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Research article

Behaviour change: Trialling a novel approach to reduce industrial stormwater pollution

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ABSTRACT

The evidence base for the performance and effectiveness of non-structural measures to manage stormwater pollution in industrial areas is relatively underdeveloped, despite their increased use in practice. This study aims to advance stormwater management practice and research by presenting a detailed case study of the development, implementation and evaluation of a targeted behaviour change trial that engaged small to medium industrial businesses in stormwater pollution prevention. Utilising a combination of different behaviour change strategies - including capacity building, social norms and commitment - a number of preventative stormwater pollution behaviours were changed in participating businesses. Our study provides a practice model for tackling stormwater pollution from a behavioural perspective that can be further developed by both practitioners and researchers to create effective and long-lasting change.

1. Introduction

Despite increased use of non-structural measures to manage stormwater pollution in industrial areas, there is still little high-quality information of their performance and outcomes, and little research has been conducted on the relative effectiveness of different approaches (Urbonas, 2000; Taylor and Wong, 2002; Taylor and Fletcher, 2007). This paper adds to the existing knowledge base by presenting a detailed case study of the development, implementation and evaluation of a targeted behaviour change trial that engaged small to medium industrial businesses in stormwater pollution prevention. Our behavioural focus is unique to existing research in the field and provides a potential prototype for tackling industrial related stormwater pollution issues.

In the following sections, we map out the research and practice field of stormwater pollution management, as well as this case study's theoretical underpinnings. We then describe the nature of the trial in detail, including its key features and business engagement approach. The preliminary behavioural and water quality outcomes are presented and we finish by considering stormwater pollution management and research implications.

1.1. Current practice and research in stormwater pollution management

Stormwater discharge and run-off are major contributors to the pollution and degradation of urban waterways (Ahlman et al., 2005; Francey et al., 2010; Walsh et al., 2012, 2016). A range of stormwater pollution Best Management Practices (BMPs) are implemented by water managers worldwide to either reduce the overall amount of discharge or to improve its water quality. These measures fall into *structural* (fixed physical facilities such as dry basins or filter strips) or *non-structural* (non-physical interventions such as regulation or education) categories (Taylor and Wong, 2002; Taylor et al., 2007). In practice, most water managers combine measures from both categories to best address stormwater pollution issues (Phillips et al., 2002; Parkinson, 2003; Ahlman et al., 2005; Taylor and Fletcher, 2007; Walsh et al., 2016).

Taylor and Fletcher (2007) identify five main non-structural BMP categories:

1. Town planning controls (e.g. requirements for low-impact development designs)
2. Strategic planning and institutional controls (e.g. city-wide stormwater quality management plans)
3. Pollution prevention practices (e.g. street sweeping)
4. Education and participation programs (e.g. awareness raising and behaviour change campaigns)

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5. Regulatory controls (e.g. local laws that reduce erosion on building sites)

Non-structural BMPs are relatively inexpensive, flexible, and broadly applicable interventions for effective stormwater management, and are increasingly being used in practice (Taylor and Fletcher, 2007). Parkinson (2003) notes their particular potential in developing nations where resources might be scarce yet where the problems of flooding and environmental pollution often have a compounding impact on communities. Despite these advantages considerably less research attention has been given to non-structural measures when compared to structural ones (see for e.g. Barrett, 2005; Deletic and Fletcher, 2006; Roy et al., 2008; Davis et al., 2010; Hamel et al., 2013; Chaffin et al., 2016). Comparatively little is known about the relative effectiveness of different non-structural measures, the key factors influencing their performance and their impact on environmental quality (Urbonas, 2000; Chapman and Isensee, 2006; Taylor et al., 2007). Taylor and Fletcher (2007) argue that the use of non-structural BMPs "has been significantly hindered by uncertainty with respect to their performance … and how this varies over time, as well as their life-cycle costs" (p. 664).) While a number of different evaluation and monitoring approaches have been utilized to better monitor the performance of these BMPs, they were often poorly designed and applied (Taylor et al., 2007).

The peer-reviewed literature has a relatively limited number of non-structural BMPs examples that attempt to influence the awareness, knowledge and behaviours of specific audiences. Relevant studies have focused on identifying public perceptions of stormwater management issues (Giacalone et al., 2010; Typhina and Yan, 2014), on engaging households in stormwater sensitive lawn-care (Dietz et al., 2004; Eisenhauer et al., 2016), and in rainwater tank installation to reduce run-off (Brown et al., 2016). Outcome measurements from these studies were typically audience participation measures, while Dietz et al. (2004) measured self-reported behaviour change by the target audience, as well as changes in stormwater quality.

Research on non-structural BMPs that specifically target businesses is also under-represented in the literature. Shelton et al. (2015) developed an extension program that engaged green professionals and Master Gardeners in stormwater management principles and primarily measuring audience participation outcomes. Of most relevance to this study was Taylor et al.'s (2007) educational campaign that targeted local merchants and the general public within a small commercial precinct to reduce litter in stormwater. Multiple indicators (including behaviour and water quality change) were utilized to identify the campaign's overall impact. While innovative in its focus on businesses and its use of a broad evaluation framework, Taylor et al. (2007) report that their work was only modestly successful in influencing business and individuals' behaviours and in reducing actual litter loads in stormwater.

As a general rule, on-the-ground practice leads research in engaging the business sector in stormwater pollution, with a much larger number of case studies available through the non-peer reviewed literature (see for e.g.; Phillips et al., 2002; Waterwatch, 2002; DEC, 2004; AECOM, 2012; and EPA (NSW), 2016). While showcasing a range of approaches to engage different business types in different locations, program impact measures are typically limited to output (resources produced, events held, etc.) and target audience participation measures.

With these features of the evidence base in mind, this case study aims to present a theoretically supported behaviour change intervention to a small but important literature; demonstrate a monitoring and evaluation framework suitable for deriving conclusions about the effectiveness of the intervention; and, build the evidence base of non-structural stormwater BMPs utilized in industrial areas.

1.2. Theoretical underpinnings

The design and implementation of this trial intervention drew on the broader literature of environmental regulation compliance. While traditional measures emphasize monitoring and sanctions against non-compliers to maximize compliance (with the centralization of enforcement responsibilities within regulatory organisations), this 'command and control' approach is being challenged by the view that influencers such as social motivation, awareness and capacity can also effect compliance (Burby and Paterson, 1993; Winter and May 2001; May 2005; Murphy et al., 2009). A 'cooperative' or 'voluntary' approach is increasingly advocated to facilitate target groups' compliance with regulation through incentives, positive reinforcement, and other non-punitive means (Burby and Paterson, 1993; Segerson, 2013).

