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NRSBU Sewage Overflow Discharge

Water Quality Assessment

on behalf of Nelson City Council

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Executive Summary

1. A consent application is being considered for untreated wastewater discharge from four pump stations to the Waimeha Inlet. Based on hydrodynamic modelling of the inlet under various environmental conditions, aberrant discharges from each pump station have been assessed for their potential effects on water quality and potential microbial illness risks to recreational users.

2. The proximity of the discharge points to the mouths of streams flowing into the inlet mean there is potential for effects on freshwater migratory fish, should discharges occur while fish are moving through the inlet. Potential effects relate largely to elevated loads of BOD in the Saxton and Songer Street discharges and subsequent acute effects on dissolved oxygen. Other potential effects include any toxicity or avoidance effects resulting from elevated nitrate and ammonia in the Saxton discharge.

3. The Saxton pump station discharge is high-risk in terms of potential freshwater ecological and microbial illness risk effects. Saxton pump station has the greatest rate and volume of discharge, frequency of discharge events, highest contaminant loads and greatest spatial extent, including intertidal areas, inlet channels and the shoreline of the inlet and Monaco Peninsula under certain conditions.

4. Given the nature of the untreated industrial wastes in the sewage entering the Saxton pump station, and the potential for high impact effects such as reductions in dissolved oxygen from high BOD loads and potentially toxic nitrogenous contaminant concentrations (e.g. nitrate and ammonia) mean there is potential for significant effects on aquatic life in the inter-tidal zone at a large distance from the outfall. These effects may impact on freshwater species utilising the estuary at various life-stages, including īnanga spawning and sensitive larval and juvenile stages of galaxiid/whitebait and other freshwater species.

5. Background illness risks have been estimated to be in the 1-5% range for the inlet in the absence of discharge events. For most discharge scenarios for all pump stations under all wind and stream flow conditions, the microbial illness risks associated with pump station discharges are generally likely to be less than 1% (the No Observable Adverse Effects Level, NOAEL) across most of the inlet. Although, under conditions created by selected discharge scenarios, and for discharges from specific pump stations, the illness risks may exceed the thresholds identified in the MfE/MoH (2003) guidelines at specific locations or along drainage channels where sewage accumulates or is less diluted.

6. Highest illness risks (>10% GI illness) were associated with shallow depressions that occur where pump stations discharge into the inlet. Undiluted sewage may remain in these depressions for some time after discharge in calm conditions, also affecting channels draining the intertidal flats immediately down-gradient of pump station discharge outfalls. The areal extent and channel length where high illness risks occur are largely affected by tide and wind; ranging from approximately 0-3,000 m at the Saxton pump station, to approximately 0-1,000 m at all other pump stations. High illness risks may extend more than 800 m from the Saxton pump station along the shoreline and affect as much as 500m of the southern shoreline of the Monaco Peninsula. The Songer Street discharge may also affect an area of approximately 500 m from the discharge point at times, including Monaco.

7. In general, the most effective means of managing the potential illness risks to recreational users of the inlet are notification, signage and beach closure. Emergency management plans should be amended to reflect the temporal and spatial extent of elevated illness risks modelled for various environmental conditions. With respect to discharge from the Saxton (or in some conditions Songer Street) pump station, closure of the inlet to recreational users may need to be widespread spatially, and cover a duration of greater than 21 hours.

8. Monitoring of faecal indicator bacteria (FIB) following discharge events is recommended to validate the illness risk profiles. Ideally, this would be combined and compared with year-round monthly FIB monitoring of the background level of microbial contaminants at representative sites within the inlet. Monthly background monitoring could occur as part of routine coastal monitoring by NCC.

9. Potential effects on contact recreation at Monaco Peninsula require careful consideration and emergency management, in addition to risks to recreational use of the wider inlet. Monaco is a highly visible area and is subject to the greatest use, based on limited survey data.

10. Background microbial illness risk within the inlet (without aberrant sewerage discharges), and the potential for shellfish gathering and subsequent effects on human health also require consideration. The latter impact remains largely unknown.

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1 Introduction and Scope

11. This report has been prepared to inform the s42A report prepared by Ms Lojkine on a notified application for overflow of untreated sewage effluent into the Waimeha (Waimea) Inlet from four pump stations operated by the Nelson Regional Sewage Business Unit (NRSBU).

12. In compiling this assessment, I have relied on the following information:

    I. The AEE appended to the consent application, including attachments, map and data bundles, and all further information as at 31 October 2017;

    II. The review of assessments of ecological effects of the application by Dr Phillips on behalf of NCC;

    III. The ornithological report prepared by Dr Fisher on behalf of NCC;

    IV. Relevant provisions of the Nelson City Council Natural Resources Management Plan (NRMP);

    V. Reports prepared on behalf of the NRSBU by MetOcean (2017), Johnston (2014, 2015 and 2017), Hudson and Wadhwa (2017), Hudson and McBride (2017), Hudson (2017), Fluent Solutions (2016), NELMAC (2017) and Greenaway (2017);

    VI. Relevant provisions of the New Zealand Coastal Policy Statement (NZCPS);

    VII. The Waimeha Inlet Management Strategy 2010; and

    VIII. Submissions received on the notified consent application.

13. The scope of this report is the potential effects on physicochemical and microbiological water quality within the Waimeha Inlet and potential ecological effects on migratory freshwater fish that pass through, or utilise, the habitat of the Waimeha Inlet as part of their life-cycle. This report should be read in conjunction with the reports of Drs Phillips and Fisher for NCC.

2 Waimeha Inlet Receiving Environment

14. The Waimeha Inlet is a large tidal lagoon to the south-west of Nelson City. It lies within the territorial boundaries of Nelson City Council and Tasman District Council. The inlet is fed by the Waimeha River (Tasman District) and a number of small coastal streams, including those within the Stoke suburb of Nelson City.

15. The portion of the inlet within Nelson City Council management is fed by streams flowing largely through urban and industrial land. The Stoke streams generally have poor water quality, commensurate with urban/industrial land use and associated sewage network infrastructure (McArthur 2016).

16. Treated sewage effluent from Nelson and Richmond is discharged at the eastern opening of the inlet adjacent to Bell's Island, where the oxidation ponds are located.

17. The inlet has seen an increase in the area affected by gross eutrophic conditions and nuisance macroalgal growth between 1990 and 2014, as a result of increased nutrient and organic loads to the inlet; it is considered ecologically vulnerable (Stevens and Robertson 2014 & 2017).

18. Water quality in the Waimeha Inlet is substantially affected by contaminant loads sourced from the Waimeha River and other streams flowing into the inlet as well as other cumulative effects from stormwater outfalls, land uses and associated discharges, including the sewage network (McArthur and Foster 2017).

2.1 Freshwater fish in the coastal environment

19. The following information has been included as context to inform decision making on the NRSBU application and was provided via a technical report (Beveridge and McArthur 2017) to the NRSBU experts for consideration in the assessment of effects undertaken by Johnstone (2017).

20. New Zealand's freshwater fish fauna comprises a large proportion of diadromous (migratory) taxa. In Nelson, some of the highest fish diversity is found within the Stoke streams, despite their poor water quality. These streams are collectively home to fifteen species of native fish, fourteen of which require access to coastal environments for some part of their life-cycle. The critical period, when sensitive juvenile fish are migrating through the inlet varies, depending upon the species. Indigenous fish move through the coastal interface throughout the year. Many of the species are classified as threatened (Table 1) and therefore trigger consideration under Policy 11(a) of the NZCPS.

Table 1: Native freshwater fishes found in the Stoke Freshwater Management Unit (FMU)

Common name	Species name	Migratory strategy
Shortfin eel	*Anguilla australis*	Migrate to sea as adults to spawn, migrate into freshwater as juveniles
Longfin eel*	*Anguilla dieffenbachii*	Migrate to sea as adults to spawn, migrate into freshwater as juveniles
Giant kōkopu*	*Galaxias argenteus*	Larvae washed out to sea, migrate into freshwater as juveniles
Torrentfish*	*Cheimarrichthys forsteri*	Larvae washed out to sea, migrate into freshwater as juveniles
Kōaro*	*Galaxias brevipinnis*	Larvae washed out to sea, migrate into freshwater as juveniles
Banded kōkopu	*Galaxias fasciatus*	Larvae washed out to sea, migrate into freshwater as juveniles
Shortjaw kōkopu+	*Galaxias postvectis*	Larvae washed out to sea, migrate into freshwater as juveniles

Common name	Species name	Migratory strategy
Īnanga*	*Galaxias maculatus*	Adults spawn in tidally inundated vegetation, juveniles migrate into freshwater as whitebait
Lamprey+	*Geotria australis*	Juveniles go to sea at 4-5 years and stay there for 3-4 years before returning to freshwater as adults to spawn
Upland bully	*Gobiomorphus breviceps*	Non-migratory
Common bully	*Gobiomorphus cotidianus*	Larvae washed out to sea, migrate into freshwater as juveniles
Giant bully	*Gobiomorphus gobioides*	Larvae washed out to sea, migrate into freshwater as juveniles
Bluegill bully*	*Gobiomorphus hubbsi*	Larvae washed out to sea, migrate into freshwater as juveniles
Redfin bully*	*Gobiomorphus huttoni*	Larvae washed out to sea, migrate into freshwater as juveniles
Black flounder	*Rhombosolea retiarii*	Largely estuarine dwelling, although some adults penetrate far into freshwater. Migrate to sea to spawn

* "at-risk, declining" species + "threatened, nationally vulnerable" species in the Department of Conservation Threatened species classification (Goodman et al. 2014).

21. In addition to the freshwater taxa there are some marine wanderers common to the Waimeha Inlet including: yellowbelly flounder, kahawai, yelloweye mullet, grey mullet and estuarine triplefin. The Waimeha Inlet provides important juvenile rearing habitat for some marine fish species. All species rely on invertebrate food sources including benthic species (discussed by Dr Phillips), amphipods (freshwater and marine) and other small crustaceans.

3 Potential Effects of Overflow Events on the Waimeha Inlet

22. Dr Phillips and Ms Johnstone discuss the potential for chronic and acute ecological effects on estuarine invertebrate macrofauna within the inlet from discharge events. These assessments are based on the hydrodynamic modelling undertaken on behalf of the NRSBU by MetOcean (2017). Dr Fisher discusses the potential of these effects to impinge on indigenous wading birds in the inlet. The following sections of this report assess the potential water quality effects on migratory freshwater fish moving through the inlet, particularly with respect to biochemical oxygen demand (BOD) and the effects this may have on dissolved oxygen in the water column and any subsequent fish avoidance. Microbiological water quality is considered in later sections of this report.

23. Low dissolved oxygen can result in avoidance behaviour in migrating freshwater fish moving through the inlet (Richardson et al. 2001) to access adult habitat in the Stoke streams (Figure 1) and has the potential to impact on freshwater biodiversity values in these streams.

24. Effects on freshwater fish abundance and diversity are inherently difficult to determine with any certainty, due to the cumulative nature of impacts occurring across both freshwater and coastal habitats. Many of the potentially affected species are of high conservation value, due to their threat status and declining populations nationally (Goodman et al. 2014).

