CULTURAL DRIVERS TOWARD LAND BASED DISPOSAL AND APPLICATIONS ENABLING THIS

Kate Simmonds (Jacobs New Zealand Ltd), David Austin (Jacobs USA) and Mark Madison (Jacobs USA)

ABSTRACT (500 WORDS MAXIMUM)

The disposal of human waste, especially to waterways, is a highly emotive topic and of particular interest to Māori, New Zealand's indigenous population. The common driver for many technological solutions, and associated resource consent conditions in New Zealand, is the abhorrence, to Māori, of direct discharge of human waste (domestic wastewater) to water, almost regardless of the degree of treatment. In Māori culture, human waste is "tapu" (unsafe/dirty/bad) and this needs to be converted to noa (safe/clean/good) prior to water contact.

Experience has highlighted the importance of early participation of iwi (tribe) and hapu (extended family group) in a partnership approach with technical advisors and the relevant local authority to identify wastewater treatment project outcomes which are acceptable to all stakeholders. This is consistent with the Treaty of Waitangi and the development of concepts and technology solutions that address cultural and spiritual matters. This also encompasses the Part Two requirements of the Resource Management Act and the development and engineering of technical and non-technical solutions that can meet the aspirations of local iwi and hapu.

Traditionally water (sea, lakes and rivers) has been a key source of food (kai moana) for Māori, regarded as their pataka (pantry). As a result, maintaining its mauri (special nature / life force) is of utmost importance. Disposal of human effluent to this pataka is considered objectionable to Māori.

This paper outlines iwi concerns around wastewater discharges to water bodies which may impact on the kai moana and recreational use of the receiving water body, and as a result negatively affect the mauri. While many of the contaminants of concern to iwi are typically limited via resource consent (i.e. nitrogen, phosphorous and faecal coliforms), often the limit is not key, and instead the treatment process and pathway for disposal are considered more relevant from a cultural perspective. For example, contact with land (Papatuanuku, the earth mother) can reduce tapu, making the wastewater more noa. There are additional concerns around the topic of drug and antibiotic discharge via domestic wastewater discharge, and the potential for bio-accumulation in the kai moana and the food chain (raupapa kame).

Treatment options are emerging globally which utilise natural land-based treatment applications and can address iwi concerns around domestic wastewater discharge to receiving waterbodies. Removing nitrogen and phosphorous using natural treatment pathways requires attention to the chemistry of soils and water, coupled with innovative methods of irrigation. This paper will touch on some successful overseas case studies which remove nitrogen and phosphorous via innovative wetland and land disposal technologies and discuss how these can be applied to communities in New Zealand to upgrade treatment plants at relatively low cost, while addressing

the issues of bi-culturalism and respecting Māori values through the use of Papatuanuku in the treatment process.

KEYWORDS

Land-based Disposal, Bi-culturalism, Natural Treatment Systems, Māori values, Wastewater

PRESENTER PROFILE

Kate Simmonds has a variety of multidisciplinary experience over her 15-year career and has worked on engineering projects in New Zealand, the UAE and Australia. Kate is a technical Senior Project Manager and brings a range of water and wastewater design capabilities including water, wastewater and stormwater infrastructure design, integrated water management to her projects. Kate also has experience working on major sustainability focussed programs including the Gippsland Water Factory (GWF) in Victoria, Australia (winner of the 2011 Gold Banksia) and Masdar City in the UAE – a city with an ambitious zero waste target.

Kate was actively involved in the Water Industry in Australia and volunteered on a number of committees. In recognition of her achievements and her commitment to the industry Kate was awarded AWA Young Water Professional of the Year, Victorian State winner (2012) and National winner (2013). Kate is now based in New Zealand and works for Jacobs in the Auckland Water team.

Mark Madison is an agricultural, environmental, and civil engineer and senior project manager with Jacobs USA. He specialises in hydraulic systems for managing soil, water, plants, and nutrient relationships for wastewater reuse, wetlands treatment, and agricultural production. His experience includes site investigation, data collection, modelling, model calibration, design, construction, management, operations, and monitoring and maintenance of irrigation, reuse systems, wetlands and uplands phytoremediation systems.

Mark served on the State of Oregon (USA) Department of Environmental Quality (DEQ) task force that wrote new municipal wastewater reuse regulations. He also served on a task force with the Oregon Department of Water Resources that developed a water marketing law and on a DEQ task force that wrote new industrial reuse regulations.

Mark is an internationally renowned expert in irrigation, water reuse, and constructed treatment wetlands.

1 INTRODUCTION

For wastewater treatment and disposal projects, the discharge of human waste, especially to waterways, is a controversial topic and is of particular interest to Māori. A key driver for many technological solutions, and the associated resource consent conditions, in New Zealand is the abhorrence, to Māori, of direct discharge of human waste (domestic wastewater) to water, irrespective of the treatment process (Bradley. J).

This paper outlines some cultural considerations, legislative drivers and iwi concerns around domestic wastewater discharge to water. The paper also outlines treatment and disposal technologies and practices which can mitigate these concerns from both an engineering and cultural perspective, embracing the principles of converting waste from tapu to noa through incorporation of Papatuanuku in the treatment process. International case studies demonstrating the success of these technologies, when integrating cultural considerations in the project development process, are also presented in this paper.

