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A RISK-BASED APPROACH FOR THE MANAGEMENT AND REGULATION OF WET-WEATHER OVERFLOWS

MANAGING AND PRIORITISING WET-WEATHER OVERFLOWS TO DELIVER BETTER, MORE COST-EFFECTIVE OUTCOMES

C Port, F Garofalow, M Cassidy, N Abulafia, T Chen, C Cantrell

ABSTRACT

Overflow points in Sydney's wastewater system allow excess wastewater to flow to stormwater drains or waterways in heavy rain to avoid flooding of homes and businesses. Sydney Water, engaging with NSW EPA, developed a risk-based approach to improve the management and licensing of these overflows. This paper outlines:

- A new risk-based approach, including the method to assess the risk of overflow points to the environment and community and identify where improvement can have the largest benefit;
- A risk-based regulatory framework to achieve better environmental and community outcomes.

This is the first time a risk-based approach has been applied across large-scale wastewater catchments (over 1,000 overflow points).

INTRODUCTION

During heavy rain, large volumes of stormwater enter Sydney Water's wastewater network, overloading the network capacity. To avoid flooding homes and businesses, the wastewater system is designed with overflow points that allow excess wastewater to flow to stormwater drains or waterways during these wet-weather events. These issues are present in almost every sewer system around the globe, including in cities both smaller and larger than Sydney.

Sydney Water is regulated for wet-weather overflows by Environment Protection Licences (EPLs) from the NSW Environment Protection Authority (NSW EPA). To meet NSW EPA requirements, Sydney Water has been working to reduce the frequency of wet-weather overflows, mainly by building large storage tanks, tunnels or bigger pipes and pumps, as well as reducing the amount of stormwater entering the sewer system.

Sydney's four major coastal wastewater systems, covering about 80% of Sydney Water's catchment area, require significant additional infrastructure to meet annual overflow frequency targets proposed in 1998 by Sydney Water. This is estimated to cost at least $5.5 billion (in 2012 dollars). The high cost of meeting containment standards is a problem shared by water utilities worldwide.

Overflow frequency is traditionally used as the measure of system performance for wet-weather overflows. It does not take into account the volume or location of the overflow, the sensitivity of the environment, or community needs and expectations for the waterway and its surrounds. Neither does it consider the risk imposed by other pollution sources such as urban stormwater runoff. Sydney Water sought to work with the NSW EPA to find a better way to manage and prioritise wet-weather overflows, with the intent to deliver better, more cost-effective outcomes.

Sydney Water has actively engaged with NSW EPA over the last two years to develop a risk-based approach to manage wet-weather overflows and a regulatory measure to include in environment protection licences.

SIMULATION AND/OR EXPERIMENT

Sydney Water's risk-based approach focuses on improving wet-weather overflows posing the highest relative risk of adverse impact and where the greatest benefit to the environment and community can be obtained.

The risk-based approach for managing wet-weather overflows is consistent with the principles of the international standard for risk management (AS/NZS ISO 31000). The principles include that it be transparent, systemic, structured, based on the best available information and aiming to protect community values.

The risk-based approach involves:

1. Risk assessment of overflow points: Understanding the risk of individual overflow points to the environment and the community.

2. Building a risk profile: To understand system-wide performance and overall levels of risk to the environment and the community. The risk profile is used as a baseline to compare and gauge progress and improvement for a set period.

3. Evidence-based decision-making: By analysing the risk profile and results of the risk assessment, overflow points can be identified and targeted for more detailed investigations and consultation to verify the risk to the environment and community, provide input to solutions, and demonstrate any improvement. This can also be used as the basis of improvement programs set through environmental licensing/regulation.

4. Adaptive approach: Using improved and updated information over time to ensure results are reflective of current conditions and community expectations.

Each of these steps is further detailed in the following sections.

Risk Assessment of Overflow Points

Sydney Water developed a process and criteria for assessing, at a desktop level, the risk of wet-weather overflows to the environment and the community.

A desktop approach allowed the risk assessement to be undertaken system-wide. This was completed for a large number of overflow points (over 1,000) in a relatively short time-frame.

It provided an informed starting point from which to focus more detailed work. The risk assessment process is focused on three waterway values, representing the risks from wet-weather overflows to the environment and community, based on established waterway objectives and guidelines, and community input. The three values are:

- Waterway ecosystem health – the potential for wet-weather overflows to impact aquatic ecosystems and riparian vegetation health.
- Public health – the potential for wet-weather overflows to impact the public health of waterway users (for example, swimming and boating).
- **Aesthetics** – the potential for wet-weather overflows to impact the community's enjoyment of the environment, in and around waterways (such as in parks), through visual pollution and/or odours.

The risk of each overflow point is assessed separately against each of the three waterway values. The risk assessment for each value involves:

- Assessing the risk of impact from overflow – considering factors of likelihood and consequence. This includes detailed criteria for system performance, environmental conditions and community usage.
- Assessing the potential for benefit to the environment and community from mitigating impact – considering what proportion of impact is from wet weather overflows compared to other sources (e.g. stormwater).
- Determining the risk category – from Category 1 (highest risk) to Category 5 (lowest risk). (Category 6 is assigned to overflow points where system modelling indicates they do not operate; hence, no potential risk for impact).

In this process, each of the three waterway values has been regarded equally. That is, there is no weighting applied to any waterway value; they are all regarded as equally important. Therefore, the highest risk category from the three waterway values is assigned as the overall risk category for each overflow point. A summary of the process is shown in Figure 7.