While there is empirical evidence that monitoring and enforcement does motivate compliance in certain groups (Gray and Shimshack, 2011), the literature cautions against over-generalising results from one sector to another, as a successful approach with one group may not work for another (May, 2005). Different stakeholders have markedly different understanding of particular issues (such as stormwater pollution) and what is required of them by way of response, and varying levels of capacity to change their current behaviours. Therefore, multiple ways of ensuring compliance are required (Winz and Brierley, 2009; Kaplowitz and Lupi, 2012).

The voluntary approach to regulation compliance is consistent with a view of behaviour that recognises the individual and social motivations of actors - along with their capacity and commitment to act - as influential conditions for regulation compliance. Burby and Paterson (1993) adopt this view in noting regulatory strategies that emphasize "capacity building and the social and moral bases of compliance *in addition* to deterrence and the threatened application of sanctions" (p.753, italics added).

As detailed below, this trial intervention draws on the voluntary approach as a theoretical framework to encourage business compliance with stormwater pollution requirements. We utilize a combination of different behaviour change strategies focusing on capacity building, social norms and behavioural commitment – in addition to the backstop of potential monitoring and enforcement from the state-based environmental regulator.

1.3. The nature of the trial – target audience, target behaviours and intervention components

This section includes descriptions of: i) the study site, ii) the target business groups, iii) the relevant stormwater pollution management behaviours and, iv) the key components of the intervention.

The research team partnered with the metropolitan water authority, the state-based Environmental Protection Authority (EPA) and the local council, to co-design, deliver and evaluate the outcomes of the intervention. Each group had carriage for particular elements, with the researchers being responsible for the design of the overall intervention, as well as training and supporting the onsite assessors (see below), developing the monitoring and development framework, and analyzing behaviour change outcomes (see Method). Prior to the design of the trial, the research team conducted a literature and practice review of national and international stormwater management and environmental regulation, as well as a series of interviews with key local stakeholders (see Jorgensen et al., 2015). This data informed the design and

implementation process by highlighting strategies and approaches deemed likely to influence behaviour by the majority of stakeholders.

1.3.1. The site and the target group

The trial took place within an industrial estate in the outer east suburbs of Melbourne, Australia. The estate is situated on, and around, an enclosed waterway that flows into a local creek with a long history of pollution, including high levels of heavy metals, hydrocarbons and pesticides (Kellar et al., 2014). There are over 1000 business sites in the estate, primarily occupied by small-to-medium industrial businesses (Senese and Rako, 2015). Stormwater pollution issues in the area are currently managed through a mix of state-based regulations, local laws, different water authority and local council infrastructures, and EPA licensing, monitoring and inspections (AECOM, 2012). A series of short-term education and engagement programs have also been implemented in the area over the past 10–15 years (Jorgensen et al., 2015).

The target industries of this intervention included electro-platers, engineering and metal workshops, mechanics, panel beaters, printers, powder-coaters and soap manufacturers. These businesses were considered by the EPA to be "high risk" to stormwater due to the materials and chemicals they regularly use and which were known to be prevalent in the waterway.

1.3.2. The target behaviours

According to the EPA (2005), the majority of stormwater pollution is the result of everyday activities (rather than major spills or incidents) that increase the likelihood of materials, liquids and other pollutants being washed down storm-water drains. The behaviours targeted are those recommended to industry by the EPA to reduce this likelihood (Davis et al., 2010; EPA Victoria, 2005; Sargent, 2015). These were grouped into the following categories:

- Keep stormwater drains clear and clean
- Store and manage liquids properly
- Secure loose materials and wastes
- Follow spill response plans and using spill kits
- Prevent washing into stormwater drains
- Notify the EPA if a spill occurs on site or is witnessed elsewhere.

All elements of the intervention (described below) focussed on engaging target businesses in these behaviours and the evaluation framework included measures to monitor behavioural changes by participating businesses.

1.3.3. Intervention structure

Featuring a mix of voluntary and traditional measures to environmental regulation compliance, the trial intervention was developed around the following four components (described in more detail below, together with supporting literature):

1. A letter mail-out to all businesses in the estate - to raise awareness and highlight community involvement and expectations.
2. The offer of voluntary stormwater pollution assessments for high risk businesses - to increase business capability and knowledge of stormwater pollution management.
3. An estate-wide communication campaign - to create broader social norms.
4. Random EPA inspections of a number of businesses in the estate – to provide a regulatory backstop for the voluntary behaviour change program.

The *letter mail-out* initiated the intervention and its design drew on social norm-based drivers of human behaviour (Cialdini, 2007; Nyborg et al., 2016) and pro-environmental motivations to inform businesses that:

- There is a pollution problem in local water waterways and it has serious impacts on society and the environment (presenting the social and moral licence for the intervention).
- The local community had been alerted to the problem and were being asked to report any polluting activity they notice.
- The EPA would be conducting random inspections in the industrial estate (presenting enforcement and possible sanctions as a backstop)
- Businesses in the high-risk category could book free and voluntary stormwater pollution assessments.

Contract assessors were engaged by the water authority to provide *stormwater pollution assessments* to high-risk businesses. Over a six-week period, the assessors approached every available business in the estate in order to introduce the project, present an EPA poster on stormwater protection, and offer assessments to all businesses they identified as high-risk (based on the EPA's parameters above). The assessments were designed to increase the capacity and commitment of businesses to the target behaviours (Burby and Paterson, 1993; Winter and May 2001), and to collect data on their participation in these behaviours. Participation in the assessments was hypothesized to be prompted by pro-environmental and pro-social motivations as well as by the revelation that the EPA would be conducting random inspections over the coming weeks. That is, any non-compliant operators among the high-risk group might perceive a greater likelihood of being discovered by the EPA given knowledge of the planned inspections (Gray and Scholz, 1991).

For businesses that agreed to participate, an initial assessment was conducted utilising a structured checklist on a computer tablet with commercially available auditing software. An individualised report of findings and recommendations was printed and shared with the business at the end of the assessment. Based on the recommendations, businesses were asked by the assessor to identify one to three changes that they could make to improve stormwater protection. This process of self-selecting target behaviours was intended to increase the likelihood of behaviour change by ensuring that the behaviours were under the control of the businesses and within their capacity to enact (Ajzen, 1991). Further, including businesses in the decision-making process was intended to increase their commitment to achieving the behavioural targets that had been arrived at collaboratively.

