Development of a Pollutant Load Algorithm (for Sydney Australia)

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Abstract
The basic data requirement needed to size devices that capture pollutants is the treatable flow rate and the expected pollutant load.

Sydney Water Corporation is in the process of implementing a scheme whereby it is required to install around 50 devices. Therefore it is justified to attempt to improve pollutant load estimating techniques. The proposed methodology focuses on actual pollutant capture data for existing devices owned and operated by Sydney Water. The algorithm utilizes a multitude of parameters and weighting factors, that can account not only for catchment characteristics such as land use but also account for activities being carried out within the catchment such as street sweeping or education campaigns. The result is a more robust and efficient method to determine pollutant loads from any new device catchment based on comparison to the existing device catchments.

In addition by widening the scope of data sources it opens the arena to the possibility of implementing and obtaining an industry standard tool for recording capture loads, reporting performance and designing devices that capture pollutants. Finally by adding a commercial element providers of "off the shelf" Devices can maintain a realistic set of performance claims that will aid catchment managers in selecting appropriate devices to remove pollutants from the urban storm water system. It is likely that the most efficient, practical and cost effective arena to implement such a tool is via a WEB ENABLED Application.

Background - [A Need to Develop Pollutant Load Estimates]

Stormwater quality from developed areas is a significant problem that is adversely impacting many of the waterways of New South Wales. For some time now waterways have been under significant pressure from various pollutants resulting in degraded water quality and ecosystem health.

Responsible authorities that manage stormwater infrastructure include Local Government Authorities, Sydney Water Corporation (SWC), Hunter Water, State Rail Authority and the Roads and Traffic Authority . In April 1998, these responsible authorities were issued with notices by the NSW EPA under Section 12 of the *Protection of the Environment Administration Act, 1991* and under Regulation 21 of *the Clean Waters Regulation, 1972* to prepare, participate and action stormwater management plans (SMP's) for the urban catchments of waterways in NSW.

These SMP's identify various strategies to combat the degradation of water quality in receiving waters. The strategies include public awareness / education campaigns, various studies to better determine specific problems, the installation of stormwater quality improvement devices (SQUID's) including gross pollutant devices (GPD's-gennerally capture pollutants > 5mm), wetlands and creek naturalization.

Sydney Water was required to participate in the preparation of these plans and to prepare its own Stormwater Environment Improvement Program (SEIP). This document lists all strategies identified within each of 17 SMP's produced that impact of Sydney Waters infrastructure for Sydney Waters contribution to improve storm water quality across the Sydney Metropolitan Area. As part of Sydney Water Corporations' (SEIP), Dated March 2001, [Ref.1], it is proposed to place around 50 GPD's along water ways including storm water pipes and channels to reduce the level of pollutants in the storm water system.

There are various types of devices for various specific needs. A GPD generally removes larger visible pollutants from the storm water system. The sizing of a GPD is reliant on the estimation of pollutant load and a treatable flow rate.

Therefore in attempting to implement the SEIP it is a general requirement that the justification of the size of a proposed device be related to a predicted pollutant load. Not only will this determine its physical size but it will also determine the costs associated with its cleaning by virtue of its pollution holding capacity compared to the pollutant load. For instance it would not be practical nor cost effective to place a device on a channel that had a pollutant holding capacity of $1.0m^3$ if the estimated load was say $20m^3$/month.

Many of the SMP's produced throughout Sydney were based on minimal data relating to pollutant load. There was little or no attempt to provide any variation or justification/ explanation for variation in pollutant load across various catchments.

As Sydney Water is in the position of holding pollution capture data for various devices spanning over several years it is in a position to provide some comment on the pollution capture characteristics of various devices on several catchments. It was found that there was quite some variation in the capture rate [m^3/ha/yr]. Therefore it was questioned whether this related to the pollutant load and its variation between catchments.

Summary of Data

Sydney Water holds a database in the form of an Excel spreadsheet containing the data relating to each inspection and each clean out of all SQUID's that it operates. Being a spreadsheet solution rather than a data base solution such as Access or similar, limits the complexity of queries that can be formulated. In addition it also makes it more difficult to link other data to the capture data. For instance linking rainfall data to determine the amount of rainfall that contributed to the amount of pollutant captured could be useful in determining the influence of rainfall on pollution captured.

