Stormwater Pond Design for Rockhampton (Queensland) Golf Course Premises

F. Akram, M.G. Rasul, M.M.K. Khan and M.S.I.I. Amir

Central Queensland University, Rockhampton Campus, QLD 4702, Australia
School of Engineering and Technology

Abstract

In recent times, pond has become the most common management practice for the controlling, treating and storing of stormwater runoff. Golf courses provide a unique setting for ponds that provide both an environmental benefit and an aesthetic amenity of golf course premises. A significant body of technical literatures concerning the design and performance of ponds indicates favourable performance of ponds, when they are designed, constructed, and maintained properly. To calculate the volume of pond, careful watershed wide analysis is needed to estimate the peak design runoff. A great deal of consideration is needed to design a safe, cost effective and legal pond. In this study peak design runoff for a delineated subcatchment was calculated from a rainfall runoff model developed by 'xpstrom' modelling software. Using the runoff coefficient (C) from this model, volume of a golf course pond was calculated using rational method. Intensities corresponding to different rainfall durations were found from Intensity Duration Frequency (IDF) curve, developed by Bureau of Meteorology (BOM) for the study area. Pond volume was calculated considering adequate management of stormwater runoff as well as ensuring availability of enough water for irrigating turf. A typical design of the stormwater pond along with important design aspects of ponds are provided in this paper. However the information contained in this paper does not replace the need to understand the site-specific design needs, nor does it supersede other requirements, such as applicable regulatory requirements.

Introduction

Ponds are indeed a beautiful addition to any landscape. There are different types of ponds, such as embankment ponds, excavated ponds, levee ponds, combined watershed-levee ponds etc. [1]. However, ponds are grossly classified as two categories; wet pond or retention pond and dry pond or detention pond. Stormwater pond systems are of two types: on-site detention pond and off-site or regional detention pond. Each one has some advantages and disadvantages over other one. Ponds are mainly filled from three sources of water, i.e. rainfall runoff, groundwater, and surface water.

The management of natural resources, especially water, is important for improving the economy and the livelihoods of people in Australia [2]. Recently, ponds became a popular practice for controlling both stormwater quantity and quality [3]. Ponds play an integral role in the environment, ecology, and beauty. They act as the great connector across the landscape, ensuring room for our amusement and recreation. In general ponds have several important benefits of flood reduction to clean water production and provide food for humans, industry and farming. Besides, they offer a suitable environment for many plants and animals. Therefore, ponds can be operated as a stormwater control structure, a water storage for irrigation, a nutrient-stripping pond, a wildlife habitat or merely as ornamental. For example, homeowners and businesses consider a pond, merely to enhance the beauty of their environment. Farmers use ponds for storing water for livestock and crops.

Golf courses rely on ponds specifically to hold irrigation water for the hundreds of acres of lawn [4]. Ponds on golf courses make a focal point in the landscape. They provide several benefits on environmental, aesthetic, and golf strategy. They supply irrigation water, protect downstream water quality by filtering nutrients, clean stormwater by letting sediments settling and create wildlife habitats. In addition, they save cost through less maintenance, reduced fertiliser and chemical usage. A well maintained pond complements the surrounding landscape and makes a positive impression by keeping water efficiently out of playing areas [5]. There are different types of ponds that can be used in a golf course setting. Ponds can be in different sizes. Ponds can be designed to work in series to combine variety and water quality benefits. When combined with a course drainage system, ponds can decrease the impact of rainfall by providing multiple drainage outlets.

Regardless of the size and functions, the building of a useful and cost-effective pond is not so simple. A great deal of consideration is needed to make a legal, cost effective and properly constructed pond, i.e. safety, availability of water, suitability of site, soil type, pond type, probable environmental impacts, seepage condition, overall maintenance etc. The other concerned factors are location, area, depths and storages of pond, inlet and outlet works, conduits within the basin, drainage area, use of the pond and budget. However, the first phase of pond design is to identify the purpose of the pond. After fixing the function of pond, the size, shape and profile of pond and species of plants around the pond are determined. To estimate the inflow into the pond a detailed watershed-wide analysis is needed [6].

