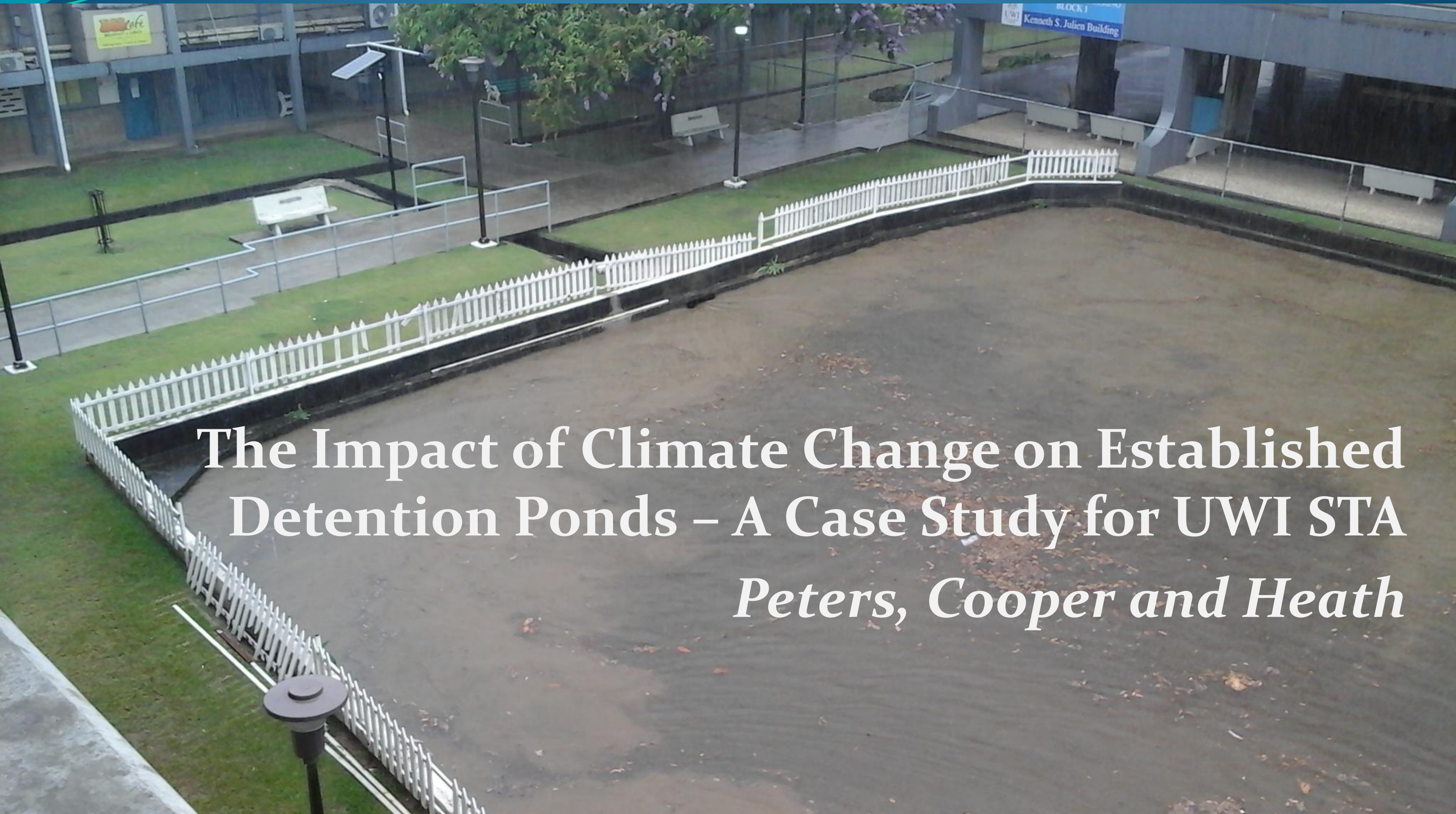

The Impact of Climate Change on Established Detention Ponds – A Case Study for UWI STA

Peters, Cooper and Heath

Presenter: Joseph Heath UWI

Presentation outline

- Background
- Literature review
- Methodology
- Results
- Conclusions

Background

- Engineers and planners are concerned with the impacts of flood events. However, there is a significant challenge to design effective urban drainage systems due to impacts from climate change and urbanization. (Seamen-Davies *et al* 2008; Huong and Pathirana 2013).

- A concern in many urbanising parts of the Caribbean, is the increasing failure of established systems that result in localised flooding. This is partly explained by the increase of 2.05% per decade in extreme precipitation over the past 25 years (Stephenson, Vincent and Allen 2014).

- Climate change can increase design intensities by 20% to 80% depending on the region (Ekstrom *et al*., 2005; Willems *et al.* 2012). This poses a problem of overloading of current drainage systems that were based on rainfall data for specific return periods which were based on historic patterns.

Background

- In response, there is a need to design sustainable drainage systems that can be upgraded or adapted with minimum cost; to function under changing conditions.