Currently the data held in the spreadsheet is for 13 devices, that will with the implementation of the SEIP rapidly increase to around 60 in the next 5 years. Currently for the 13 devices there is 72 device-years of data, that is to say an average of around 5.6 years of data for each device.

The range in catchment size is from 14.0 hectares to1128 hectares.

The summarized data indicated that it could not be justified to apply a generic pollution load derived from one or several catchments with often dissimilar characteristics to the subject catchment.

Therefore there appeared to be adequate justification to investigate the cause of variation in capture loads, and also adequate need to justify the determination of a general algorithm or methodology that could provide a sound means of explaining or predicting variation in pollutant load from various catchments.

CAPTURED RUBBISH FROM FILTERED SAMPLE OF DEVICES										
			CAPTURED RUBBISH ---> LITTER / ORGANICS					SEDIMENTS CAPTURED		
		Catchment	Years	Average	Average per	Percent	Percent	Years	Average	Average per
	INC LU DE	Area	Monitored	per year	ha per year	organic	litter	Monitored	per year	ha per year
		ha		(m3)	(m3)				(tonne)	(kg)
GROSS POLLUTANT TRAPS										
Bondi, Roscoe St	1	46	8.34	144.65	3.14	71.73	28.27	8.34	66.23	1440
Bondi, Lamrock Ave	1	46	8.27	143.38	3.12	71.69	28.31	8.27	62.49	1360
Botany	1	890	8.61	190.25	0.21	78.58	21.42	8.61	195.17	220
Orissa St, Canterbury	1	55	8.33	112.82	2.05	75.91	24.09	8.33	13.37	240
Roslyn Gardens	1	14	7.61	43.78	3.13	74.51	25.49	3.14	4.40	310
Wolli Creek	1	1128	7.28	296.70	0.26	76.92	23.08	7.51	258.69	230
Rouse Hill Basin 5	1	430	0.28	0.00	0.00	0.00	100.00	0.28	97.57	230
Rouse Hill Basin 13	1	295	0.50	0.00	0.00	0.00	100.00	0.50	54.45	180
Rouse Hill Basin 28	1	981	0.50	0.00	0.00	0.00	100.00	0.50	54.45	60
Rouse Hill Basin 29	1	1527	0.43	8.14	0.01	0.00	100.00	0.43	62.77	40
TOTAL ALL GPTs	**10**	**GROSS POLLUTANT TRAPS**								
TRASH RACKS & SCREENS										
Cup & Saucer Creek	1	500	8.29	259.88	0.52	76.26	23.74	8.29	38.33	80
Mackey Park, M'ville	1	90	8.24	292.31	3.25	73.06	26.94	8.24	33.67	370
DPS 2, Marrickville	1	48.53	5.79	209.63	4.32	69.62	30.38	5.87	29.96	617
TOTAL ALL TRs	**3**	**TRASH RACKS & SCREENS**								
Summary			Data	Rubbish						
for No of		Catchmen	Collected	Captured				Accum	Sediment	Sediment
Devices		(ha)	Years	m3/yr	m3/ha/yr	% Org	%Litter	Years	tonnes/yr	kg/ha/yr
TOTALS --------------->	13	6050.5	72.44	1701.54	20.01	668.28	631.72	68.28	971.56	5377
Min		14.0	0.28	0.00	0.00	0.00	21.42	0.28	4.40	40
AVERAGES ---------->		**465.4**	**5.57**	**130.89**	**1.54**	**51.41**	**48.59**	**5.25**	**74.74**	**414**
Max		1527.0	8.61	296.70	4.32	78.58	100.00	8.61	258.69	1440

* This table provides a summary of data. Note however that the Rouse Hill devices had not been in service for their first year and no data was available at that time.

What is the likely cause of Variation in Capture rates?

Pollution capture rates for a device with a certain upstream catchment must be related to certain measurable parameters.

Every catchment has a multitude of parameters that describe its characteristics, and that may be utilised to differentiate it from another catchment. At the most basic level is the size of the catchment. Other factors relate to the hydrologic response of the catchment. These include;

- rainfall characteristics (Quantity, Intensity, location of rainfall),
- catchment surface characteristics (land use , proportion of impervious surfaces)
- type of conveyance system in place (Natural creek, pipes, channel)
- number of pollution capture devices upstream

However the most influential parameter impacting the capture load is of course the pollutant load. This in itself also has a multitude of factors or parameters that impact on the variation of load washing off a particular catchment.