Sydney Water, in consultation with experts, the NSW EPA and selected stakeholders, developed risk criteria. These represent the key factors that affect the likelihood and consequence of the risk – as well as the potential for benefit – for each of the waterway values. Overflow frequency is still a consideration, however, volume of overflow, sensitive species present, community usage of the surrounding area and stormwater pollution are also important factors. The robustness of the approach has been tested and enhanced through expert involvement and review. A simplified summary of the intent of the risk assessment criteria is shown in Figure 8.

To ensure we could directly compare the risk of overflow points, it was important that the assessments were made on the same basis or level of information. Only data that is available for all overflow points was used. Proxy measures for the criteria were developed that draw on information currently available for all overflow points. These assessments will be updated in the future to use more detailed, local data from catchment assessments to inform and verify the risk of individual overflow points. Figure 8 also shows the proxy measures and data sources used in the current risk assessment.

To ensure a robust process and results, independent specialist review and sensitivity testing of the risk assessment criteria has been undertaken. Quality assurance of the risk assessment results was also completed.

Building A Risk Profile

A risk profile was developed showing the numbers of overflow points in each of the six risk categories from the risk assessment. A risk profile can be developed for each of the three waterway values as well as an overall profile. The risk profile(s) is based on current conditions (system performance, population, environmental conditions and community usage) and represents the overall risk of the wet weather overflows to the environment and community. This risk profile can be used as a baseline to compare and gauge progress and improvement over time. It can also be used as a basis for environmental licensing and/or regulation. The results from the risk assessment were used to produce a baseline risk profile for the potential for impact from wet-weather overflow points across the four major coastal wastewater systems. The assessment was based on 2013 data, the most recent model of conditions available for all four systems at the time the assessment was undertaken (late 2014).

Evidence-Based Decision-Making

The risk assessment process draws on information that is available for all overflow points at a desktop level.

The risk assessment and risk profile is used to provide a preliminary indication of overflow points where more detailed investigations should be targeted to verify the risk to the environment and community. The risk-based approach allows us to evaluate the risk from wet-weather overflows for each overflow point across the four major coastal wastewater systems and then compare the risks and set priorities. To ensure that the risk assessment and profile was a sound basis for decision-making and environmental licensing and regulation, the outcomes of the risk assessment were checked against the outcomes of:

- **Community consultation** – Sydney Water consulted widely across the four major coastal catchments, including working with six workshop groups through three workshops on what they saw as issues for waterways (including wet-weather overflows), the risk assessment process, the results of the risk assessment process, how it is intended to be used for regulation, and Sydney Water's planned improvement over the next five years.
- **Cost-benefit analysis** – Sydney Water developed a cost-benefit analysis tool that considered the non-market value of areas surrounding wet-weather overflow points, including a value of the environment and use by the community. Comparing this value with the cost of solutions to reduce risks, the overflow points where the greatest gain could be achieved for money invested (i.e. "bang for buck") could be identified.
- **Catchment assessment** – Sydney Water conducted pilot catchment assessments across four wastewater catchments (Upper Parramatta River, Lane Cove River, Vineyard Creek and Duck River, Prospect Creek). These included assessing the effects of overflows, assessing possible solutions, identifying benefits to the community and analysing costs and benefits.

The outcomes from these activities were found to generally align with the results of the risk assessment. This provided the confidence that the risk profile was a sound basis for decision-making and demonstrating improvement for environmental licensing and regulation.

Adaptive Approach

There are assumptions and limitations of the risk assessment. To avoid underestimating the risk, Sydney Water has been conservative in evaluating overflow points against the criteria. We will validate the assumptions we used in this risk assessment process and reduce the limitations over time by incorporating further information from site-specific catchment assessments. The initial risk assessment of an overflow point will need to be reviewed, and potentially adjusted, when further information becomes available.

Detailed studies may reveal that impacts are greater or smaller than originally assessed. Sydney Water has developed a risk assessment adjustment method to allow further information from site assessments to be taken into account in verifying the risk of a wet-weather overflow point to the surrounding environment and community.

The risk-based approach includes the means to use improved and updated information over time to ensure it is reflective of current conditions and community expectations.

To do this, the risk assessment of overflow points will need to be periodically reviewed. Sydney Water proposes to do this every five years. The risk assessment of each overflow point would be updated to include:

- Refinements to the risk assessment process, including verifying assumptions;
- Updated data on system performance;
- Updated data on conditions, including changes in stormwater management and other sources of pollution;
- Changes in community values and uses (for example, swimming sites and access to waterways);
- New technology.

This process of adaptive management will ensure that efforts for improvement remain focused on where the greatest benefits can be most effectively gained for the environment and community.

DISCUSSION AND RESULTS ANALYSIS

Sydney Water applied the risk-based approach to over 1,000 overflow points (representative of all overflow points) across Sydney's four major coastal wastewater systems: North Head, Malabar, Bondi and Cronulla. From this, we were able to:

- Compare the outcomes of the risk-based and frequency approaches;
- Use the risk profile to identify the greatest opportunity to reduce risk;
- Identify waterways with overflow points with the greatest potential for impact;
- Demonstrate how equivalent outcomes can be achieved more cost effectively;
- Develop a framework for licensing and regulation of wet-weather overflows using the risk-based approach.

Comparing The Outcomes Of The Risk-Based And Frequency Approaches

The risk assessment results and overflow frequency for overflow points in the four major coastal systems were analysed to better understand how effective continuing with the current frequency targets would be in reducing the risk from wet weather overflows on the environment and community.

Figure 1 shows this comparison. Sydney Water graphed each overflow point showing volume (x axis) against frequency of overflow (y axis) and its risk category (colour). The dotted line represents the frequency target (generally four overflows per year on average). Points below the line are overflow points that meet the frequency target and points above the line are in excess of the target. Figure 2 shows the analysis, but limited to Category 1 and Category 2 overflow points.