3.1 Whakatū pump station

25. The Whakatū pump station is located near the mouth of Saxton Creek and known īnanga spawning sites within the tidally-influenced lower reaches of the creek. Larval and juvenile īnanga and other migrating indigenous fish species may be affected in the event of a discharge at Whakatū in close proximity to the discharge point and tidal channel, although the risk and volume of discharge from this site have been identified in the application and associated information as very low.

3.2 Songer Street pump station

26. High concentrations of BOD have been measured in the effluent at Songer Street (Johnstone 2014). Concerns regarding BOD are explained more fully with respect to the Saxton pump station in the section which follows. The Songer Street discharge plume is located near the mouth of Orchard Stream and has the potential to affect migrating juvenile freshwater fish in the event of a discharge by reducing the available dissolved oxygen in the water column and potentially causing avoidance by fish of any affected areas.

3.3 Airport pump station

27. The proximity of the Airport pump station to the mouths of Jenkins Creek and Poorman Valley Stream, and the modelled discharge dilution contours, suggest that under some discharge conditions, juvenile or larval freshwater fish moving through the estuary may be affected by elevated contaminant concentrations and associated effects on dissolved oxygen. Poorman Valley Stream has the highest freshwater fish diversity in the streams flowing into the Waimeha Inlet (Beveridge and McArthur 2017), with many of the identified species having an 'at-risk and declining' threat status. Any discharge that occurs in this area, during inward migration of juvenile diadromous species or outward movement of larvae, could result in reduced biodiversity values in the stream through avoidance of discharge contaminants or low dissolved oxygen.

3.4 Saxton pump station

28. The Saxton Pump Station is of particular concern because of the potential for high contaminant loads introduced by industrial waste from Nelson Pine Industries (NPI), Alliance meat processing works, ENZA and others. Background water quality monitoring results collected by Ms Johnstone show decreased dissolved oxygen saturation in the vicinity of the Saxton and Airport pump stations (Figure 2; Johnstone 2017). The applicant has indicated the Saxton pump station is responsible for the majority of overflow discharge events (Johnstone 2017). Given the current state of the inlet in this area, any discharge from the Saxton pump station has the potential to contribute to cumulative impacts on dissolved oxygen, via elevated BOD.

29. Median Biochemical Oxygen Demand (BOD_5) was noted to be 2000 mg/L in the Nelson Pine Industries wastewater (Johnstone 2014; Figure 4). This is an exceptionally high BOD value. Potential exists for exposure to BOD concentrations of this level to result in acute effects, such as hypoxia (suffocation through low dissolved oxygen saturation in the water column), potentially causing mortality in invertebrates and fish, including freshwater species migrating between freshwater and coastal ecosystems.

30. Johnstone (2014) notes that median concentrations of total nitrogen were high in the Alliance effluent when compared to untreated wastewater (median TKN of 100mg/L). In my experience, elevated nitrogenous concentrations are common in untreated meat-processing effluent. The proportion of total nitrogen discharged as ammonia or nitrate is of greatest concern with respect to the potential for direct toxicity effects on aquatic life or avoidance effects on invertebrates and migrating freshwater fish.

31. BOD and nitrogen related effects are well described in the New Zealand and international literature (Jones 1952; Hickey and Vickers 1994; Richardson 1997; Mitchell et al. 1999; Richardson et al 2001; Landman et al. 2005).

32. The modelled discharge plume from an overflow event from the Saxton pump station has the widest spatial distribution of the four pump stations. Under high tide conditions, the plume has the potential to affect larval or juvenile migrating freshwater fish leaving or entering the Saxton Creek (including īnanga, which spawn in the lower, tidally affected reaches of the creek). Under low tide conditions the plume spreads into the main channel of the inlet and has the potential to affect larval or migrating freshwater fish across the Saxton, Orchard, Orphanage, Poorman Valley and Jenkins streams.

33. The cumulative effect of multiple contaminants (e.g. BOD_5, ammoniacal nitrogen, suspended sediments) and any subsequent effects of dissolved oxygen on larval and juvenile freshwater fish moving through the inlet is not known. ANZECC species protection guidelines used by Ms Johnstone in her assessment may not provide adequately for these sensitive life stages of migratory freshwater fish, many of which are at-risk and declining nationally.

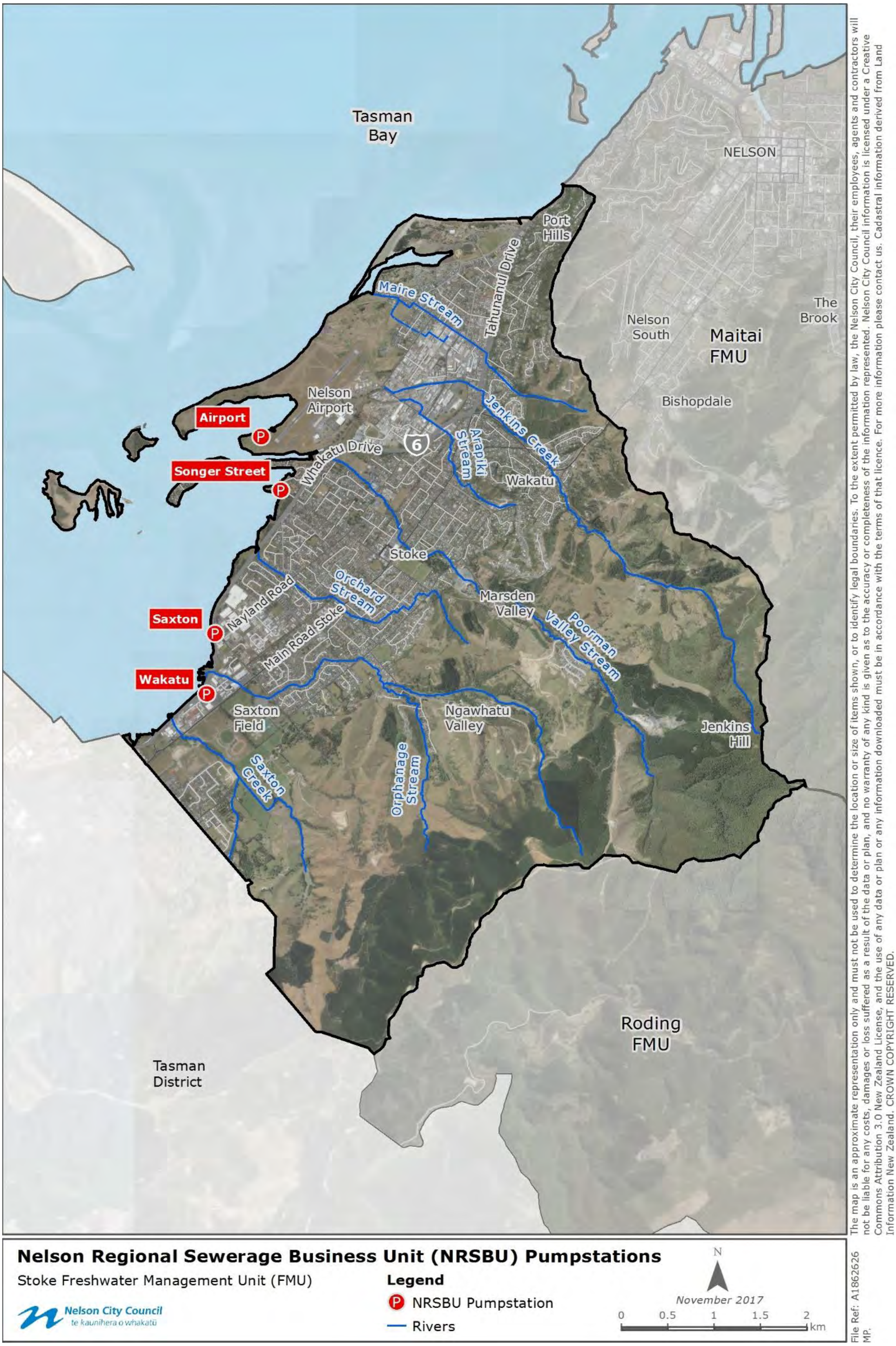

Figure 1: Map of Waimeha Inlet showing pump station locations and streams in the Stoke suburb of Nelson.

3.5 Water quality standards for ecological values

34. The Nelson Resource Management Plan (NRMP) contains a schedule of coastal marine water quality standards for Fishing, Fish spawning, Aquatic Ecosystem, Aesthetic classed waters (FEA) which include:

    1) *The natural temperature of the water shall: a) not be changed by more than 2°C, and b) not exceed 25°C, and*

    2) *The concentration of dissolved oxygen shall exceed the higher of 6mg/l or 80% saturation, and*

    3) *There shall be no significant adverse effects on aquatic life arising from the discharge of a contaminant into water, a pH change, the deposition of matter on the foreshore or seabed, or any other cause, and*

    4) *There shall be no: a) production of any conspicuous oil or grease films, scums or foams or floatable or suspended material, and b) conspicuous change in the colour or visual clarity, and c) emission of objectionable odour in the receiving water.*

35. Many of the NRMP standards cannot be easily assessed with respect to these discharges, given the current availability of data.

36. The NRMP sets a minimum dissolved oxygen standard of 6mg/L or 80% saturation (whichever is higher). It is likely the high BOD concentrations in the Saxton and Songer Street discharges would cause the dissolved oxygen saturation to drop below the plan standard when discharges occur, particularly within the less diluted areas of the discharge plume. Dissolved oxygen saturation and concentrations in background water quality samples collected from the inlet (Johnstone 2017; Figure 2) are below NRMP thresholds in the vicinity of the Saxton, Whakatū, and Airport discharges already. These sites may be vulnerable to impacts that further reduce dissolved oxygen (such as high BOD loads in aberrant discharges).

37. Ms Johnstone concludes that, based on the MetOcean modelling, the potential for adverse effects is largely restricted to tidal channels. However, it is these channels juvenile and larval fish utilise (via tidal movement in many cases) to facilitate access between freshwater and marine habitats.

38. Measures to reduce or remove BOD and other contaminant loads from discharges to the inlet will be needed to avoid adverse effects on migrating freshwater fish.

4 Contact Recreation and Public Health Risks - Microbiological Water Quality

39. Submitters on the application have raised concerns about the public health risk of discharges of untreated sewage effluent to the inlet. Descriptions of recreational activities undertaken in the inlet in the submissions include stand-up paddle boarding, kayaking and swimming as well as passive recreation adjacent to the estuary, such as walking, running and cycling. Many of the primary contact activities occur year-round in the inlet and the area utilised for such activities is likely to extend beyond the designated contact recreation (CR) zones currently identified in the NRMP and the application.

40. A Quantitative Microbial Risk Assessment (QMRA) was undertaken by Hudson and McBride (2017) and the context of the inlet, in terms of background microbial risk was described by Hudson (2017) on behalf of the applicant.

41. In response to a request for further information on the spatial and temporal distribution of microbial risk to recreational users of the inlet, a hydrodynamic model was developed by MetOcean (2017). The MetOcean report investigated a series of scenarios, including: the volume of untreated sewage likely to be discharged from each pump station in a four-hour period; the tidal stage at the time of discharge, whether stormwater inflows to the Waimeha Inlet were high or low; and wind speed and direction at the time of discharge. This model was coupled with the QMRA by Hudson and Wadhwa (2017). This has enabled time-series and risk contour mapping of the areal extent of microbial and contaminant risks, which has contributed usefully to understanding the potential effects and informing the emergency management response to any future discharge events.

