POINT-SOURCE IMPACT METHODOLOGY - A NEW WAY TO LOOK AT DISCHARGES

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ABSTRACT

Quantifying the impact of point-source discharges on water quality is crucial for regulatory authorities who undertake the management of freshwaters. By knowing the point-source contribution of contaminants to rivers, the diffuse component can be calculated and appropriate resource management decisions can be made. In order to quantify the impact of point-source discharges on the environment a new methodology, the Point-source impact method, (PIM) has been developed. The aim of this methodology is to provide an instream, effects-based classification of a discharge across all water quality parameters.

The PIM is a statistically driven classification tool that builds on work carried out by Horizons Regional Council. The PIM method provides an improvement on other methods for analysing point-source impact. The method does this by enabling both the permit holder and the regulatory authority to understand the impact of each discharge on the immediate downstream environment and determine the direct and cumulative impacts of diffuse contamination and other point-sources upstream of the discharge. The method is particularly useful in situations where a discharge may not demonstrate catchment-wide impacts but is causing a localised water quality problem. Additionally analysis using this method can aid the permit holder in prioritising upgrades required to the discharge treatment process to improve effluent quality.

KEYWORDS

Water quality; Point-source; freshwater; contaminant; environment effects; receiving environment

1 INTRODUCTION

Worldwide, there is increasing pressure on fresh water as a result of anthropogenically-driven degradation of water quality - particularly relating to increasing eutrophication and faecal contamination of waterways. State and trends in New Zealand water quality reflect the world situation and indicate a shift in importance from point-source to diffuse contaminant sources (Scarsbrook, 2006; Ballantine and Davies-Colley*.,* 2009). As a result, freshwater management in New Zealand is moving towards placing a greater responsibility on the agricultural sector to account for diffuse pollution of freshwaters. However, point-sources are still an issue in some catchments.

The main influences of point-source discharges on freshwaters relate to the physical and chemical characteristics of the wastewater, and the type and concentration of contaminants (Cotman *et al,* 2008). The effect of a discharge within the receiving environment is further influenced by the flow and the consequent dilution of that discharge by the receiving water body (Cotman *et al.,* 2008, Roygard & McArthur, 2008). The impact of point-sources on freshwaters is greatest during low flow conditions when run-off and leaching from the surrounding landscape is minimal, and the dilution of the discharge is reduced (Manawatu-Wanganui Regional Council, 1998; Roygard & McArthur, 2008; Cotman *et al.,* 2008).

As water quality expectations become more stringent it is becoming more important for holders of discharge permits to prioritise their improvement efforts and focus on the contaminants directly affected by the discharge. This is particularly relevant for territorial local authorities throughout New Zealand as they struggle to effectively manage multiple municipal waste discharges, while trying to keep the costs to upgrade treatment systems within the capacity of their communities to fund them. There is currently no integrated rapid assessment method to determine the contaminant contributions from various sources, and therefore no quick way to prioritise treatment system upgrades in the context of the effects of the discharge on the receiving environment.

As a result the variety of contaminants and effects of point-source discharges require an adaptable methodology to assess the impact of the discharge on physical, chemical and biological parameters whilst providing simple and easily interpreted results. This paper presents a new method developed for determining and classifying localised impact of point-source discharges on freshwaters. The work draws on a Masters of Applied Science the leading author undertook at Massey University (see Clark; 2010).

The point-source impact methodology (PIM) was developed to classify in-stream effects of discharges to water bodies from monitoring data collected as part of Horizons discharge monitoring programme (Roygard, 2009; Clark, 2009). The initial development of the method stemmed from Horizons policy effectiveness monitoring/consent impact graphs which are presented in near real time on the WaterQualityMatters website (Horizons Regional council, 2010).

Figure 1 demonstrates an example of the consent impact graphing Horizons undertakes to evaluate the potential effect of a discharge in the context of flow and environmental standards. Water quality data upstream and downstream of a point-source discharge is plotted in a scatter plot with the upstream data plotted on the x-axis and the downstream on the y-axis. Soluble inorganic nitrogen upstream and downstream of Palmerston North STP is compared to Proposed One Plan standards (red lines). The blue line indicates a 1:1 relationship between upstream and downstream.