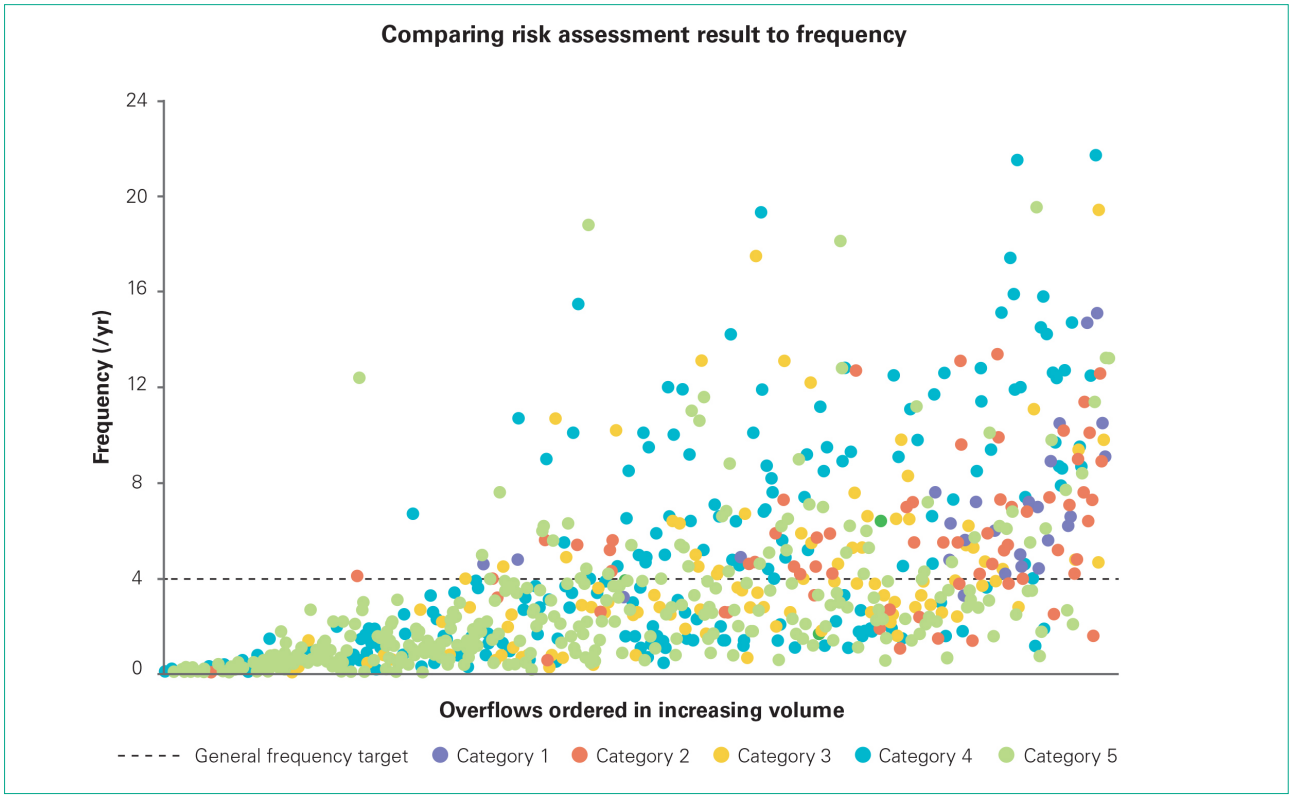

Figure 1. Comparison of overflow points by frequency, volume and assessed risk.

Figures 1 and 2 show:

- There are overflow points that operate below the target frequency but present a relatively high risk to the environment and community. This is where improvement work would deliver potentially greater environmental and community benefit, and may be relatively cost effective, but would not be addressed under the current frequency targets.
- There are many overflow points that exceed the frequency target but are assessed as relatively low risk. Improvement work at these overflow points would deliver potentially little environmental or community benefit at extremely high cost (billions of dollars).
- Frequency or volume does not always correlate to the potential impact of the overflow. The receiving environment plays a major role.

By improving overflow points that pose a higher risk, even if they already meet the target frequency, greater environmental and community benefit can be achieved.

Continuing to invest in improving the sites above the frequency target that are assessed as relatively low risk will not deliver as much environmental or community benefit.

Using The Risk Profile To Identify The Greatest Opportunity To Reduce Risk

From the results of the risk assessments, a risk profile was developed for all wet-weather overflow points across the four major coastal wastewater systems (Figure 3). The number of overflow points in each risk category is shown with risk categories 1–6 in order of potential for impact (highest to lowest).

The risk profile shows that while the vast majority of overflow points have been assessed on the lower end of the risk scale (Category 4–6), there are a number of overflow points (99) in Category 1 and Category 2 that should be focused on to reduce potential impact to the environment and community.

Future investment should be concentrated on reducing the potential for impact from these overflow points.

The risk profiles from the risk assessments for each waterway value (waterway ecosystem health, public health and aesthetics, shown in Figure 4) provided greater visibility of the nature of the potential impacts that should be focused on in order for the greatest benefit to be obtained.

These risk profiles show:

- **Waterway ecosystem health** – there are still sites Sydney Water can investigate for potential improvement.
- **Public health** – only two sites remain as higher risk (Category 2). This clearly indicates that wet-weather overflows are not currently posing as high a risk to public health relative to the other values. This reflects the success of the works to date that have targeted sites of risk to public health. It also supports a change in approach for wet-weather overflow management from one primarily focused on reducing risk to public health.

Figure 2. Comparison of higher risk overflow points by frequency, volume and assessed risk.