At this stage it is difficult to make any conclusions about the variation of load from one catchment to the next. It is likely to be the interaction of many factors that have an influence on the movement of pollutant within the catchment.

Factors affecting pollutant load

The factors that impact on the pollutant load at any given point in a catchment relate to several processes that cause the pollutant to be at that point in the catchment at that given time. These processes include the BUILDUP of pollutant on the catchment. The REDISTRIBUTION of the pollutant by various processes including being blown away by wind being removed by mechanical means etc. The WASHOFF of the pollutant from the catchment surface into a stormwater drain or watercourse. The TRANSPORT of the pollutant down the storm water system. The CONTAINMENT or TRAPPING of pollutant either temporarily or permanently within the drainage system, either by design or otherwise. The DISLODGEMENT of temporarily TRAPPED pollutant in the stormwater system. Finally there is the CAPTURE & REMOVAL of pollutant by GPD’s.

THE BUILD UP.
Is impacted by;
Behavior of People (littering), Type of vegetation in catchment, Placement of Garbage Bins in catchment, Time elapsed since last rainfall….Etc.

REDISTRIBUTION
Is impacted by;

Servicing of Garbage Bins, Street sweeping, Climate factors, Prevailing wind direction & average wind speed…. Etc.

WASHOFF
Is impacted by;
Rainfall Volume (How much rainfall), Rainfall Intensity (The rate of rainfall), Frequency of Rainfall (the number of times it rains), The types of surfaces within the catchment….Etc.

TRANSPORT
Is impacted by;
The type of drainage system, Volume of Runoff & Flow rate…Etc.

CONTAINMENT or TRAPPING
(In conjunction with DISLODGEMENT is essentially an extension of BUILDUP).
Often litter is trapped in parts of the drainage system this is another factor that impacts the BUILDUP. It may be in badly configured pits or on branches that overhang an open drain.

DISLODGEMENT
At some point a storm event may dislodge the trapped litter. Then the litter that had previously been transported along part of the drainage system is again being transported.

CAPTURE & REMOVAL
Is impacted by;
The type of device, The type of diversion if an offline device, The impact of blockages, The condition of the device, The holding capacity (has it been cleaned or is it already full)….Etc.

-Note the aim is to be able to dynamically add as many parameters regarding the pollution behaviour on the catchments as may seem fit. In addition influence weightings for each parameter can provide the ability to assess the relative impact of one parameter over another.

SIZING OF DEVICES LISTED IN THE SEIP

In committing itself to implement the SEIP Sydney Water has to go through the process of DEFINE (Define the location size flow rate etc. to finalise feasibility), DESIGN (the device, the diversion requirements for construction), ACQUISTION (the implementation of contracts for construction).

Currently the DEFINE phase is underway for around 20 projects including around 15 GPD's. Initially it was thought that the sizing of the devices would be reliant on the review of the SMP's that identified the need for the project. The basis being that the SMP's would surely have identified loads and flow rates. However it was found that the majority of SMP's were based on very conceptual often one-line statements about the placement of a device. The only reference to pollutant load was generally regarding availability of reports or research underway or completed in other areas. One such report is from the CRC for Catchment Hydrology titled, "From Roads to Rivers, Gross pollutant removal from urban waterways" REF. 2. However it is difficult to justify applying the strictly localized findings in Melbourne to a vast array of varying catchments in Sydney.

Current approach

The approach that has been adopted to date has been to filter capture data held in the 'excel' spreadsheet by size of catchment. In addition the CRC data can be included also for comparison or to allow it to be averaged with the resulting capture load data. The treatable flow rate is usually selected as a 1 in 3-month flow or a 1 in 6-month flow, and the appropriate hydrologic analysis completed for the upstream catchment.
The filtering technique is limited to only the most basic catchment data of size and proportion impervious.

Although this provides some level of filtering the range of capture rate is still variable. For instance in the catchments ranging between 10 and 50 hectares the variation in capture rates is from 3.12 to 4.32 with an average of 3.43 m3/ha/yr.
Similarly for catchments in the range between 100 and 1200 hectares the range is 0.21 to 0.52 with an average of 0.33 m3/ha/yr.
This variation indicates that for smaller catchments 31.27ha +/- 17.27ha (55.2% variation) the median capture rate is 3.72 +/- 0.6 - (16% Variation).
Whilst for the larger catchments 814 +/- 314ha (38.6% variation) the median capture rate is 0.37 +/- 0.15 – (42% variation).