42. Hudson and McBride (2017) note at Appendix D that "*QMRA is still an emerging discipline, with a number of issues that will take years to resolve. Nonetheless, experience indicates that QMRA is a more informative approach to human health risk assessment relative to that provided by levels of indicator bacteria derived from epidemiological studies at sites generally far removed from the effects of discharges from large wastewater treatment plants*." I agree that the addition of QMRA, coupled with the hydrodynamic model of the inlet has substantially improved our understanding of the spatial and temporal scale of risks from microbial contaminants and is the best currently available tool for assessing those risks in this case.

4.1 Background microbial risk in the Waimeha Inlet

43. The microbial water quality context report (Hudson 2017) provides a useful description of the current microbial risks to recreational users in the absence of an aberrant discharge event from a pump station. Hudson (2017) summarised the background risks as:

"*For approximately two years in three:*
- *A 1-5% risk of GI[1] illness exists.*
- *Up to 2% risk of AFRI[2] illness exists.*

For approximately one year in three:
- *A 1-5% risk of GI illness exists.*
- *An approximately 2-4% risk of AFRI illness exists."*

44. Dr Hudson then states "*These risks apply to contact recreation that involves activities such as swimming, surfing, scuba diving and dinghy-boat sailing. These are illness risks, not infection risks. These risks do not apply to "non-normal" circumstances, i.e., when an epidemic status exists in the community."*

45. Faecal indicator bacteria (FIB) loads sourced from streams flowing into the inlet following rainfall were found to be, at times, greater than the full FIB load produced from the Bell's Island sewage discharge (Hudson 2017). This is consistent with known effects of sewage infrastructure leakage and overflow from urban areas to streams in Stoke (McArthur and Foster 2017). Leakage and

[1] Gastrointestinal Illness.
[2] Acute Febrile Respiratory Illness

overflow of sewage networks following rain is an issue that is currently being considered by NCC, tangata whenua iwi, and community stakeholders in the development of the freshwater and coastal aspects of the draft Nelson Plan.

46. In general terms, background microbial water quality in the inlet declined from west to east and was found to be worst near Parkers Cove (the Maire Stream outflow). According to Hudson (2017), sites in the inlet that receive stormwater inflows (either directly or via streams) are unlikely to achieve satisfactory grading in terms of the Ministry for the Environment and Ministry of Health Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE/MoH 2003). The risk factors identified in the Guidelines exist for much of the foreshore of the inlet. These illness risk factors exist in the absence of aberrant discharges of untreated sewage from the four pump stations considered in this assessment, with the discharges of untreated sewage exacerbating the situation at times.

47. The NRMP standards for CR zones are: a median not exceeding 35 Enterococci/100ml, including a specific limit of 275 Enterococci/100ml for Monaco Beach. Figure 2 shows the Monaco site 95th percentile and median of bathing season samples are within the NRMP limits, however this sampling only occurs over the summer months. NRMP CR standards are currently met at Monaco Beach, based on summer sampling, although there is a likely background risk of GI illness of 1-5% and up to 2% risk of illness related to AFRI, based on the recent QMRA work, which is closely associated with rainfall in the stream catchments.

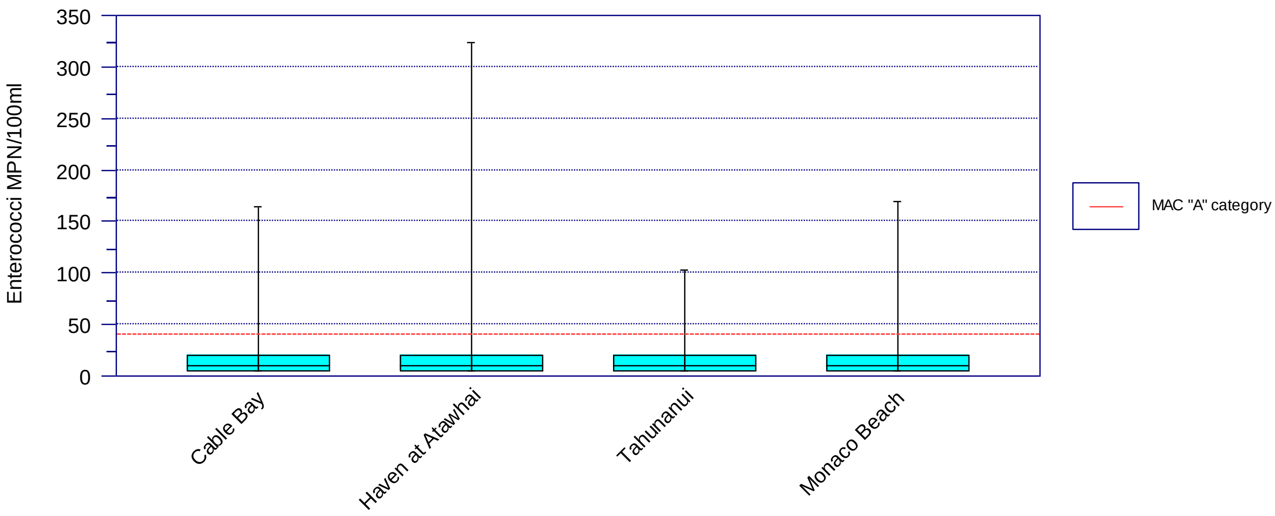

Figure 2: Enterococci (MPN)/100ml for marine recreational bathing sites in Nelson, collected weekly from December until April between 1998 and 2015. Box = 75th and 25th quartiles, mid-point line = median, bars = 5th and 95th data percentiles. MAC "A" category = Microbiological Assessment Category for 95th percentile[3].

[3] Sourced from: McArthur KJ 2016. Nelson Freshwater Quality: an analysis of state and issues. The Catalyst Group Report No. 2016/068 prepared for Nelson City Council. Pp. 120.

4.2 Illness risk from shellfish collection

48. The QMRA work undertaken by Dr Hudson and others did not directly assess the risks of microbial contaminants from ingestion of shellfish collected from the inlet. This assessment was not undertaken because shellfish collection was not identified as a key 'use' of the inlet, based on advice and a report on the recreational use of the Monaco Peninsula by Greenaway (2017). I note the Greenaway (2017) report and advice communicated by email to the authors of the QMRA was based on a very limited sample of individuals and covered only the Monaco Peninsula area. It is possible that some shellfish collection does take place in the inlet from time to time, and tangata whenua iwi have expressed a desire to be able to collect shellfish from the inlet[4].

49. Hudson and McBride (2017) note "*Movement of relatively undiluted sewage could potentially lead to shellfish contamination some distance from the initial discharge location. As a consequence of their filter-feeding behaviour, shellfish are able to concentrate contaminants, including viruses*." An earlier version of the Cawthron report, appended to the application (Johnstone 2014 and 2015), stated that shellfish collection was not suitable throughout the Waimeha Inlet, due to cumulative contamination from numerous sources[5].

5 Microbiological Risks Associated with Pump Station Discharge Events

50. Hudson and Wadhwa (2017) found that for most discharge scenarios for all pump stations under all wind and stream flow conditions, the illness risks associated with pump station discharges are generally likely to be less than 1% (the No Observable Adverse Effects Level, NOAEL) across most of the inlet. Although, under conditions created by selected discharge scenarios, and for discharges from specific pump stations, the illness risks may exceed the thresholds identified in the MfE/MoH (2003) guidelines at specific locations or along drainage channels where sewage accumulates. The risks associated with each pump station are considered separately below.

51. Highest illness risks (>10% GI illness) were associated with shallow depressions that occur where pump stations discharge into the inlet. Undiluted sewage may remain in these depressions for some time after discharge in calm conditions, also affecting channels draining the intertidal flats immediately down-gradient of pump station discharge outfalls. The areal extent and channel length where high illness risks occur are largely affected by tide and wind; ranging from approximately 0-3,000 m at the Saxton pump station, to approximately 0-1,000 m at all other pump stations. High illness risks may extend more than 800 m from the Saxton pump station along the shoreline and affect 500m of the southern shoreline of the Monaco Peninsula. The Songer Street discharge may also affect approximately 500 m of Monaco Peninsula at times.

52. Dr Hudson provided additional clarification of the risks for each pump station under each environmental condition by email on 27 October 2017 (Appendix 1). Because background illness risks have been estimated to be in the 1-5% range for the inlet without discharge events, I have

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[4] Author's own observations based on discussion with Iwi Working Group representatives tasked with engagement on the draft Nelson Plan.

[5] Shellfish gathering (SG) is identified in the NRMP as occurring at 10-40 metres depth in Tasman Bay, and is not an identified value for the inlet. If it is the case that shellfish collection from the inlet is not safe or suitable for human consumption, and coastal water quality is not managed for this purpose, there is a need for public awareness of this issue, potentially through erection of permanent signage to notify the public of the background microbial and on-going contaminant risks of collecting shellfish from the estuary.

only assessed higher levels of illness risk associated with each pump station below. I am unaware of current methods employed by NCC to manage general risks to recreational users of this level of illness risk in the absence of discharge events.

53. Recommended management solutions below are considered only with relevance to illness risk to recreational users, and thus do not combine management of ecological and human health risks.

5.1 Whakatū Pump Station

54. The application and supporting reports note this pump station is the least likely to be subject to overflow events and has considerably lower volumes than the other pump stations if a discharge were to occur (Fluent Solutions 2016). Therefore, the risk of an aberrant discharge is lowest from the Whakatū pump station, although noting that it does not have a wet-weather flow pump like the others. Discharge from this pump station has not occurred in the last ten years. The key issues identified by the QMRA assessment (Hudson and Wadhwa 2017) relate to the pooling of sewage, due to a depression in the intertidal area at the discharge point.

55. The key risk conditions for a potential discharge from the Whakatū pump station occurring are high tide coinciding with either a northerly or southerly wind. The areal extent of discharge risks is not greatly influenced by rainfall.

56. Elevated risks of illness (i.e. >5% GI illness risk) from microbial contaminant discharges from the Whakatū pump station are largely confined to the channel through the intertidal flats and are not generally associated with the shoreline under any conditions.

57. The 'plume' of the discharge does reach the western point of the Monaco Peninsula under high tide and suitable wind conditions approximately 21 hours after a four-hour discharge event. However, the dilutions and associated risk profile at Monaco Peninsula under this scenario are the same as the background risks already present in the inlet, particularly following rainfall.

58. Given the above factors, management of illness risk to recreational users through notification and signage, particularly in the Monaco Peninsula area, is likely to be an effective method to keep recreational users safe in the event of a discharge. The time-series and contour plots provide an excellent template for the spatial extent and duration of any emergency management action to keep the public safe and should be included within any emergency response plan.

59. The potential for risks to remain after 21 hours has not been modelled in the time-series plots and thus remains unknown. Advice on eventual dissipation of the discharge plume under worst-case conditions may be needed to inform the duration of any emergency response.

