WASTEWATER INFLOW AND INFILTRATION REDUCTION COSTING TOOL

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ABSTRACT

A significant amount of work has been undertaken in New Zealand to monitor and model wastewater collection networks. A key driver of this work has been to better understand the effects of rainfall induced inflow and infiltration on network performance in terms of overflows, flooding and its affect on planning for growth.

The modelling techniques employed are often cutting edge but have not always delivered the business justification that is required of network managers for their investment decision making. When assessing how much inflow and infiltration reduction is required to achieve target levels of service, the modelling does not generally address the commercial benefits and business case variables to levels required of network managers today.

Watercare and CH2M Beca have developed a tool that will assist network managers in their business case justification and future decision making. The tool is able to provide a level of understanding to the various inflow and infiltration components and their corresponding allocation of funding to best meet level of service outcomes. This paper describes one case study into assessing and understanding inflow and infiltration in such a way as to assist network managers.

KEYWORDS

Business case, Inflow and infiltration, Modelling, Rehabilitation, Network managers, Decision making

1 INTRODUCTION

Many municipal wastewater networks suffer from the adverse effects of wet weather Inflow and Infiltration (I&I). The most common effect of I&I is network surcharging and uncontrolled discharges during times of heavy rainfall. This loss of network collection capacity during heavy rainfall also places restrictions on population growth and future development within the areas affected by the I&I. Using basic design standards, every litre of stormwater per second entering a wastewater system is equivalent to reducing a catchment's ultimate serviceable population by around 20 to 30 households.

A significant amount of work has been undertaken in New Zealand to assess and understand the effects of rainfall induced I&I on wastewater network performance in the hope of finding a solution and business case for its mitigation. Key to this work has been the development of monitoring programmes and dynamic collection system computer models. The modelling techniques employed have often been cutting edge but have not always delivered solution benefits in terms that easily support cost / benefit analysis or business case justification. The questions of "why", "how much" and "what payback" are often hard to quantify in terms that satisfy a company's or Council's business needs. As a consequence, the often high cost of an I&I solution can be hard to justify for its benefits using conventional cost benefit analysis. This can result in network managers basing their business cases to proceed with I&I solutions on "it's good practice" or "it's just the right / sustainable thing to do" type arguments. While this approach is commendable, it leaves the decision to invest open for debate and, as such, it may not stand up to scrutiny from a change in management, Directors or Councillors.

Watercare and CH2M Beca have undertaken the first steps to assist network managers in better quantifying the business case for investing in I&I reduction projects. Together they have developed a database tool which links levels of I&I reduction and technology with real life investment costs. This tool has been developed using actual costing data sourced from a number of I&I control projects recently completed within the Auckland Region. The tool is designed to be indexed and updated to remain current and, as such, to assist network

managers in the development of capital investment budgets for these works for inclusion in the regional asset management planning process.

This paper summarises the motivation behind the development of the tool as well as the approach to its development and intended future use.

2 DISCUSSION

2.1 BACKGROUND AND MOTIVATION

There has been much discussion and study throughout the world with regard to I&I and its effect on wastewater collection systems.

In New Zealand, the effect of Inflow & Infiltration has a significant impact on wastewater infrastructure, customers through flooding of property and public areas, together with the receiving environment, through additional discharges from constructed overflows.

Before adequate rehabilitation can be undertaken to alleviate the problems caused by I&I and improve the wastewater infrastructure, the processes of the I&I must be fully understood. For example, is the wastewater network in a general state of disrepair or are specific issues, such as collapsed pipe or cross connections from major stormwater lines causing major excess wet weather flows? Existing CCTV records, maintenance databases and flow survey information should be reviewed at this stage.

Consideration must be given to the rehabilitation of the network before large I&I removal programmes are embarked upon. Detailed cost benefit exercises should be completed to assess the effect of rehabilitating cracks in pipes, grouting manhole joints and correcting damaged lateral connections, versus storing spills at the downstream end of a subcatchment. In many cases, less disruption to the customer may be a major consideration to the service provider, particularly if overflow frequency can be lessened by downstream storage.