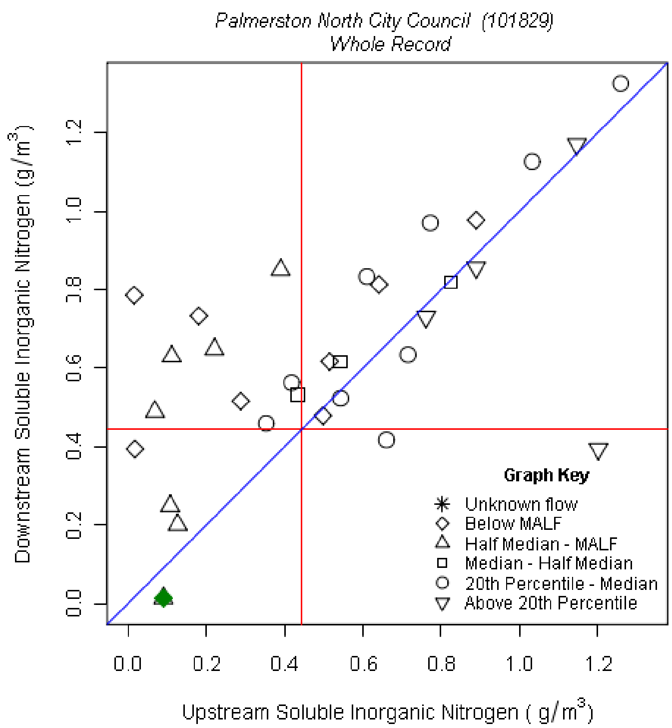

Figure 1: Example of a consent impact graph. (Source: WaterQualityMatters, accessed 13 February 2010).

While this method is useful for determining the impact of a single point-source discharge it does not provide the permit holder or the regulatory authority the ability to compare effects with other discharges in the same catchment.

2 METHOD

The PIM combines Horizons' consent impact method with a statistical analysis and classification component to provide regulatory authorities and key stakeholders with a simple tool to assess the impact of discharges on the receiving environment. The PIM can also pinpoint water quality parameters where the treatment process is not meeting set standards.

The PIM methodology takes the consent impact graphing a step further to classify the degree of influence a discharge is having on water quality at the downstream site. This requires monitoring upstream and downstream of the discharge point. The upstream monitoring site (located a sufficient distance upstream that any influence on water quality as a result of back flow from eddies or seepage from unlined ponds is removed) acts as a control by accounting for the diffuse contamination / cumulative impact of upstream discharge on the river. The downstream monitoring site (located at the bottom of the mixing zone as stipulated in the resource consent) provides a measure to calculate the effect of a discharge.\

Water quality parameters selected for measurement should be representative of a full suite of physical (temperature, flow, turbidity etc.) chemical (nitrate, ammoniacal nitrogen, dissolved reactive phosphorus (DRP) etc.) and biological (periphyton biomass, Quantitative Macroinvertebrate Community Index etc) parameters to get the best understanding of the water quality issues in a particular water body (Scarsbrook &McBride, 2007).

The PIM method is undertaken in four steps;

- Setting up data for analysis
- Data analysis
- Classifying the data and implementation of the conceptual model
- Interpreting the results

2.1 SETTING UP THE DATA FOR ANALYSIS

Paired samples (an upstream and downstream sample) are required for each parameter. Where a sample is missing a result from the upstream or downstream site the sample on the same date from the other site should be removed. Where the results of the analysis are returned as less than the detection limit the < is removed and half the value of the detection limit is use for analysis. If greater than the upper limit of detection the > is removed and the upper detection limit values is used for analysis (according to the methods in Scarsbrook and McBride; 2007).

2.2 DATA ANALYSIS

Paired samples for a discharge are analysed parameter by parameter using the Wilcoxon signed-rank test to a p value of <0.05. The Wilcoxon signed-rank test is a two tailed non-parametric test of two related samples. A non-parametric test is the most appropriate to use because water quality data does not typically display a normal distribution (Scarsbrook & McBride, 2007); additionally non-parametric tests are also appropriate when dealing with small sample sizes (Gilbert, 1987).

The test assesses the null hypothesis that the difference between the medians of the two samples is zero. In this methodology the constant is the chosen parameter (for example DRP) and the variables are the sampling locations (in this case upstream and downstream of a discharge). When the null hypothesis is rejected the two datasets are statistically different from each other enough to determine which site is displaying a statistically significant change in the water quality parameter.

2.3 CLASSIFYING THE DATA AND IMPLEMENTATION OF THE CONCEPTUAL MODEL

The median of the data for each site by parameter is calculated. The median is selected as the statistic to use over the mean because it removes the effect of extreme values on the result (Scarsbrook & McBride 2007; Roygard & McArthur, 2008).

The results of the Wilcoxon signed-rank test are combined with the calculated medians and compared with the standards or guideline values. This provides a means of classifying the data into one of eight classes. The steps to classify each of the discharges by parameter are described as a decision support flow chart in Figure 1.