2 CULTURAL CONSIDERATIONS

Many of the concerns that communities have regarding wastewater disposal are the same as those of tangata whenua. However, for Māori these concerns are substantiated by the regulatory requirements in New Zealand, which require projects to consider:

- Māori relationships with their ancestral lands, water, sites, waahi tapu, and other taonga
- The kaitiaki (guardianship) obligations that tangata whenua have for the environment
- Treaty of Waitangi principles (Resource Management Act, 1991).

There are three key principles which underpin the relationship between the Government and Māori under the Treaty of Waitangi - the three "P's", as they are often referred to. These are the principles of **partnership**, **participation** and **protection**.

Partnership involves working together with iwi, hapū, whānau and Māori communities, engaging with Māori community and relies on us welcoming and having genuine relationships with the Māori community. Historically for many Māori there have not been "open door" policies and Māori have not felt welcomed and valued in local government. These relationships take time and effort. However, once there is genuine relationship building, it becomes much easier to discuss and agree on strategies for a number of topics of issue, including wastewater treatment and disposal.

Protection means actively protecting Māori knowledge, interests, values, and other tāonga. Protection is valuing, validating and protecting local knowledge and the mauri and mana of the local area including the land and the water.

Participation should emphasise positive Māori involvement at all stages of a project. Participation is equity for Māori and the Māori voice. Participation requires not only the opportunity to participate, but also a forum in which participation is welcomed and encouraged.

Māori place great store on personal relationships of long standing and face-to-face communication is the preferred method of communication (Harmsworth, G., 2005). As mentioned earlier, these relationships do not grow overnight and a substantial time investment in developing a relationship platform as a prelude to consultation is a fundamental requirement to success. A familiarity with the cultural protocols within which most hui (meetings) with tangata whenua are conducted is vital to success.

Consultation in the context of a wastewater project presents multifaceted cultural issues that have origins in Māori spirituality. For example, in the traditional Māori world, places or activities related to human wastes were deemed tapu (spiritually unsafe). Anything deemed tapu was avoided and it was understood that the consequences of tapu violation ranged from misfortune to serious illness, even death because of the intrinsic spiritual risk. Assigning the concept of tapu to human waste protected Māori from health risks through the imposition of the strongest social control imposed by traditional Māori society. The traditional concept of Tapu has been carried through to today's contemporary world, resulting in the consequent abhorrence to Māori of effluent disposal to water ways.

Engaging with tangata whenua to address contemporary wastewater issues requires understanding that the traditional view of tapu is the starting point, and that most Māori believe anything to do with human waste is spiritually dangerous. To become spiritually safe requires interaction of the human waste with land as a minimum.

A highly simplified interpretation of the traditional Mäori view of the water cycle reflects this idea of parallel and linked physical and spiritual worlds. Water passes in its purest spiritual form (waiora) as rain down to the earth. Here the mauri is at its most pure. Reaching the earth, it will be affected by a range of natural events and actions. Failure to protect water quality harms not only its physical nature, but also its very essence, or mauri, which can only be restored as the water passes through the earth and into the sea (and then back to rain). In a purely physical sense this reflects the idea that water can be cleansed of many pollutants by passing through vegetation and the earth before entering the sea. If the spiritual dimension is to be restored, water must pass through the earth, or Papatuanuku (Ferguson et al, 2003).

3 LEGISLATIVE DRIVERS TO COLLABORATION

Three key pieces of legislation exist which set out the principles to be followed with respect to Māori-tangata whenua considerations on human waste-domestic sewage and wastewater systems.

The first is the Environment Act 1986 which sets out the principles of the management of natural and physical resources, including intrinsic ecosystem and community values, the Treaty of Waitangi, the sustainability of natural and physical resources, and the needs of future generations.

The second is the Resource Management Act 1991 (RMA), a statute that controls all development in New Zealand. The purpose of RMA is *"…to promote the sustainable management of natural and physical resources"* where sustainable management means: *"…managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their health and safety…"*

The third significant piece of legislation is the Local Government Act 2002 (LGA) which identifies that purposes of local government in New Zealand is: *"… to promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future."*

Whilst the RMA is all about "sustainable management of natural and physical resources" and the LGA is all about the "sustainable development of communities", there is a high degree of alignment between these two pieces of legislation.

The RMA is an effects based and enabling legislation. Accordingly, the assessment of new and existing water and wastewater infrastructure on the natural and physical environment needs to focus on the various types of effects that are encompassed in the meaning of effect as set out in this legislation. This approach clearly puts the focus on the effects of the water / wastewater infrastructure and service on the natural and built environment, including people and communities, rather than on the technology and infrastructure itself.

Part Two of the RMA requires *"in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for the following matters of national importance:*

(e) the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga:" The RMA also requires consideration of principles of the Treaty of Waitangi (Te Tiriti o Waitangi) being New Zealand's founding document signed in 1840 between the British Crown and the Māori chiefs.

The special position afforded Māori under the RMA and other statutes has led to the development of many participatory partnership type approaches in development of resource consent processes and consent conditions and associated technology solutions. For example, the response to Māori objection to the direct discharge of treated human waste (domestic sewage) direct to water, no matter how well it is treated, has resulted in a number of land contact type processes where the treated domestic sewage contacts Papatuanuku (earth mother) in a rock channel, riparian strip or pond before discharge to surface or marine waters (e.g. the Hastings Wastewater project includes a rock channel as part of the process).

3.1 CONSULTATION ON RESOURCE CONSENTS

Section 36A of the RMA explicitly states that neither an applicant nor a local authority has a duty to consult any person (including Māori) about a resource consent application unless this is required under other legislation. However, an Assessment of Effect should identify any persons who will be affected by a proposal, any consultation undertaken, and any response to the views of any person consulted.