The assessors made a follow-up visit to participating businesses two to three weeks after the initial assessment. Based on the influence of public commitment to a change, these follow-ups were deliberately included to ensure a greater chance of businesses actually completing the stormwater protection actions they had committed to (Burn and Oskamp, 1986; Cialdini, 2007). They also allowed assessors to examine the level of compliance to stormwater protection behaviours and identify any improvements made since the last visit.

An *estate-wide communication* campaign was implemented at the same time the assessors were active in the estate. Intended to assist with broader community awareness raising and social norm creation (Nancarrow et al., 1998), this component included EPA "Report Pollution" signage throughout the estate, media releases for local media outlets, and a stormwater drain stencilling program for all estate street drains and, where possible, drains on business sites.

As the final backstop to the intervention, *businesses inspection by the EPA* occurred in the estate after the assessment and the

communication components. The EPA typically conduct inspections in the estate once or twice a year and agreed to delay inspections to follow the other elements of the program. As noted earlier, it was hypothesized that mentioning the possibility of inspections in the letters, as well as during the business recruitment process and during the assessments, the likelihood of high-risk businesses participating in the program and complying with required behaviours would increase (Burby and Paterson, 1993).

2. Material and methods

2.1. Sample description

Through systematic door-to-door visits, assessors identified a total of 823 active businesses in the estate. This excludes all unoccupied sites or businesses that were closed at the time the assessors were in the estate. A total of 268 of the above businesses were identified as high-risk based on EPA parameters and formed the sample of this study. A break-down of businesses included in the sample is described in Table 1.

2.2. Measuring intervention impacts

Taylor and Fletcher (2007) and Taylor et al. (2007) argue that evaluation of non-structural BMPs is often poorly designed and implemented, and in many cases, only captures certain impacts associated with an intervention. They advocate a combination of measures for a more complete monitoring and evaluation framework. These include indicators that track:

- The implementation and delivery of the intervention, as well as the target audience participation.
- Changes in the awareness, knowledge and behaviours of the target audience.
- Changes in stormwater quality and water-system health.

In accordance with these principles, we developed a monitoring and evaluation framework for this case study that captured:

1. Measures of target audience participation.
2. Changes in compliance behaviours by high-risk businesses that participated in the voluntary assessments.
3. Water quality data in stormwater system and local waterway of the industrial estate.

Measures of participation were obtained from the assessors reports of their activities in the estate and their engagement with different business types.

Changes in compliance behaviours were measured through comparison of results from two assessment visits (initial and follow-up) taken by the assessors with participating businesses. Assessors utilized a structured check-list that tracked levels of compliance with the stormwater pollution prevention behaviours recommended by the EPA. The checklist allowed assessors to record both self-reported responses from businesses, as well as their own observations about a business site, its operation and management procedures. Table 2 shows the different questions included in the checklist and their alignment with the EPA stormwater management recommendations. Answers to these questions were either dichotomous (yes/no) or reported on a 5-point Likert scale.

An external consulting group were engaged by the metropolitan water authority to conduct pollution sourcing tests throughout the estate. These tests were conducted several months before the implementation of the behaviour change trial and then two months after the trial was completed (Kellar et al., 2016). Sampling at twelve different sites, the pollution sourcing primarily concentrated on identifying heavy metal levels (cadmium, chromium, copper, lead, silver, zinc and mercury) before and after the behaviour change intervention, and then comparing these with previous sampling data collected in the estate.

Table 1
Sample description of businesses in the industrial estate.

Description	# businesses
Businesses sites identified	823
High risk businesses	268
High risk business categories:	
· Mechanics	76
· Electroplaters	58
· Metal works/Engineering workshops	57
· Printers	16
· Panel beaters/Powder coaters	36
· Soap manufacturers	8

3. Results

3.1. Participation and activity outcomes

Of the total businesses sampled in the estate, 286 (35%) acknowledged they had received the initial letter from the water authority. A total of 530 (64%) businesses accepted the educational poster handed out by the assessors. As part of the communication campaign, 162 street drains were stenciled throughout the estate and four EPA "Report Pollution" signs were installed.

Of the high-risk businesses identified on the estate, 49 (19%) agreed to participate in an initial assessment. Table 3 provides a break-down of the different businesses that participated in this intervention component. Twelve 'Other' businesses did not fit into the original high-risk categories provided by the EPA, but following consultation with the EPA, were considered high risk by the nature of their activities or their size. These were predominantly food manufacturing and chemical storage businesses.

Of the 49 businesses that participated in the initial assessment, 40 (82%) then took part in the follow-up assessment.[1]

Comparing Tables 1 and 3, it can be seen that the pattern of participation by business type is broadly representative of the overall distribution of high-risk businesses categories in the estate, with mechanics and engineering workshops being the largest categories, and soap manufacturers and printers being less common. Electroplaters were also a large category in the estate, but were not as strongly represented in the assessments as might be expected. This could be the consequence of a previous project in the estate that specifically targeted electroplaters (Jorgensen et al., 2015) and therefore businesses in this category did not want to participate in another behaviour change program.

3.2. Initial assessment findings

The initial assessments revealed that the different behaviours within the six target categories identified by the EPA (see Table 2) were undertaken to varying degrees by the sampled businesses. The data in Fig. 1 illustrates the extent to which these behaviors were observed in the sample ($N = 49$) during the initial assessment. While generally high levels of compliance already existed, several

[1] The nine businesses that dropped out appeared to be more or less representative of the 40 businesses that remained in the sample at the follow-up visit (i.e. those that dropped out were not dominated by one particular businesses category).

Table 2
Different focus categories of assessment checklist.

Checklist question	Alignment to EPA recommendations
• Stormwater drains on site are clean?	Keep stormwater drains clear and clean
• Stormwater drains on site have no nearby spills?	
• Stormwater drains on site are protected (bunding etc.)?	
• Site clean and well maintained?	
• Bulk liquids isolated from stormwater drains?	Store and manage liquids properly
• No uncovered waste bins/skips kept outdoors?	Secure loose materials and wastes
• No escaped waste/other materials on floor?	
• Spill kit present?	Follow spill response plans and using spill kits
• Spill kit close to liquid storage and use areas?	
• Staff trained in spill kit use?	
• Spill response plan available?	
• Staff aware of spill response plan:	
• Water from equipment washing doesn't go into stormwater drains?	Prevent washing into stormwater drains
• Waster from floor cleaning doesn't got into stormwater drains?	
• No oil changed on site goes into stormwater drains?	
• EPA hotline visible on premises?	Notify the EPA if a spill occurs on site or is witnessed elsewhere.