5.2 Songer Street Pump Station

60. Songer Street pump station is the second smallest discharge in terms of rate and volume, although it is still significantly larger than Whakatū. Johnstone (2017) identifies three discharge events from the Songer Street pump station since upgrades in 2013, although Fluent Solutions (2016) record only one event since 2010. The modelled Songer Street pump station discharge plume extends around the southern shore of Monaco Peninsula, an identified contact recreation area. The proximity of the discharge point to Monaco significantly elevates the potential risk to recreational contact in the event of a discharge.

61. The areal extent of elevated illness risk is associated with wind and high tide conditions. Under high tide conditions with wind, the discharge plume spreads rapidly around Monaco Peninsula (i.e. within 4 hours) and persists for at least 21 hours. The fate of the discharge plume beyond this time has not been modelled.

62. Management of elevated illness risks to recreational users through notification and beach closure is the most effective means to keep recreational users safe from microbial contaminants, although such management will be very visible at this site, due to the proximity to housing and the higher use.

5.3 Airport Pump Station

63. The Airport pump station was determined to have a low risk of overflow due to the additional capacity on site to store sewage for 0.7 hours under wet weather conditions, and 2.7 hours under dry conditions. However, the Airport pump station has the second highest rate and volume of discharge (after Saxton).

64. The areal extent of illness risk (i.e. >5% GI illness risk), elevated above background levels without discharge, is relatively small from the Airport pump station due to the enclosed nature of the embayment at the discharge outfall. Northerly and southerly winds do increase the spatial extent of elevated illness risks under low tide conditions, independent of rainfall.

65. Given the small and isolated nature of the area subject to elevated illness risk, management through closure of the walking/biking track and provision of a detour may be a viable and effective emergency response. The area most affected is the small peninsular to the north-west of the Airport adjacent to Oyster Island.

5.4 Saxton Pump Station

66. According to the application, Saxton pump station has the highest potential discharge volumes and rates, number of historic discharges, highest microbial risk and contaminant footprint.

67. The areal extent of elevated illness risk from a discharge at the Saxton pump station is substantially increased during low tide conditions with wind. Although, under calm conditions, high tides result in larger affected areas. There were only minor differences in areal extent in dry versus wet catchment conditions. Contour plots show that under low tide conditions with wind, the highest illness risk spreads along the shoreline and affects multiple channels in the central area of the inlet. Wet conditions, mean the elevated illness risk area reaches the tip of Monaco Peninsula. A discharge from the Saxton pump station under wet, windy conditions during low tidal stage will affect a large area of the inlet, as well as the area of highest likely recreation use at Monaco Peninsula.

68. Time series plots for Saxton pump station show that under all conditions with a high tidal stage, elevated illness risk profiles disperse initially along the inlet shoreline between 6 and 12 hours following a four-hour discharge event, and then spread extensively along main channels and across intertidal areas from 12 to more than 21 hours after a discharge event. Under low tide conditions, less of the shoreline adjacent to the pump station is affected over these time periods, but there is a greater longitudinal effect of elevated illness risk in channels, extending well into the main egress channel of the inlet, including Monaco Peninsula and beyond, at least 21 hours following a

modelled discharge event. The fate of the discharge plume beyond 21 hours has not been modelled and remains unknown.

69. The composition of the sewage discharged from the Saxton pump station contains large volumes of untreated industrial effluent from Nelson Pine, Alliance meatworks and ENZA, as well as municipal sewage. The analysis of Hudson and Wadhwa (2017) assumed the composition of the sewage was uniform across all pump stations. As this is not the case, I queried Dr Hudson via email as to whether there was any data on relative concentrations of microbial pathogens between the pump stations to test whether this assumption held true. I also asked whether the industrial effluent, particularly from the Alliance meatworks, would be likely to result in an elevated microbial illness risk. Dr Hudson confirmed there were no data available to characterise the relative concentrations of pathogenic organisms across the NRSBU sewer network. He conferred with Dr McBride and responded to my questions on pathogen selection in the QMRA (norovirus) and potential effects of other pathogens from the Alliance waste as follows:

> "*One of the steps in the QMRA process involves selection of pathogens of interest or concern. In general, virus concentrations are much greater than those of bacterial pathogens. Viruses have generally greater infectivity and their sequelae are generally more severe. This makes selection for aberrant discharges justifiable….*
>
> *… virus concentrations are generally greater than other pathogens. In the case of the Alliance discharge, other potentially pathogenic organisms (principally bacteria) are likely to be present at increased concentrations, but overall the greatest infection risk (and most severe infection sequelae) are still likely to be associated with the virus load in untreated sewage*."

70. Dr Hudson's responses provide me with some confidence that although sewage was assumed to be uniform with respect to pathogens across each of the pump stations, the selection of norovirus as the modelled pathogen of interest in the QMRA analysis is still likely to adequately and appropriately describe the illness risk profile for any Saxton pump station discharge.

71. Notwithstanding this, in my opinion the scale of effect (both to recreational users and aquatic fauna) from the Saxton pump station is significantly greater than from the other three pump stations; triggering the need for an elevated level of management intervention to avoid, remedy or mitigate potential illness effects on recreational users.

72. During expert conferencing discussions I asked whether, considering the nature of the waste entering the Saxton pump station from industrial sources, there was potential to withhold industrial waste from the NRSBU network when forecast weather events of a scale likely to result in a discharge were imminent.

73. Mr Butler responded in his letter outlining the further information provided on behalf of the applicant (dated 25 October 2017, updated 31 October 2017). In section 5 of his letter Mr Butler discusses this scenario and states:

> *"For example, the industries produce wastewater broadly as follows[6]:*
>
> *NPI: ~1000 cubic metres per day;*
>
> *ENZA: ~600 cubic metres per day;*
>
> *Alliance ~600 cubic metres per day;"*

74. Mr Butler goes on to note that, based on an event in July 2017, industrial waste volumes may have contributed as little as 5.5% to peak flows through the Saxton pump station. The remainder of the sewage volume being comprised of infiltration and inflow to the sewage network within the NCC and Tasman District Council (TDC) networks. He considers holding back of the industrial waste volumes would do little to alleviate pressures on the NRSBU network and Saxton pump station. While this assumption may hold true with respect to hydraulic load, it does not address my concerns with respect to microbial or contaminant concentrations and loads from these industrial contributors to the Saxton discharge.

75. According to the NRSBU contributors contingency contract report by NELMAC (2017), provided in the further information bundle, ENZA have the storage capacity to withhold discharge to the Saxton pump station for eight hours. Alliance meatworks are able to lower their storage tanks when a rain event is forecast, however this provides limited capacity (~2 hours) for cessation of discharge into the NRSBU system. Production would need to cease to stop the inflow of waste. Nelson Pine Industries have up to 8 hours of dry weather flow capacity in a stormwater pond, although this capacity may be reduced if it has been raining previously.

76. Capacity for large industrial dischargers to hold back effluent from the reticulated sewage system could be further investigated to reduce the risks of significant adverse effects occurring from high contaminants loads in overflows from the Saxton pump station.

77. Further, consideration and resourcing of programmes to reduce inflow and infiltration within the NCC and TDC sewer networks will contribute to alleviating pressures on the pump stations and reducing the background microbial risk in the inlet associated with the discharge of sewage via streams and stormwater outfalls following high rainfall. This is identified in the report by Fluent Solutions (2016).

[6] Although the NRSBU contributors contingency report by NELMAC (2017) identifies that each contributor can produce in excess of 1000 cubic metres per day.

6 Monitoring Recommendations

78. Faecal indicator bacteria (FIB) monitoring is recommended in relation to future discharges from the pump stations. FIB samples collected following a discharge event should be used to validate the spatial and temporal extent of microbial illness risk to recreational users, depending on the environmental conditions at the time of discharge, and to inform and update emergency management responses to exclude recreational users from areas of risk.

79. Monitoring is also recommended at the modelled spatial and temporal extent of discharge plumes to validate the dilution contours for BOD_5, ammoniacal-nitrogen, nitrate and other contaminants of interest with respect to acute toxicity or potential for fish avoidance effects. Dissolved oxygen monitoring should also be undertaken in the water column at these locations following a discharge event from either the Songer Street or Saxton pump stations.

80. Alternatively, whole effluent testing recommended by Dr Phillips could be undertaken in a manner which also considers potential impacts on freshwater fish at the appropriate life-stage relevant to movement/migration through the inlet.

7 Summary

81. A consent application is being considered for un-treated wastewater discharge from four pump stations to the Waimeha Inlet. Based on hydrodynamic modelling of the inlet under various environmental conditions, aberrant discharges from each pump station have been assessed for their potential effects on water quality and microbial illness risks to recreational users.

82. The proximity of the discharge points to the mouths of streams flowing into the inlet mean there is potential for effects on freshwater migratory fish, should discharges occur while fish or their larvae are moving through the inlet. Potential effects relate largely to elevated loads of BOD_5 in the Saxton and Songer Street discharges and subsequent acute effects on dissolved oxygen, and the potential for any toxicity or avoidance effects resulting from low dissolved oxygen or elevated nitrate and ammonia in the Saxton discharge.

83. The Saxton pump station discharge is high-risk in terms of potential freshwater ecological and microbial illness risk effects. Saxton pump station has the greatest rate and volume of discharge, frequency of discharge events, highest contaminant loads and greatest spatial extent, including intertidal areas, inlet channels and the shoreline of the Inlet and Monaco Peninsula under certain conditions.

84. Given the nature of the untreated industrial waste entering the Saxton pump station, and the potential for high impact effects such as reductions in dissolved oxygen from high BOD loads and potentially toxic nitrogenous contaminants (e.g. nitrate and ammonia), there is potential for significant effects on aquatic life in the inter-tidal zone and inlet channels at a large distance from the outfall. These effects may impact on freshwater species utilising the estuary at various life-stages, including īnanga spawning and sensitive larval and juvenile stages of galaxiid/whitebait and other native fish species.

85. Background illness risks have been estimated to be in the 1-5% range for the inlet without discharge events. For most discharge scenarios for all pump stations under all wind and stream flow conditions, the microbiological illness risks associated with pump station discharges are generally likely to be less than 1% (the No Observable Adverse Effects Level, NOAEL) across most of the inlet. Although, under conditions created by selected discharge scenarios, and for discharges from specific pump stations, the illness risks may exceed the thresholds identified in the MfE/MoH (2003) guidelines at specific locations or along drainage channels where sewage accumulates.

86. Highest illness risks (>10% GI illness) were associated with shallow depressions that occur where pump stations discharge into the inlet. Undiluted sewage may remain in these depressions for some time after discharge in calm conditions, also affecting channels draining the intertidal flats immediately down-gradient of pump station discharge outfalls. The areal extent and channel length where high illness risks occur are largely affected by tide and wind; ranging from approximately 0-3,000 m at the Saxton pump station, to approximately 0-1,000 m at all other pump stations. High illness risks may extend more than 800 m from the Saxton pump station along the shoreline and affect 500m of the southern shoreline of the Monaco Peninsula. The Songer Street discharge may also affect approximately an area 500 m from the discharge point at times, including Monaco.

