factor, is the area of the wetlands or rain garden in m^2 and the capital costs are given in $000's. Analysis of the literature gave rough values for the cost factors as 0.0775 for wetlands [17] and 0.137 for rain gardens greater than 100 m^2 in size and 0.25 for rain gardens less than 100 m^2 in size [18]. This however, does not resolve the issue of overestimating the wetlands area. To more adequately reflect the land area available, the sizing became a factor for the user to assign.

In the stormwater window of the software, when the wetlands or rain garden treatments are selected, the software will provide a new selection box for the size of the treatment system as a percentage of the impervious area of the catchment. These are taken from the Water Sensitive Urban Design Engineering Procedures developed by Melbourne Water <REF>. This gives a treatment area of between 1 and 5% of the impervious catchment for wetlands treatments and between 0.5 and 2% for rain gardens. The defaults were set as 2% and 1% for wetlands and rain gardens respectively. This then had the impact of changing the nitrogen and phosphorus reduction factors during treatment. The details of this is given in the software updates outlined in Appendix A as well as in the document “Background to the Sports Field Irrigation Software: Version 4” and won’t be repeated here.

The review process also uncovered a bug in the calcium requirements calculation that underestimated demand due to using the wrong target for the sodium adsorption ratio. This was updated to reflect more sensitive systems.

7. Communication

As part of the project communication is considered of significant importance. Throughout the project communication objection have been kept in mind with three main avenues utilized: conferences, seminars and press releases/other communications.

In terms of conferences, the main target was the OzWater conferences where a paper was presented in 2009 and a poster in 2011. This forum allows communication to water authorities as well as some local councils. The work was also presented at a lunchtime session at the 2010 National Local Government Asset Management & Public Works Engineering Conference hosted by the Municipal Association of Victoria. It received significant attention from local governments in Western Australia where water resources are becoming a major concern.

A seminar was held in May 2011 with water authorities after completion of Milestone 4. This was aimed to give the water authorities more detail on how the software worked. This also helped feed some points in the review. A seminar has been planned for South East Water and their local councils in August 2011 and future seminars in City West Water and Victoria University are being planned. Interest has also arisen in Coliban Water where a seminar may be provided.

At the completion of Milestone 2 in early 2009 a general media release was made with regards to the findings of the socioeconomic impacts. This was made during the period of water restrictions and got some significant coverage in the Melbourne and Adelaide radio, including on Melbourne's 3AW and Gold.

For the future, a second media release is planned once the project is finalised, as per the original communication plan. A final presentation is also planned in OzWater '12 and the possibility of academic publications will be investigated.

8. Conclusions

To date the project overall has received positive feedback and different aspects of the project have already been in demand by local councils. After having undergone trial and been reviewed, the software, as the final component of the project to be completed, now needs promotion to ensure continuing uptake in the Melbourne area.

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Appendix A – List of Updates to Software

v 1.005

- The calculation for field capacity of bush and lawn areas in the Stormwater Catchment Window were updated from:

Soil Texture Type	Field Capacity (mm.cm^{-1})
Sand	0.8
Loamy Sand	1.4
Sandy Loam	2.0
Loam	2.7
Poor-Structured Clay	2.5
Good-Structured Clay	4.0

To:

Soil Texture Type	Field Capacity (mm.cm^{-1})
Sand	0.6
Loamy Sand	0.9
Sandy Loam	1.3
Loam	2.0
Poor-Structured Clay	1.3
Good-Structured Clay	1.9

This brings them into line with the values used in calculations for the minimum growth requirements for sports fields used elsewhere in the software.

- Fixed bug in nutrient calculations for decentralized wastewater use
- Updated estimate for bush evapotranspiration from 1.65 to 1.46 to represent new literature values
- Updated estimate for the base flow recession constant from 0.001 to 0.02 to more accurately reflect literature values.
- Potable water estimates were updated from:

Parameter	Estimate	Form
Sodium (ppm)	6.45	
Potassium (ppm)	0.9	
Magnesium (ppm)	1.5	
Calcium (ppm)	6.15	
Dissolved Solids (mS.cm^{-1})	0.081	Conductivity
Nitrogen (ppm)	0.645	Nitrate
Phosphorus (ppm)	0.001	Total Phosphorus

To:

Parameter	Estimate	Form
Sodium (ppm)	7.3	
Potassium (ppm)	1.35	
Magnesium (ppm)	1.85	
Calcium (ppm)	9	
Dissolved Solids (ppm)	71	Total Dissolved Solids
Nitrogen (ppm)	0.815	Nitrate
Phosphorus (ppm)	0.007	Total Phosphorus

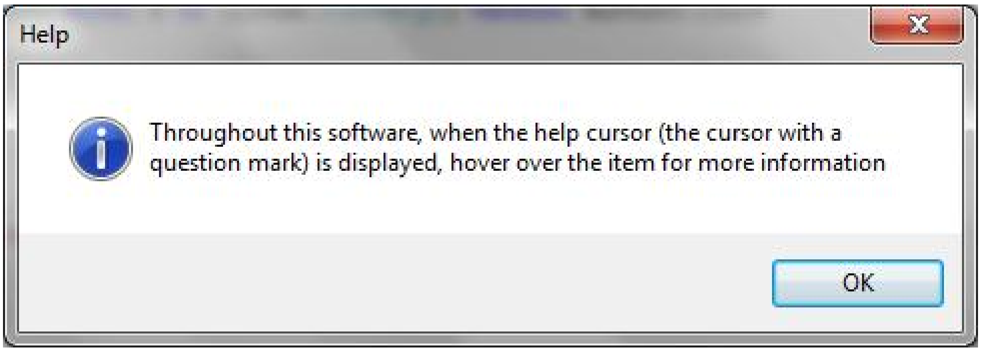
This reflects to values in the 2010 drinking water quality reports.

- Fixed bug in the calculation of N, P and K demand that used N demand in all cases and that incorrectly subtracted the supplied nutrient when determining demand (instead of doing this when calculating the shortfall)

v. 1.006

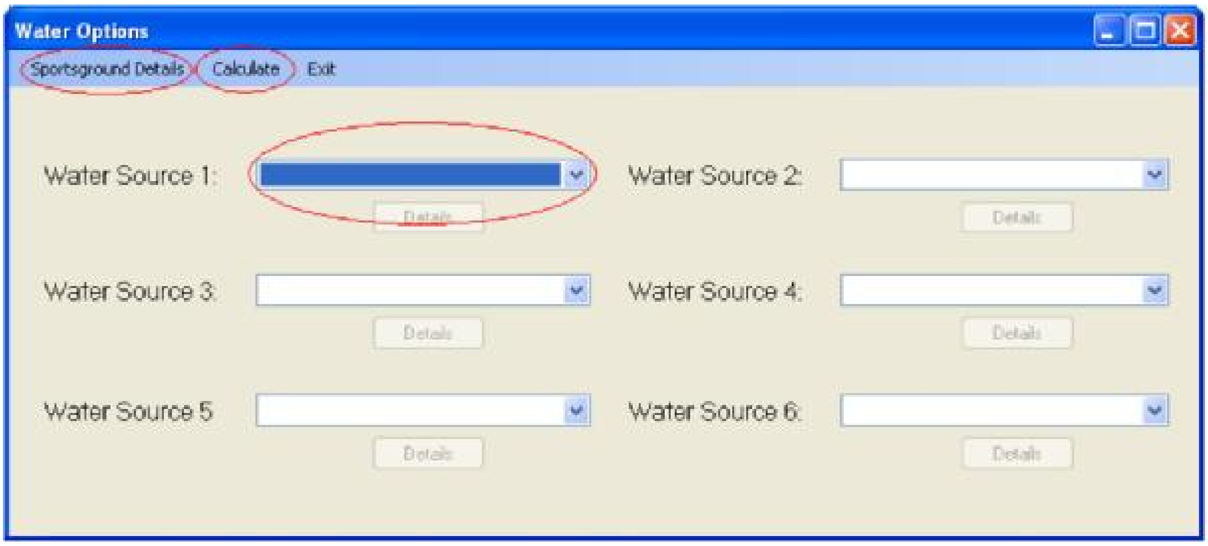
Major Changes

- When the programme opens, the following dialog is displayed:

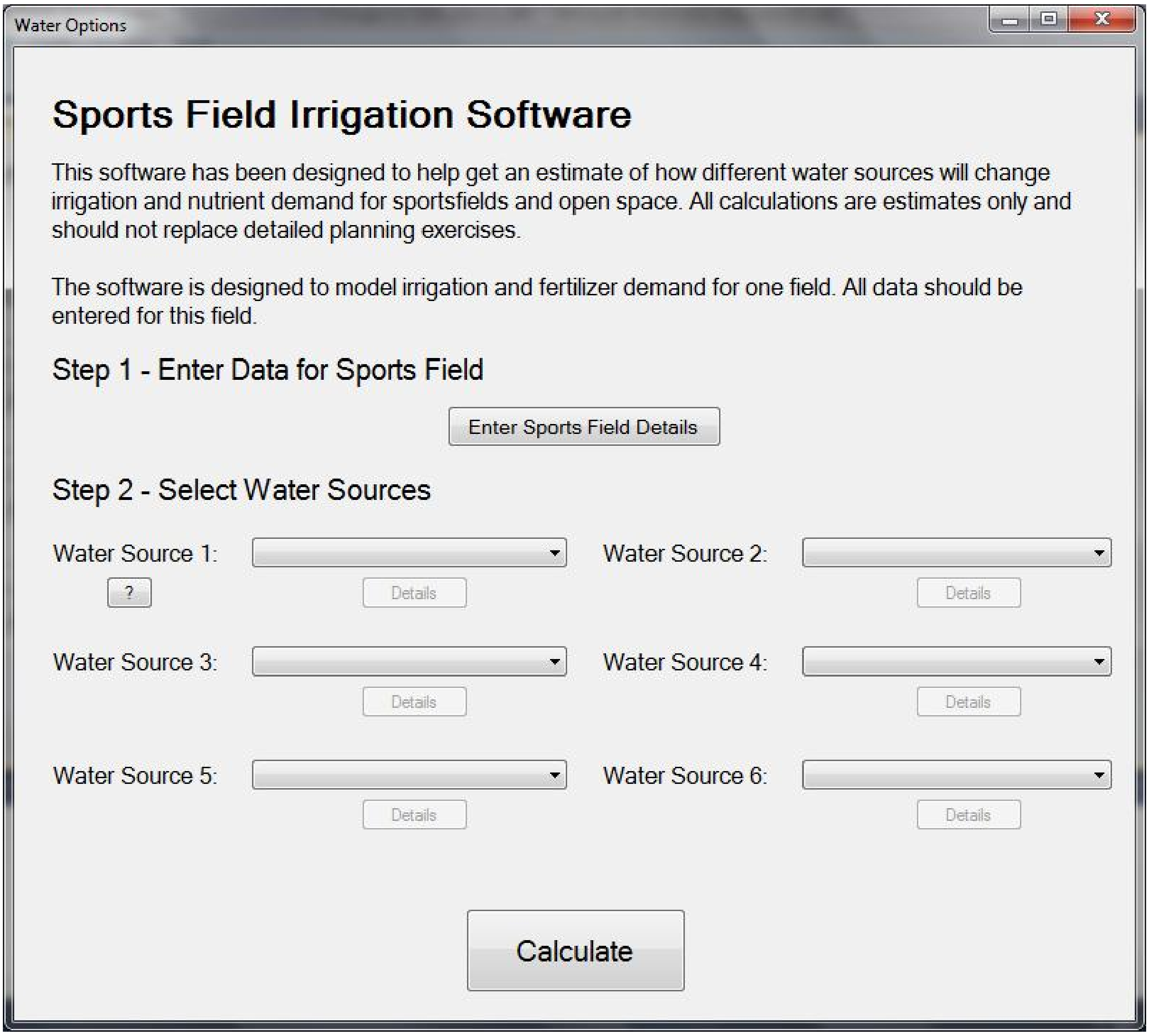


Throughout this software, when the help cursor (the cursor with a question mark) is displayed, hover over the item for more information

- Front page has been altered to more clearly outline the steps required. The menu strip was removed and buttons added for entering the sports field details and for performing the calculation. The initial page was changed from this:



To this:



Sports Field Irrigation Software

This software has been designed to help get an estimate of how different water sources will change irrigation and nutrient demand for sportsfields and open space. All calculations are estimates only and should not replace detailed planning exercises.

The software is designed to model irrigation and fertilizer demand for one field. All data should be entered for this field.