Prior to any I&I control works being undertaken, it is important that the catchment in question has been assessed in detail to provide a 'benefit analysis'. This allows us to target areas of I&I where the most benefit will be achieved. In some cases, the effect of improving I&I at the upstream end of a catchment may result in no works being required at the downstream end of a catchment if the desired level of service is achieved.

Hydraulic models can help us plan and target these catchment areas. It is also important to have good recent flow data to assist with this process. There is strong evidence that the source of I&I can be located using 'roving' flow monitors. This requires monitoring the downstream areas of branches in a particular catchment and moving the roving monitors upstream after each rainfall event until the source of I&I is established. This may significantly reduce cost as well as disruption to the householder by focusing on specific areas rather than undertaking a total catchment separation for example.

The effectiveness of Inflow & Infiltration control projects in terms of the amount of stormwater reduction is widely published and what is clear (but not always obvious) is the variability of outcome. The variability in the ranges of effectiveness can give significantly different cost benefits and is difficult to predict. Some evidence suggests that pipe material and age can be linked to the level of I&I present in a given wastewater network. Generally, the older the system, the more leaky the pipes tend to be. From the information gathered in the Auckland region, it is clear that the higher the level of pre-rehabilitated flow, the more effective the reduction. Thus, I&I control in a 'leaky' catchment can be highly effective and is likely to provide significant cost benefit.

However, the relationship between overall I&I reductions, network capacity provided and improvement in level of service is site specific and has historically been difficult to predict. Accurate hydraulic models can greatly assist in determining this relationship, together with information regarding system age, material and maintenance records.

It should be recognised that the performance of the newly rehabilitated network will deteriorate with time and this performance deterioration should be considered when planning an I&I control strategy. The common

rehabilitation techniques can only be considered as 'quick fixes' as they fail to address the I&I processes that lead to the original problems.

The deterioration will generally occur as a result of: -

- Mismade or illegal connections which may re-occur over time
- Manhole repairs may revert to the pre-rehabilitation condition
- Pipe liners or lining materials may partially or completely leak
- Lateral or pipes may continue to settle following new development

2.2 DEVELOPMENT OF THE TOOL

In order to develop the most accurate database of control effectiveness versus cost, a large dataset was sought. Information and data was requested by Watercare from Local Network Operators in the Auckland Region and the following information was used in the initial dataset

Waitakere City Council (Ecowater) – Various information supplied by council including the 'New Lynn I&I Control Mini Catchment 9 Rehabilitation Effectiveness Analysis' report. This showed significant reduction of I&I following the rehabilitation of the system. Internal reports and discussion were used to collate additional information.

North Shore City – North Shore City has successfully completed extensive I&I control projects. Discussions suggested there is evidence that the age of sewers in the North Shore may have an effect on rehabilitation technique. It has been noted that Level 3 rehabilitation (public and lateral) must be undertaken to achieve significant improvement in I&I levels in older networks.

Metrowater – Post rehabilitation information for the pilot studies within the Hillsborough Catchment, including cost of rehabilitation per hectare was supplied.

Manukau Water – Information provided highlighting the cost of rehabilitation at Cockle Bay and Mellon's Bay.

2.3 SUMMARY OF DATA USED IN DATABASE

The most complete information available came from the work carried out for Metrowater in Hillsborough. Pre and post I&I control flow monitoring was carried out following three stages of work. The stages of work were

- Level 1 – Rectification of all inflow defects and manhole defects.
- Level 2 – Includes Level 1 plus sealing of all sewer mains.
- Level 3 – Includes Level 2 plus sealing of house laterals.

The costs and the approximate associated reduction in I&I volume reduction is presented below in Table 1.