- Long term environmental and social factors should be taken into consideration when making decisions about drainage designs.

- Detention/retention pond is an important element of Best Management Practices for sustainable urban drainage systems (SUDS)
- They are used to manage storm water and can maintain the outflow from the post-developed basin to a flow similar to that under the pre-developed condition **(Park et al 2012; Charlesworth 2010; Maine Department of Environmental Protection 2006; Ravazzani *et al*., 2014).**

Background

- There are various objectives and criteria of drainage systems.
- Drainage systems to be sustainable they should integrate water quality, water quantity, and biodiversity and amenity aspects (Stahre, 2006: Charlesworth, 2010).
- Some scientists have attempted to simulate detention ponds using numerical modelling (Jaber and Shulka 2007; Narayanan *et al*., 2014)
- Stochastic search algorithm, a Genetic Algorithm (GA), has been used by Park et al. (2012) to optimize the detention pond design.
- The performance of any specific structure will depend on the pond's design, the characteristics of the area contributing runoff to the pond, and the degree of maintenance (Nipper 2016).

Background

- Further, while there have been call for increased use of detention ponds, in Trinidad (IDB 2013), little research has been done on the actual performance detention ponds.
- Poorly designed ponds or unplanned changes such as an urbanizing catchment can make the ponds ineffective and cause problems of flooding, pollution or damage to the environment.
- The **Faculty of Engineering Detention Pond (FEDP) functions** well under average rain storm conditions, however, it has been known to exacerbate the flooding problem on the St. Augustine campus during high intensity rainfalls resulting in the flooding of laboratories and offices.

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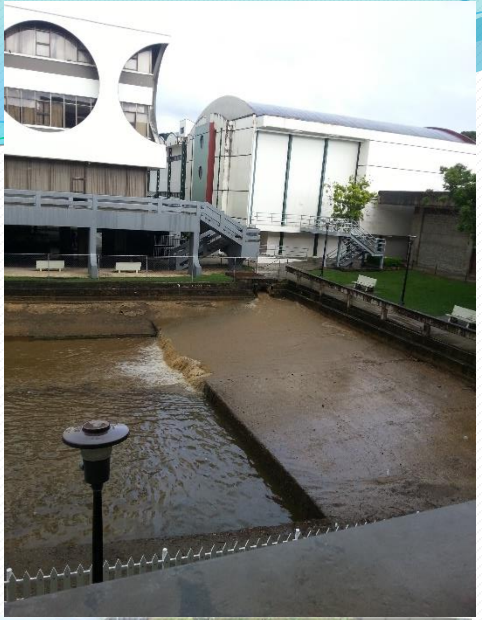


AIM OF STUDY

The aim of this study is therefore to investigate the performance of a detention pond under various conditions including climate change

Study Area -HISTORY

- In the early 1900's St. Augustine campus area was used for agriculture
- The current pond was used as an irrigation system and drinking water for animals. (Brereton 2011)
- By mid 1900's the UWI was established and the pond converted to a detention pond
- There were wetland properties to be used by students for biodiversity studies.

STUDY AREA

COORDINATES:
675038 m East
1176521 m North

As urbanization of the Campus and climate change increases it is not clear how the pond may function in the future increased precipitation

Study area

- The wetland system within the pond was maintained by the removal of vegetation and sediments every two or three years, at tremendous cost.

- In 2015, after a number of floods, the wetland system was removed and a pumping system was introduced