Table 3
Descriptive statistics of businesses that participated in the initial assessment.

High risk business type	# participated
• Metal works/Engineering workshops	15
• Mechanics	15
• Panel beaters/Powder coaters	5
• Electroplaters	1
• Printers	1
• Soap manufacturers	0
• Other	12

the type and frequency of actions committed to by the businesses participating in the initial assessment. Nearly all businesses (96%) committed to putting up the EPA's poster showing their hotline telephone number. This is not surprising given its relatively low cost of adoption. Other common behaviors undertaken – such as moving materials to isolate them from stormwater drains, installing stormwater drain protections and purchasing a spill kit – also could fall into the category of low-effort and low-cost, however, longer term behaviors involving planning and spending

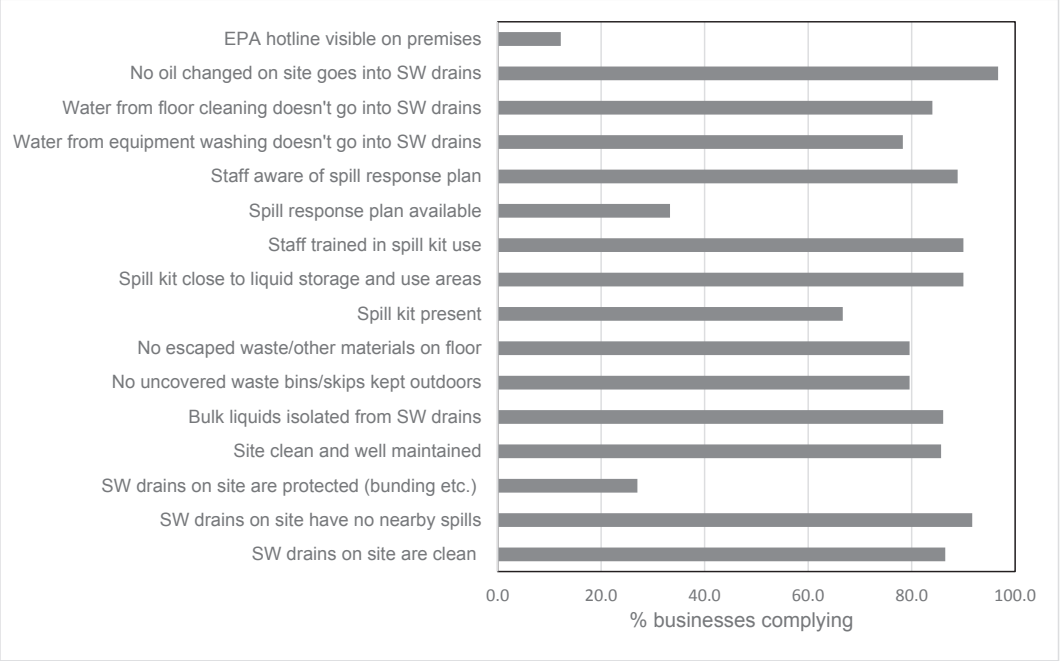

Fig. 1. Percentage of businesses already complying with storm water protection behaviours during initial assessment.

behaviours were not undertaken by most businesses, namely, purchasing spill kits; installing stormwater drain protections; developing spill response plans; and, making the EPA hotline visible for use in the case of a spill.

Based on recommendations from their initial assessment, businesses were asked to commit to one to three actions that they would complete by the follow up visit. Fig. 2 provides a summary of showed lower levels of adoption.

3.3. Behaviour change outcomes identified in follow-up assessment

The follow up assessment revealed that 80% of the businesses in the follow-up sample (N = 40) had completed the actions they had committed to. Fig. 3 compares the compliance rate (in percentage)

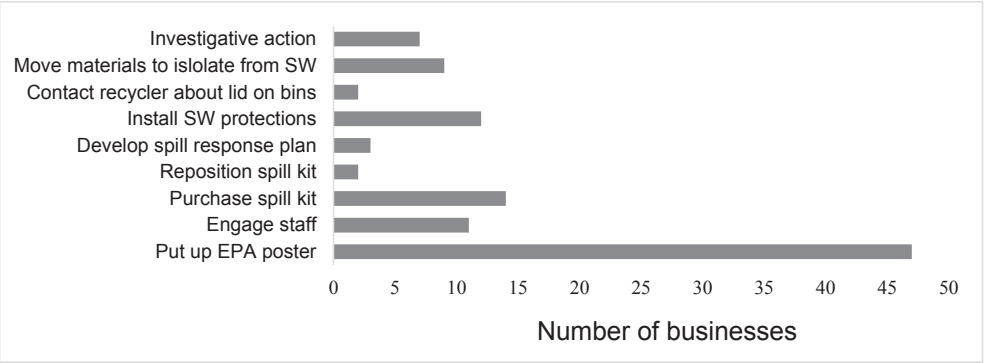

Fig. 2. Type and frequency of actions committed to by businesses at the conclusion of the initial assessment.

of businesses to the stormwater pollution prevention behaviors between the initial and follow-up assessments. Overall, Fig. 3 shows an increasing trend in the performance of the desired behaviors, with the exception of 'storm water drains are protected' and 'water from equipment washing doesn't go into SW drains'. Initial compliance with the former behaviour was relatively low and remained so at follow-up whereas the latter behaviour showed relatively high compliance at baseline and follow-up. These results are consistent with some of the main commitments made by businesses during their initial assessment (see Fig. 2), and shows that the commitment to installing protection for stormwater drains, such as bunding, was not fulfilled by most businesses.

The data in Fig. 3 suggest a trend of improvement across many of the behaviours targeted by the intervention and measured in the evaluation. Statistical analyses were conducted to identify statistically significant differences between the initial and follow-up assessments but these results should be interpreted cautiously given the small sample size. Furthermore, the effect of sample attrition from initial assessment to follow-up cannot be quantified within the current research design.

McNemar and Wilcoxon statistical tests were used to evaluate the significance of the improvements by businesses in complying with stormwater protection behaviours from the initial to the follow-up assessment. The critical value for alpha was set to 0.1 rather than the traditional 0.05 level in order to address the higher Type II error rate owing to the small sample size (Maxwell, 2000; Tabachnik and Fidell, 2001). Results showed a significant increase in the 'number of businesses displaying the EPA hotline' χ^2 ($1, N = 38$) $= 32.03$, $p < 0.001$) the number of businesses with 'spill kits present' ($N = 35$, $p < 0.050$) and in the number of businesses with 'spill response plans' ($N = 13$, $p < 0.10$).