Early consultation with Māori is best practice for resource consent applicants (where Māori interests may be affected) in order to establish a working relationship with tangata whenua, demonstrate compliance with the relevant provisions in Part 2 of the Resource Management Act, and to reduce the likelihood of future difficulties arising, including litigation. Consultation is not only informing and sharing information with Māori, but also listening to their thoughts, issues and viewpoints, and incorporating these into the final outcome.

There is a requirement under the RMA during National Policy Statement/Regional/District plan preparation for local authorities to consult tangata whenua, through iwi authorities, and take into account any relevant planning documents recognised by an iwi authority. Local authorities must also provide iwi authorities with a copy of the relevant draft proposed policy statement or plan, allow iwi authorities adequate time and opportunity to consider the draft document and provide any advice, and have particular regard to any advice received from those iwi authorities on the draft document. It is much more proactive to have Iwi address their concerns early in the plan itself, rather than at the final point of a project cycle, whereby no relationship has been built and often this lack of courtesy results in opposition at consent hearings, etc.

3.2 WHAKAHONO A ROHE (IWI PARTICIPATION ARRANGEMENTS)

Mana Whakahono a Rohe provide a mechanism for councils and iwi to reach an agreement on ways tangata whenua may participate in RMA decision making and to assist local authorities to comply with their statutory duties under the RMA. Both councils and iwi authorities can initiate the process to form a Mana Whakahono a Rohe.

A Mana Whakahono a Rohe must discuss:

- How iwi will participate in plan making processes
- How required consultation with iwi will be undertaken
- How council and iwi will work together to develop monitoring methodologies
- How council and iwi will give effect to the requirements of any relevant iwi participation legislation (or agreements under such legislation)
- A process for managing conflicts of interest
- A process for resolving disputes.

A Mana Whakahono a Rohe may also identify how council will consult or notify an iwi authority on resource consents matters (where required), where an iwi authority may be given limited notification as an affected party, how iwi authorities (if there are 2 or more) will work collectively together to engage with council, any delegation of roles from an iwi authority to a person or group, and any other arrangements relating to RMA processes.

Once a Mana Whakahono a Rohe has been finalised, councils must review their internal policies and processes to ensure they are consistent with the Mana Whakahono a Rohe.

4 MĀORI KAITIAKITANGA FOR MANAGEMENT OF NATURAL RESOURCES

Kaitiaki is the Māori term used for the concept of guardianship, for the sky, the sea, and the land. A kaitiaki is a guardian, and the process and practices of protecting and looking after the environment are referred to as kaitiakitanga. For tangata whenua, the role of kaitiakitanga in the management of natural resources and the integration of human wastewater into natural resources is a matter of the utmost importance. In developing community wastewater solutions, consenting decisions need to provide for the traditional relationship that tangata whenua have with their ancestral lands, waters, sacred places and other “taonga” (treasures). The intent is to ensure cultural and heritage matters important to tangata whenua are identified and considered as part of any development proposal.

With regard to kaitiakitanga, tangata whenua thereby have a protection role to the environment that complements the statutory role of local authorities. This point is reinforced by the requirement in administration of the RMA that all participants must regard the principles of the Treaty of Waitangi. While the prime responsibility for the inclusion of Treaty principles rests with Government, in development terms, project proponents need to consider the principle of partnership, generally through consultation with tangata whenua; or the principle of mutual benefit where developers need to show what their project(s) can provide in terms of beneficial environmental or cultural outcomes.

In considering tangata whenua views, what is of fundamental importance is that there is a significant cultural objection to the discharge of treated human wastewater to natural water almost regardless of the level of treatment.

In considering wastewater management and disposal, tangata whenua view the situation in a holistic manner and do not focus on the methods of treatment, contrary to the traditional engineering approach. The linkage of nature and humankind as one, forms part of the fundamental basis from which this holistic approach is undertaken.

5 FROM TAPU TO NOA - TREATMENT PATHWAYS

Tapu (forbidden or restricted) and noa (ordinary or free from restriction) are key Māori cultural concepts that continue to influence and inform present Māori praxis and thinking on all aspects of society, including biowaste management. Traditional management of human waste effluent was highly prescriptive. Processes and procedures were nested within cultural values and ethics that in turn were influenced by local context and circumstance. The tapu and noa constructs work in conjunction with other values to govern human behaviour and relationships with the environment at any point in time. However, tapu and noa are not fixed and can change through time as a result of a specific action or consequence; thus, influencing the ability to interact or use an object or resource which create interesting management implications for human waste (Ataria et al).

All humans possess tapu, the prestige/power that is inherited from the Atua (God, Spirit), and are therefore very tapu. This spiritual tapu logically extends to human body parts and waste products excreted by humans that are therefore, by association, also tapu. This elevated tapu state demands that prescriptive procedures and processes are implemented to avoid instances of extension/consequence where the tapu associated with the waste creates a destructive outcome when it interacts with tapu from another entity/thing. Therefore, historically in Māori culture, rituals and practices were established to mediate between the spiritual dimensions (world of the Atua) and the practical world of people and their relationships to the material environment for positive outcomes: protection of human and environmental tapu.

The notion of tapu and noa as being transitory, introduces the prospect that things deemed tapu could potentially change their spiritual state over time – assuming that the requirements of time, a detailed knowledge of the composition of the waste stream, and the appropriate cultural and management process have all been satisfied. Although arguably not as mainstream as separation, there are some accounts of latrine sites, over time, becoming sites for productive gardens, or where human waste is applied to areas later used to grow kai. However, whether this was intentional change of land use for productive crop growth or reflected a change in ownership is not clear in all cases.