For the Smaller Catchments:

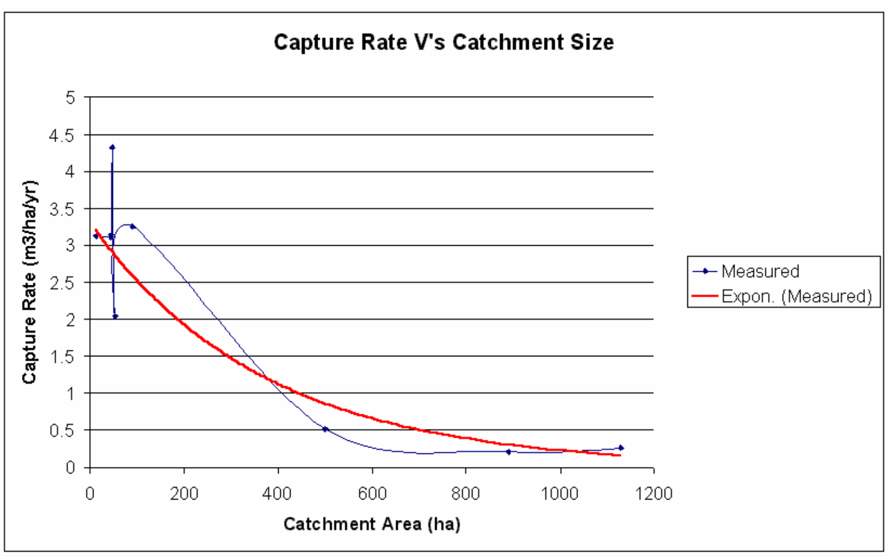
Catchment Range	CAPTURED RUBBISH FROM FILTERED SAMPLE OF DEVICES				
No Smaller than >	**10**	CAPTURED RUBBISH ---> LITTER / ORGANICS			
No Greater than >	**50**				
Exclude Rates <	**0.1**	Catchment	Years	Average	Average per
		Area	monitored	per year	ha per year
	INCLUDE	ha		(m3)	(m3)
GROSS POLLUTANT TRAPS					
Bondi, Roscoe St	1	46	8.34	144.65	3.14
Bondi, Lamrock Ave	1	46	8.27	143.38	3.12
Roslyn Gardens	1	14	7.61	43.78	3.13
TOTAL ALL GPTs	3	GROSS POLLUTANT TRAPS			
TRASH RACKS & SCREENS					
DPS 2, Marrickville	1	48.53	5.79	209.63	4.32
TOTAL ALL TRs	1	TRASH RACKS & SCREENS			
	Summary		Data	Rubbish	
	for No of	Catchmen	Collected	Captured	
	Devices	(ha)	years	m3/yr	m3/ha/yr
TOTALS ---------------->	4	154.5	29.99	541.44	13.71
Min		14.0	5.79	43.78	3.12
AVERAGES ---------->		**38.6**	**7.50**	**135.36**	**3.43**
Max		48.5	8.34	209.63	4.32

For the larger catchments:

Catchment Range					
No Smaller than >	**100**	CAPTURED RUBBISH FROM FILTERED SAMPLE OF DEVICES			
No Greater than >	**5000**		CAPTURED RUBBISH ---> LITTER / ORGANICS		
Exclude Rates <	**0.1**	Catchment	Years	Average	Average per
		Area	monitored	per year	ha per year
	INCLUDE	ha		(m3)	(m3)
GROSS POLLUTANT TRAPS					
Botany	1	890	8.61	190.25	0.21
Wolli Creek	1	1128	7.28	296.70	0.26
TOTAL ALL GPTs	2	GROSS POLLUTANT TRAPS			
TRASH RACKS & SCREENS					
Cup & Saucer Creek	1	500	8.29	259.88	0.52
TOTAL ALL TRs	1	TRASH RACKS & SCREENS			
	Summary		Data	Rubbish	
	for No of	Catchmen	Collected	Captured	
	Devices	(ha)	years	m3/yr	m3/ha/yr
TOTALS ----------------->	3	2518.0	24.18	746.83	1.00
Min		500.0	7.28	190.25	0.21
AVERAGES ---------->		**839.3**	**8.06**	**248.94**	**0.33**
Max		1128.0	8.61	296.70	0.52

What can we learn from this?
In isolation it is very difficult to come up with any conclusions! Except that on face value GPD's on larger catchments do not capture pollutants at anywhere near the rate of those on smaller catchments.