In this study water balance approach has been followed to estimate the stormwater pond storage. The upstream flow of the pond was estimated using the popular rational method. A rainfall runoff model has been developed for the total watershed to estimate C. Assuming the outflow rate of pond, the pond storage for different rainfall duration has been calculated. In addition to pond storage, different aspects of a typical pond design are presented and discussed in this paper.

Study Area

The study was performed on a golf course which is situated on the western part of Rockhampton city, Queensland, Australia. The Rockhampton Golf Club is a 18 hole, par 72 course, located on the Capricorn tropic and the doorway to the Capricorn coast, and Australia's outback [7]. It is surrounded by the Rockhampton Airport and the charming Botanic gardens and Murray lagoon of Rockhampton. An image of Rockhampton Golf Course, taken from Google map is shown in figure 1(a). At the left bottom inset of the map a picture of Rockhampton golf course, showing two ponds are presented in figure 1(b).

The area of the golf course is about 54 hectares. No town water is used for irrigation on the Course. On the golf course, there are five ponds. Currently water is pumped for irrigation from the holding dam on the Course beside the 16th Fairway. The dam is filled up by the precipitation which falls on the Course. In dry

months it is topped up with water pumped from the Lion Creek (a branch of the Fitzroy River), and delivered to the dam via a channel running alongside the airport. Almost all of the runoff coming onto the Course from 'The Range' flows through other dams on the Course and thence into the Murray Lagoon. The rate of pump, used to irrigate the course is 30 litre/sec and 0.8 mega litres/day water are generally used during peak periods throughout the summer. Therefore, on an average, pump runs for 7.5 hours per day. There is a possibility of using other dams at a future date, but the cost and logistics of connecting them to the existing irrigation system are currently prohibitive. In this study attempts have been taken to retrofit the existing irrigation pond and address the important aspects of pond design.
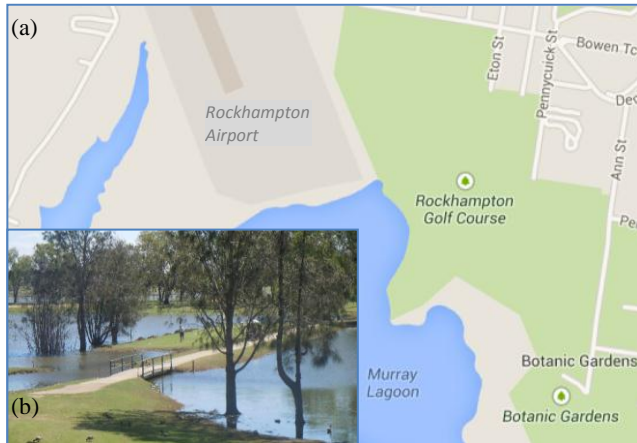

Figure 1. The study area: (a) Image from Google Earth; (b) Ponds of Rockhampton Golf Course.

Pond Storage Calculation

Sizing of stormwater pond is normally based on the maximum volume found from different rainfall intensities, determined for the most critical wet seasons. There are different way to determine pond size. For pond sizing, the reservoir routing method is more complex and time consuming than the empirical equations. Here the simple water balance approach has been used. The water balance is defined by the general hydrologic equation, which is basically the law of conservation of mass as applied to the hydrologic cycle. The simplest form of this equation comes as equation (1). Water balance equations can be assessed for any subsystem of the hydrologic cycle, for any size of area, and for any period of time.

$$\text{Inflow} = \text{Outflow} + \text{Storage volume} \qquad (1)$$

This basic conservation of volume equation for a reservoir for a time interval Δt can be expressed as equation (2).

$$S_{t+\Delta t} - S_t = \sum I_{vol} - \sum O_{vol} \qquad (2)$$

Where S_t and $S_{t+\Delta t}$ are the storage volume at the beginning and end of the time interval Δt respectively, and $\sum I_{vol}$ and $\sum O_{vol}$ denote the total inflow and outflow volumes of a reservoir during the period of time interval Δt.