87. In general, the most effective means of managing the potential illness risks to recreational users of the inlet are public notification, signage and beach closure. Emergency management plans should be amended to reflect the temporal and spatial extent of elevated illness risks as modelled for various environmental conditions. With respect to a discharge from the Saxton (or in some conditions Songer Street) pump station, closure of the inlet to recreational users may need to be widespread spatially, and cover a duration of greater than 21 hours.

88. Monitoring of FIB following discharge events is recommended to validate the illness risk profiles. Ideally, this would be combined and compared with year-round monthly FIB monitoring of the background level of microbial contaminants at representative sites within the inlet as part of coastal monitoring undertaken by NCC.

89. Potential effects on contact recreation at Monaco Peninsula require careful consideration and emergency management, in addition to risks to recreational users of the wider inlet. Monaco is a highly visible area and is subject to the greatest recreational use, based on limited survey data.

90. Background microbial illness risk within the inlet (without aberrant sewerage discharges), and the potential for shellfish gathering and subsequent effects on human health also require consideration, although the latter remains largely unknown.

8 Author's Experience and Expertise

91. My name is Kathryn (Kate) McArthur and I am a consultant freshwater ecologist and water quality specialist residing in Palmerston North. I have been contracted by Nelson City Council (NCC) to provide advice within these expert areas on the potential effects of consent application RM165144.

92. I hold a Bachelor of Science with Honours in Ecology and a Master of Applied Science with Honours in Natural Resource Management, both from Massey University. My areas of post-graduate research included the influence of land use on freshwater macroinvertebrate communities and the interaction between policy and science for improved water resource management, with a focus on water quality objectives and limits. I have 16-years post-graduate experience in water resource management, and I joined The Catalyst Group (an environmental consultancy based in Palmerston North) as the Practice Leader - Water in 2012.

93. Before joining The Catalyst Group, I held the role of Senior Scientist – Water Quality with Horizons Regional Council (Horizons). Over 6 years with Horizons I coordinated the State of the Environment (SOE), periphyton and discharge monitoring programmes for water quality and aquatic biodiversity, produced expert evidence for many resource consent hearings and enforcement actions (relating mainly to takes of, and discharges to, water). During my work on Horizons' combined Regional Policy Statement, Coastal and Regional Plan (the One Plan) I led the identification of Sites of Significance – Aquatic work, completed the framework of water management zones for the region, reviewed and refined the river, lake and coastal water quality targets, and project managed water quality evidence for the One Plan hearings and Environment Court proceedings.

94. I have authored and co-authored a range of reports and publications, including authoring and co-authoring papers in peer-reviewed journals on topics such as: the relationship between flow and nutrients in rivers; nutrient limitation; methods for monitoring native fish; the calculation of in-river nutrient loads and limits, and the setting of water quality objectives and limits in resource management policy. I have provided evidence in these areas before the Environment Court, and in Board of Inquiry and Independent Hearing Panel processes.

95. Most recently, I have provided ecological, water quality and water policy advice to NCC, Nelson Airport Limited, Northland Regional Council, Ngāti Kahungunu Iwi Incorporated, Hawkes Bay Regional Council, the national Iwi Leaders Group, the Department of Conservation and the Ministry for the Environment. I provided expert evidence for the Foxton wastewater treatment plant discharge by Horowhenua District Council to the Foxton Loop, connected with the Manawatū Estuary and Ramsar listed estuarine wetland.

96. I am a member of the National Objectives Framework reference group for the National Policy Statement for Freshwater Management amendments, and I am assisting a collaborative biodiversity group on the drafting of a national policy statement on indigenous biodiversity.

97. I have been a member of the New Zealand Freshwater Sciences Society (NZFSS) since 2001 and I am currently elected onto the Society's executive committee. I have been a member of the Resource Management Law Association of New Zealand (RMLA) for seven years, and was the RMLA scholarship recipient in 2010 for my work on water quality limits for the Manawatū River. I am a guest lecturer in environmental planning and science at Massey University and an accredited and experienced RMA hearings commissioner.

98. While this is not a hearing before the Environment Court, I confirm that I have read the code of conduct for expert witnesses contained in the Environment Court Consolidated Practice Note (2014). I have complied with it when preparing this written statement and I agree to comply with it at the hearing. I confirm that the assessment and the opinions I have expressed in this memorandum are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

99. As member of a constituent body (NZFSS) of the Royal Society of New Zealand (NZFSS) I also have a duty to uphold the Society's Code of Professional Standards and Ethics[7].

9 References

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[7] https://royalsociety.org.nz/who-we-are/our-rules-and-codes/code-of-professional-standards-and-ethics/royal-society-of-new-zealand-code-of-professional-standards-and-ethics-in-science-technology-and-the-humanities/

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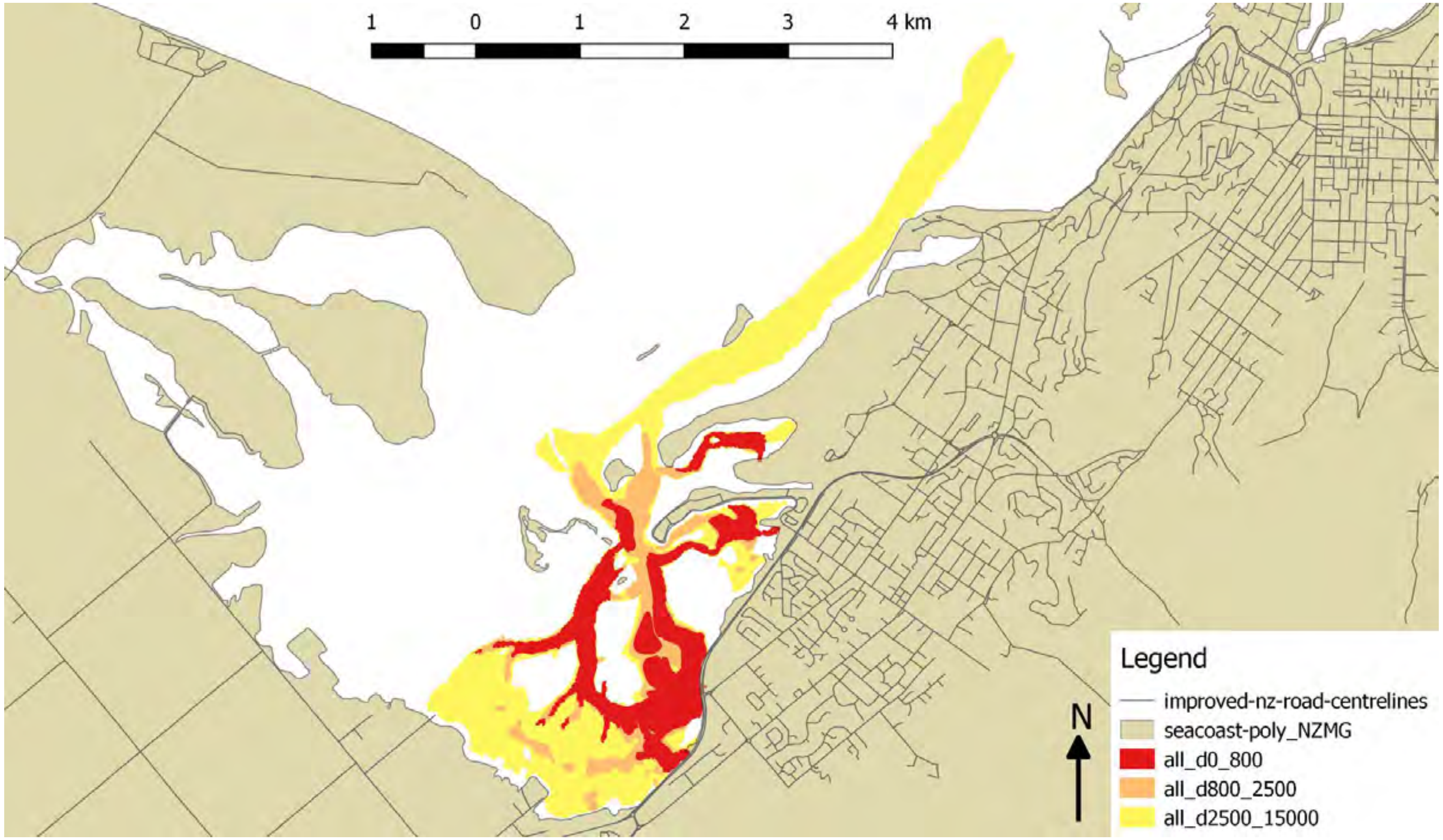
Appendix 1: Information provided by Dr Hudson in response to emailed questions, 27 October 2017



Extent of areas predicted to be impacted by aberrant discharges for all model scenarios. Note that the extent of each risk zone is the combined area for all four pump stations under all scenario conditions, i.e. it is a worst-case situation that can never be achieved (e.g. wind conditions cannot be calm, from the south and from the north simultaneously). Refer to the figures and tables that follow to obtain an estimate of the areal extent and length of perimeter for each risk level for each pump station and each scenario.