Table 1: Summary of Rehabilitation Works in Hillsborough

Rehabilitation Level	Total Source Detection & Rehabilitation Costs ($/ha)	Total Source Detection & Rehabilitation Costs ($/km)	Likely I&I Volume Reduction (%)
Level 1	11,900 – 20,900	70,300 – 96,100	34.7% – 43.1%
Level 2	57,000 – 79,500	383,300 – 415,600	28.7% – 39.8%
Level 3	114,300 – 209,500	563,800 – 802,900	48.7% – 71.5%

* Note: Inflow and Infiltration control work was carried out in 2006.

2.4 DISCUSSION OF DATA & INFORMATION OBTAINED

For the Hillsborough data, the lowest cost rehabilitation works produced the smallest reduction in I&I volume, while the most expensive works produced the greatest reduction in I&I volume.

On the basis of the above limited information, relationship between cost and percentage reduction in I&I volume was assumed linear. It is suspected that the relationship in general is non linear with higher costs resulting in only marginal additional reductions of I&I. As more detailed information becomes available, this hypothesis can be tested.

Because higher levels (Levels 2 & 3) of works are more expensive to implement, they are likely to only be cost-effective if the desired reduction in I&I is high. In reality, the percentage reduction is also likely to depend on the severity of the I&I, although there was not enough data available to confirm this.

The work in North Shore City on an older network (over 70 years old) indicated that undertaking level 1 and 2 works resulted in little improvement in the level of I&I achieved. A significant reduction in the level of I&I was only observed on this network when all three levels of I&I control works were implemented.

In the process of collecting data it was discovered that 85% of overflows in the Waitakere system occur during dry weather. This indicates that there are significant groundwater infiltration or maintenance issues. Before committing funds for I&I control, the issue of pipe maintenance needs to be considered by means of reviewing CCTV, root clearance and silt removal programmes.

Of note across all datasets was the large variability in levels of reduction in I&I achieved, regardless of which technique of I&I control is used. The implications of this is that it can be misleading to extrapolate results from a small dataset to the whole region as the resulting cost and the benefits achievable may be significantly under or over estimated.

2.5 METHODOLOGY FOR DEVELOPING DATABASE

The purpose of the database is to create cost estimates for different types of I&I control works. To achieve this, the following assumptions were necessary: -

- Indicative future costs for I&I control works are based on recent costs for similar projects undertaken by various local network operators (within the Auckland region).
- Indicative costs are directly related to factors such as the reduction in I & I and the scope of control work carried out.

The cost estimating spreadsheets have the following features:

- That it be electronic to be able to be run on a standard PC.
- Be able to generate an indicative cost estimate that can be printed.
- Being able to reference lookup tables to define the cost estimate.
- Ease of use.
- Simplicity in input/changing of information.
- Flexibility to alter spreadsheet values as more information becomes available.

2.6 INTERFACE

The spreadsheet has been created through an MS Excel Interface as shown in Figure 2.

The interface utilises user defined fields and checks lookup tables to calculate values as shown in the yellow boxes in Figure 2. The interface has been created in three sections as follows: -

- Catchment Data
- Catchment specifics and rehabilitation requirements
- Rehabilitation and analysis

The lookup tables should be treated as live documents and updated when new information becomes available from I&I rehabilitation works undertaken in the Auckland Region. This data update should be managed such that a full audit trail exists, including sources of data and date of update. A new version of the interface should be created following each update. The current version uses 2006 data.

A guide to using the I&I tool can be found in appendix A.