Study area

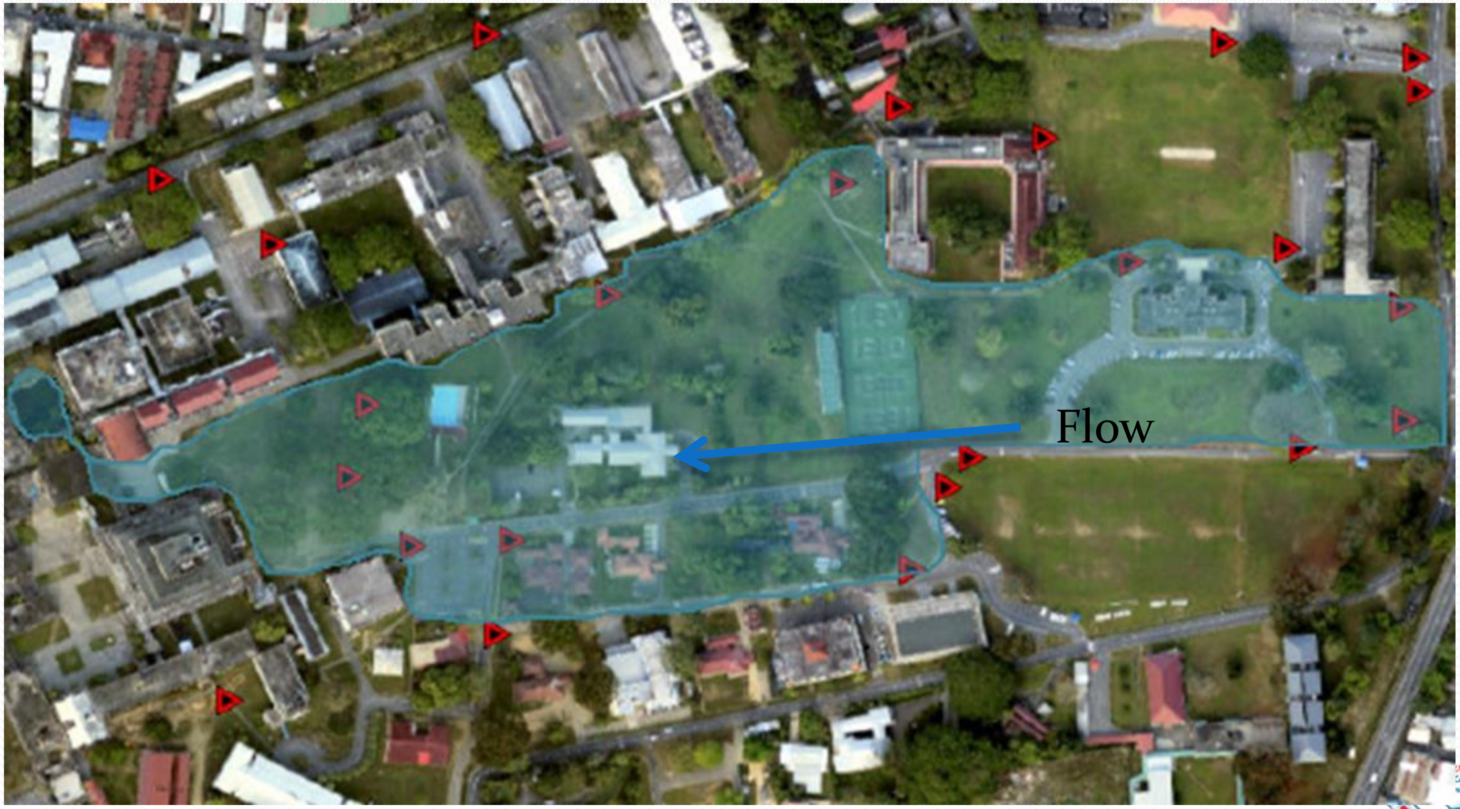
- Loss of multidisciplinary use in the operation of the pond particularly the biodiversity component.

- A single-objective approach intended to improve the performance by increasing storage

- The pumping system introduced to lower the level of pond between storms.

CHARACTERISTICS OF SITE

- The catchment that feeds the detention pond is approximately 75100m^2 with the longest water course of 735m, an average slope of 0.0082 and a time of concentration of 20 minutes.



METHODOLOGY

- Creation of Pond Model (through direct measurements)
- Obtain characteristics of site as well as the inlet and outlet structure
- Determination relationship between the changes in storage, pond volume, pond depth and pond discharge
- Generation of Unit Hydrograph(UH) using SCS method
- Use of UHs for generating **Storm Hydrographs**
- Simulation of pond performance using modified Puls method
- Microsoft Excel programme was developed for the simulations

Simulation scenarios

1. Pond full
2. Pond being Partially full
3. Pond full with Pump Activated
4. Pond Partially Full with Pump Activated

CHARACTERISTICS OF THE SITE

- The Characteristics of the site which included Area, Slope, and Longest Water Course was obtained using arcGIS.
- The predominant soil condition of the area was also obtained form soil maps and the hydraulic condition of the soil was derived from tables.
- The time of concentration was calculated using Kirpich Equation which is recommended for watersheds up to 200 acres.