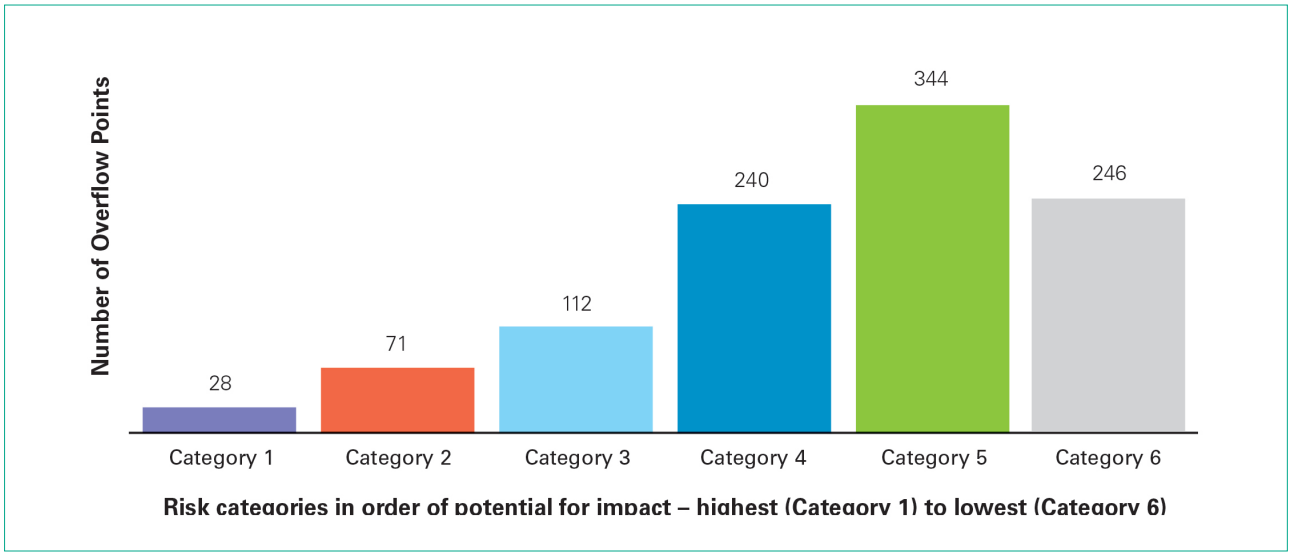

Figure 3. Baseline wet-weather overflow risk profile (2015).

- **Aesthetics** – most of the higher risk overflow points have the potential to affect how the community can use and enjoy waterways through aesthetic impacts. Focusing on reducing the risk of aesthetic impacts to the environment and community from higher risk wet weather overflow points will provide the greatest reduction in risk across the four major coastal systems.

Identifying Waterways With Overflow Points With The Greatest Potential For Impact

The locations of all overflow points in the four systems and their overall risk category were mapped. The locations of the higher risk overflow points (Category 1 and 2) are shown in Figure 5 and highlight where works to reduce risk should be focused to most effectively reduce the risk of wet-weather overflows.

From the map, it can be seen that overflow points in Category 1 and Category 2 tend to cluster on common waterways. This highlights the waterways and wastewater network catchments that can be further investigated as a priority to reduce risk at potentially multiple overflow points at one time.