Figure 1: Template of Costing Tool

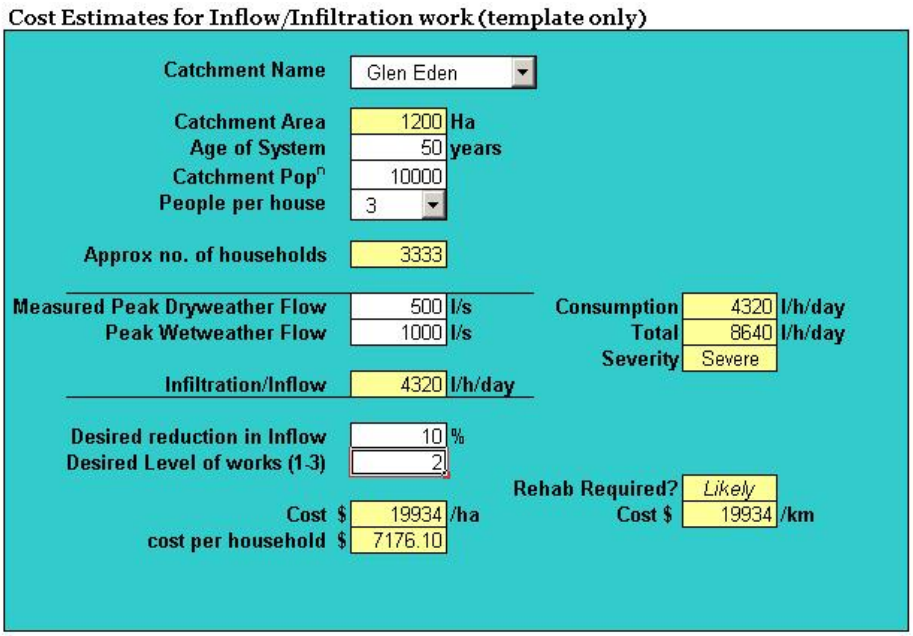


Table 2: Severity of I&I

Infiltration (l/h/day)	Classification
0	Low
900	Med
1500	High
1800	Severe

The final section allows the user to select how much they want to reduce I&I, and the level/type of rehabilitation / control works they wish to undertake. These levels relate to the following actions:

- Level 1 – Rectification of all inflow defects and manhole defects.
- Level 2 – Includes Level 1 plus sealing of all sewer mains.
- Level 3 – Includes Level 2 plus sealing of house laterals.

If the user enters a level of works inappropriate for the desired reduction in I/I (e.g. Level 1 for a desired 90% reduction), a warning appears.

2.7 COST VERSUS VOLUME REDUCTION

On the basis of the Hillsborough dataset, Figures 3 & 4 below indicate cost curves comparing cost per hectare of catchment and cost per km of wastewater network. The curves indicate different relationships depending on the level (1, 2 or 3) of I&I control considered. It should be noted that the size of the dataset used was limited

and the level of confidence in the prediction of these cost curves is limited. Pilot testing is planned and collection of further data will be required to further improve the level of confidence in these curves.

Figure 2: Relating Cost, Level of Works and % I/I Reduction (/Ha)

