Development of a hydraulic regime for land treatment of municipal wastewater on erosion prone slopes

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ABSTRACT

In New Zealand, small communities have traditionally used surface water for the discharge of treated municipal wastewater. In order to protect and improve water quality in coastal and inland waters there is pressure on communities to find alternative means of effluent discharge. Land treatment of wastewater is a relatively well accepted and understood mode of discharge.

This paper examines a case study where a land treatment system was designed for use on marginal land. Land treatment was identified as a treatment option for an inland community with a small permanent population and an aged reticulation system. The town has an existing discharge to water in a phosphorus sensitive environment.

The land treatment site is disadvantaged in that the topography is typically steep, creating access and erosion issues. For the life time of the land treatment system the owners will have an established hardwood plantation on the site. The selection of crop creates limitations in the ability for nutrient removal by crop uptake. The addition of wastewater has the potential to exacerbate erosion on the site if not managed conservatively, with corresponding damage to infrastructure, reduction in treatment capacity and export of sediment and nutrients from the sites.

In the design process it was identified that no model exists which could account for all site, climate and wastewater flow constraints. The development of tools to integrate the site water balance with the land use capability was required. An iterative process was used to estimate the impact of different hydraulic regimes on erosion potential of the sites. This paper describes how the necessary tools were developed, and how they were applied to the case study site.

INTRODUCTION

Historically the vast majority of small communities in New Zealand have discharged wastewater to surface water due to the low technology requirement and low cost of the establishment and maintenance of these systems. These discharges have created or contributed to a legacy of surface water and coastal water pollution. Increasingly there is pressure due to regulatory authorities, social and cultural concerns over surface water discharges to find alternative discharge methods.

Land treatment of effluent is a relatively well understood mode of discharge. It has not been widely adopted due to capital and ongoing costs, perceived management requirements and regulatory constraints. However, as the treatment technology required to achieve standards for discharge to water, and social and cultural obligations of TLAs are considered, the use of land treatment for communities of varying sizes is an increasingly favoured option.

DEVELOPMENT OF LAND TREATMENT PARAMETERS FOR MARGINAL LAND

In the selection of a land treatment site a number of factors are considered. For maximum renovation of applied wastewater a land treatment system would ideally be situated on flat land of extensive area. Soils which are deep and moderately to moderately well drained are well suited to land treatment of wastewater. In addition, it is desirable that a crop demanding high nutrient supply which can be removed from the site regularly is established to maximise water use and nutrient uptake.

It is seldom the case that sites facilitating the maximum renovation of wastewater are available. Cost of land and distance from a WWTP can make the use of such land prohibitive for land treatment. Site constraints, climate and land owner requirements may limit the crop able to be established on the site. The use of more marginal land must be considered as the access to premium land diminishes.

This paper describes the process undertaken by CPG to develop a hydraulic regime for use on marginal land for a case study site.

CASE STUDY: PERMANENT TOWN OF 1,900 PEOPLE

General

The case study is concerned with a small inland community. The community's wastewater is reticulated to an existing wastewater treatment plant (WWTP) and discharged to surface water. The reticulation system is up to 80-100 years old in places and infiltration and ingress of water to the sewer is a significant contributor to flows.

Faced with expensive upgrades to the WWTP to meet stringent treatment requirements for the continued discharge to water, and public resistance to water discharges, the examination of alternative discharge options was undertaken. The location and cost of optimal land for land treatment initially precluded this option, however an opportunity arose to apply the towns wastewater to steep country located close to the WWTP.

A detailed field and desktop investigation of the potential land treatment site identified a risk of erosion ranging from slight to severe over the entire site. Evidence of erosion on the site suggests that past erosion has occurred and it was deemed likely that under any management erosion would occur in the future. However, if the site is to receive effluent for land treatment the risk of erosion has important implications for the land treatment system including:

- Damage to infrastructure;
- Reduction in treatment capacity through modification of the soil properties and damage to crop; and
- Off-site transport of sediment and nutrients.