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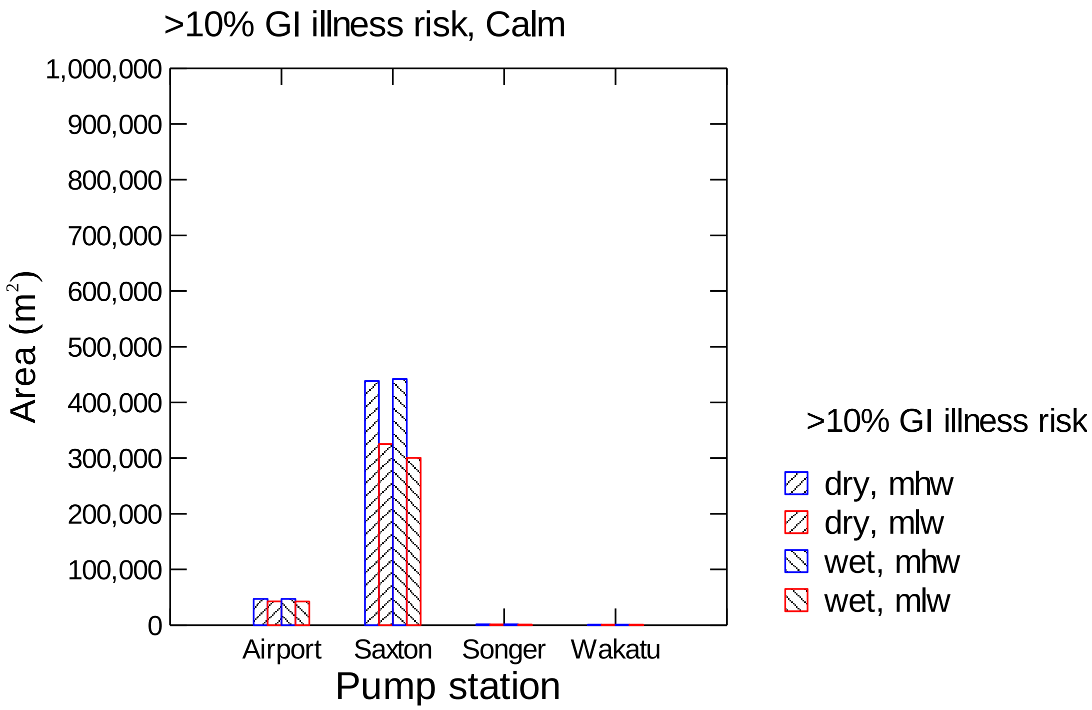
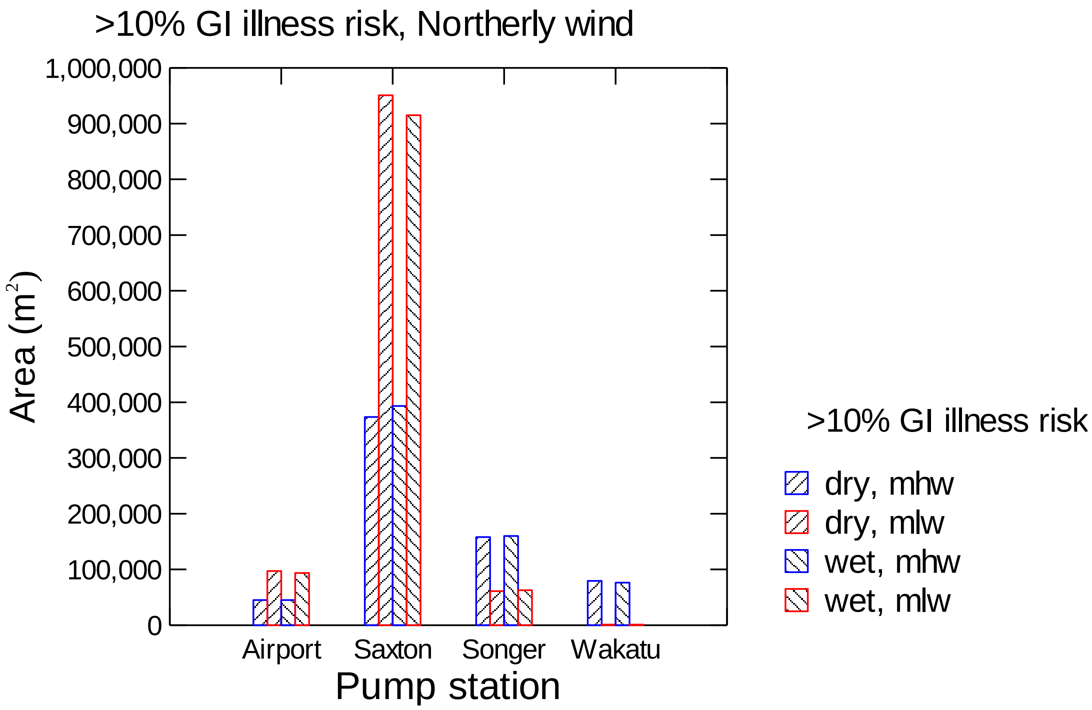
Appendix 2: Caucusing clarifications document (provided by email from Dr Hudson, 27 October 2017)





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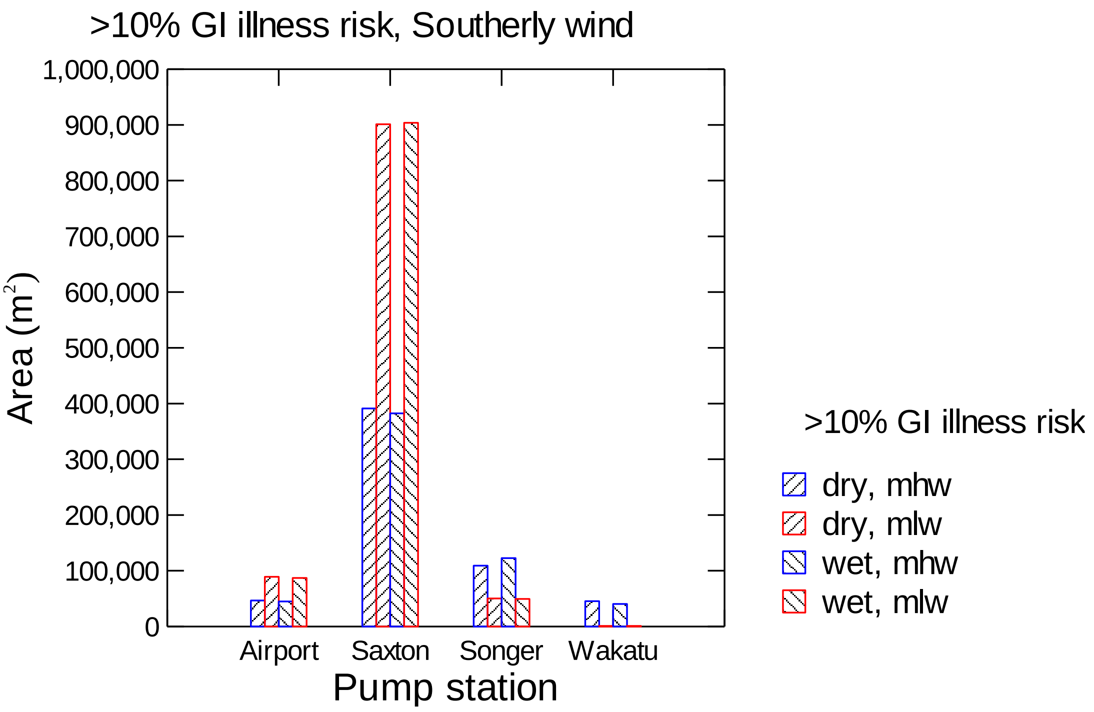

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800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Area (m^2)
Airport
Saxton
Songer
Wakatu
Pump station
>10% GI illness risk
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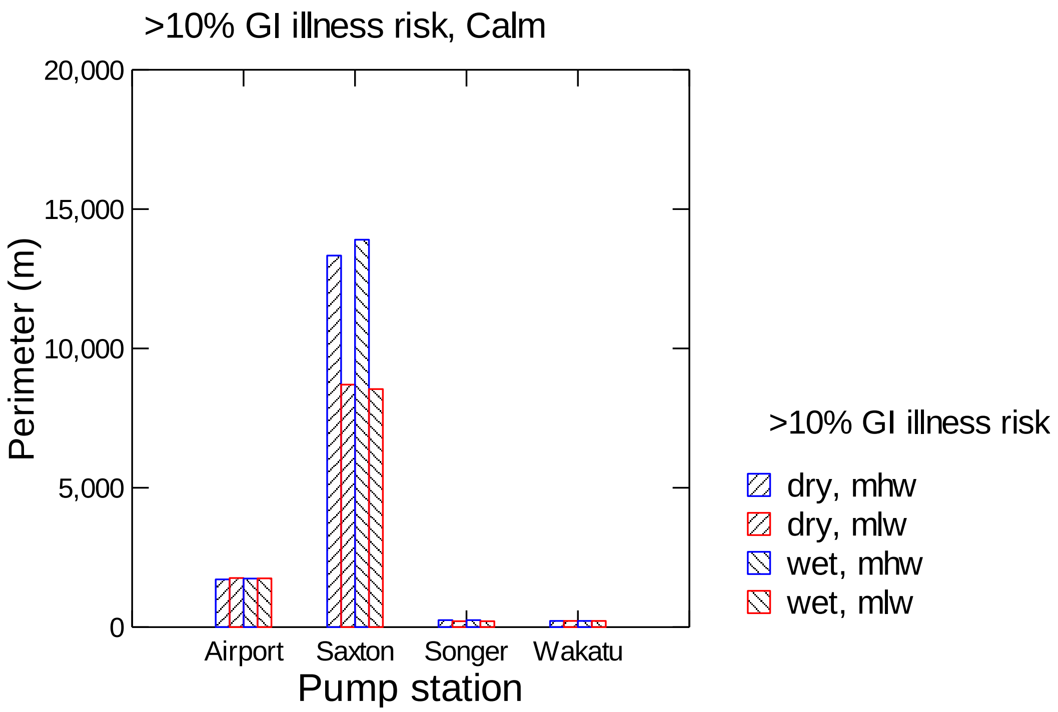
dry, mlw
wet, mhw
wet, mlw



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10,000
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Perimeter (m)
Airport
Saxton
Songer
Wakatu
Pump station
>10% GI illness risk
dry, mhw
dry, mlw
wet, mhw
wet, mlw

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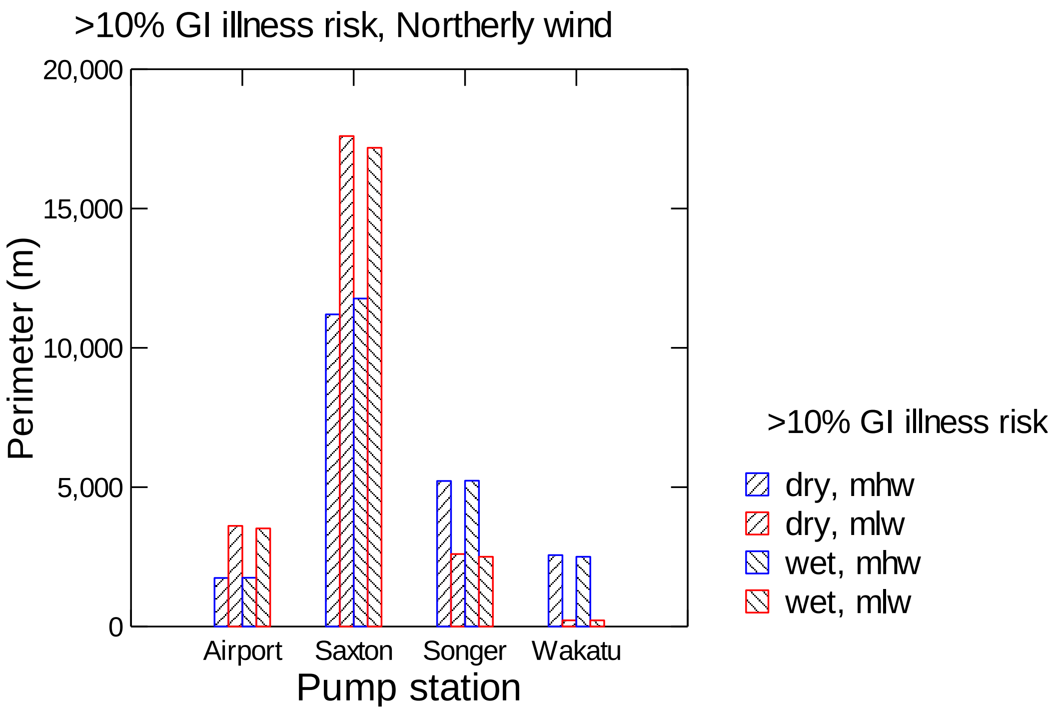