Many Māori consider that within the realms of Papatūānuku and Ranginui there exist a range of established processes and relationships that continuously cycle chemicals through the spiritual states of tapu (restricted state) and noa (relaxed or normalised state). In a scientific context these processes could be termed bio- and physico-chemical transformation which acts to breakdown and modify chemical compounds to basic building blocks for other uses or re-partitioning back into the environment. Compounds that have been synthesised with properties that convey resistance to these natural processes are often met with opposition – particularly if their intended use involves direct deployment into the environment or at some point during the life cycle of these products environmental exposure occurs (Ngā Kaihautū Tikanga Taiao, 2012).

Historically the ability for Māori to exercise local control over the separation and disposal of waste was much easier. Today it is far more difficult to control what goes into the wastewater system and where it is treated and disposed of – especially where households are connected to a reticulated system. This is due to legislative and policy requirements and the complex ethnic composition of New Zealand communities. There is also greater scientific awareness of, and ability to study, complex mixtures of contaminants, such as household pharmaceuticals and emerging contaminants from industry or new consumer product ingredients for personal care and hygiene. Influencing household consumption or behaviours (and/or the formulation of consumer products) to reduce or eliminate the disposal of chemicals of this nature is a key challenge.

Tapu and noa are Māori cultural concepts that operate alongside other concepts and values to inform traditional knowledge and resource management frameworks. There is a breadth of cultural knowledge on the topic of biowaste, biosolids and wastewater management, a willingness and openness to explore new forms of co-management, and an expectation of being involved in decision making. Where this is the case Māori view biowastes and biosolids as something that should be owned and responsibly managed, rather than forgotten about or left to the environment to cope with.

There are a significant number of Local Authority domestic sewage (municipal wastewater) treatment and disposal schemes that include often as a final stage arrangements where the treated human wastewater contacts land – Papatuanuku (earth mother) before discharge to natural water, be it coastal waters or fresh waters. The rationale for many, if not all these facilities is to provide a spiritual cleansing of the otherwise treated human wastewater by the contact removed back with Papatuanuku (land). In a number of cases tangata whenua and iwi and hapu have appreciated that the arrangements used do not necessarily improve the measurable quality of the treated wastewater, and in some cases such as wetlands and ponds can deteriorate the quality by algae growth and bird deposits for example. There are now cases where tangata whenua have decided not to require such land contact arrangements but to instead adopt an enhanced standard of treatment. This occurred for example in the Hamilton City Wastewater case where a "best for river" approach was adopted rather than a land contract Terra 21 wetland (Bradley, J).

6 TREATMENT OPTIONS

Discharge of wastewater to the land, rather than surface water or other water receiving bodies, is the oldest practice of engineered treatment systems. Today, it is widely practiced for decentralised wastewater treatment. Standard engineering texts describe the variety of design methodologies from household septic systems to advanced treatment systems for clusters of homes and villages (Crites and Tchobanoglous, 1998). In the late 19th Century, sewage farms sought to spread wastewater widely to percolate into soil (Kinnicutt et al., 1919). These practices continue in modern form as land application systems and soil-aquifer treatment systems (Crites et al., 2005) and continue to be refined with advanced irrigation practices (Austin et al., 2018). A recent development has been to use wetlands without surface outflows that recharge groundwater (Figure 1 and Figure 2).

Discharge of treated effluent to surface waters has evolved as a practical response to volume of wastewater flows. The hydraulic capacity of soil limits is a primary limit to discharge. Clean rain readily exceeds the capacity of soil to adsorb it. An additional issue is that wastewater constituents readily clog even highly conductive soils. Sewage farms in the 19th Century demanded ever-increasing land areas to treat raw wastewater. Primary treatment to settle out solids alleviated the problem, but biochemical oxygen demand (BOD) and total suspended solids (TSS) of settled wastewater remaining in the water quickly exceeded the capacity of land available to ever-expanding urban areas. Advances in disinfection allowed the discharge to surface water of treated wastewater to the surface waters, thereby protecting public health while improving the quality of urban river water, infamous in that era as miasmas of filth.

Figure 1. 4G groundwater recharge wetlands, Pasco County, Florida. Wetlands receive 19 MLD of secondary effluent to percolate downward to water table. Total nitrogen, which is almost all nitrate, is reduced to background concentrations by natural means as it passes through wetland soils.

By the early 20th Century the trajectory of what was then called sanitary engineering was overwhelmingly oriented to the demands of huge flows of urban wastewater for which surface discharge was the only practical option in urban areas. It is no exaggeration to state that the modern world of massive urban area could not exist without the evolution of these technologies and infrastructure. Indeed, the first great generation of sanitary engineers of the late 19th and early 20th centuries saw themselves, and were seen by the public, as engaged in a heroic, humanitarian enterprise of fundamental importance.

Figure 2. Wakodahatchee wetland in Palm Beach County, Florida, USA. The wetland takes approximately 19 MLD of secondary effluent and infiltrates it to groundwater in 18 ha of wetlands. There are approximately 1.2 km of boardwalks through the wetland that the public enjoys daily. The wetland is surrounded by urban development and is a top bird-watching area in Florida.