Hydrologic Analysis

Proper hydrologic analysis is needed to keep the stormwater pond functional and sustainable [8]. A detailed analysis provide storage needs, flooding risk and contributing watershed dynamics [9-12]. Sharif et al. did the trend analysis of hydrologic data like rainfall, evaporation and temperature of 31 stations in the Fitzroy Basin for the period 1954 to 2010 [13]. There are many computer models and even some spreadsheet routing analysis that are available to facilitate these determinations. Amir et al. (2012) developed an integrated hydrological and hydrodynamic model using MIKE 11 [14]. Akram et al. (2014) compared four routing

techniques using xpstorm to produce peak discharge in the study area for 5 year ARI and 24 hour duration [15]. The rainfall intensities for the study area corresponding to different ARI and duration and the details of the modelling approach can be found in Akram et al. (2014). Before development of rainfall runoff model, catchment delineation must be done. In this study area, automatic catchment delineation has been done using digital elevation model and ArcGIS [16]. From the hydrologic model, C of the subcatchment was found to be 0.35 which is within the recommended value for lawns 0.17 to 0.48 [17].

Rational Method

As the study area is small part of whole subcatchment, the design inflow for the study area was calculated using rational method. Rational method is one of the oldest but still remains the most widely used routing technique both in Australia and overseas. This method is a popular tool for estimating peak runoffs from small catchments, though it is less rigorous than other hydrologic procedures. In the rational method, the peak discharge is given by the equation (3).

$$Q = 0.278CIA \qquad (3)$$

Where; Q is peak discharge, m^3/s; C is runoff coefficient; I is rainfall intensity, mm/hr; A is catchment area, km^2.

Using C of rainfall runoff model, the proposed runoff flow rates for different rainfall durations from contributing area have been estimated. Rainfall intensity was acquired from IFD curves specific for the Rockhampton, produced by the BOM, Australia. Outflows from pond has been assumed to be some percent of contributing area. Storage volume has been estimated by deducting the outflow from the inflow. The maximum storage volume has been chosen for pond design. The detail pond volume calculation using spreadsheet has been presented in table 1 [17].

For the case study area, A is 54 ha; C from the model is 0.35 and storm recurrence interval is 100 yrs. Using these values runoff inflow for different rainfall intensities have been estimated by rational method which is shown in column five of table 1. Assuming maximum allowable outflow as 5% of contributing area, the outflow volume has been calculated. Now using equation (1), detention volume has been calculated. For getting required retention storage, A is multiplied by 1 cm of rain. Finally adding detention and retention storages, total storage volume for different rainfall durations have been found. From table 1, it is found that the maximum volume of pond is around 14,000 m^3. Using the first and last column of table 1, a graph has been produced. The graph shows that initially required volume of storage increases until 30 min duration, then maximum storage volume achieved for 30 min to 60 min rainfall duration. After that the curve shows a decreasing trend. After 245 min duration, the curve becomes negative.

Typical Pond Design and Guidelines

Large variety of pond designs are available with a wide variety of features. Different designs have different requirements. No single solution or design can be fitted for all situations. A typical pond design along with some design criteria important for golf course pond are presented below.

Design Calculation

Total volume of pond is 14,000 m^3. The pond is assumed to be rectangular and the pond depth d is 2 m. Therefore, the area of the pond is 7000 m^2. Let the ratio of length to width of the pond is 3:1. Therefore the length and width of the pond will be 48 m and 146 m respectively. Using these dimensions a drawing of typical pond design is presented in figure 3. The top and side view of pond are shown in figure 3 (a) and 3(b) correspondingly.