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Perimeter (m)
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Songer
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Pump station
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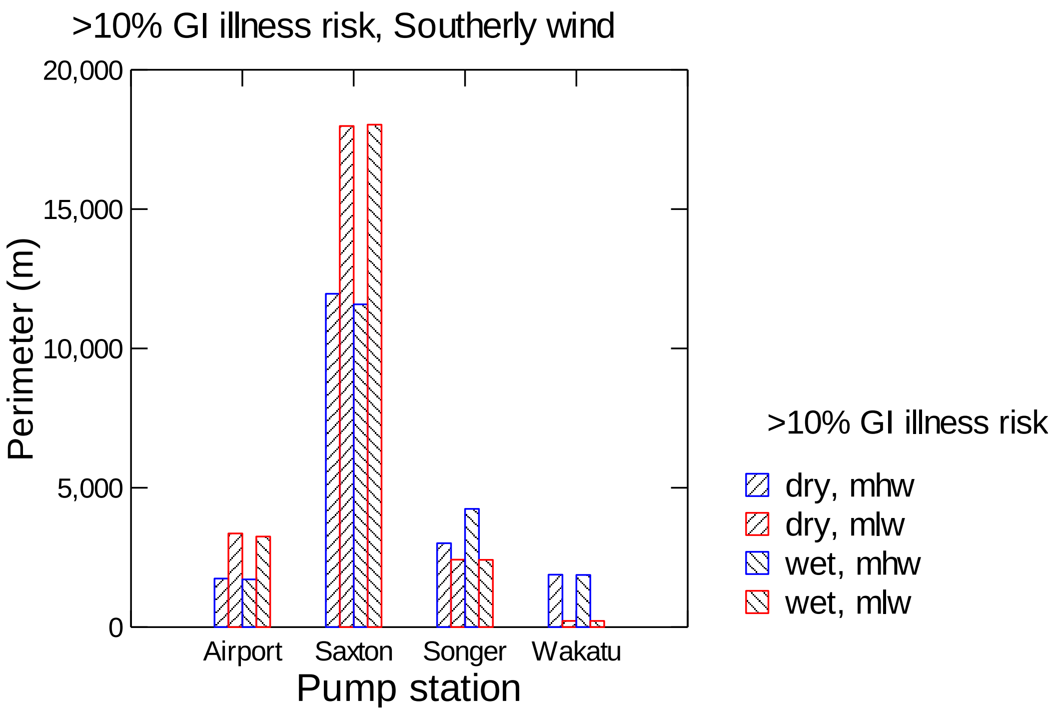
dry, mlw
wet, mhw
wet, mlw



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Perimeter (m)
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Pump station
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dry, mlw
wet, mhw
wet, mlw

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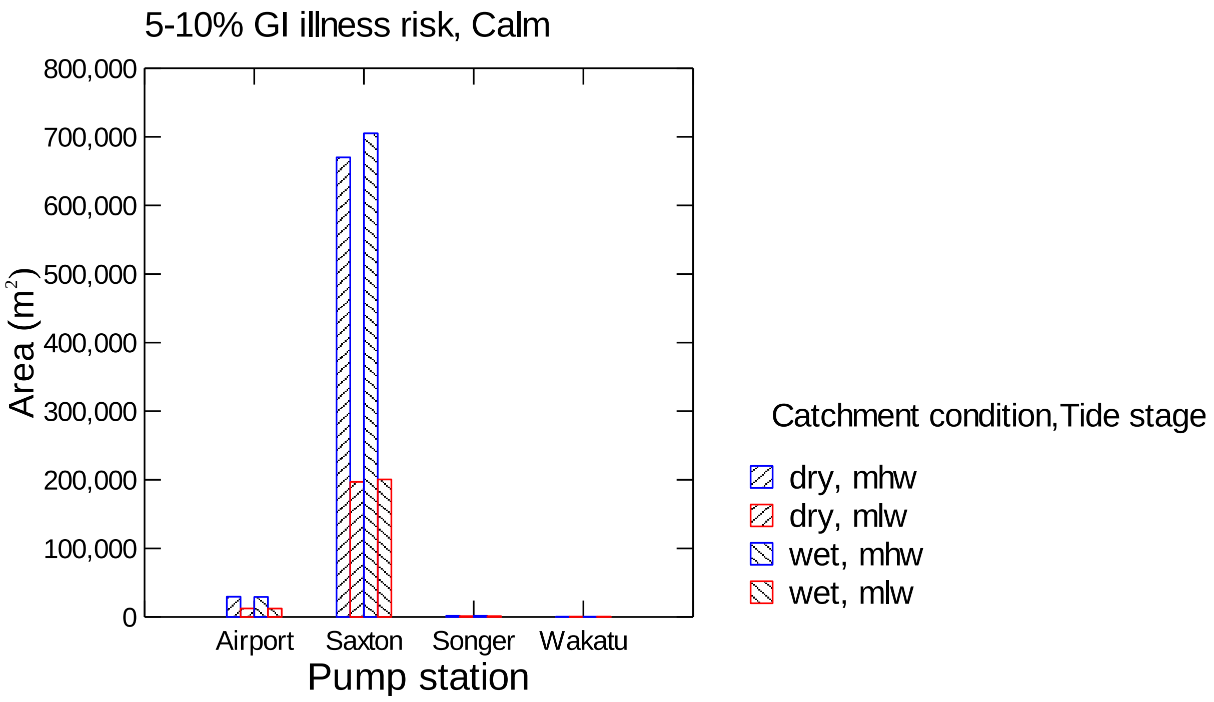
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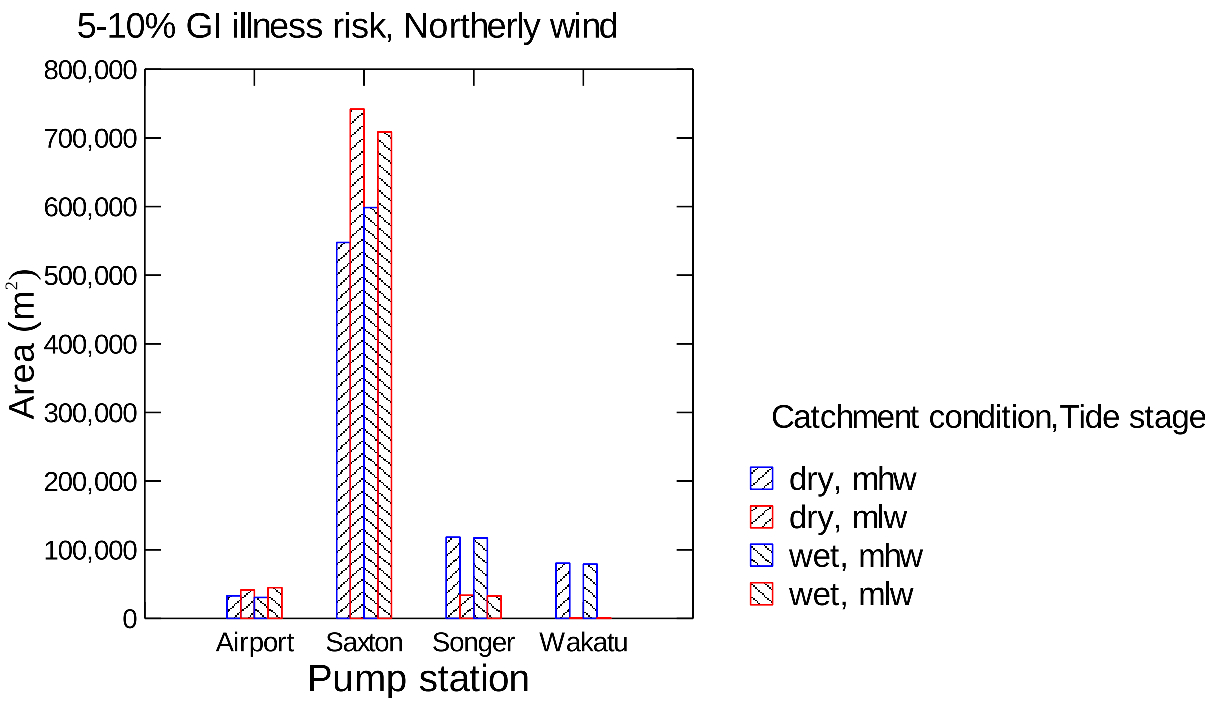
100,000
0
Area (m²)
Airport
Saxton
Songer
Wakatu
Pump station
Catchment condition,Tide stage
dry, mhw
dry, mlw
wet, mhw
wet, mlw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Airport
Saxton
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Pump station
Catchment condition,Tide stage
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dry, mlw
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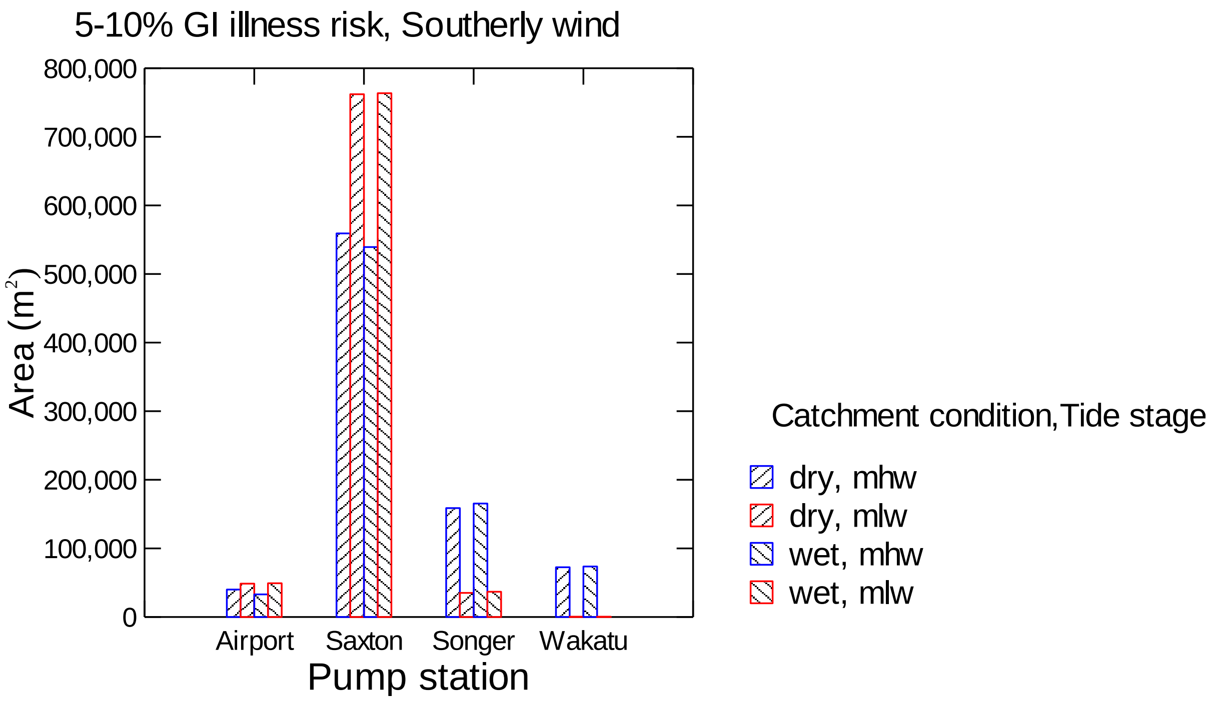