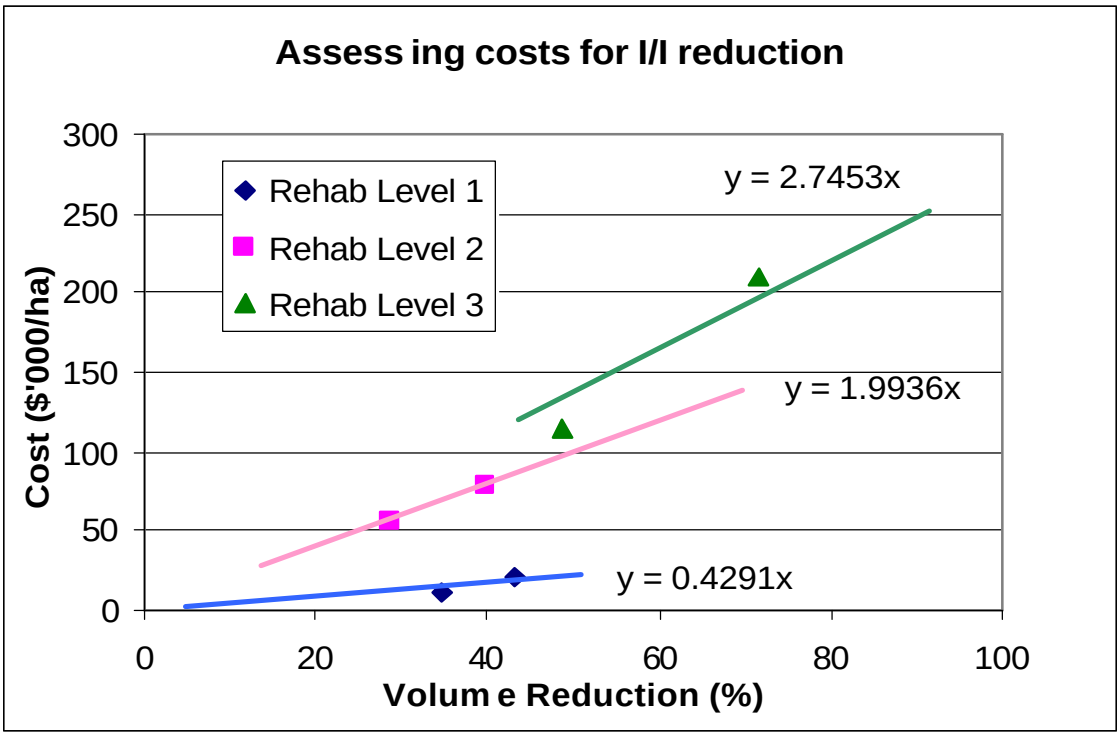
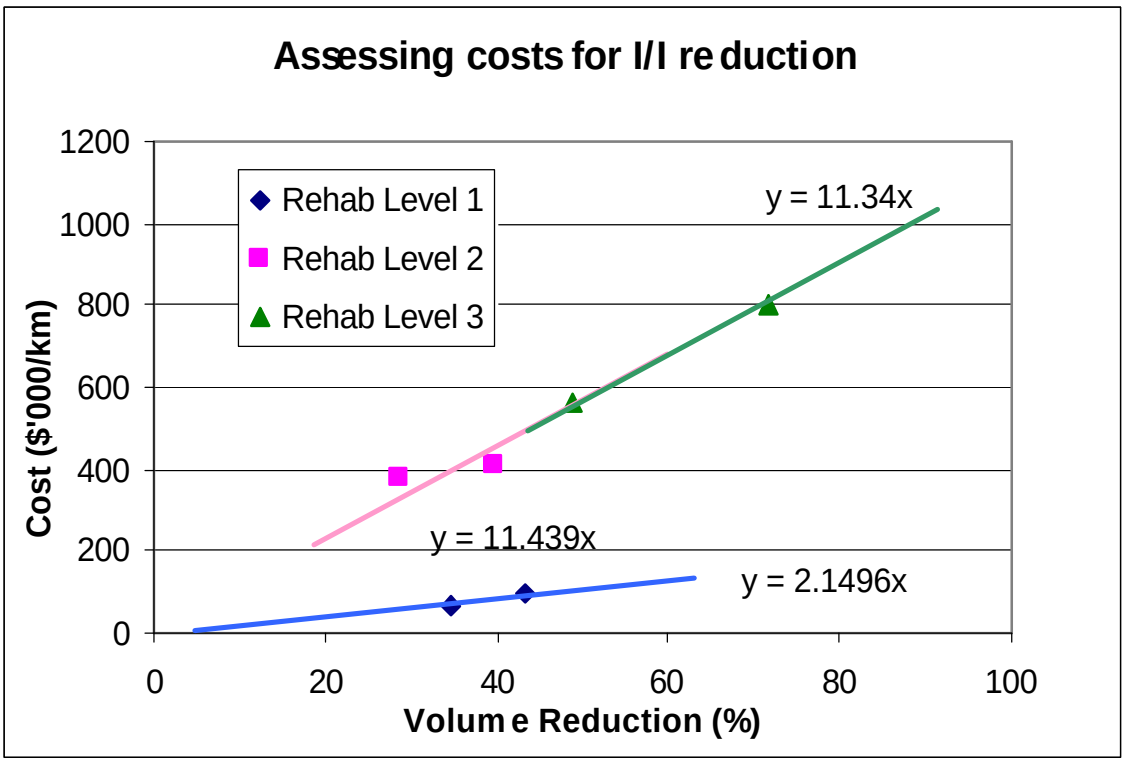


Figure 3: Relating Cost, Level of Works, and % I/I Reduction (/km)



2.8 APPLICATION OF THE TOOL

It has been agreed that additional research is required to 'test' the tool and compare its results to works that have been and are currently being undertaken in the Auckland region. This work will utilise ongoing flow survey information. Watercare, EcoWater and Metrowater have supplied funding for this work. The results will be available before the presentation of this paper, but at present, the data is not available for inclusion in this report.