In design of a land treatment system on the erosion prone slopes, the most important consideration was identified to be the minimisation of erosion. Since the application of wastewater to the site has the potential to exacerbate erosion CPG needed to model the movement of water received to the site and account for impacts on adjacent landforms. There was also a need to predict the impact of increasing the site moisture status on erosion.

A number of models exist to describe parts of the proposed application, however no widely available models were identified that incorporated the site, climatic and effluent flow elements of the land treatment system. A process was developed to determine a suitable hydraulic regime for the site.

Site hydraulic management

Typically in design of a land treatment regime the soil hydraulic characteristics of the site are used to develop a sustainable rate of application which will avoid excessive drainage or run-off of the applied wastewater. Additional consideration of the impacts of slope and erosion potential were considered in the development of a hydraulic regime for the site. From this, the ability of the site to receive, retain and renovate the wastewater was incorporated into a water balance for the site in order to determine an appropriate hydraulic regime. Figure 1 shows a stepwise process for the development of a hydraulic regime.

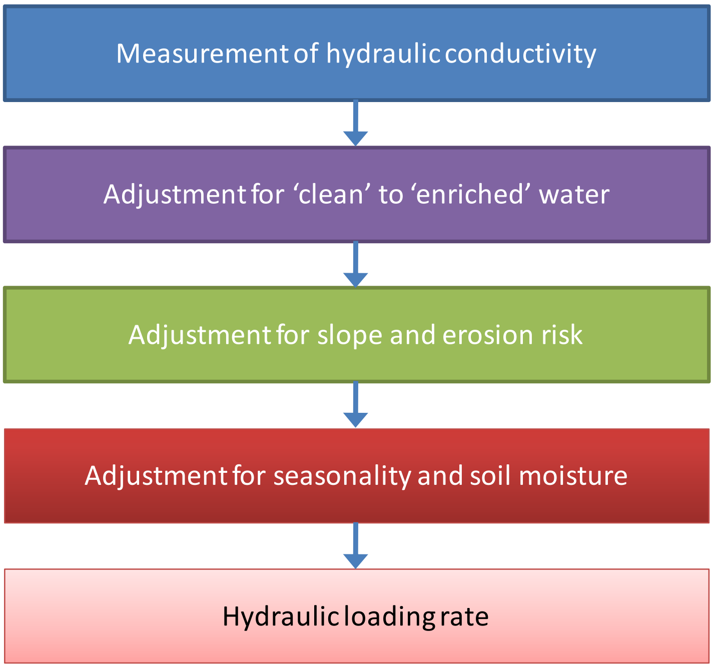

Figure 1. Development of the hydraulic regime.

Adjustment for erosion risk

The erosion risk has been summarised by the development of the Irrigation Management Units (IMUs) described elsewhere (Hainsworth *et al.*, 2010). The IMUs divide the site into areas labelled as no, low, moderate or high input, indicating the relative capacity of the area to receive varying amounts of effluent. The hilly topography of the site encourages the downslope movement of water thereby creating an increased risk of run-off and potential accumulation of water downslope by both run-off and lateral movement within the soil. Consequently a reduction in the hydraulic loading rate calculated for a flat site is required. The hydraulic loading was reduced according to the IMU, whereby the application depth for High Input > Moderate Input > Low Input areas.

Adjustment for seasonality and soil moisture

Water accumulation may occur in the soil due to the effects of the climatic regime and soil properties. When the soil moisture content is close to field capacity additional water will result in drainage or run-off; with runoff being more likely than deep percolation due to the slope, underlying soil and geological properties. This movement of water is related to the available water holding capacity (AWHC) of the soil. The hydraulic loading should account for the potential for rain to have occurred in the period preceding irrigation and to allow for rain to occur during or immediately following irrigation. This may occur at any time of year; however the effects are larger in winter due to the corresponding lower evapotranspiration which is the main mechanism for removal of water from soil on the site. In order to account for the seasonality of the land treatment system the hydraulic loading was modified in accordance with the soil moisture content as determined by the water balance.

Water balance

A daily water balance was used by CPG to optimise the application of the wastewater under conditions which provide for minimal storage requirements, cater for peak seasonal loading, utilise a minimal land area and provide for simple robust system management. In addition the water balance considers the system requirements under wet year conditions to ensure adequate provision is made for storage and land area.