Wilcoxon signed rank tests also indicated that the general cleanliness of sites increased significantly, N − Ties = 11, ($p = 0.033$), two-tailed. A total of nine businesses were cleaner after the initial assessment (Sum of Ranks = 55.00), whilst only two businesses were less clean (Sum of Ranks = 11.00). More than half ($N = 26$) of the businesses showed no change in their level of cleanliness when comparing the two assessment stages. Overall, the Wilcoxon results showed a large effect ($r = 0.64$) of the intervention on this particular behaviour.

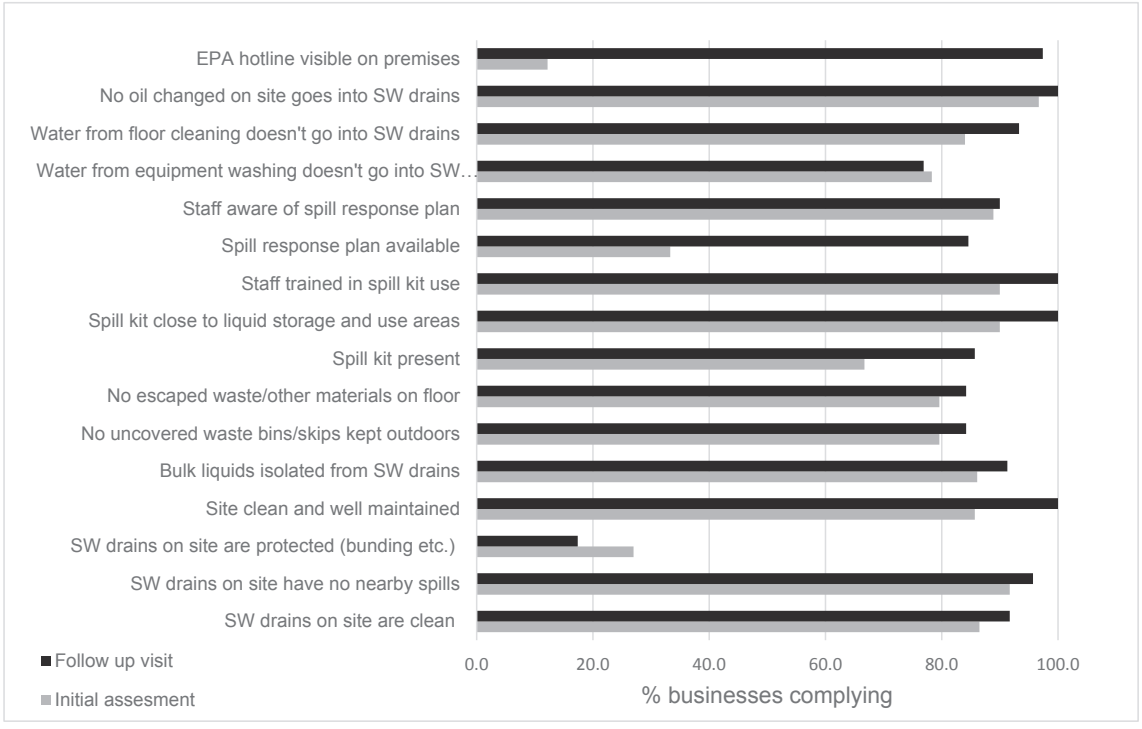

Fig. 3. A comparison of the behaviors observed between the 'initial' and 'follow up' assessments.

Other positively improved behaviours shown in Fig. 3 are not supported in the analyses. This includes the two slightly diminishing behaviors (i.e. 'water from equipment washing doesn't go into SW drains' and 'SW drains on site are protected').

3.4. Water quality outcomes

Based on sampling at twelve different in the estate before and after the behaviour change intervention, Kellar et al. (2016) conclude that:

> "The pre- and post sampling … show significant areas of pollution that contain high concentrations of a number of metals and pose an extreme risk to the environment. The metals of concern include lead, zinc, silver, copper, chromium and cadmium. For the majority of metals *there was no reduction in concentrations* after the Behaviour Change Program (post sampling compared to pre-sampling and background sampling concentrations) at any of the sites …. However, it does appear that *lead concentrations have reduced substantially at [one site] and within the creek …* indicating the program may have led to a reduction of this metal." (pg. 23, italic added).

The consultants go on to recommend further monitoring at the different sites up to a year after the intervention, to account for possible longer-term effects of the behaviour change trial. They also recommend that other sources of stormwater pollution beyond the behaviours of businesses, such as leaking sewers, and contaminated land, be investigated (Kellar et al., 2016).

4. Discussion

This study aimed to contribute to the existing knowledge base of non-structural stormwater BMPs by presenting a detailed case study of the development, implementation and evaluation of a targeted behaviour change trial that engaged small to medium industrial businesses in stormwater pollution prevention. The trial targeted key stormwater protection behaviours recommended to businesses from the EPA and drew on a mix of voluntary and traditional measures to promote increased compliance.

In general, compliance with stormwater protection was already high amongst participating businesses before the intervention. However, statistically significant increases in compliance with particular stormwater protection behaviours – including use of spill kits, development of spill response plans and displaying the EPA hotline – were identified. There was also an indication that a number of sites had increased their general cleanliness (reducing the amount of pollution to stormwater drains after rainfall) as a consequence of the trial.

Water quality in stormwater systems and local waterway did not show any changes when measured two months after the behaviour change intervention had completed, with the exception of a reduction in lead concentrations at one sample site and in the waterway.[2] These results notwithstanding, stormwater pollution can be the outcome of a complex series of interactions and sources that are often difficult to identify and isolate especially in sites that have a mix of business types and pollution profiles (Francey et al., 2010; Walsh et al., 2012). This suggests that even when a non-structural BMP such as this trial is successful in changing the behaviours of a target audience, it might have little discernible effect on water quality (Ahlman et al., 2005; Johnson et al., 2012). In a modelling study of non-structural BMPs impacts on stormwater quality, Ahlman et al. (2005) concluded that the "non-structural BMPs applied did not give a sufficient reduction in pollution to meet the desirable environmental quality criteria. To meet these criteria, additional BMPs must be implemented, preferably a combination of both non-structural and structural measures." (p.9).