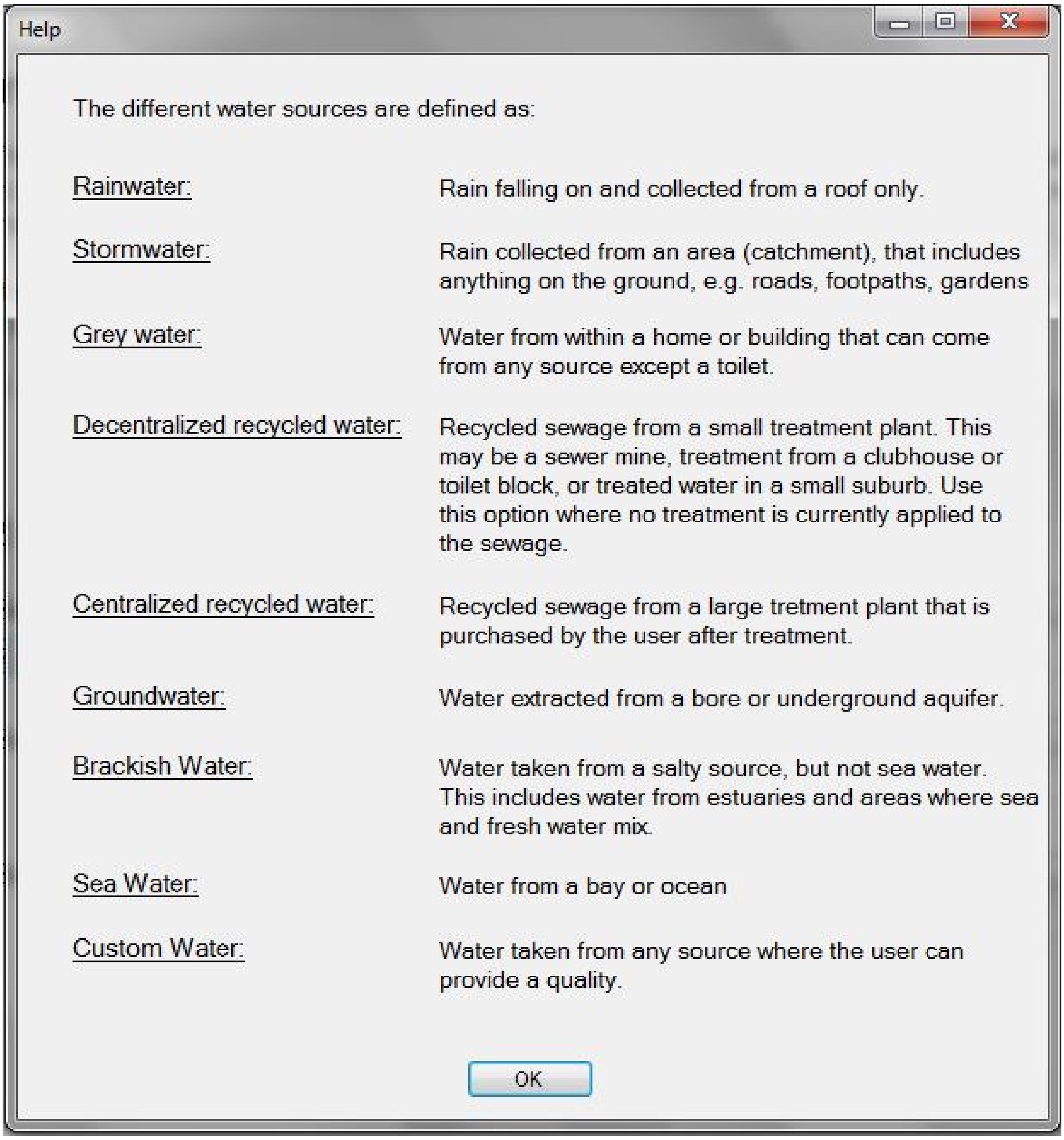
Step 1 - Enter Data for Sports Field

Step 2 - Select Water Sources

N.B. Only the schematic changes are important. Please note that the first screenshot was taken while the programme was running in Windows XP while the second was taken when the programme was running in Windows 7. This is the main reason for differences in the appearance of the window itself.

- After overestimations during trial, Class 1 and Class 2 field levels were removed from the programme
- The term “Level of Field” was changed to “Level of Growth Required”
- In the “Level of Field”/”Level of Growth Required” drop down box, the Classes were replaced with more descriptive phrases:
    - Class 3 became “Strong”
    - Class 4 became “Average”
    - Class 5 became “Just Acceptable”
- Data entered into the Sports Field Data Window, Potable Water Window, Rain Water Window, Brackish Water Window, Custom Water Window, Ground Water Window, Secondary Treated Recycled Water Window, Tertiary Treated Recycled Water Window, Reverse Osmosis Treated Recycled Water Window, Grey Water Window, Decentralized Recycled Water Window, Sea Water Window, Storm Water Window and Storm Water Catchment Window will be recalled when reopened.