However this is a dangerous statement to make unqualified! It is more than likely also however that the pollutant load as an average shows the same trend as the capture rate for these particular catchments. This may be investigated by including land use data in the data filtering process.



This is part of the reason to enter into the phase of developing a new approach / methodology / algorithm.

AIM OF DEVELOPING THE ALGORITHM

The aim is to provide a robust consistent approach in determining the projected pollutant yield from any catchment. Initially this will be utilised to determine appropriate GPD's for the Sydney Waters' SEIP.

At this stage it is unclear if the final outcome will come down to the determination of an algorithm ore equation of some relationship between factors, or if the development of the investigating tool will provide the platform for the method.

The aim of the investigating tool is to provide a means to differentiate catchment pollutant generation and capture behavior.

METHODOLOGY IN DEVELOPING THE ALGORITHM

It is proposed to undertake the development in stages the stages can be described as follows:

STAGE 1.

Create Database application from EXCEL Spreadsheet, adding catchment data for each of the existing devices. That is the current pollutant capture data recorded whenever a GPD is cleaned is to be transferred from Excel into a data base format.

The DATA being held is as follows:

GPD POLLUTANT CLEANOUT DATA		
PARAMETER in DATABASE	Measured Unit	Outcome
Name of Device	Name	
Date of Clean out Inspection	Date	Time history of capture
Quantity of Pollutant removed or observed	m^3	Amount captured
Comment		

Added to this data will be information about the device and its upstream catchment.

The data includes:

DEVICE DATA & UPSTREAM CATCHMENT DATA		
PARAMETER in DATABASE	Measured Unit	Outcome
Name of Device		
Location		
Position Co-ordinate	X, Y (km)	Relative position
Type of Device		
Size (dimensions & volume)		
Design Flow Rate		
Estimate of potential for blockage		
Exclusion Bars		
LANDUSE (linked to Landuse data)	Hectares or %	% impervious
Catchment Area		
Calculated % Impervious		
Large Venues (Shops, Sportsground)	Area	
Major Roadways	Traffic volume	
CATCHMENT Practices/Influence		Factors & Weightings can be set
Street sweeping		That influence the predicted
Provision of Garbage Bins		Pollutant load that would be
Socio economics		Difficult to determine by any
Education campaign activity	Yrs active	Other methods*

*The aim in the long term is to add characteristics about the catchment and users of the catchment to provide a method to gauge the response of the catchment with regard to pollutant load. Note: it may be useful to add a time history data base of other activities such as street sweeping and the activity of education campaigns……The influence of these factors on the resultant predicted load aid in producing an algorithm by determining the relative importance of many parameters. Parameters can be added, included, or dismissed at will to review the outcome. {In addition, it may be advantageous to have a time history of land use and practices for the catchment.}