When considering the nature of the particular behaviours that had changed – either to do with emergency responses in event of a spill or with reducing the *likelihood* of pollutants going to stormwater – perhaps it is no surprise that there weren't any noticeable impacts on stormwater quality from this intervention. 'Poor' business behaviours that add to pollutants within stormwater – such as washing water flowing into stormwater drains – were already uncommon amongst participating businesses and were not significantly affected by the trial.

4.1. Strengthening behavioural outcomes

When considering which stormwater pollution behaviours had changed in participating businesses, it is possible to identify a trend towards relatively easy and low costs behaviours (such as putting up a poster or adding extra documentation to management plans). The behaviour of installing physical stormwater protections (such as concrete bunding) on site was at low frequency in the sample during the initial assessment and did not increase significantly by the time of the follow up visit despite a number of businesses having committed to it. Establishing these protections is more time consuming and costly than other pollution prevention behaviours and this would be a barrier to quick action from businesses. This is supported by other behaviour studies (see for e.g. Stern, 2000) which suggest that when a behaviour is more difficult or costly, its association with attitudinal factors (in this case, a desire to 'do the right things' for stormwater pollution prevention) is weaker.

The issue is also complicated by the fact that many businesses lease their sites and as such are not allowed to make hard infrastructure changes such as bunding. This suggests that financial incentives targeted at business owners, as well as site owners, might do more to change this particular behaviour than any of the features of the current trial. The inclusion of financial mechanisms aimed at addressing the cost of bunding as a barrier to behaviour were considered early in the development of the intervention (Jorgensen et al., 2015). However, such measures can raise ethical issues for some stakeholders who do not want to be seen to be paying potential polluters to comply with stormwater regulations. Despite this, the point remains that financial incentives may be an attractive means for businesses that support environmental outcomes but have limited resources to achieve them.

4.2. Increasing participation outcomes

Approximately 20% of the targeted business types participated in stormwater assessments through this project. An additional number of businesses, while choosing not to participate in the 'formal' assessments, nevertheless engaged the assessors in lengthy discussions on improving their stormwater protection performance. While this level of recruitment was respectable, it also suggests that the behavioural influencers utilized in this trial to increase participation – social norms, the opportunity to increase business capacity and commitment, and the back-stop threat of monitoring and enforcement – only go so far in this particular case with the target audience.

[2] As businesses in the estate are connected to a single stormwater pipe that led to a single sampling device, it would be possible to investigate changes in each sampling site with the specific pollutants expected to emanate from particular business types situated along the pipe. Due to some contractual restrictions, we were not able undertake a more nuanced analysis of the physical quality data. This more spatially informed analysis may have served to provide insights based on expectations for change in specific pollutants at specific locations.

As a side note, the letter mail-out did not generate any requests from businesses to participate in the assessments, these all came from the face-to-face interaction with the assessors during the time in the estate. As a vehicle for engagement with the target group of businesses, the more impersonal (and easily misplaced or misdirected) format of letters, is clearly not very effective.

We already mentioned the possibility of financial incentives to increase compliance with more 'costly' behaviours and these could also be utilized here to increase participation in the assessments. There is also an opportunity to account for the different size of businesses with regards to which influencers might be used to increase participation. Anecdotally, assessors recounted that small to medium businesses were typically more responsive than larger businesses to their visits and to the 'out of the blue' offer of an assessment, while this was not possible for businesses that are part of a larger company, often with headquarters located elsewhere.

This is supported by some of the compliance literature has focused on how business characteristics such as size can influence compliance. Gray and Shadbegian (2005) found that pulp and paper mills owned by larger firms did not respond much to inspections, but rather to enforcement actions of a different kind. Gunningham et al. (2005) reported that general, specific and implicit deterrence were much more important to small and medium-sized businesses than to large ones. The authors argued that smaller businesses were mostly reactive in their responses to regulation whereas large organisations are often more proactive and seek to develop strategies that capitalised on the opportunities that regulation presented (e.g. developing innovative solutions for mitigating the costs of compliance that also have good business outcomes such as cost saving).

This suggests that a behaviour change program that utilises an opportunistic, 'inspection-style', door-knocking approach will have greater success to encourage participation from small-to-medium businesses than from with larger ones, and a different approach is therefore needed to engage larger businesses. In their recent study of the uptake of energy efficiency opportunities in small to medium business, Henriques and Catarino (2016) call for more targeted work that recognises and responds to the heterogeneity within this sector. The same could be said for high-risk businesses within an industrial site, and the need to develop interventions that respond not just to the type of a businesses, but also its size.

Providing incentives to assist with the installation of stormwater protections and a more targeted approach for larger businesses, all have strong potential to increase businesses participation for assessments. In addition, we would advocate for a longer period in which the assessors were on the ground within the estate in order to increase business participation. A longer period would have allowed the assessors to establish a recognised presence within the estate and form deeper relationships with different businesses. Strengthened relationships between regulators and 'those regulated' has been found to significantly improve compliance to environmental regulation and this would have been a useful influencer to increase businesses participation in this particular trial (Winter and May 2001; Curtis et al., 2014).

5. Conclusion

The evidence base of non-structural BMPs is underdeveloped and needs further case studies such as this one to advance both practice and research, with a particular emphasis on capturing outcomes and articulating 'what works'. While the impact of this behaviour change trial on stormwater quality could not yet be determined, it showed encouraging signs of having positively changed stormwater pollution prevention behaviours of participating businesses. Fig. 4 provides a conceptual flowchart of our study, its findings and implications for policy, practice and research.