Through this era, public policy and engineers have devoted less attention to small communities and town that have access to land for treatment. The late 20th Century saw a new focus on upgrades to treatment for smaller flows. The definition of small flows is somewhat arbitrary. To engineers working in large cities flows in the 1 to 10 MLD seem small. To those working in rural areas flows of 0.1 to 1.0 MLD may seem substantial. Small clusters of homes or villages fall in the 0.01 to 0.1 MLD range. Despite four order of magnitude in flow range there is one common trait that unites these flows: the reasonable potential for discharge to soil in rural and semi-rural areas (Figure 3).

At the high end of this flow range it becomes harder to find land that can take flows of treated water. If one assumes a hydraulic capacity of 2.5 cm/d, 10 MLD would require 40 ha. Given 100% redundancy, 80 ha would be needed. Such an area, perhaps more, may be reasonable in rural areas. A comprehensive discussion of design issues for land discharge is beyond the scope of this paper. However, it is possible to frame the issues.

Figure 3. Land application system in Roseburg, Oregon, USA. Flow to this system is 13 MLD of advanced secondary effluent on 137 ha. The system is designed for phosphorus removal during dry weather. The irrigation plan keeps the soil permanently wet. Year-round discharge to land would be possible if irrigation were subsurface drip, but a larger area might be necessary for this hilly terrain. It is expected that in the 50-year expected lifespan of this system Roseburg urban development will expand around this area.

A high degree of treatment is needed to protect groundwater. The question of "How clean is clean enough?" depends on many site-specific and technical factors. Answers to this question remain an active area of scientific investigation. As a minimum discharge must be clear with very low BOD and TSS. Sustainable application rates entail BOD and TSS less than 5 mg/L, discharge needs to be disinfected, and soils must have a fairly low clay content to avoid collapse of the soil structure caused by discharge salinity. Offsets of discharge from water supply wells are also essential. Engineering practice is sufficiently advanced to address the many factors that go into effective and safe infrastructure.

A common misconception is that wet climates are unsuitable for soil discharge. It is true that surface irrigation of wet soils is not acceptable engineering practice because discharge will run off into surface water without treatment afforded by percolation through soils. Subsurface drip irrigation, a technology perfected in the late 20th Century, is required for soil discharge in wet climates. Subsurface driplines over thousands of hectares of land are established irrigation practice. Installed about 150 mm below the soil surface, discharge in wet soils percolates and does not rise to the surface. Site-specific conditions determine the design constraints and opportunities for soil discharge. Nevertheless, the depth of design experience obtained over many years from agricultural engineering can be used to effectively address these design challenges.

Additionally, there is discharge via pressure distribution in subsurface chambers. The discharge sprays upward into half-pipes or u-shape infiltration chambers which are buried with their tops about 0.25 below the soil surface. The discharge then trickles into the soil. Because the system is in the surface horizon, there is better treatment than vadose zone leach fields of traditional septic systems. This method was pioneered by the US company, Orenco Systems, Inc. and has since become standard in hundreds of installations. It is unaffected by soil moisture, except separation from ground by a meter or two is required.

There is also discharge to the sky (Figure 4 and Figure 5). Evapotranspiration systems irrigate trees at the rate of tree uptake. This rate varies through the year, but there is also a balance of soil moisture and a plume of discharge in the root zone of trees. Engineering methods strike this balance of discharge and evapotranspiration on an annual or seasonal basis.

Figure 4. Poplar plantation in Woodburn, Oregon. The woodlands are irrigated with effluent from the lagoon treatment system.

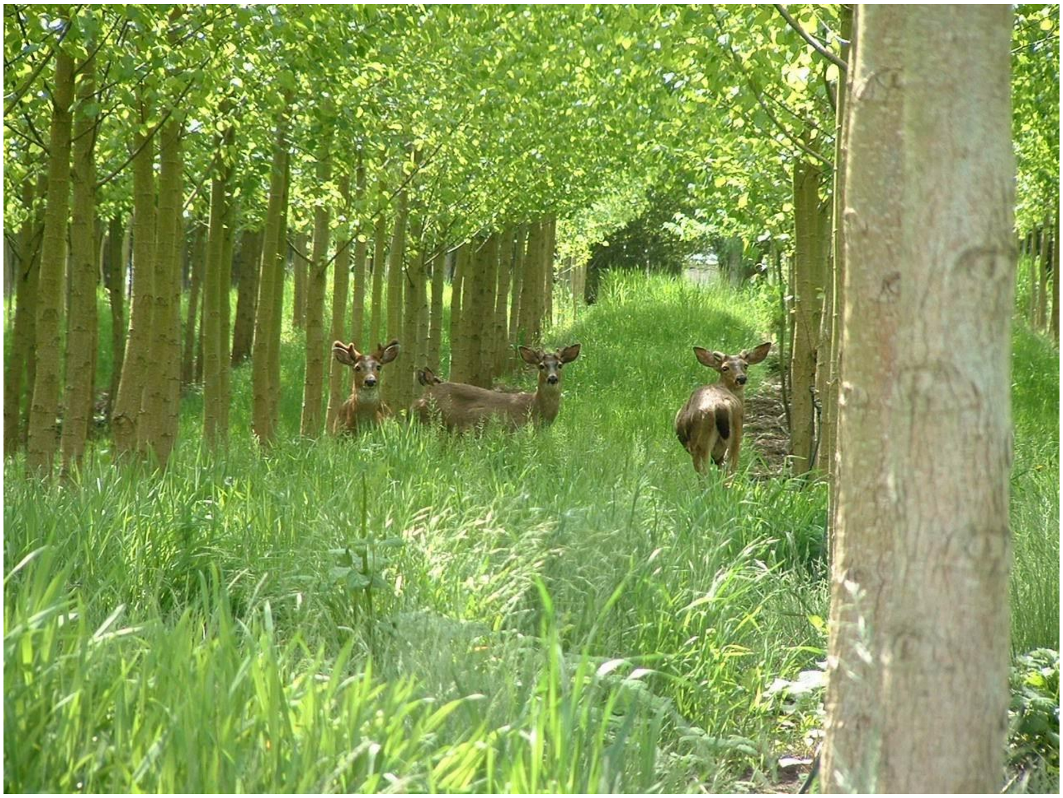

Figure 5. Inside the Woodburn poplar plantation.