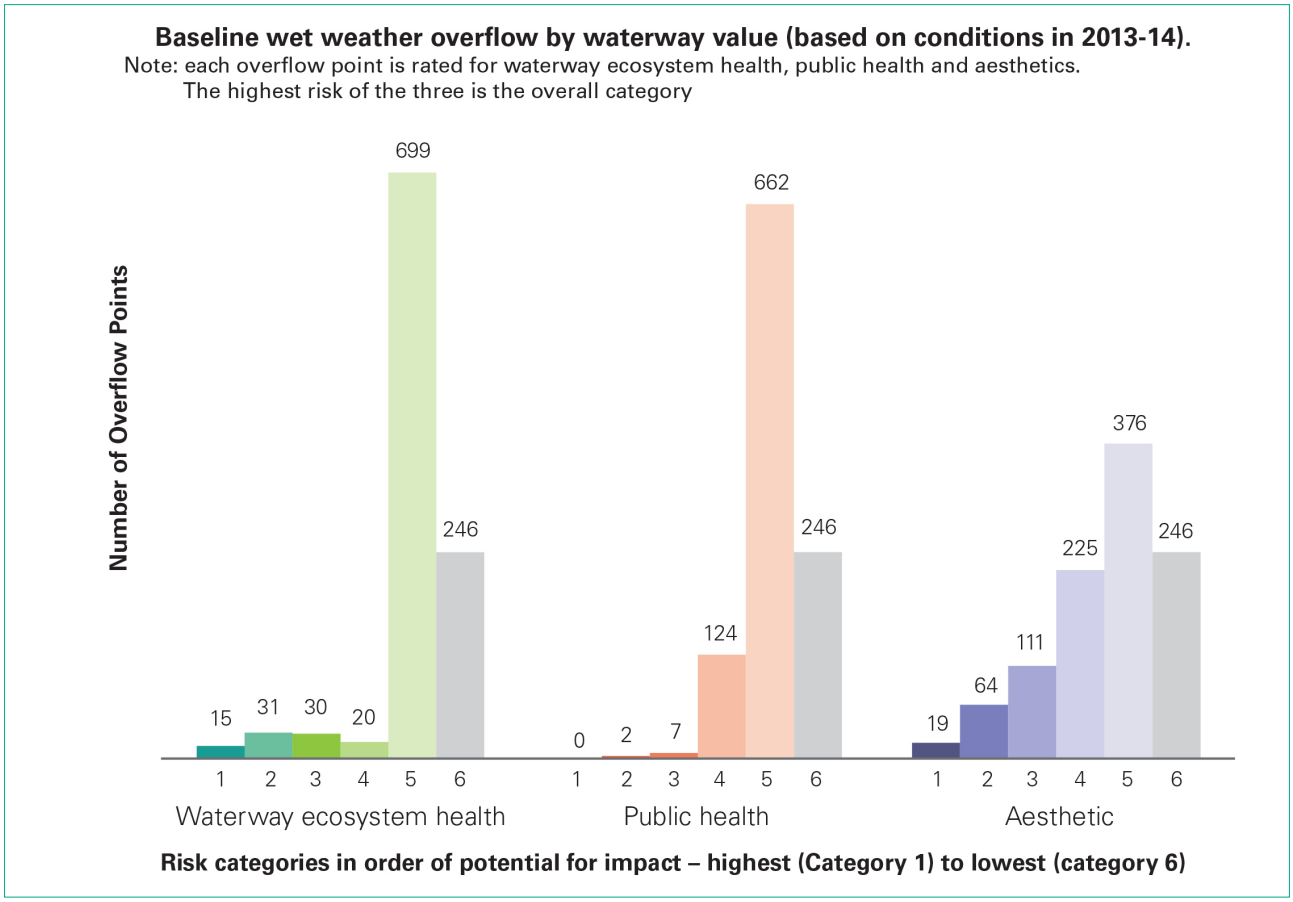

Figure 4. Risk profile for each waterway value.

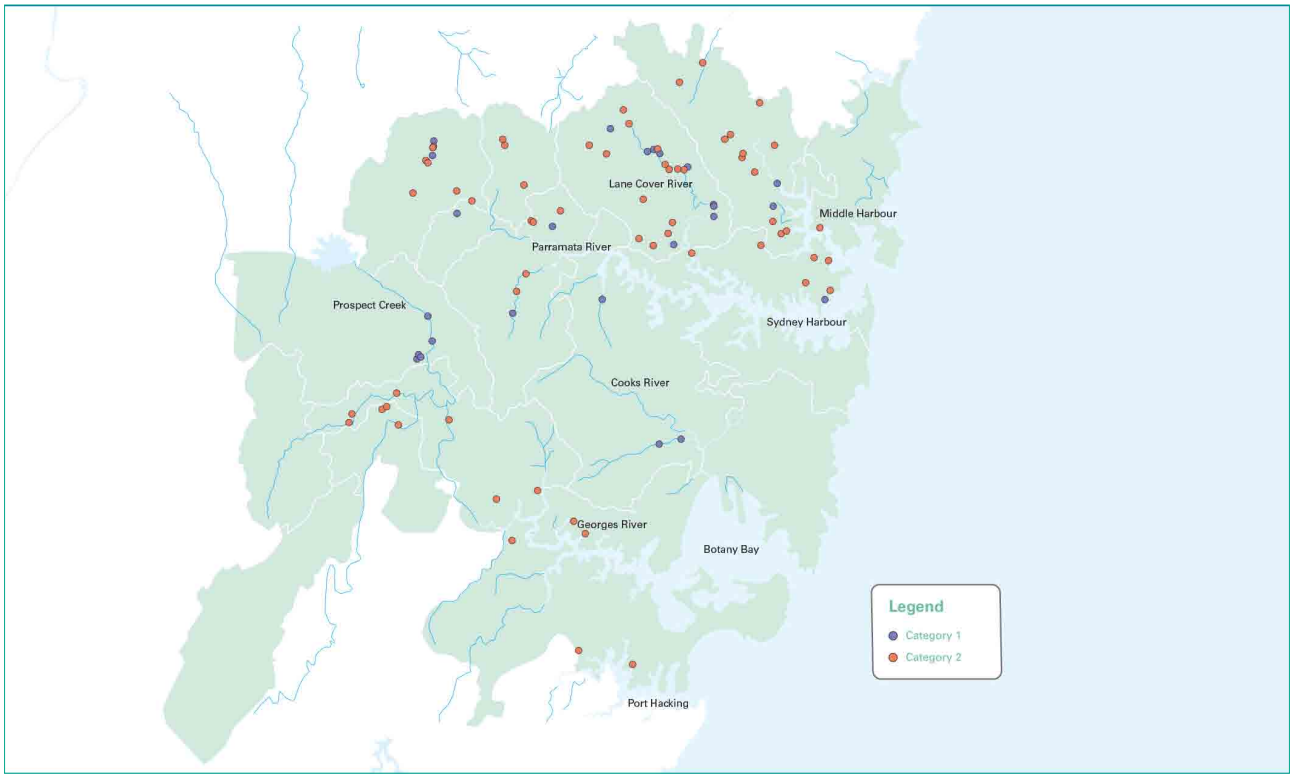

Figure 5. Category 1 and 2 overflow points in the four major coastal wastewater system (current conditions).