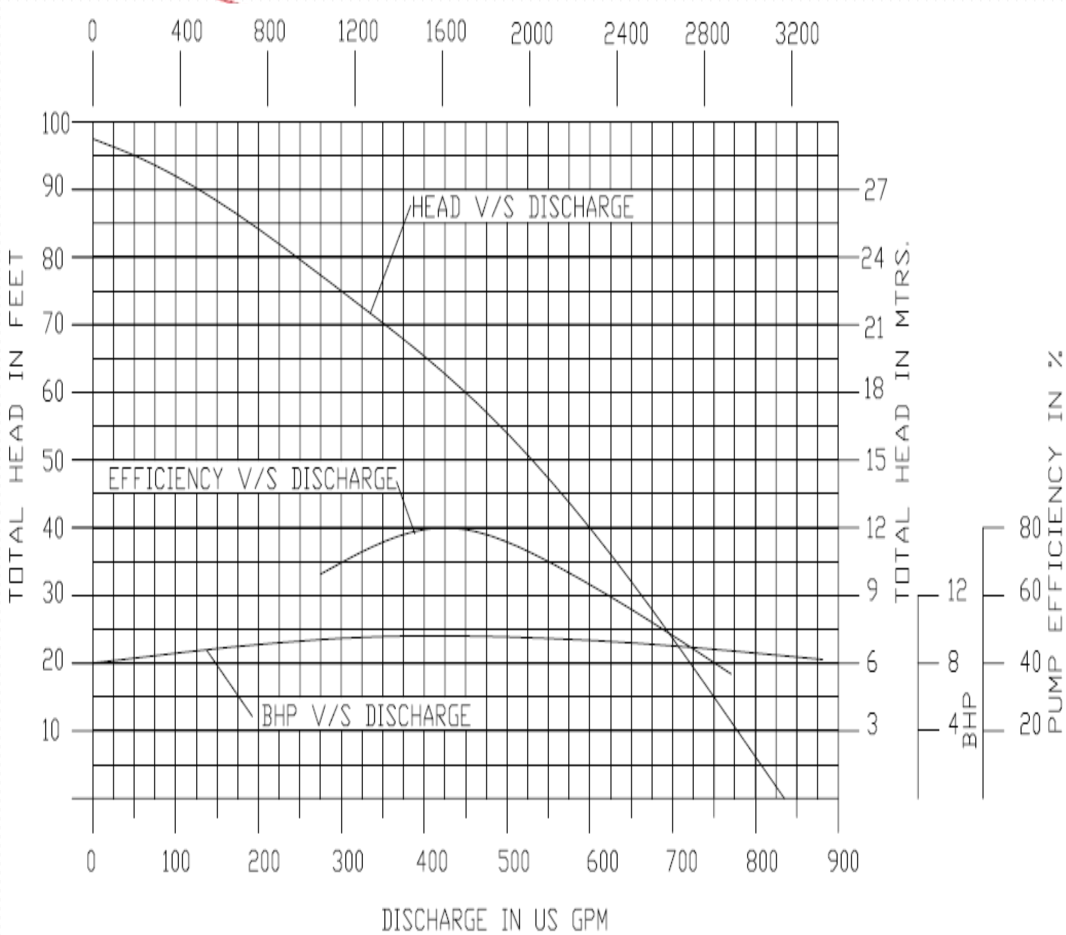
$$Tc = 0.0195\left(\frac{L^{0.77}}{S^{0.385}}\right)$$

Analysis of inlet and outlet structures

- **Inlet:**
  - characterised as a box culvert

- **Outlet**
  - Broad Crested Weir
  - Rectangular Orifice
  - Sump Pump

SUMP PUMP:



- The Automatic pump is switched on when the depth of water at the downstream end of the pond is **2.2m**.
- It has a maximum pump efficiency flow rate was 0.027m³/s corresponding to a head of **0.73m** obtained from the pump curve.

CONSTRUCTION OF UNIT HYDROGRAPH

- The unit hydrograph was generated using SCS triangular unit hydrograph method
- This method required use of curve number which was dependent on land cover, soil and hydraulic condition.
- The respective subarea of each land cover was measured using arcGIS
- Excel spread sheet was generated for computation

RESULTS AND ANALYSIS

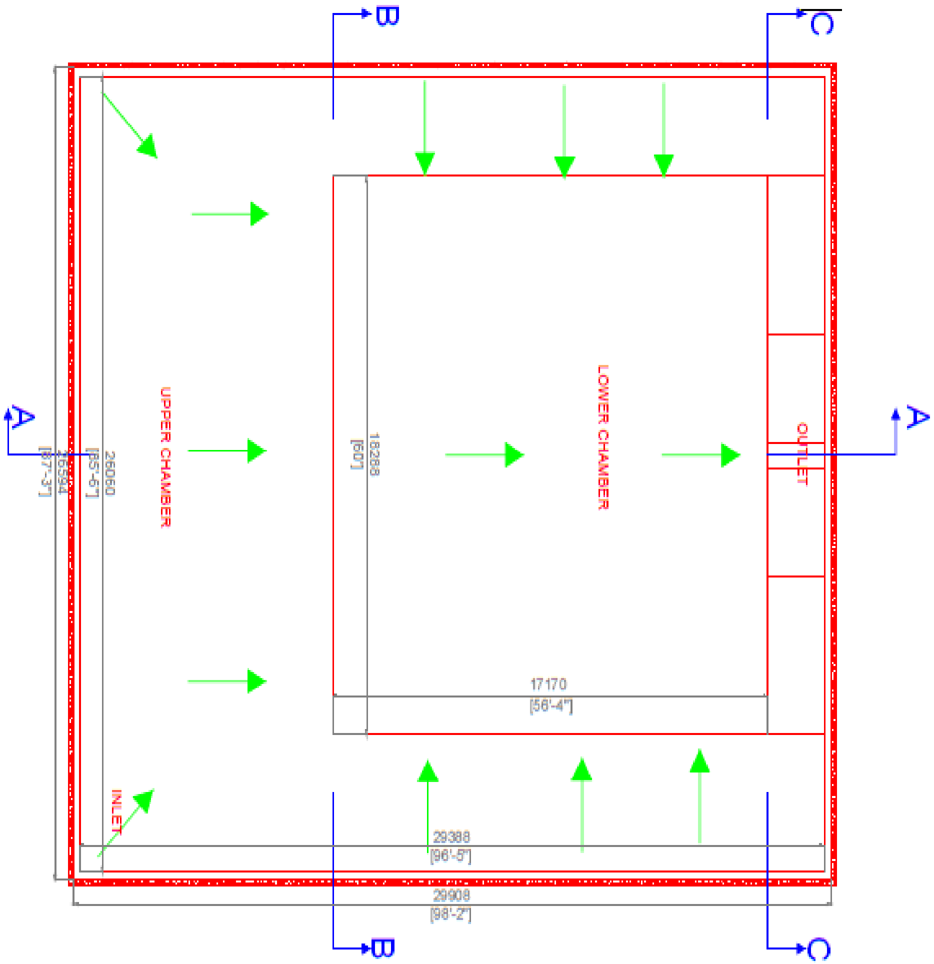
RESULTS AND ANALYSIS: DETENTION POND DETAILS