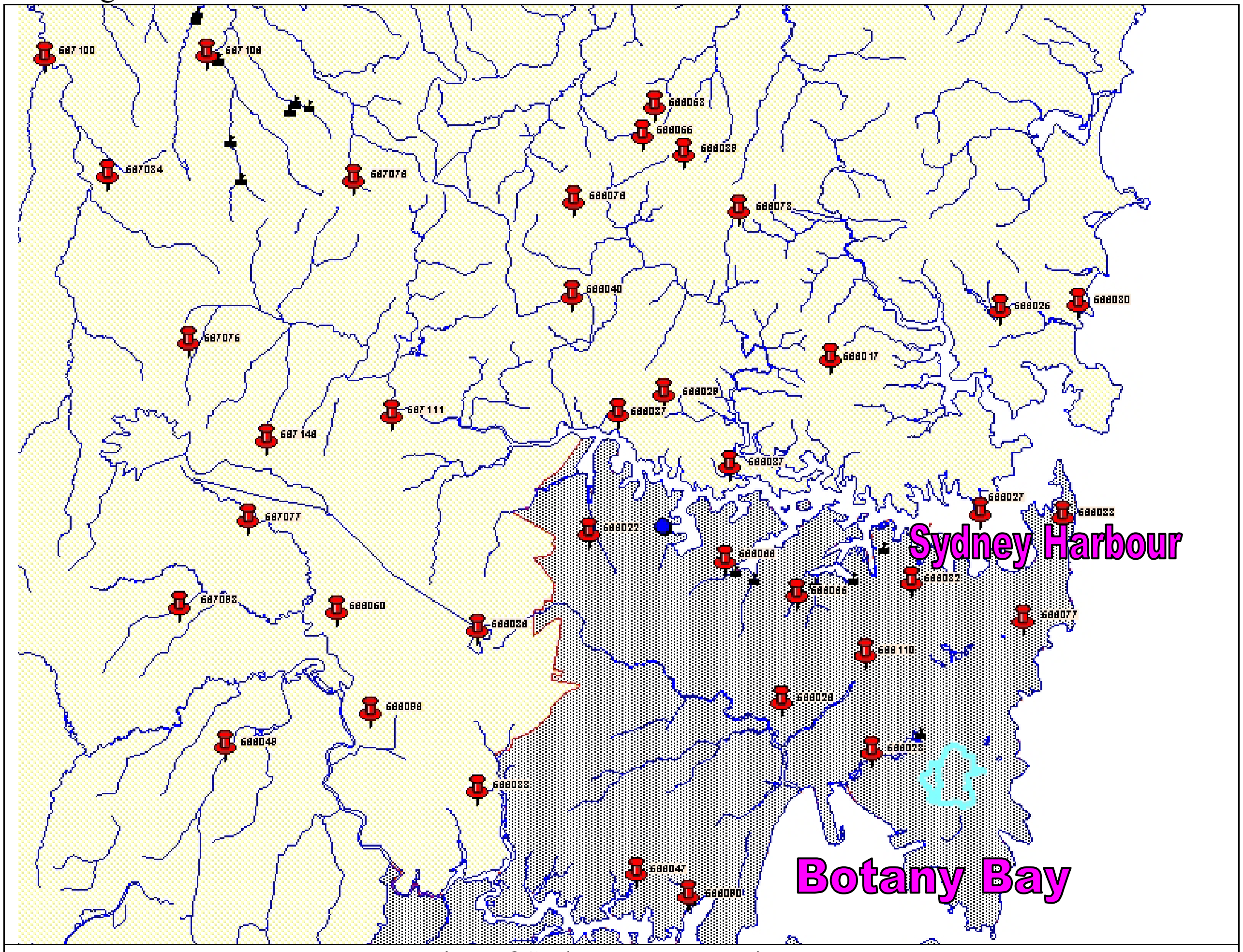
Added to this will be a database of standard adopted land uses. Include estimated % imperviousness and estimated average pollutant load.

STANDARD LANDUSE DATA		
PARAMETER in DATABASE	Measured Unit	Outcome
LANDUSE Name		Identifier
% Impervious	%	Flows
Estimated Pollutant Load	m^3/ha/year	Compare Load

The outcome of this will provide some answers to the variation in load with catchment size. By comparing land uses and proportions of various land uses in many catchments a relationship or trend in pollution load may be developed.

STAGE 2.
ADDING A LINK TO REAL RECORDED RAINFALL

Sydney Water is fortunate to have ready access to rainfall data. It operates around 50 rain gauges through Sydney and the opportunity exists to link data from real rainfall records to the clean out data for each of the GPD's. By doing this the time history of pollutant captured can be compared to the time history of recorded rainfall, thereby allowing estimates of pollutant load to be expressed in terms of (m^3/ha/mm) of rainfall for each catchment. In addition the relative impact of individual storm events, rainfall intensities and the total volume of rainfall can all be investigated for all devices.