Beyond these methods, there are long-established practices of infiltration basins and seasonal land application with a lagoon storage in wet seasons. The emerging practice of wetland infiltration allows yet more options for discharge to soils. Engineers have excellent options to design discharge to a wide variety of terrain, soils, and underlying groundwater hydrogeology.

A general design approach begins at the land. The technical irrigation and infiltration opportunities and constraints of the land in question can be analysed with confidence. With these analyses in hand it is possible to continue straight into a technical match of treatment options. The cost of construction and ownership become central issues.

It is easy to miss culture in this process. It is better to spend time with culture when considering discharge to soil. For a cluster of homes, a small field can be set aside. The whole process may be a simple matter. For a larger community land use decision becomes important. Will there be an irrigated forest, field, or something else? How will the public interact with 1 ha of soil application, 10 ha, 100 ha? It is not a simple question. Communities must be part of the answers. The role of engineers in this process is to work with the community to match what is technically viable on the land with the desired use of that land.

In an abstract sense, the treatment technology itself may not be highly relevant. Whatever technology is selected it must produce water with low BOD, low TSS, and be disinfected. Fully nitrified water is often desirable because ammonia discharged to groundwater can induce anoxia. Anoxic groundwater is not suitable for drinking water supplies and can cause environmental problems as it surfaces in springs and streams. If water is not nitrified, irrigation design can take that into account, but it typically entails a larger irrigation area.

The treatment profile of unit processes for soil discharge begins the same as in any treatment system. There must be a primary process that removes gross solids, followed by an aerobic process that removes BOD and nitrifies ammonia. Typically, soil discharge systems if fully nitrified omit disinfection to save cost. However, disinfection is required for large system that significantly impact groundwater. Adopting a surface water discharge standard for soil discharge would ensure environmental and public safety. There is significant natural attenuation of pathogens as effluent passes through soil. Thus, disinfection prior to discharge adds a large safety margin.

Repurposing existing treatment systems or rethinking design of established practice merits careful consideration soil discharge. Watercare has pioneered a novel way of upgrading treatment lagoons at Wellsford. Installation of ultra-filtration that draws upon polished water produced a very high quality, disinfected effluent. The filters are de-rated for drinking water treatment, but still have a long-life in wastewater, especially in this application. Water from filters in this sort of application would be irrigation or infiltration ready. Nitrification may be required in smaller irrigation areas. This kind of high-tech/low-tech mixture is a sustainable practice that minimises capital and energy intensity of infrastructure.

Novel approaches to wastewater end use and discharge are required in today's approach to planning, design and implementation. The inclusion of cultural impacts and considerations, as well as a thorough consultation process at all stages of a project, are fundamental to a successful project outcome. Jacobs have been involved in a number of projects overseas which incorporate land-based disposal due to cultural and environmental drivers away from discharge to water. The following section summarises a number of international case studies demonstrating successful outcomes where community and cultural considerations are integrated with the technological opportunities offered, with a focus on land-based disposal.

7 CASE STUDIES

7.1 BELFAIR/LOWER HOOD CANAL WRF FOREST LAND APPLICATION SYSTEM DESIGN, MASON COUNTY, WASHINGTON

In order to improve water quality conditions in the Hood Canal, Mason County was required to address de-centralised growth and septic system nutrient loading to this estuarine system. Jacobs worked closely with Mason County to develop and implement a plan for the unincorporated community of Belfair, resulting in decommissioning septic systems, installing a new sewage collection system, and developing an advanced treatment water reclamation facility (WRF), as well as a reclaimed water storage and irrigation system.

Due to water quality limitations in the Hood Canal, a sensitive spawning habitat in local streams, and tribal restrictions, no surface water discharge could be permitted for the new WRF. With the WRF located on commercial timber forestlands, Jacobs worked with the County and neighbouring landowners to develop a system for reuse of the treated effluent to enhance timber production on the sandy and gravelly site soils.

A 190 megalitre reclaimed water storage pond was developed to provide winter-time storage, pumping and filtration systems were developed, and a 39-acre solid-set robust forestland sprinkler system was developed for the initial phase of development.

7.2 NATURAL TREATMENT SYSTEM AND HIGH RATE IRRIGATION FOR PHOSPHORUS TREATMENT AND WATER QUALITY IMPROVEMENT, ROSEBURG URBAN SANITARY AUTHORITY—ROSEBURG, OREGON

In response to a Total Maximum Daily Loads study for the South Umpqua River, the Roseburg Urban Sanitary Authority (RUSA) developed a natural treatment system to address the resulting new phosphorus, temperature, and chlorine residual discharge limits. Jacobs supported RUSA in assessing the feasibility of various alternatives for land application of effluent or biosolids from their wastewater treatment facility.