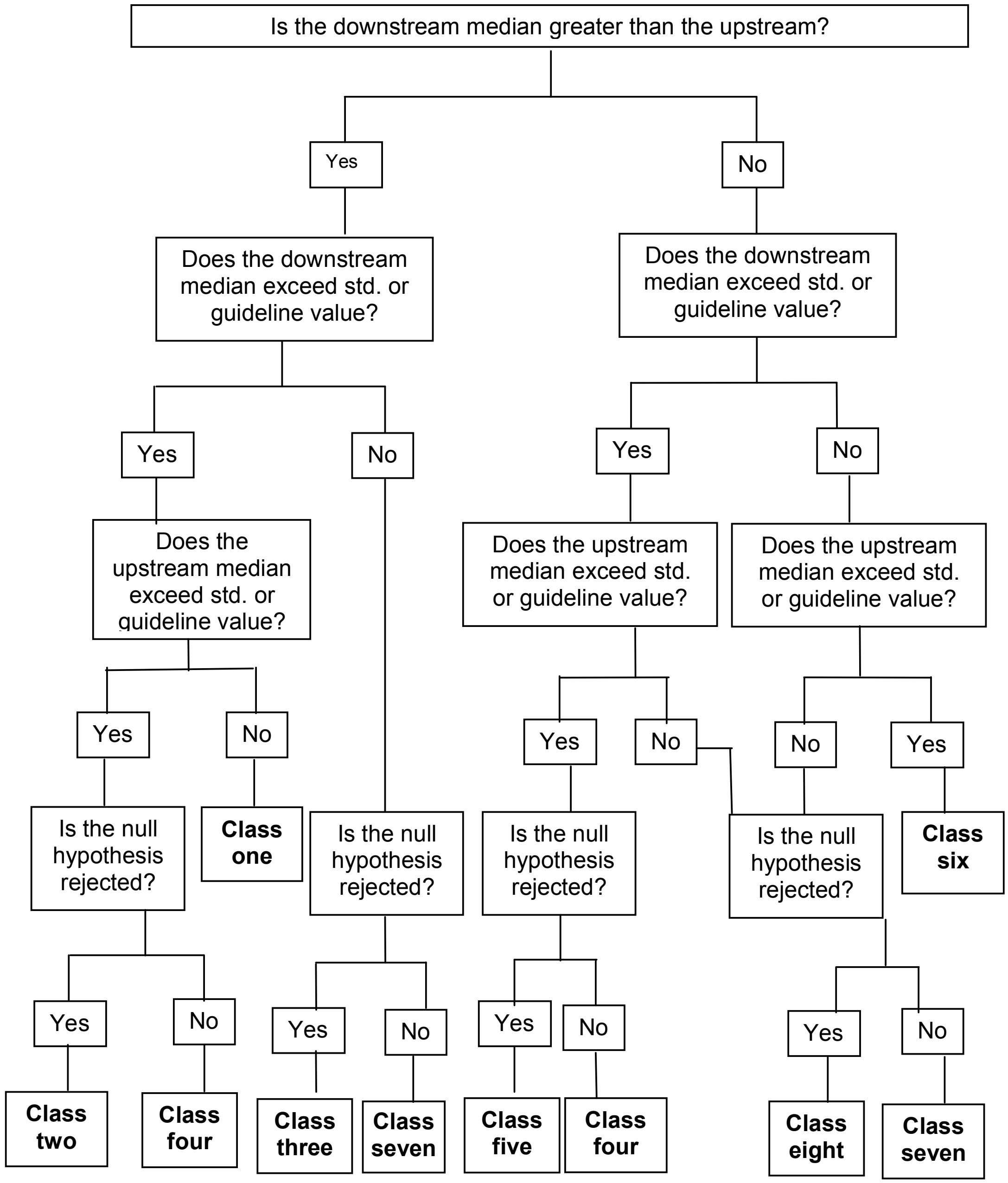

Figure 1: Decision support flow chart for classifying the results of the Wilcoxon signed-rank test. Std. is used in the diagram to denote water quality standard or guideline value.

In the case of parameters that decrease in value with increasing impact (for example, Black Disc and QMCI) the quantifiers presented in Figure 1are inverse (i.e. the first question will be Is the downstream median LESS than the upstream? and so on).

Figure 2 provides a visual representation of where each of the classes is located on the consent impact graph (Horizons Regional Council, 2010). The visual representation provides the ability for all discharges in a catchment or all discharges where standards or guideline values for the receiving water body are the same to be compared parameter by parameter by plotting the median concentration of upstream vs. downstream.