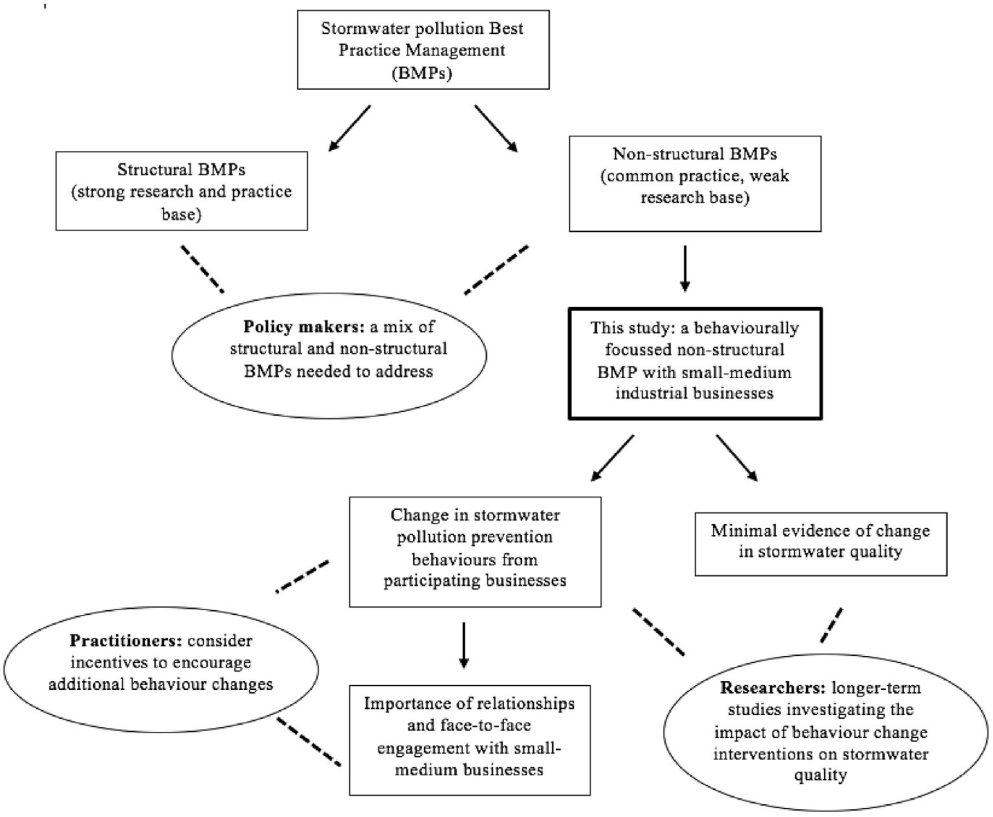

Fig. 4. Conceptual flowchart of study, findings and implications.

This case study provides a behaviourally-informed practice model that can be applied across a range of jurisdictions and locations dealing with similar issues. Practitioners, policy makers and researchers can use this model to target key pollution prevention behaviours in industry and to gain a better understanding of the issue from the perspective of the target group. We show that a focused intervention can address a lack of awareness and poor business practice in order to reduce the risk of stormwater pollution incidents occurring across a range of industry types. In addition, the importance of establishing relationships, and the value of face-to-face engagement with a target group, are also highlighted when designing effective and appropriate change interventions.