2.9 RISKS AND FUTURE ISSUES

The data is limited in these respects:

- The data set used is very small, compromising the accuracy of the results.
- The level of acceptable I&I is likely to differ between catchments.
- It is a simple representation of a complex process, and other factors that have not been included (such as construction time, ground condition) may have an effect.

2.10 LINKING INFLOW / INFILTRATION REDUCTION TO DESIRED OUTCOME

Any reduction in I & I is only of benefit when it leads to a benefit in line with a desired outcome for wastewater network planning. A desired outcome within this context is a reduction in the frequency of overflows from manholes, reduction of the per capita wet weather flow to below, say 900 l/h/d, or population that can be now accommodated due to capacity now freed up in the wastewater network due to I&I control works.

In each catchment, the linkage between desired outcome and percentage reduction in I&I is different and is essentially determined by the capacity of the network relative to the load being accepted by the network.

For example, a reduction in I&I volumes in an area that is free from overflows and pipes that are not fully utilised under dry weather flows is much less beneficial than a reduction in an area that has dry and wet weather overflows.

It is essential then that any I&I control strategy is focused and targeted on these outcomes.

2.11 DETERIORATION IN INFLOW & INFILTRATION FLOWS AND MAINTAINING THE BENEFITS OF A CONTROL PROGRAMME

It is important to note that on completion of I&I control works, the system will continue to deteriorate and the level of I&I will increase. The main mechanism for this will be the gradual increase in connections from hard standing area to the wastewater network usually on private land and the deterioration of the sewer fabric and manholes on private land. Thus the potential for undoing the gains achieved by I&I control works is greater in the private rather than in the public wastewater network.

Thus a significant challenge for local network operators is educating the general public. It is a natural reaction to shy away from change and many people do not understand the processes involved with storm and wastewater drainage.

2.12 IMPROVING THE TOOL

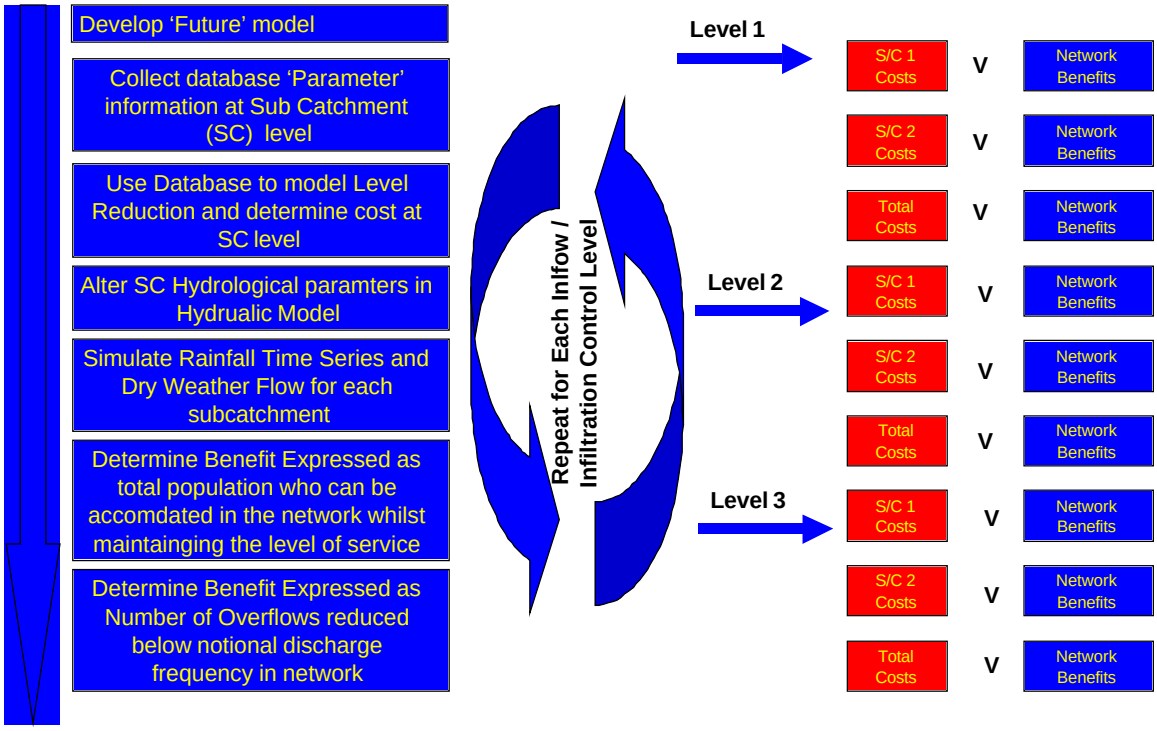
It is recognised that the database developed as described here and the associated hydraulic model can be used to make the linkage between the level of I&I control works carried out (and associated costs) and the benefits (outcomes from the works).