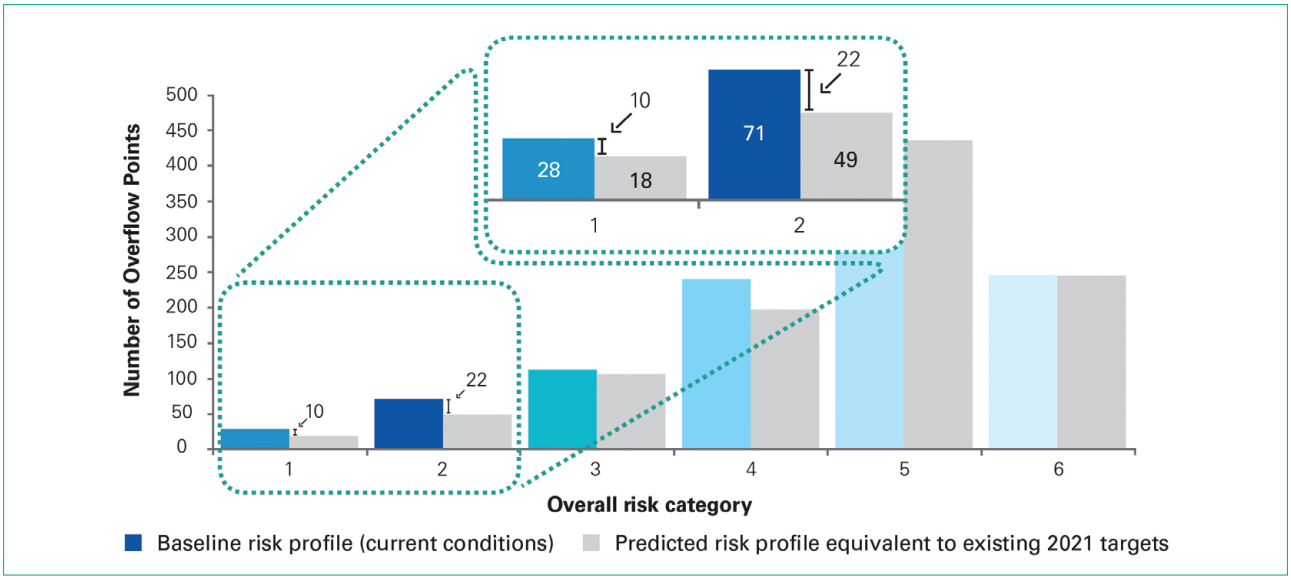

Figure 6. Improvement to risk category by 2021.

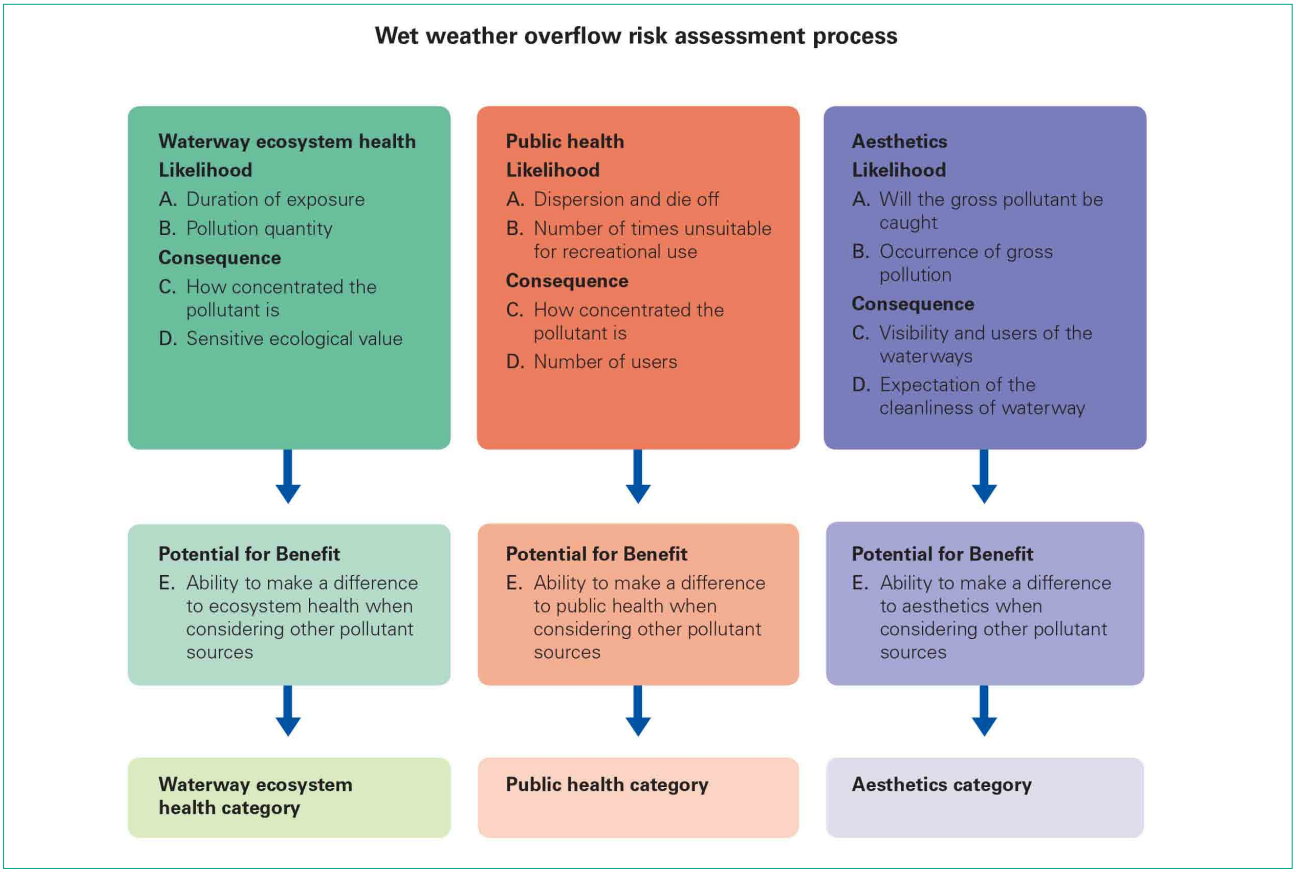

Figure 7. Wet weather overflow risk assessment process.

Table 1. Proposed improvement levels (2016–2021).