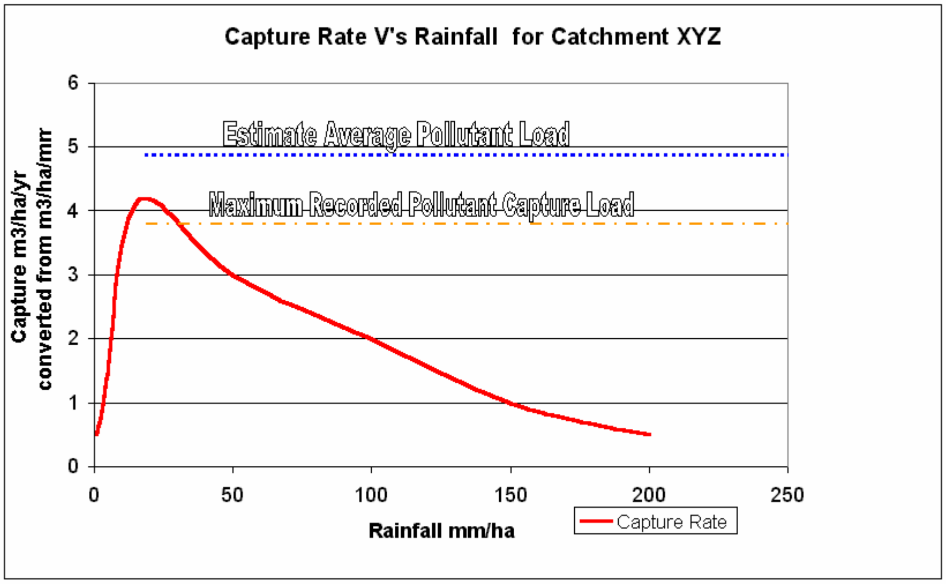


Location of Sydney Waters Rain gauges

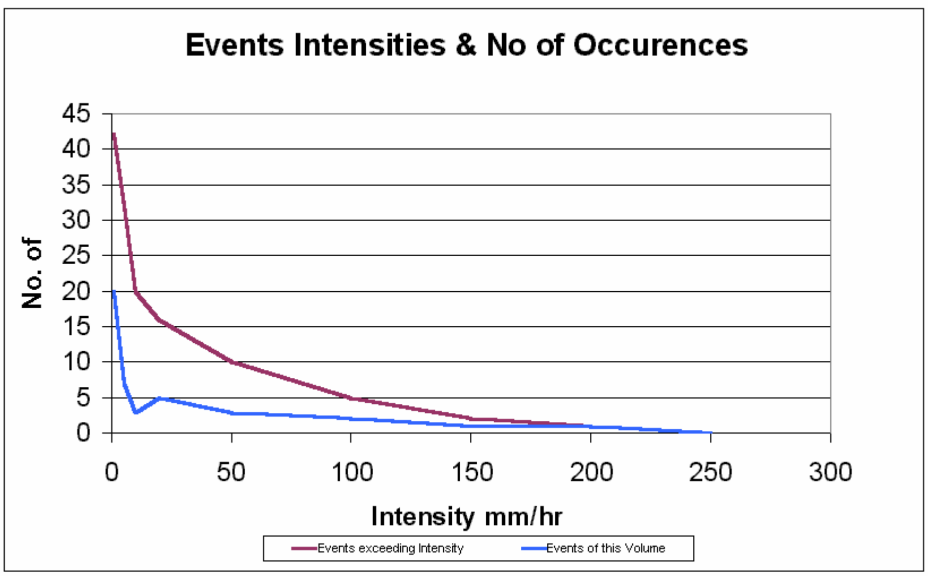
The aim is to provide a means to understand the interaction between catchment characteristics (Landuse etc.), practices within the catchment (street sweeping etc.) and rainfall on the pollutant load and capture load.

The outcome of this is expected to give insight into the variability of pollutant capture related to rainfall that can be linked to pollutant load.

For instance what is the optimum amount of rainfall or intensity of rainfall that results in the highest capture rate for each of the catchments? Trends in capture rates will have a ceiling and this ceiling will provide insight into the actual load from the catchment.



Included also will be an Intensity Frequency Duration (IFD) rainfall generator. So that automated analysis of the real recorded rainfall can be carried out in terms of a standard comparable measure across various catchments. So that a device designed to capture a 1 in 6 month flow or a 1 in 5 year flow can be compared in terms of performance.



STAGE 3.
ADDING A NEW PROPOSED GPD.

Yet another database is added, this time it is virtually identical to "Device & Upstream Data" database in STAGE 1. Except that there is NO capture data for this device yet (as it is still a proposal).

The Algorithm as a Dynamic Relational Data Base

So at this point we have a series of data bases that include the position of the proposed device, the position of existing devices, the position of existing rain gauges, and all catchment and capture data for all devices held in the data base.

It is now possible to set up a series of complex queries to the databases that can return an estimate of pollutant load from the catchment of the proposed device.

How?