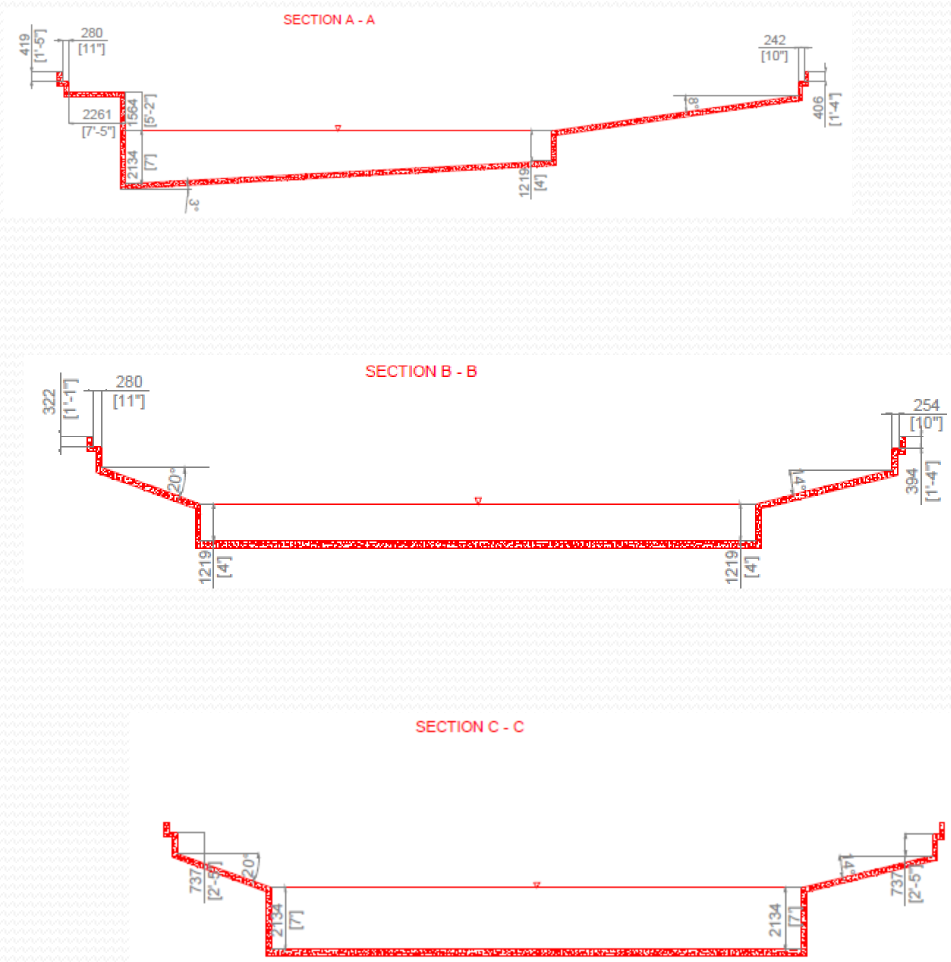
- The pond is rectangular in shape with dimensions of 30m by 26.5m, has a total storage capacity of 1872m^3 and a maximum depth of 3.7m.

Capacity of the Various Chambers :