- A “Select All Estimates” button was added to all water quality windows.
- The term “Use System Value” was replaced by “Use Estimate”
- In the main window a “?” button has been added. Clicking this button opens the help window shown below:



The different water sources are defined as:

Rainwater:	Rain falling on and collected from a roof only.
Stormwater:	Rain collected from an area (catchment), that includes anything on the ground, e.g. roads, footpaths, gardens
Grey water:	Water from within a home or building that can come from any source except a toilet.
Decentralized recycled water:	Recycled sewage from a small treatment plant. This may be a sewer mine, treatment from a clubhouse or toilet block, or treated water in a small suburb. Use this option where no treatment is currently applied to the sewage.
Centralized recycled water:	Recycled sewage from a large tretment plant that is purchased by the user after treatment.
Groundwater:	Water extracted from a bore or underground aquifer.
Brackish Water:	Water taken from a salty source, but not sea water. This includes water from estuaries and areas where sea and fresh water mix.
Sea Water:	Water from a bay or ocean
Custom Water:	Water taken from any source where the user can provide a quality.

- In the main window a series of tooltips has been added:
    - Step 2 – Select Water Sources – “Select up to six water sources from the drop down boxes below and click the details button to provide quality and volumes available. Click the "?" for descriptions of different water sources.”
    - Water Source n – “Click the"?" for help on water sources”
    - Details buttons – “Click to provide information on water quality and volumes available”
    - Water source dropdowns – “Click the "?" for descriptions of the water sources”
    - ? button – “Click here for an description of different water sources”

- Potable water and centralized recycled water has now been given an operational cost that can be adjusted in the Potable Water Window. The defaults for potable water and tertiary water were established using the July 2011 costs approved by the Essential Services Commission and averaged across Melbourne. The MF/RO cost default is 95% the cost of potable water and the secondary treated recycled water defaults to the tertiary recycled water cost.
- In the Potable Water Window the following tooltips have been added:
    - Volume Available – "Enter the volume available to the nearest kL or select unlimited."
    - Volume Available Text Box – "Must be a whole number"
    - Water Quality – "Enter the concentrations of the specified chemicals. If they are unknown select "use estimate"."
    - Cost – "Enter the cost of potable water in $/kL"
    - Dissolved Salts Form – "Select either conductivity or total dissolved salts from the dropdown menu."
    - Dissolved Solids – "Enter either the total dissolved salts (TDS) concentration in ppm or the conductivity of the water in mS/cm"
    - Sodium – "Enter the concentration of sodium in the water in ppm."
    - Potassium – "Enter the concentration of potassium in the water in ppm."
    - Magnesium – "Enter the concentration of magnesium of the water in ppm."
    - Calcium – "Enter the concentration of calcium of the water in ppm."
    - Nitrogen – "Enter the concentration of nitrogen in the water in either ppm total nitrogen, ppm total Kjeldahl nitrogen or ppm nitrate."
    - Nitrogen Form – "Select either total nitrogen, total kjeldahl nitrogen or nitrate from the drop down menu."
    - Phosphorus – "Enter the concentration of phosphorus in the water in either ppm total phosphorus or ppm orthophosphate/phosphate."
    - Phosphorus Form – "Select either total nitrogen, total kjeldahl nitrogen or nitrate from the drop down menu."
    - All text boxes except Volume Available – "Must be a number."
    - Use Estimate – "If you are uncertain of a concentration check this box to use an estimate for Melbourne."
    - Use All Estimates – "Use this button to select all estimates for water quality."
- In Rain Water Window, adjusted the initial value for reliability to 100%.
- Redefined nitrogen demand for field where clippings are not removed from 24 $g.m^{-2}$ to 0.
- Error in calculation of calcium demand, where the square of the SAR was replaced by 9 regardless of the desired SAR was corrected.
- Water quality data entered in the Custom Water Window are now transferred to the simulation (previously they did not).
- In the Storm Water Window, the treatment regime Wetlands/Disinfection was removed and the treatment Rain Garden was added. The costing models were updated, however the energy usage and greenhouse gas emissions have not been detailed in the literature and have been assumed to be the same as Wetlands for the moment. The new cost models are:

$< 100m$

$$\$ \quad = 0.25 \times$$
$$\$ \quad = 0.0125 \times$$
$$> 100\mathrm{m}$$
$$\$ \quad = 0.137 \times$$
$$\$ \quad = 0.00685 \times$$

- The cost models for the wetlands treatment for stormwater were updated. The costing now relies on the wetlands area rather than flow. The new models are:

$$\$ \quad = 0.0775 \times$$
$$\$ \quad = 0.00155 \times$$

- In the Storm Water Window, when either the Wetlands or Rain Garden treatments are selected a new numeric appears asking for the area of the treatment as a percentage of the impervious catchment area. The options are 1, 2, 3, 4 and 5% for the wetlands and 0.5, 1, 1.5 and 2% for the rain garden. This assists in calculating the costs and also impacts on the total nitrogen and total phosphorus reductions. The new f_N and f_P factors are:

Wetlands		
Area as % of impervious catchment area	f_N	f_P
1	0.71	0.55
2	0.59	0.39
3	0.52	0.32
4	0.47	0.27
5	0.44	0.25

Rain Garden		
Area as % of impervious catchment area	f_N	f_P
0.5	0.74	0.6
1	0.64	0.25
1.5	0.59	0.19
2	0.56	0.16

- For stormwater treatment systems, the area of the rain garden and the area of the wetlands are now calculated using:

$$= \% \quad \times \quad \times \ \% \quad + \% \quad + \%$$
$$= \% \quad \times \quad \times \ \% \quad + \% \quad + \%$$

- In the Storm Water Catchment Details Window, the requirement to click the second subsurface tab before continuing has been removed.
- In the Storm Water Catchment Window, the evapotranspiration crop factors and the soil moisture capacity for bushland and gardens is now prefilled. The Use Estimate button for the crop factors has been removed.
- In the Sports Field Details Window the following tooltips have been added:
  - Turf Type - “The turf type is defined as warm- or cool-season. Common warm-season turfs include couch, kikuyu and zoysiagrass, while cool-season turfs include tall fescue, annual bluegrass and kentucky bluegrass”

    - Soil Type – “This is the soil for the root zone or top few cm only”
    - Area of Field – “The area of the field or open space to be irrigated”
    - Level of Growth Required – “The level of growth required of the turf. A turf in high demand for competition would be one requiring strong growth, while one used for training or only casually would need just acceptable growth.”
    - Appropriate Climatic Data – “Select the nearest location. Each location represents a weather station with 10 years of data.”
    - Are Clippings Removed? – “Are the lawn clippings removed after mowing? This helps to determine fertilizer demand”
- There was a bug that didn’t deselect water uses on multiple runs. Ultimately this meant that, for example, if potable water was selected for the first run and was changed to rainwater for the second run, potable water would still be used on the second run. This has been corrected.
- A bug where the stormwater operational costs were missed from the total operational costs calculations has been corrected.
- All output graphs have been altered to use years on the x-axis rather than days. This has, in turn, led to the axis looking less “busy”. A secondary result is that the output graph for water use is no longer a stacked graph, but a simple scatter graph.
- In the Sportsfield Details Window a new option for “Comparison” was added under the Turf Type. This will allow the user to perform a simple comparison of potable water use and costs for a warm-season and cool-season turf at the same site.

Minor Corrections

- Corrected Centralized Recycled Water Use variable from “integer” values to “double”.
- Typing mistake in Grey Water Optimization Error Window corrected (“Optimiztion” to “Optimization”)
- Typing mistake in Centralized Recycled Water Tank Size Optimization Window corrected (“deentralized” to “centralized”)
- Error in Brackish Water Tank Size Optimization Error Window corrected (“deentralized recycled water” to “brackish water”)
- Error in Seawater Tank Size Optimization Error Window corrected (“deentralized recycled water” to “treated seawater”)
- Corrected typo in the Grey Water Window and Decentralized Recycled Water Window. The first tab title was changed from “Known Quantity and Volume” to “Known Quality and Volume”
- In the Local Tab of the Grey Water Window the Treatment drop down menu was changed to a drop down list.
- An error in the output where the decentralized recycled water treatment was given the heading “Rain Water Treatment” has been corrected.