In preparation of the water balance concept, a range of key input parameters were considered. These include:

- Wastewater flows to the WWTP;
- Rainfall to the site and to the WWTP ponds;
- Potential evapotranspiration under the proposed crop;
- Canopy interception;
- Rainfall runoff;
- Available land area and application depths; and
- AWHC and soil water storage capacity.

Figure 2 shows the input and output parameters of the water balance.

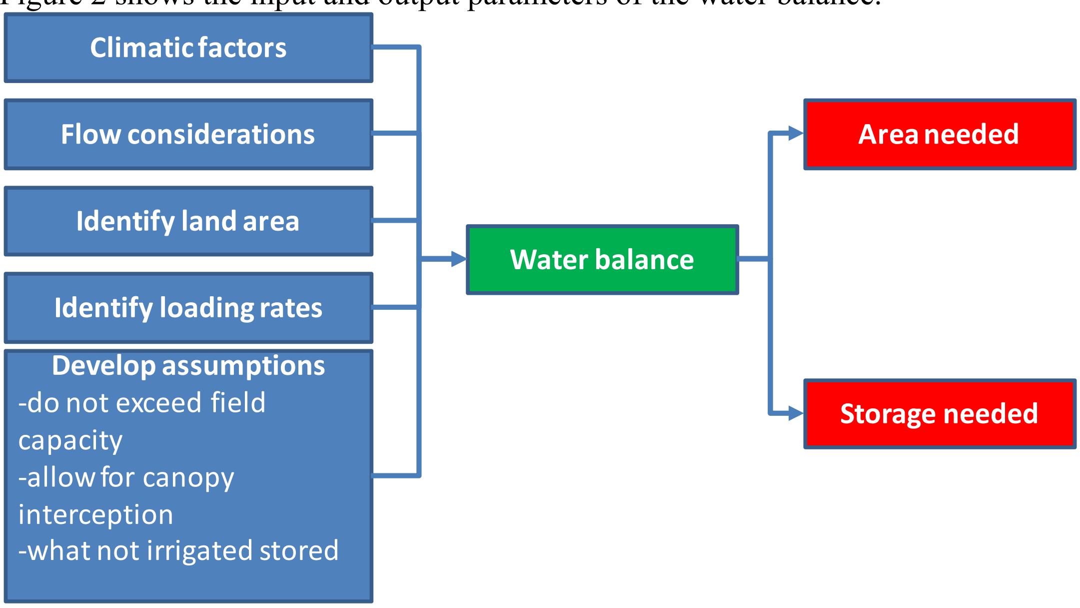

Figure 2. Schematic of water balance concept.

For the minimisation of erosion risk the water balance model utilised in this project uses a deficit application approach, whereby no drainage is allowed following irrigation. The water balance determines whether sufficient land area is available and gives the necessary storage volumes required to enable wastewater application to be withheld. In this case a trigger stopping irrigation when soil moisture was 5 mm below field capacity was used.

Initial water balance results

The results of the initial water balance analysis indicated that at the calculated rates of application onto the nominated land area available, the storage pond would be unable to be emptied annually. This resulted in an ever increasing storage requirement each year. The only way to empty the pond was through the application of wastewater to soils where field capacity would be exceeded, or alternatively use a larger land area.

A fundamental design consideration was to ensure that field capacity was not exceeded on the moderate and low input areas, and as a result this necessitated increasing the land area. The water balance was used to determine the minimum additional area needed.

CONCLUSIONS

Land stability and nutrient retention are key to the sustainability of land treatment of municipal wastewater on marginal land. Development of a conservative hydraulic management regime for a land treatment system on erosion prone land is critical to the system design. An approach which incorporates a detailed assessment of the erosion risk under the modified land use with a detailed water balance has been used successfully to assist with the system design and predict the need for additional land and storage.

REFERENCES

Hainsworth, S., Beecroft, K., Lowe, H., Broughton, A. 2010. Land treatment of municipal effluent on erosion prone slopes. Pp. 166-169. In: *Land Treatment Collective Conference Proceedings 2010*.