Duration (Minutes)	Duration (Hours)	100-Year Rainfall Intensity (mm/hr)	100-Year Rainfall (mm)	Proposed Runoff Flow rate (m³/s)	Proposed Runoff Inflow (m³)	Allowable Outflow Rate (m³/s)	Allowable Outflow (m³)	Required Detention Storage (m³)	Required Retention Storage (m³)	Total Storage (m³)
5	0.08	314	26.167	16.485	4945.5	2.7	810	4135.5	5400	9536
10	0.17	241	40.167	12.6525	7591.5	2.7	1620	5971.5	5400	11372
30	0.50	142	71	7.455	13419	2.7	4860	8559	5400	13959
60	1.00	96.3	96.3	5.05575	18200.7	2.7	9720	8480.7	5400	13881
120	2.00	63.5	127	3.33375	24003	2.7	19440	4563	5400	9963
180	3.00	49.3	147.9	2.58825	27953.1	2.7	29160	-1206.9	5400	4193
360	6.00	32	192	1.68	36288	2.7	58320	-22032	5400	-16632
720	12.00	21	252	1.1025	47628	2.7	116640	-69012	5400	-63612
1440	24.00	14.1	338.4	0.74025	63957.6	2.7	233280	-169322	5400	-
2880	48.00	9.44	453.12	0.4956	85639.7	2.7	466560	-380920	5400	-
4320	72.00	7.22	519.84	0.37905	98249.8	2.7	699840	-601590	5400	-

Table 1. Estimation of Maximum Pond Volume
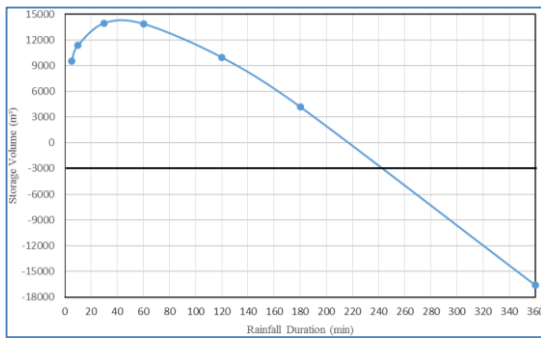
Figure 2: Rainfall duration vs required pond storage

Figure 3: Diagram of a typical pond design: a) top view; b) side view

General guides for calculating pond volumes other than rectangle are presented in table 2 [18], where all dimensions are in meter, volume in cubic meter and D_{avg} denotes the average pond depth. Mostly, output volumes are approximations, as pond sides are typically not vertical or pond bottom is not flat. Some other guidelines for pond design are discussed below.

Inlet and outlet

Normally a pond does not need any special inlet structure, if active recreation facility is not concerned [17]. A culvert as a low-level outlet would be appropriate there. Relevant literatures are available for the design recommendation [18].

Forebay

Forebays are placed near pond inlets to decrease required dredging areas through deeper sediment trapping.

Trickle Ditch

It is a channel that ensures water flow from inlet to outlet to prevent stagnation even during low flow.

Vegetative Shelf

Vegetative shelf around the pond acts as a transition between open pond water and its surrounding, may cover 10-20% of total pond area [18] . Usually 1 to 3 m shelf is constructed and the recommended slopes are 10:1 to 6:1.

Freeboard

For open pond, a minimum 0.3 meter freeboard is required above the computed 100 year water surface elevation. Detail design of Inlet-outlet, Forebay, Trickle Ditch, Vegetation Shelf and Freeboard is beyond the scope of this paper.

Pond Design Guidelines

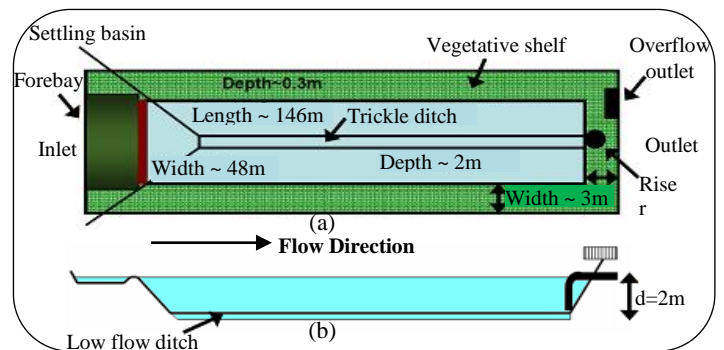To minimize potential problems of pond, the following guidelines should be maintained while designing pond.