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References

Ahlman, S., Malm, A., Kant, H., Svensson, G., Karlsson, P., 2005. Modelling non-structural Best Management Practices– focus on reductions in stormwater pollution. Water Sci. Technol. 52 (5), 9–16.
AECOM, 2012. Stormwater Pollution Hotspot Identification Study: Dandenong Creek. AECOM Australia Pty Ltd consultancy report, Fortitude Valley, Queensland.
Ajzen, I., 1991. Theories of cognitive self-regulation: the theory of planned behaviour. Org. Behav. Human Decis. Process 50 (2), 179–211.
Barrett, M.E., 2005. Performance comparison of structural stormwater best management practices. Water Environ. Res. 77 (1), 78–86.
Brown, H., Bos, D., Walsh, C., Fletcher, T., RossRakesh, S., 2016. More than money: how multiple factors influence householder participation in at-source stormwater management. J. Environ. Plan. Manag. 59 (1), 79–97.
Burby, R.J., Paterson, R.G., 1993. Improving compliance with state environmental regulations. J. Policy Anal. Manag. 12, 753–772.
Burn, S.M., Oskamp, S., 1986. Increasing community recycling with persuasive communication and public commitment. J. Appl. Soc. Psychol. 16, 29–41.
Cialdini, R., 2007. Influence. The Psychology of Persuasion. Collins Business, New York.
Chaffin, B., Shuster, W., Garmestani, A., Furio, B., Albro, S., Gardiner, M., Spring, M., Green, O., 2016. A tale of two rain gardens: barriers and bridges to adaptive management of urban stormwater in Cleveland, Ohio. J. Environ. Manag. 183 (Part 2), 431–441.
Chapman, J.A., Isensee, M., 2006. Stormwater pollution prevention education effectiveness. World Environ. Water Resour. Congr. 2006, 1–9.
Curtis, J., Strengers, Y., Strempel, A., Clarke, M., Horne, R., 2014. Improving Compliance Outcomes: Understanding the Behaviours and Practices of Business Environmental Performance. BehaviourWorks Australia and RMIT University consultancy report, Victoria.
Davis, A., Traver, R., Hunt, W., 2010. Improving urban stormwater quality: applying fundamental principles. J. Contemp. Water Res. Educ. 146 (1), 3–10.
Deletic, A., Fletcher, T., 2006. Performance of grass filters used for stormwater treatment—a field and modelling study. J. Hydrol. 317 (3–4), 261–275.
DEC, 2004. Did it Work? Summary Report on the Evaluation of the NSW Urban Stormwater Education Program. Department of Environment and Conservation (NSW), Sydney.
Dietz, M., Clausen, J., Filchak, K., 2004. Education and changes in residential nonpoint source pollution. Environ. Manag. 34 (5), 684–690.
Eisenhauer, B., Brehm, J., Stevenson, N., Peterson, J., 2016. Changing homeowners' lawn care behavior to reduce nutrient runoff. Soc. Nat. Resour. 29 (3), 329–344.
EPA NSW, 2016. Case Studies: Effective Stormwater Education from. http://www.environment.nsw.gov.au/stormwater/casestudies/. (Accessed 24 October 2016).
EPA Victoria, 2005. Reducing Stormwater Pollution: a Guide for Industry. EPA Victoria, Publication 978. http://www.epa.vic.gov.au/~/media/Publications/978.pdf. (Accessed 25 October 2016).
Francey, M., Fletcher, D., Deletic, A., Duncan, N., 2010. New insights into the quality of urban storm water in South Eastern Australia. J. Environ. Eng. 136 (4), 381–390.
Giacalone, K., Mobley, C., Sawyer, C., Witte, J., Eidson, G., 2010. Survey says: implications of a public perception survey on stormwater education programming. J. Contemp. Water Res. Educ. 146 (1), 92–102.
Gray, W.B., Scholz, J.T., 1991. Analyzing the equity and efficiency of OSHA enforcement. Law Policy 13, 185–214.
Gray, W., Shadbegian, R., 2005. When and why do plants comply? Paper mills in the 1980s. Law Policy 27, 238–261.
Gray, W.B., Shimshack, J.P., 2011. The effectiveness of environmental monitoring and enforcement: a review of the empirical evidence. Rev. Environ. Econ. Policy 5, 3–24.
Gunningham, N.A., Thornton, D., Kagan, R.A., 2005. Motivating management: corporate compliance in environmental protection. Law Policy 27, 289–316.
Hamel, P., Daly, E., Fletcher, T., 2013. Source-control stormwater management for mitigating the impacts of urbanisation on baseflow: a review. J. Hydrol. 485, 201–211.
Henriques, J., Catarino, J., 2016. Motivating towards energy efficiency in small and medium enterprises. J. Clean. Prod. 139, 42–50.
Johnson, B., Duffin, M., Murphy, M., 2012. Quantifying a relationship between place-based learning and environmental quality. Environ. Educ. Res. 18 (5), 609–624.
Jorgensen, B.S., Spano, M., Smith, L., 2015. Enhancing Our Dandenong Creek: Management Strategies to Reduce Pollution in Old Joe's Creek. Consultancy report for Melbourne Water, Melbourne, Australia.
Kaplowitz, M., Lupi, F., 2012. Stakeholder preferences for best management practices for non-point source pollution and stormwater control. Landsc. Urban Plan. 104 (3), 364–372.
Kellar, C., MacMahon, D., Jeppe, K., Hassell, K., Myers, J., Long, S., Allinson, M., Sharley, D., Pettigrove, V., 2014. Technical Report 45: Enhancing Our Dandenong Creek Pollution Prevention Program. Centre for Aquatic Pollution Identification and Management, University of Melbourne, Victoria.
Kellar, C., MacMahon, D., Sharley, D., Tillet, B., Marshall, S., Long, S., Pettigrove, V., 2016. Technical Report No. 68: Enhancing Our Dandenong Creek Summary Report for 2015-2016. Centre for Aquatic Pollution Identification and Management, University of Melbourne, Victoria.
May, P.J., 2005. Compliance motivations: perspectives of farmers, homebuilders, and marine facilities. Law Policy 27, 317–345.
Maxwell, S.E., 2000. Sample size for multiple regression. Psychol. Methods 5 (4), 434–458.
Murphy, K., Tyler, T.R., Curtis, A., 2009. Nurturing regulatory compliance: is procedural justice effective when people question the legitimacy of the law? Regul. Gov. 3, 1–26.
Nancarrow, B.E., Syme, G.J., Morris, P.N., Jorgensen, B.S., Casella, F.C., 1998. Stormwater Management in Australia: the Feasibility of Neighbourhood Action and Community Information. Urban Water Research Association of Australia, No. 142, Canberra, Australia.
Nyborg, K., Anderies, J., Dannenberg, A., Lindahl, T., Schill, C., Schlüter, M., Adger, W., Arrow, K., Barrett, S., Carpenter, S., Chapin III, F., Crépin, A.S., Daily, G., Ehrlich, P., Folke, C., Jager, W., Kautsky, N., Levin, S., Madsen, O., Polasky, S., Scheffer, M., Walker, B., Weber, E., Wilen, K., Xepapadeas, A., de Zeeuw, A., 2016. Social norms as solutions: policies may influence large-scale behavioral tipping. Science 354 (6308), 42–43.
Parkinson, J., 2003. Drainage and stormwater management strategies for low-income urban communities. Environ. Urban. 15 (2), 115–126.
Phillips, B., Spry, R., Smith, G., 2002. Stormwater education in the port macquarie industrial area. In: Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002. Institution of Engineers, Australia, Barton, A.C.T.
Roy, A.H., Wenger, S., Fletcher, T., Walsh, C., Ladson, A., Shudter, W., Thurston, H., Brown, R., 2008. Impediments and solutions to sustainable, watershed-scale urban stormwater management: lessons from Australia and the United States. Environ. Manag. 42 (2), 344–359.
Sargent, B., 2015. A systematic stormwater literature review. In: 9th International Water Sensitive Urban Design (WSUD 2015). Engineers Australia, Barton, ACT, pp. 468–481.
Segerson, K., 2013. Voluntary approaches to environmental protection and resource management. Annu. Rev. Resour. Econ. 5, 161–180.
Shelton, D.P., Rodie, S., Feehan, K., Franti, T., Pekarek, K., Holm, B., 2015. Integrating extension, teaching, and research for stormwater management education. J. Contemp. Water Res. Educ. 156 (1), 68–77.
Stern, P.C., 2000. New environmental theories: toward a coherent theory of environmentally significant behavior. J. Soc. Issues 56 (3), 407–424.
Senese, C., Rako, D., 2015. Old Joes Creek Pollution Prevention Assessments. DJR Environmental Pty Ltd report, Melbourne, Victoria.
Tabachnik, B.G., Fidell, L.S., 2001. Using Multivariate Statistics, fourth ed. Harper-Collins, New York, NY.
Taylor, A., Wong, T., 2002. Non-structural Stormwater Quality Best Management Practices – a Literature Review of Their Value and Life-cycle Costs. Cooperative Research Centre for Catchment Hydrology, Victoria.
Taylor, A., Fletcher, T., 2007. Nonstructural urban stormwater quality measures: building a knowledge base to improve their use. Environ. Manag. 39, 663–677.
Taylor, A., Curnow, R., Fletcher, T.D., Lewis, J., 2007. Education campaigns to reduce stormwater pollution in commercial areas: do they work? J. Environ. Manag. 84, 323–335.
Typhina, E., Yan, C., 2014. Managing dog waste: campaign insights from the health belief model. Appl. Environ. Educ. Commun. 13 (2), 73–82.
Urbonas, B., 2000. Assessment of stormwater best management practices. In: Field, R., Heaney, J.P., Pitt, R. (Eds.), Innovative Urban Wet-weather Flow Management Systems. Technomic Publishing, Lancaster USA.
Walsh, C., Booth, D., Burns, M., Fletcher, T., Hale, R., Hoang, L., Livingstone, G., Rippy, M., Roy, A., Scoggins, M., Wallace, A., 2016. Principles for urban stormwater management to protect stream ecosystems. Freshw. Sci. 35 (1), 398–411.

Walsh, C., Fletcher, T., Burns, M., 2012. Urban stormwater runoff: a new class of environmental flow problem. PLoS ONE 7 (9), 1–10.
Waterwatch Victoria, 2002. Stormwater Education Manual – Industry Booklet. Victorian Stormwater Action Program, Waterwatch Victoria.
Winter, S.C., May, P.J., 2001. Motivation for compliance with environmental regulations. J. Policy Anal. Manag. 20, 675–698.
Winz, I., Brierley, G.J., 2009. Mental Models in Urban Stormwater Management. School of Geography, Geology and Environmental Management, The University of Auckland, NZ.