Such an expert system could determine what level of I&I control works is;

- Likely to result in the highest benefit to cost ratio
- Likely to result in little additional benefit, and
- Where an I&I control programme is unlikely to be able to achieve the desired outcome in terms of manhole overflows reduced or additional capacity made available for future growth.

Figure 4 below illustrates an indicative flow chart of such an Expert System, followed by a description.

Figure 4 – Expert System Flow Chart



This process is described below.

- The process assumes that a future demand scenario will be used to test and determine the I&I control programme. The future demand scenario should include an allowance for both flows from projected increases in population and a 'natural' increase in I&I caused by deterioration.
- Data to feed into the database as parameters will be gathered at a subcatchment level to determine the cost of I&I and the likely reduction in I&I which will result within the subcatchment for each of the levels control works. It should be noted that the selection of the subcatchment is arbitrary and will be determined by available data and the homogeneous nature of the parameters across the entire catchment.
- The model Hydrological parameters for each subcatchment would be adjusted to reflect the predicted reduction in I&I.
- The model would then be simulated to determine benefits attributable to conducting that level of I&I control works within the catchment both in dry and wet weather, with these benefits expressed as additional population which can now be accommodated or number of manhole overflows eliminated.
- This process will be repeated for each subcatchment for each of the three levels and will be used to generate a family of cost / benefit curves, one for each subcacthment, which can be plotted on the same axis.

3 CONCLUSIONS

A significant amount of work has been undertaken in the Auckland region to monitor and model wastewater collection networks to better understand the effects of rainfall induced inflow and infiltration (I&I). Although the modelling techniques have been cutting edge, they have not necessarily assisted in the business justification process. Watercare and CH2M Beca have developed a tool that will assist network managers in their business case justification for I&I control investments. The tool is able to provide a level of understanding to the various I&I components and their corresponding allocation of funding to best meet level of service outcomes.

The tool can assist in linking the level of I&I works carried out (and associated costs) and the benefits (outcomes from the works).

The mechanics of I&I can be very different on a catchment by catchment basis and can be affected by the age of the wastewater network, materials, soil, water table and many other factors. The I&I tool is a good starting point for assessing the effects of removing I&I from a wastewater network. However, there are risks associated with the tool and this should be considered when undertaking cost benefit analyses.

Additional work will be required to further test and refine the tool moving forward based on the currently limited datasets it is built from. Pilot testing of the tool is expected over the next 12 – 24 months, with the results feeding into a review and refinement process for the tool.

The deterioration of the network's performance needs to be closely monitored and involvement of private householders through education would be beneficial in maintaining the performance of wastewater networks.

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- North Shore City Council

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