Pond Shapes	Volume Equations
	$\pi x R^2 x D_{avg}$
	$\pi x (AxB) x D_{avg}$
	$0.45x(A+B)xLxD_{avg}$
	$\pi x R^2 + (WxL) x D_{avg}$

Table 2. Pond Volume Equations for Ponds of Different Shapes.

- Simple pond shape is encouraged for good water circulation
- The pond length should be 3 to 5 times the pond width
- The inlets and outlets need to be far enough to minimize short-circuiting; and should be protected from scour erosion and be covered by appropriate safety gratings
- 1 to 2 m permanent standing pond water is needed for sediment scouring protection, fish survival on winter and reduction of rooted aquatic plants growth.
- Side slopes should be no steeper than 3:1 (H:V) to improve safety and aesthetics and facilitate maintenance
- For low pond depths, outlet should be designed for low outflows to maximize particulate retention
- A drain should be provided for complete dewatering of pond
- Change of water elevation should be minimized to reduce mosquito problems
- A plan is needed for heavy equipment access to pond edges.

Pond Maintenance

Regular inspection and maintenance under a wide variety of conditions is important to get effective pond. Otherwise pond

becomes nuisance, eyesore and health hazard [6]. Proper maintenance ensure safety, quality water, improved drainage, increased flood control, recreational and aesthetics benefit. Ponds can be designed with minimum maintenance requirement, but maintenance free pond is not possible. Golf courses are highly managed areas. Use of chemicals or fertilizers and mowing near the ponds may cause algal blooms that can be avoided using vegetative pond shelf. Ponds might need to be dredged to remove contaminated bottom sediments [6]. The major detention pond usually needed to dredge around after ten years of pond construction . Extra pond depth can lengthen dredging intervals. Pond water on the golf course should be tested 2–4 times a year. The water quality parameters for irrigation include PH, electrical conductivity (EC); nitrate, nitrite, phosphorus, TKN; sodium, calcium, chloride, magnesium and bicarbonate or carbonate. Other routine tasks may include removal of debris and litter from outlets, grass cutting, managing unwanted vegetation, fence repairing, removal of excessive algae and other aquatic plants, mosquito control, and possible fish stocking. Vibrant communication with golf course personnel is necessary to facilitate proper pond maintenance.

Conclusion and Recommendation

Ponds are especially useful for golf courses, where they play a vital role in water conservation and providing sufficient irrigation water to turf. However, stormwater management and water quality might be other important reasons for golf course. If pond can be incorporated into the golf course properly, it ensures a better return on investment, time savings, cleaner surroundings, and finally a brighter world for future generations. Recent research and design advances improved the pond usage. Besides, recommendations for pond construction and use are well documented and readily available. The golf course pond volume calculation and the typical design presented here, are an attempt to present a general understanding of stormwater pond in golf course premises. However the involvement of specialist designer for the implementation is needed.

If pond construction is not required for business purpose or environmental up gradation, best not to construct them. Because water lost from the pond through evapotranspiration and seepage takes huge toll on water bodies, wildlife and fish. If pond construction is integral to irrigation or for other specific reasons, appropriate guidelines should be followed. Designer must explore the permits and approvals of local, state and federal Government. While the design, construction and management of the pond is very vital, it is equally significant to assess the impact of the pond on the surrounding water bodies and landscapes.

Acknowledgments

References

[1] Queensland Governments Department of Environment and Heritage Protection, Wetlands, 2013, viewed 23 July 2014 < https://www.ehp.qld.gov.au/ecosystems/wetlands/wetlands.html>.

[2] Vining, K.C. & Vecchia, A.V., Water-balance Simulations of Runoff and Reservoir Storage for the Upper Helmand Watershed and Kajakai Reservoir, Central Afghanistan, in *Scientific Investigations Report 2007–5148,* U.S. Geological Survey, 2007, 16 p.

[3] Bass, K., Burchell, M., Evans, R., Hunt, W., & Line, D., Stormwater Wetlands for Golf Courses, 2012, viewed 24 June 2014, <http://www.bae.ncsu.edu/extension/ext-publications/water/protecting/ag-765-stormwater-golf-course.pdf>.