Category	Baseline (current)	Improvement level
1	28 overflow points	Reduce number of Category 1 overflow points to 18
2	71 overflow points	Reduce number of Category 2 overflow points to 49

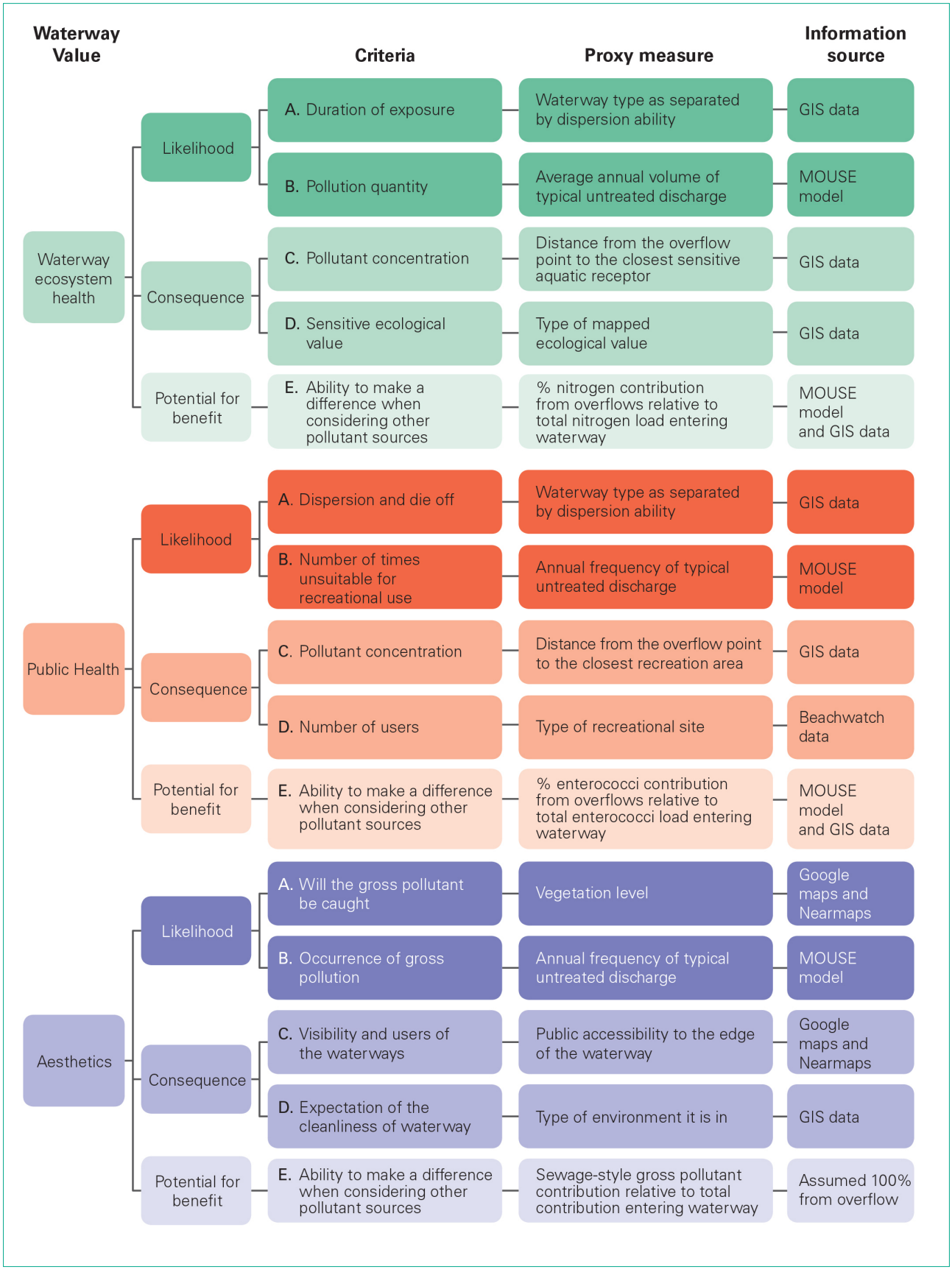

Figure 8. Risk assessment criteria.

Demonstrate How Equivalent Outcomes Can Be Achieved More Effectively

The NSW EPA required that Sydney Water provide at least the same environmental outcome as our previously proposed frequency targets would have achieved by 2021.

To demonstrate this, Sydney Water needed to understand what the performance of the wastewater system would be if the frequency targets previously proposed were met. Using the risk-based approach, we simulated this scenario using:

- The environment and community use assessments done as part of risk assessment;
- Our wastewater system model, assuming that the current frequency targets are met at all overflow points and the predicted population in 2020.

Using these two elements, Sydney Water re-assessed all overflow points using the risk assessment process. A risk profile for how the four systems would perform in 2021 if the frequency targets were met was developed from the results, which we compared against the current situation. Figure 6 compares the current risk profile to the predicted risk profile if the frequency targets were achieved in 2021.

This shows that, if we are primarily interested in at least meeting the higher risk categories (Category 1 and 2), there are 10 Category 1 and 22 Category 2 overflow points that need improvement (i.e. risk reduced to Category 3 or below) to achieve an equivalent level of risk to what the frequency targets would have achieved.

Sydney Water estimates that the cost to achieve this by 2021 is $146 million. This is far less than the estimate to meet the frequency targets across the four major coastal systems of $5.5 billion ($2012).

Licensing And Regulation Using The Risk-Based Approach

From the risk-based approach, Sydney Water and NSW EPA, in consultation with the community, have developed a regulatory framework for wet-weather overflows that can be applied to environment protection licences.