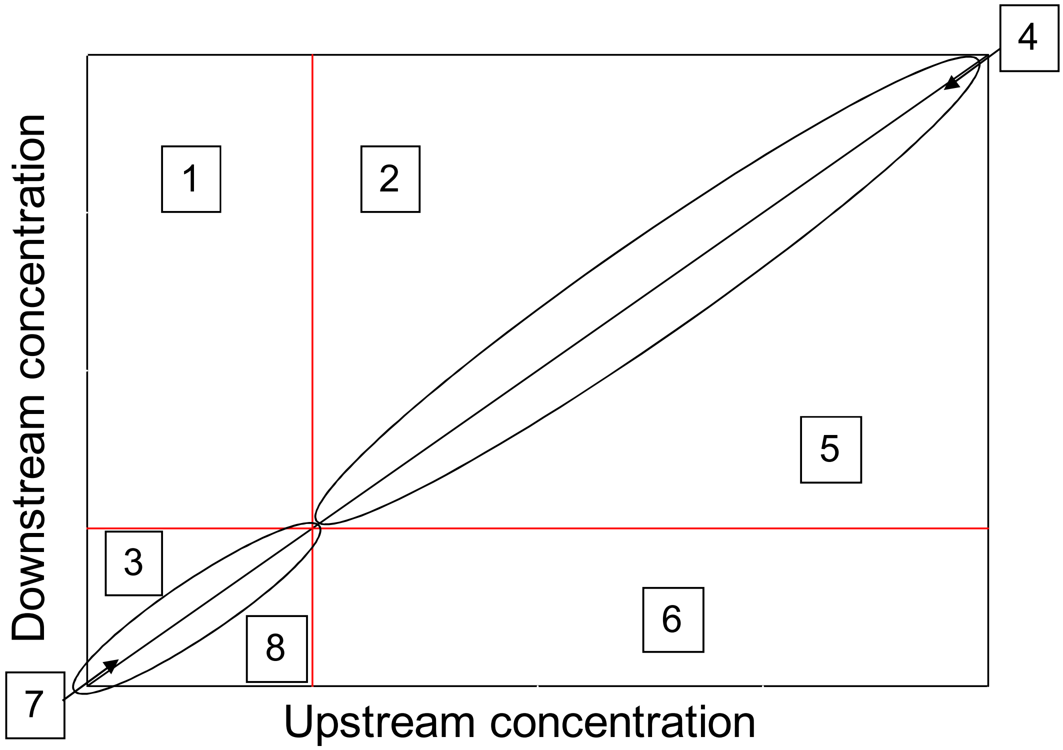

Figure 2: *Classification of discharge impact on the immediate receiving environment. The red lines show the standard/guideline limit for both the upstream and downstream sites. The black line represents a 1:1 relationship between upstream and downstream of the discharge. The bubble represents data close to a 1:1 relationship and therefore classifying as class four or class seven.*

In the case of Black Disc and QMCI parameters the PIM graph method works equally well, except that the downstream value is plotted on the x rather than the y-axis.

3 INTERPRETATION OF THE RESULTS

Table 1 provides a simplified version of the classification criteria for the PIM. Classes one to three indicate the discharge is having an impact on the quality of the receiving water whereas classes four and seven indicate no statistical difference between upstream and downstream samples. Classes five, six and eight indicate there is an upstream catchment issue where the discharge is diluting the concentration of the contaminant between the upstream and downstream monitoring sites.

As shown in Table 1, class one indicates a more than minor effect where the discharge is causing an exceedence of the standard or guideline value.

Classes two and three indicate the discharge is still causing a noticeable degradation in receiving water quality although the standard is exceeded at both sites in class two and is not exceeded at both sites in class three.

In classes one and two the recommendation to the discharger and the regulatory authority is to prioritise an upgrade of the treatment plant to remove or reduce the concentration of the parameter in question. However in class three, consideration of the effect the discharge is having on the receiving environment for the parameter in question would be advisable, because although the discharge is not causing an exceedence of the standard there is a noticeable effect on the receiving water body at that locality.

Table 1: Results of the statistical analysis and classification for impact of point-source discharges. NB. DS = Downstream US = Upstream.