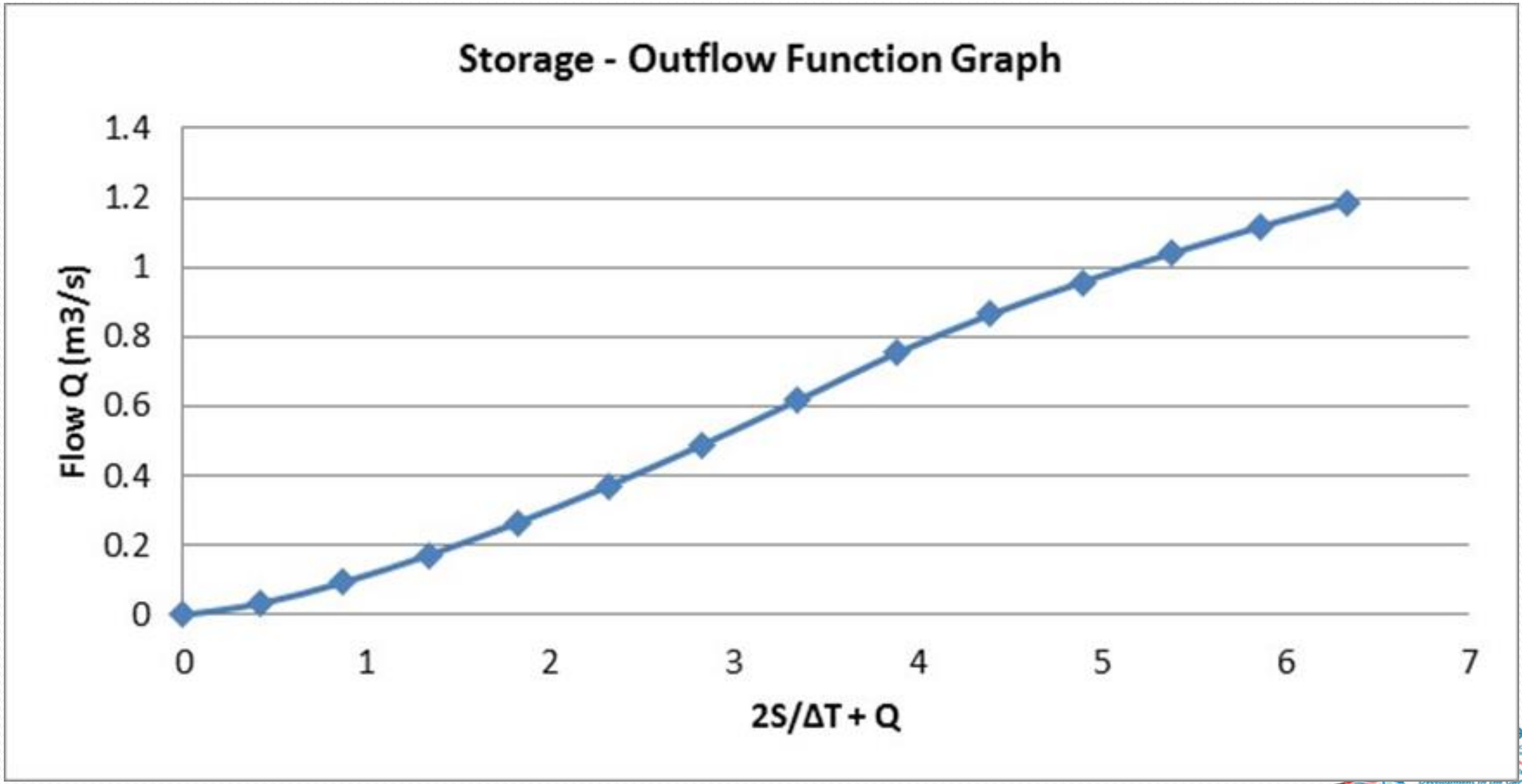
- Lower chamber volume = 468 m^3
- Upper chamber volume = 140 4m^3
- Total volume = 1872 m^3