Sydney Water is currently proposing to NSW EPA to change the licences for the four major coastal wastewater systems to regulate wet-weather overflows using this risk-based approach.

This includes requirements to:

- Achieve an improvement level (reduction in risk profile) over a period up to five years;
- Demonstrate achieving environmental outcomes through detailed site investigations;
- Demonstrate continual improvement through the risk-based approach;
- Submit a five-year work plan and an annual report to the NSW EPA;
- Report publicly on progress every year;
- Report at the end of a period (up to five years) to demonstrate the improvement achieved;
- Review the risk assessment for each overflow point at the beginning of each period, including the latest information on environmental conditions, as well as community values and uses;
- Propose a new improvement level to NSW EPA at least every five years.

The improved environmental outcome to be achieved over the five-year period is defined as an 'improvement level', which stipulates the number of overflow points within a risk category at the end of the period, compared to a baseline risk profile set at the start of the period.

The risk profile achieved by meeting the current frequency targets was used as the basis for determining the proposed improvement levels for wet-weather overflows proposed for 2016–2021 (refer to Table 1).

Advantages in working to the improvement levels over the current frequency-based approach are that it enables Sydney Water to:

- Target areas of greatest risk and where greatest benefit can be gained;
- Have the flexibility to prioritise investigations on a waterway catchment basis;
- Deliver environmental and community outcomes more cost-effectively using the most appropriate solutions.

Annual progress reporting to the NSW EPA will include progress of catchment assessments, work and activities, and progress towards achieving the improvement level. At the end of the improvement period, the improvement in risk achieved is reported, relative to the baseline risk profile.

The baseline risk profile will be re-set for the beginning of each improvement period. Sydney Water will incorporate updated environmental conditions and uses into the new baseline risk profile for the next improvement period.

We will factor in:

- Refinements to the risk assessment process, including verifying assumptions;
- Updated data on system performance;
- Updated data on conditions – including changes in stormwater management and other sources of pollution;
- Changes in community values and uses (for example, swimming sites and access to waterways);
- New technology.

The ongoing, continuous improvement proposed under this approach, with progressive improvement levels being set and achieved, will lead to a better overall outcome over time than a fixed frequency target.

CONCLUSION

The risk-based approach provides a robust way of prioritising investment to improve wet-weather overflows, where the environmental and social benefits have traditionally been difficult to measure.

This approach provides a superior way to manage and regulate wet-weather overflows because it:

- Identifies and targets improvement to areas of greatest risk and where greatest benefit can be gained;
- Aligns regulatory performance with environmental and community outcomes;
- Is adaptive to ensure outcomes are aligned with community uses and aspirations for waterways and the environment;
- Allows solutions to match problems, for cost-effective delivery of outcomes;
- Allows for proactive, constructive, consistent management and incorporates best practice approaches.

Under this approach, Sydney Water can achieve environmental and community outcomes more cost effectively than under the traditional frequency-based approach.

Through this process of adaptive management, Sydney Water can progressively reduce risks from wet-weather overflows. Ongoing improvement levels being set and achieved will lead to a better overall outcome than the existing frequency target would have achieved. This will ensure overflows do not inhibit waterways from achieving the shared outcomes that councils, government and other stakeholders are working towards.

This paper won the Best Paper award at Ozwater'16 in Melbourne May 10–12.

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THE AUTHORS

Catherine Port (email: CATHERINE.PORT@sydneywater.com.au) is a Chemical Engineer with over 14 years' experience in the water industry and is currently the manager of Product and Asset Management at Sydney Water. She was the Project Director for Sydney Water's Wet Weather Overflow Strategy and Regulation Project, which developed the risk-based approach for the management and regulation of Sydney Water's Wet Weather Overflow program, proposed to NSW EPA.

Frank Garofalow is Director Water Regulation for the Department of Primary Industries – Water within the NSW Government, and is responsible for the regulation of water usage and water and sewage treatment. Prior to this, Frank held a role within NSW EPA responsible for the environmental regulation of major infrastructure in NSW including road, rail and water and sewerage, and a variety of roles with local government.

Michele Cassidy is an Environmental Scientist with experience in applying environmental planning and management to a wide range of major infrastructure, property, maintenance and operational projects. Michele has over 18 years' experience in the water industry ranging from aquatic ecology, environmental impact assessment to environmental regulation. She is the Senior Environmental Regulatory Specialist to the Wet Weather Overflow Strategy and Regulation Project, and is involved in developing the risk-based approach for the management and regulation of Sydney Water's Wet Weather Overflow program.

Natasha Abulafia is a water industry professional specialising in environmental management, quality systems and project management. With over 20 years' experience working with Sydney Water, Natasha has demonstrated capabilities to lead the environmental planning and management component of works delivering outstanding on-site management. She was part of the team that developed the new strategy and the risk-based approach for the management of Sydney Water's Wet Weather Overflow program and development of the proposal to NSW EPA.

Tiffany Chen is currently a Graduate Chemical Engineer working in Service Delivery, Wastewater Networks at Sydney Water. Her experience includes regulation, safety, process optimisation, operations and sustainability. Tiffany was a key member of the project team in the development of Sydney Water's risk-based approach for the management and regulation of wet weather overflows and development of the proposal to NSW EPA.

Clint Cantrell is MWH's Global Practice Leader for wastewater and stormwater, and is a technical specialist in the assessment and mitigation of risk associated with pollution from wastewater overflows and stormwater runoff. His experience in consulting and public utilities includes large city master planning, sewer system assessments and rehabilitation, SSO and CSO programs, regulatory negotiations, hydraulic and water quality modelling, stormwater flood programs, wastewater master planning, implementation of wet weather control and treatment technologies, and capital improvement planning.

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