Jacobs provided the design and construction oversight of the system which includes 30 MLD capacity reuse and irrigation pump stations, nearly 1.6 km of 600 mm conveyance pipeline, a 25 megalitre storage pond, 2-acres or constructed wetlands, approximately 200 acres of drip and micro-spray irrigation for agronomic rate and high-rate land application irrigation, drainage, and restoration of 94 acres of historic natural wetlands. Restored and created wetlands are used for polishing and wetlands mitigation credits.

Extensive soil and groundwater investigations and groundwater modelling were conducted to assess the subsurface capacity for accepting excess irrigation. A soil column phosphorus retention study at Jacobs's Applied Science Lab established the capacity of the farm's clay soils to adsorb and retain phosphorus for more than 50 years.

7.3 MUNICIPAL EFFLUENT AND BIOSOLIDS MANAGEMENT, POPLAR TREE SYSTEM FOR EFFLUENT AND LIQUID BIOSOLIDS IRRIGATED REUSE

The City of Woodburn was required to upgrade its existing secondary treatment facilities to meet stringent new effluent ammonia loading limits before discharge to the Pudding River.

The initial system components included separate irrigation and liquid biosolids pump stations, a micro-spray irrigation application system, hard hose reel liquid biosolids application equipment, and a SCADA system to provide automatic control with minimal daily input and supervision. Since 1999, this site has successfully operated allowing agricultural reuse of up to 4 MLD of effluent for irrigation in July and August of each year. The agricultural reuse operations have been successful in reducing ammonia discharge to the river enabling continued compliance with water quality criteria while producing a marketable wood fibre crop.

Jacobs implemented a broad public education program to build community acceptance and pride in this innovative facility. This included conducting poplar plantation tours, producing an educational video about the facility, organising school science poplar projects, and facilitating media coverage.

7.4 PHYTOREMEDIATION AND HYDRAULIC CONTROL OF A GROUNDWATER PLUME IN SOUTHERN CALIFORNIA

The objective of this project is to regain hydraulic control of groundwater plume containing hexavalent chromium [Cr (VI)]. The project includes two major elements: extraction of groundwater and discharge of the extracted water through subsurface drip and low energy surface irrigation.

The irrigated fields, cultivated with a variety of grasses, are known as Agricultural Treatment Units (ATUs) and are designed to treat chromium in the extracted groundwater to water quality standards. In addition, the crops have removed approximately 120 tons of nitrate nitrogen from the aquifer over the first 9 years of operations. The irrigation system supplies a precise amount of water to the crop, which the crop then uses and transpires, while adding carbon to the soil.

The management of farmland in the desert of southern California illustrates the use of phytoremediation in a long term, large field-scale hydraulic control of a groundwater plume containing chromium, nitrate, and total dissolved solids.

CH2M (Jacobs) involvement began with the design of the initial project in 2003 as a subsurface irrigation system on 75 acres. Subsequently, 230 irrigated acres have been added to the initial site over the past 13 years, utilising different irrigation technology, including drag drip irrigation and drop hoses on centre pivot and linear move irrigation machines.

Multiple groundwater extraction wells pump flows ranging up to 6000 litres per minute, depending on the season, to irrigated crop fields encompassing over 300 acres. The water is delivered directly to the treatment zone in the soil through the irrigation system. The crops selected for the fields are a mixture of warm and cool season grasses, deep rooting wheat, winter oats, and alfalfa, allowing some crops to be dormant at different times of year. In addition, the crops selected are adapted to the area, drought resistant, and tolerant to the relatively high levels of total dissolved solids (TDS) also present in the irrigation water.

CH2Ms management of the farmland includes the development of recommendations for the crops in cooperation with the owner-client and the farmers, and in consultation with State agricultural extension agents; water balance modelling; irrigation scheduling; soil and plant tissue analysis. The monitoring program consists of extraction well system performance monitoring and a detection monitoring program for the ATUs. Extraction system performance monitoring uses the monitoring wells to verify capture of the Cr (VI) plume. The ATU detection monitoring program also includes flow monitoring, soil pore liquid monitoring, soil monitoring, and plant tissue monitoring.

System optimization occurred during system start-ups, and CH2M provides regular adjustments to the irrigation and farming techniques to maximize crop water uptake and provide high yield production of commercial agricultural crops. Regular maintenance support is provided during site visits and remotely to the local site operators.

8 CONCLUSIONS

The discharge of human waste, especially to waterways, is a controversial topic of particular interest to Māori. A key driver for many technological solutions is the abhorrence, to Māori in a cultural context, of this discharge to water, irrespective of the level of treatment prior. Consultation in the context of a wastewater project presents multifaceted cultural issues that have origins in Māori spirituality.

A simplified interpretation of the traditional Mäori view of the water cycle reflects this idea of parallel and linked physical and spiritual worlds. Water falls as rain to the earth. Failure to protect the water quality harms both its physical nature, and its mauri, which can only be restored as the water passes through the earth and into the sea. In a physical sense this reflects the idea that water can be cleansed by passing through vegetation and the earth (Papatuanuku).

Experience has highlighted the importance of early participation of iwi and hapu in a partnership approach with technical advisors and the relevant local authority to identify wastewater treatment project outcomes which are acceptable to all stakeholders. This is consistent with the Treaty of

Waitangi and the development of concepts and technology solutions that address cultural and spiritual matters.

Three key pieces of legislation exist which set out the principles to be followed with respect to Māori-tangata whenua considerations on human waste-domestic sewage and wastewater systems. Part Two of the RMA requires *“in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for the following matters of national importance:*

(e) the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga.” The RMA also requires consideration of principles of the Treaty of Waitangi (Te Tiriti o Waitangi).