[4] Pond Construction for Residential and Commercial Practices, Best Management Practices for Water Conservation and Pond Management, viewed 24 June 2014, < http://www.seleniumtaskforce.org/images/WWU_-_Pond_Construction_Guide.pdf>.

[5] Hartwiger, C., Bubble Bath: Keeping Golf course ponds clean using oxygen circulation and barely straw, Green Section Record, 2002, viewed 11 July 2014, <http://gsr.lib.msu.edu/2000s/2002/020518.pdf>.

[6] Pitt, R. & Voorhees, J., The Design, Use and Evaluation of Wet Detention Ponds for Stormwater Quality Management Using WinDETPOND, Department of Civil and Environmental Engineering, University of Alabama, Tuscaloosa, Alabama, 2003.

[7] The Rockhampton Golf Club, Viwed 24 June 2014, < www.rockygolfclub.org.au>.

[8] Akram, F., Rasul, M.G., Khan, M.M.K., & Amir, M.S.I.I., A Review on Stormwater Harvesting and Reuse, WASET, *International Journal of Environmental, Ecological, Geological and Mining Engineering*, **8(3)**, 2014, 183-192.

[9] Amir, M.S.I.I., Khan, M.M.K., Rasul, M.G., Sharma, R.H. & Akram, F., A Review of Downscaling and 1-D/2-D Hydraulic Model for Flood Studies, in *Central Region Engineering Conference*, 2012, Rockhampton, Australia.

[10] Amir, M.S.I.I., Khan, M. M. K., Rasul, M.G., Sharma, R. H. & Akram, F., Automatic Multi-objective Calibration of a Rainfall Runoff Model for the Fitzroy Basin, Queensland, Australia, WASET, *International Journal of Environmental Science and Development*, **4(3)**, 2013, 311-315.

[11] Amir, M.S.I.I., Khan, M.S.A., Khan, M.M.K., Rasul, M.G., & Akram, F., Tidal River Sediment Management–A Case Study in Southwestern Bangladesh, WASET, *International Journal of Civil, Architectural, Structural and Construction Engineering*, **7(3)**, 2013, 183-193.

[12] Akram, F., Rasul, M.G., Khan, M.M.K., & Amir, M.S.I.I., A Comparative View of Groundwater Flow Simulation Using Two Modelling Software - MODFLOW and MIKE SHE, in *18th Australasian Fluid Mechanics Conference*, 2012, Launceston, Australia.

[13] Amir, M.S.I.I., Khan, M.M.K., Rasul, M.G., Sharma, R.H. & Akram, F., Rainfall, Temperature and Evaporation trends in the Fitzroy Basin, Queensland, Australia, in *34th Hydrology and Water Resources Symposium,* Sydney, Australia, 2012.

[14] Amir, M.S.I.I., Khan, M.M.K., Rasul, M.G., Sharma, R.H. & Akram, F., Numerical Modelling for the Extreme Flood Event in the Fitzroy Basin, Queensland, Australia, WASET, *International Journal of Environmental Science and Development,* **4(3)**, 2013, 346-350.

[15] Akram, F., Rasul, M.G., Khan, M.M.K., & Amir, M.S.I.I., A Comparison of Different Hydrograph Routing Techniques in XPSTORM Modelling Software: A Case Study, WASET, *International Journal of Environmental, Ecological, Geological and Mining Engineering,* **8(3)**, 2014, 208-218.

[16] Akram, F., Rasul, M.G., Khan, M.M.K., & Amir, M.S.I.I., Automatic Delineation of Drainage Networks and Catchments using DEM data and GIS Capabilities, in *18th Australasian Fluid Mechanics Conference,* Launceston, Australia, 2012.

[17] Australian Rainfall and Runoff (2001), Volume 1, A guide to flood estimation, Engineers Australia .

[18] MPCA, Stormwater Detention Ponds, 2000, viewed 29 June 2014, <http://www.pca.state.mn.us/index.php/view-document.html?gid=7156>.