The proposed device catchment characteristics are compared to all other catchments in the existing device database. A filter selects catchments that match various criteria regarding catchment characteristics, relative location, and rainfall data. The existing device capture data is also scrutinized. A pollutant load is derived from the filtered set of data. It is justified to say that this estimate is the best estimate based on the data held in the database on the basis of the query set up.

As the knowledge base grows skewing factors can be added that automatically can take into account variation in predicted loads. In time as the data base grows these estimates will become continually more precise.

In the next five years Sydney Water will have increased its knowledge base from 13 devices to around 60 devices. And from the date they are installed will be collecting data on a regular basis.

As the Data set Grows…..

As the data grows the results will continually provide better estimates of load. It may be possible to enter factors for education campaigns within a catchment that match the resulting capture loads being measured. Thereby it provides a means to justify expenditure on various types of solutions.

The next logical step is to attempt to encapsulate other data sources. Currently in Sydney there are many other authorities operating GPD's. The data they hold regarding capture histories for their devices is of limited value in isolation. Yet once included with other data sets it provides an opportunity to gain a much better understanding of pollutant load from various catchments.

How can this data be integrated?

Currently all owners of GPD's are required to report the quantities of pollutant captured, removed, and disposed on an annual basis to the EPA. The problem is that there is no standard format of recording or reporting and yet again the data is therefore difficult to compare and of little value.

Can this be improved?

WEB BASED CENTRALISED DATA BASE

- Firstly by providing a platform where all GPD owners can record the pollutant load captured every time they clean a device; it provides a means of standardizing methods. (Firstly in advising how to measure and record and secondly in the method of reporting.)
- Secondly once the data is held in a centralized location many people can utilize the outcome of analysis of that data. Providing the means of ensuring a consistent approach in justifying the requirement to construct a new Device in a particular location.
- Thirdly it may be advantageous for suppliers of commercially available devices to provide data about their devices. This may make the selection of appropriate devices simpler and consistent.
- Fourthly by utilising capture history data for commercially available devices that have been installed it may be possible to report, discuss, question, and dismiss or adjust claims of device performance made by suppliers. This will lead to realistic performance data for new devices.
- Fifthly

How can all this be achieved?

By porting the database that is being set up to aid in providing load estimates for Sydney Water's SEIP to an Internet Enabled Application.

It is envisaged that the developments currently underway could lead to the provision of such a tool. A centralized DATABASE of pollutant capture data, and the associated catchment / Landuse data.

CONCLUSIONS

The work being undertaken in conjunction with the implementation of Sydney Water's Stormwater Environment Improvement Program, is providing a realistic, robust methodology of estimating pollutant loads from catchments. It is based on an innovative approach of filtering measured pollutant capture data from existing devices and real recorded rainfall, and utilising the filtered subset to determine a more realistic pollutant load for a catchment upstream of a proposed device.
The collection of pollutant capture data associated with these devices is continuing. As the number of devices that come into service increases with the implementation of the SEIP, the amount of data held will increase and in time the knowledge gained will lead to a much better understanding of the interaction of factors that influence pollutant load and capture.

Proposals are underway to investigate the feasibility of implementing such an approach to develop an industry standard tool, for recording capture loads, reporting performance in a standardized format. This tool with extensions could also become an industry standard for designing pollutant capture devices.

The key lessons learned include:

- Currently there is poor understanding of the variability of pollutant loads from catchments;
- Existing data is not being utilised to its fullest extent;
- Pollution load estimating is extremely complex, and requires a flexible approach to enable justification for adopting loads from existing catchment data;
- It is possible to formulate a method that filters data based on comparative analysis;
- Pollutant Capture data linked to real recorded rainfall data provides insight into the variability of pollutant load;
- Data can be improved and shared by storing it centrally;
- Centralization also promotes uniform approaches to recording and reporting findings about the data;
- It is possible to provide an industry standard approach for recording pollution capture data, reporting on performance of installed devices, and designing appropriate pollution capture devices by implementing a WEB BASED solution that has at its core a centralized database of recorded capture data;
- With appropriate tools it is possible to provide estimates of Pollutant loads from pollutant capture data.

REFERENCES

Ref. 1. Sydney Water Corporation (2001). "Stormwater Environment Improvement Program".

Ref. 2. CRC for Catchment Hydrology (1998). "From Roads to Rivers, Gross pollutant removal from urban waterways".