The special position afforded Māori under the RMA and other statutes has led to the development of many participatory partnership type approaches in development of resource consent processes and consent conditions and associated technology solutions. For example, the response to Māori objection to the direct discharge of treated human waste (domestic sewage) direct to water, no matter how well it is treated, has resulted in a number of land contact type processes where the treated domestic sewage contacts Papatuanuku (earth mother) in a rock channel, riparian strip or pond before discharge to surface or marine waters.

In considering wastewater management and disposal, tangata whenua view the situation in a holistic manner and do not focus on the methods of treatment, contrary to the traditional engineering approach. The linkage of nature and humankind as one, forms part of the fundamental basis from which this holistic approach is undertaken.

Tapu and noa are key Māori cultural concepts that influence and inform Māori views regarding wastewater management. However, tapu and noa are not fixed and can change through time as a result of a specific action or consequence; thus, influencing the ability to interact or use an object or resource which creates interesting management implications for human waste – supporting the drive toward land-based disposal and the restoration of the mauri of the water by passing through Papatuanuku.

Many Māori consider that within the realms of Papatūānuku and Ranginui there exist a range of established processes and relationships that continuously cycle chemicals through the spiritual states of tapu and noa. In a scientific context these processes could be termed bio- and physico-chemical transformation which act to breakdown and modify chemical compounds to basic building blocks for other uses or re-partitioning back into the environment.

There is a breadth of cultural knowledge on the topic of biowaste, biosolids and wastewater management, a willingness and openness to explore new forms of co-management, and an expectation of being involved in decision making. Where this is the case Māori view biowastes and biosolids as something that should be owned and responsibly managed, rather than forgotten about or left to the environment to cope with.

There are a significant number of Local Authority domestic sewage treatment and disposal schemes that include, often as a final stage, arrangements where the treated human wastewater contacts land – Papatuanuku – before discharge to natural water. The rationale is to provide a spiritual cleansing of the wastewater by the contact with Papatuanuku.

Discharge of wastewater to the land, rather than surface water or other water receiving bodies, is the oldest practice of engineered treatment systems. Today, it is widely practiced for decentralised wastewater treatment. Discharge of treated effluent to surface water has evolved as a practical response to the increasing volume of wastewater flows in concentrated urbanised areas.

The hydraulic capacity of soil limits is a primary limit to land-based discharge. Clean rain readily exceeds the capacity of soil to adsorb it. An additional issue is that wastewater constituents readily clog even highly conductive soils. Sewage farms in the 19th Century demanded ever-increasing land areas to treat raw wastewater. Primary treatment to settle out solids alleviated the problem, but biochemical oxygen demand (BOD) and total suspended solids (TSS) of settled wastewater remaining in the water quickly exceeded the capacity of land available to ever-expanding urban areas. Advances in disinfection allowed the discharge to surface water of treated wastewater to the surface waters, thereby protecting public health while improving the quality of urban river water, infamous in that era as miasmas of filth.

The late 20th Century saw a new focus on upgrades to treatment for "smaller" flows. Regardless of the flow range there is one common trait that unites these flows: the reasonable potential for discharge to soil in rural and semi-rural areas.

A high degree of treatment is needed to protect groundwater. The question of "How clean is clean enough?" depends on site-specific and technical factors. As a minimum discharge must be clear with very low BOD and TSS. Sustainable application rates entail BOD and TSS less than 5 mg/L, discharge needs to be disinfected, and soils must have a fairly low clay content to avoid collapse of the soil structure caused by discharge salinity. Offsets of discharge from water supply wells are also essential.

A common misconception is that wet climates are unsuitable for soil discharge. However, subsurface drip irrigation over thousands of hectares of land are established irrigation practice. Installed about 150 mm below the soil surface, discharge in wet soils percolates and does not rise to the surface. Additionally, there is discharge via pressure distribution in subsurface chambers. The discharge sprays upward into half-pipes or u-shape infiltration chambers which are buried below the soil surface. The discharge then trickles into the soil.

There is also discharge to the sky. Evapotranspiration systems irrigate trees at the rate of tree uptake. This rate varies through the year, but there is also a balance of soil moisture and a plume of discharge in the root zone of trees. Engineering methods strike this balance of discharge and evapotranspiration on an annual or seasonal basis.

Beyond these methods, there are long-established practices of infiltration basins and seasonal land application with a lagoon storage in wet seasons. The emerging practice of wetland infiltration allows yet more options for discharge to soils, and can provide the added benefit of groundwater replenishment in water deprived areas. Engineers have excellent options to design discharge to a wide variety of terrain, soils, and underlying groundwater hydrogeology.

A general design approach begins at the land. The technical irrigation and infiltration opportunities and constraints of the land in question can be analysed with confidence. With these analyses in hand it is possible to continue straight into a technical match of treatment options. The cost of construction and ownership become central issues.

The emphasis of treatment described in this paper and presented in the case studies is not on a particular upstream technology or suite of technologies. There is a rich engineering practice with many suitable choices across small to medium scales that will provide water suitable for soil discharge or infiltration. Discharge to soil or to infiltration is inherently different to surface discharge. To a great extent, the engineering design work is complete once water enters the pipe ready for discharge. That is not true for soil discharge or infiltration systems. There is a great deal of engineering design work required. The discharge system itself typically has an important treatment function. Moreover, larger systems can be intimately connected to society and nature.

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