DETENTION POND MODEL

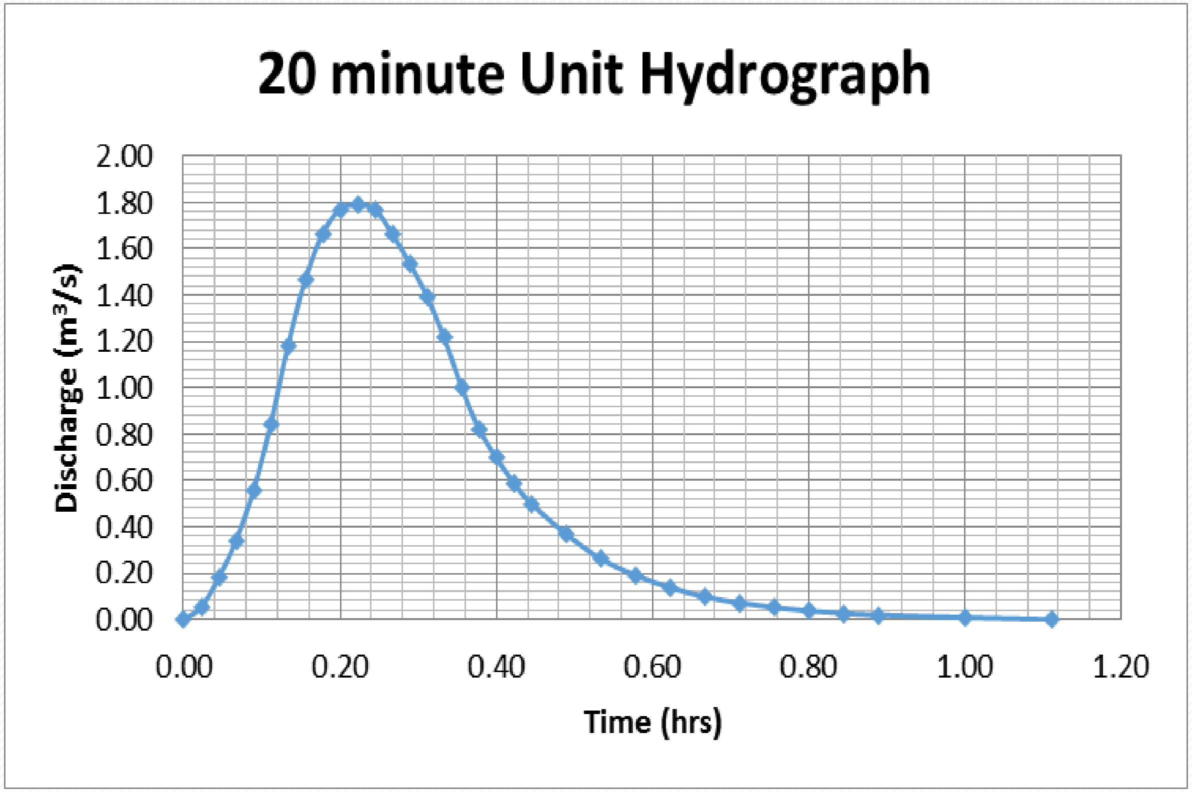




STORAGE OUTFLOW FUNCTION



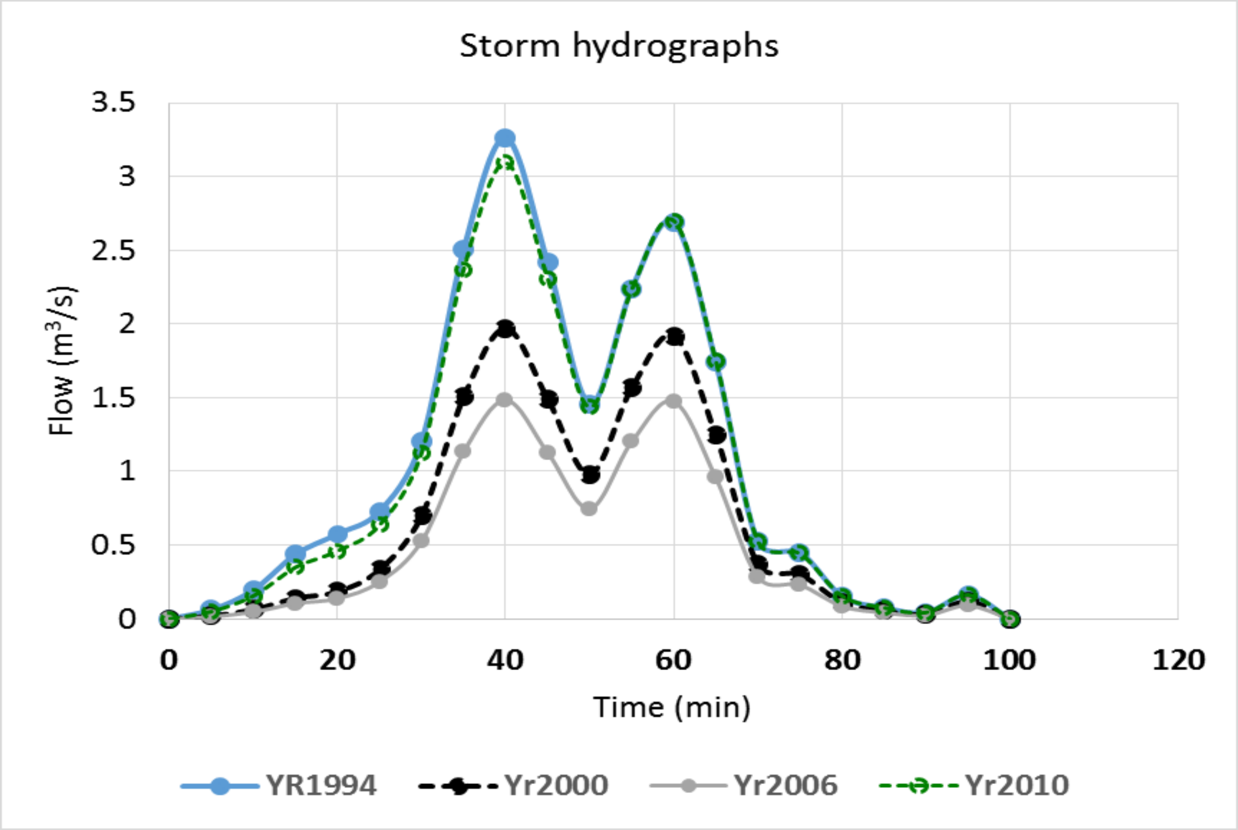
UNIT HYDROGRAPH



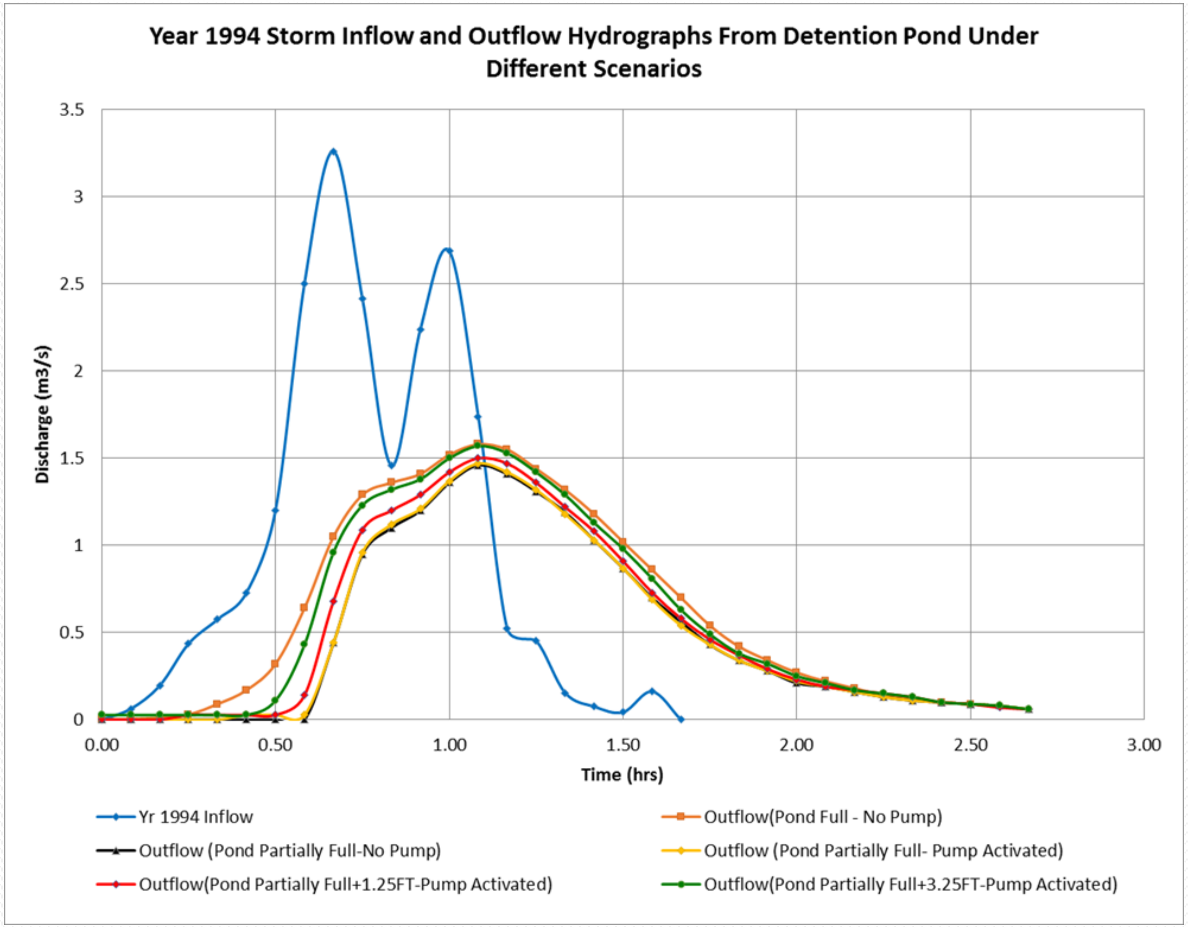
The time of runoff, is realistic as based on anecdotal information the flows from storms last for about 40 minutes to an hour after the cession of storms.

STORM HYDROGRAPH

Year	1994	2000	2006	2010
Total rain (mm)	127	82	86	110
Distribution of rain as a (%) over 20 min periods ($1^{st}/2^{nd}/3^{rd}$)	30/45/25	31/42/26	31/41/28	31/43/25



HYDROLOGIC FLOOD ROUTING UNDER DIFFERENT SCENARIOS



OVERALL RESULTS – reduction in peak flows

Year	1994	2000	2006	2010
Inflow peak flows	3.26	1.97	1.48	3.09
Reduction in peak flow with pond full (%)	51	42	37	50
Reduction in peak flow (0.99m)	51.9	42.2	41.3	51.2
Reduction in peak flow (0.38m)	54.5	48	50.0	52.2
Reduction with pond empty (surface at level of pump)	55.2	51	59	54
Pond at pump level and pump activated	55.9	51.0	59.0	54.4

Performance under climate change scenario

- For a 25 year storm, the pond would result in the peak flow reducing by 32% in 2030 and 34% by 2050.
- For an increase of 15% to 20% in total precipitation and precipitation intensity it was found that the average reduction in peak flow was 48% compared to 45% under current conditions.

CONCLUSION

- The most important condition in operating the pond with a pump activated is when the pond is empty.
- Hence the pump is most useful in emptying the pond after a storm.
- If the pump is activated when the pond is close to full or full, the peak of the outflow could increase negating the purpose of the presence of the pump