Class	DS median > US median	DS median > Standard	US median > Standard	Is the null hypothesis rejected?	Contamination source
Class one	✓	✓	×	n/a	Point-source
Class two	✓	✓	✓	✓	Combination but Point-source is exacerbating the problem
Class three	✓	×	×	✓	Point-source – but meets the standard
Class four	n/a	✓	✓	×	Diffuse/cumulative impact of other discharges
Class five	×	✓	✓	✓	Diffuse/cumulative impact of other discharges
Class six	×	×	✓	n/a	Diffuse/cumulative impact of other discharges
Class seven	n/a	×	×	×	Diffuse/cumulative impact of other discharges - but meeting standards
Class eight	×	×	×	✓	Diffuse/cumulative impact of other discharges - but within standard/guideline limits

Where more than one parameter has been analysed and classified the resultant classes can be summed across all parameters to give an overall score for each discharge providing the ability for holders of multiple discharges to prioritise based on degree of effect the discharge is having. In order to provide an overall score each class has been assigned a numerical value (Table 2) and summed across all parameters for each discharge. The discharge with the lowest score would be the highest priority for remediation.

Table 2: Scores assigned to each class

Class	Score
One	1
Two	2
Three	3
Four	4
Five	5
Six	6
Seven	7
Eight	8

4 DISCUSSION

The PIM allows for the recognition of localised effects of a discharge on the receiving water body. Localised analysis is crucial for effective management of water quality around point-sources particularly where analysis methods that are designed to investigate catchment wide effects of discharges fail to detect changes in water quality as a result of the discharge. It is important to understand localised effects in order to determine the impact of a discharge on aquatic communities and other water body values (for example, contact recreation).

The application of the PIM differs from consent impact graphs in that it facilitates the summary and consequent classification of a discharge from a range of samples. Additionally classes for all parameters can be summed to give an overall score for the discharge. This allows for comparison between a number of discharges held by the same consent holders for example a District or City Council. The discharge with the lowest combined score would be the highest priority for remediation. In some cases, for example where parameters may be considered to have a greater impact on the values of the receiving water body than others, a weighting might be applied, the PIM classification system can accommodate this.

Although there are a number of advantages of the PIM there are several limitations to its use. These can all be overcome.

The first limitation is that the PIM only provides a localised impact assessment of the discharge. This is because the impact is only assessed on the immediate downstream monitoring site and does not provide an overall impact analysis for other downstream receiving environments. To resolve this issue when assessing a consent application PIM can be used in conjunction with a loading methodology to calculate the effect on a catchment scale.

The second limitation is that standards or guidelines need to be identified for the receiving water body. The establishment of standards or guideline values prior to application of the PIM is crucial because standards provide an environmental bottom line to compare monitoring results to and assess the effects against.

The third limitation is that water quality monitoring data is required to carry out a PIM assessment. However, the limitation only exists if the analysis was required immediately, in most cases water quality data upstream and downstream of discharge can be collected easily but requires time. Horizons combined State of the Environment and discharge monitoring programme is specifically designed for this type of analysis to take place for major point-source discharges in the Manawatu-Wanganui Region. (Roygard, 2009; Clark 2009)

The fourth limitation recognises the importance of flow on water quality. The PIM methodology in its current form does not allow for flow to be factored into the analysis. In cases where flow data has been collected this limitation can be overcome by using the PIM to analyse data assigned to various flow categories; alternatively the PIM can be applied using paired loadings in place of concentrations.

The biggest disadvantage to the PIM and other methods for analysing the impact of point source discharges is that if there is poor upstream water quality the discharge may appear to be having little impact on the receiving water. In this instance, a more appropriate consideration for resource managers would be that if the capacity for the river to assimilate pollution were already exceeded, should other discharges to water be allowed to further add to the degradation?

5 CONCLUSIONS

Combining both point-source and diffuse management allows for a more holistic approach in the management of water quality. The PIM is an appropriate tool to guide both resource managers and dischargers to achieve this by;

- prioritising where effort and money should be spent upgrading a discharge for a better effluent quality;
- prioritising issues to deal with at multiple discharges; and
- for use in an environmental impact assessment of the discharge.

Using the PIM as part of an assessment alongside complementary methods to inform decision-making can result in a better understanding of the effects of the discharge.

PIM provides both the consent holder and the regulatory authority with the ability to:

- Understand the impact of each discharge on the immediate downstream environment; and
- Determine the degree of impact from diffuse contamination, and the cumulative effect of other point-sources upstream of the discharge.

6 FURTHER RESEARCH

Research is required to determine how flow affects the results of PIM. For example, high nitrogen concentrations from the discharge may only be an issue when the river is in low flows, because in high flows the diffuse component becomes more prominent. This would allow the discharger to prioritise when they carry out treatment methodologies such as phosphorus dosing.

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