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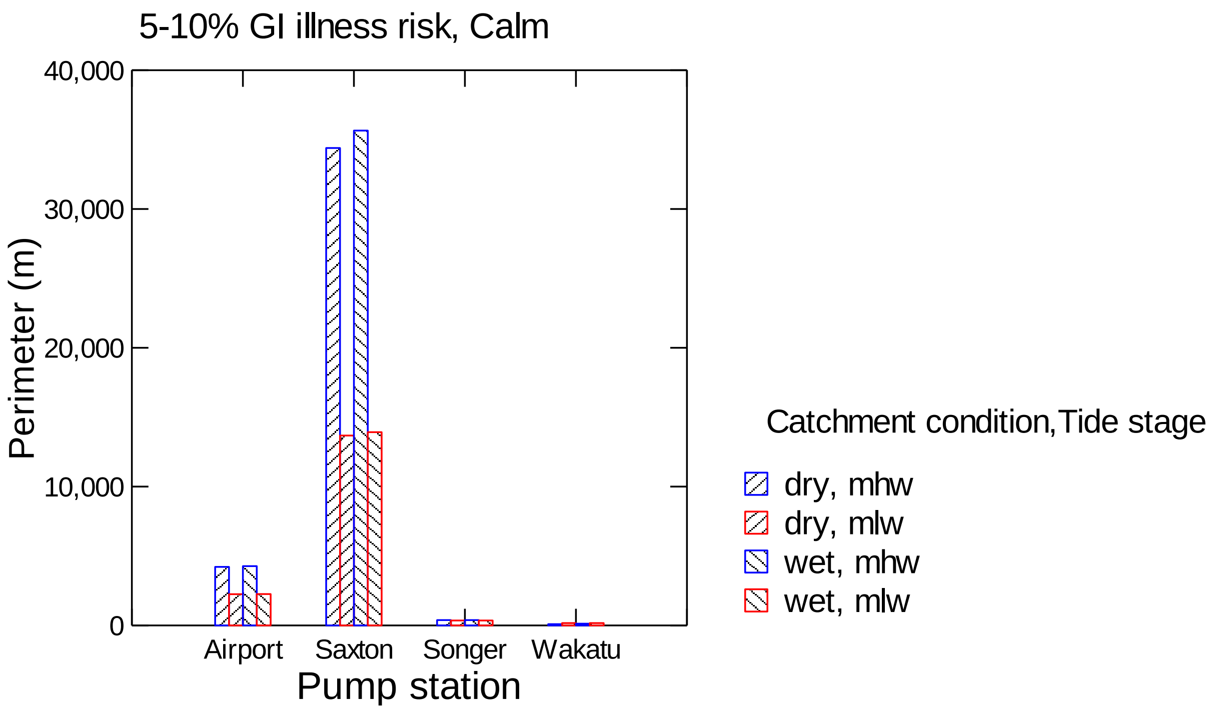

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Pump station
Catchment condition,Tide stage
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dry, mlw
wet, mhw
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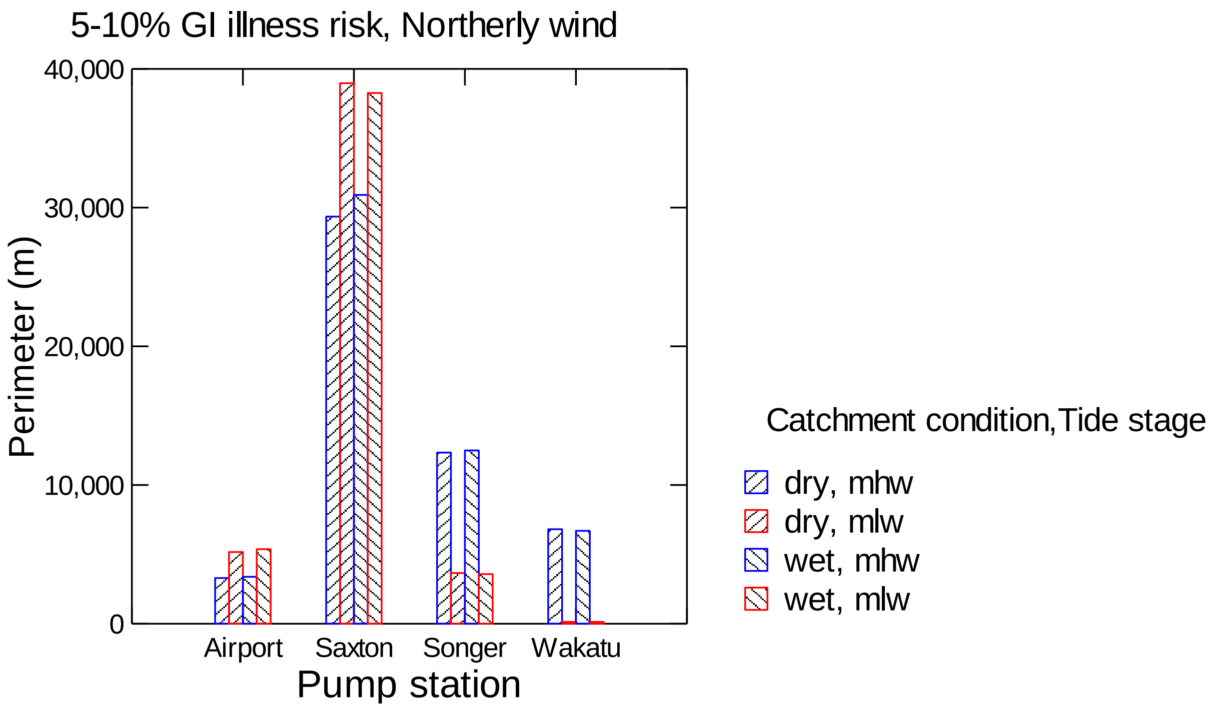
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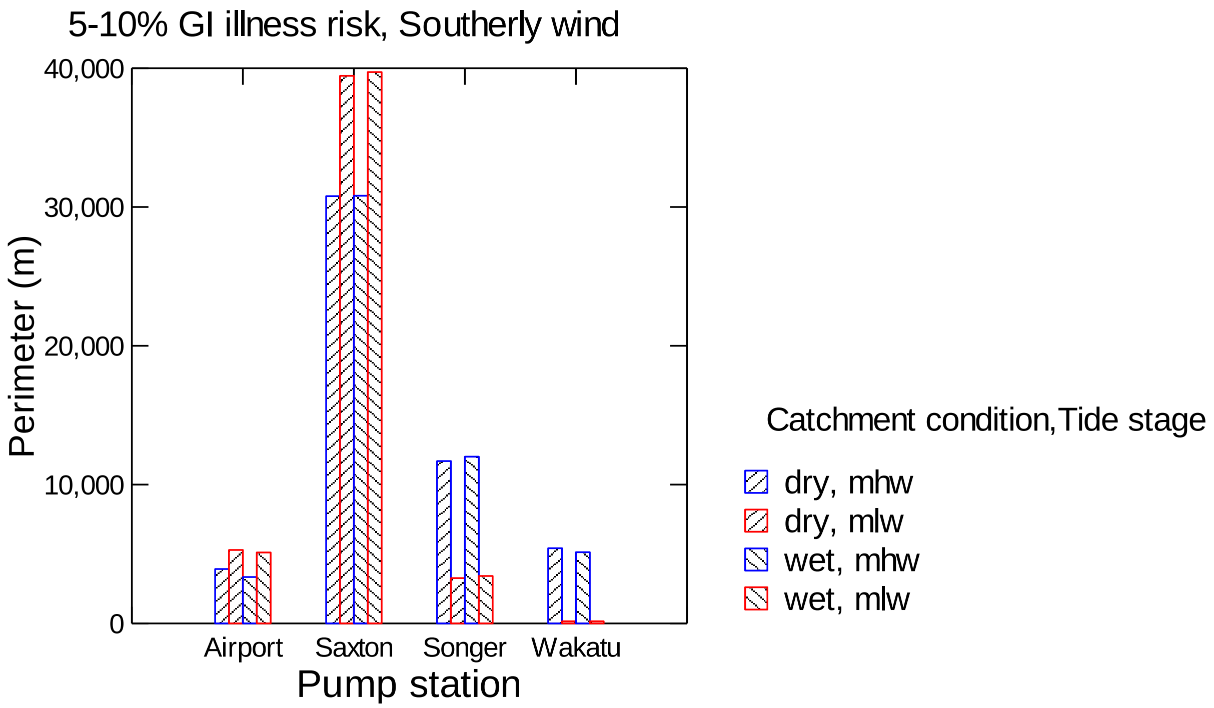
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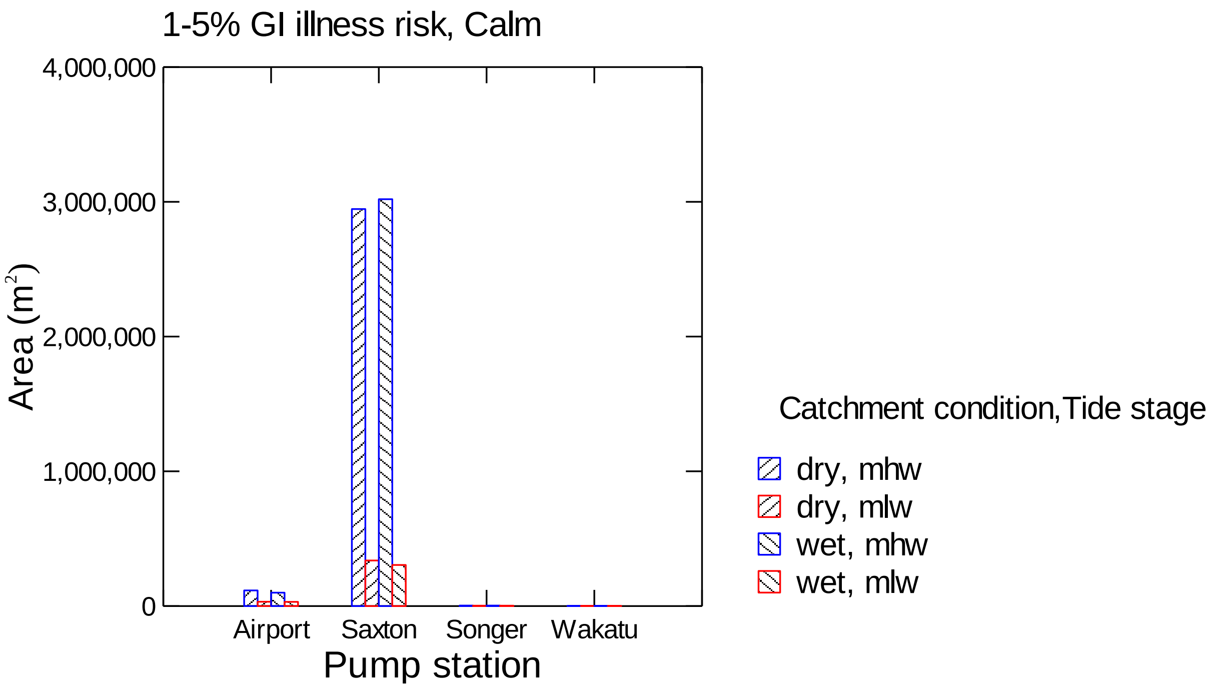
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Area (m2)
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Pump station
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dry, mlw
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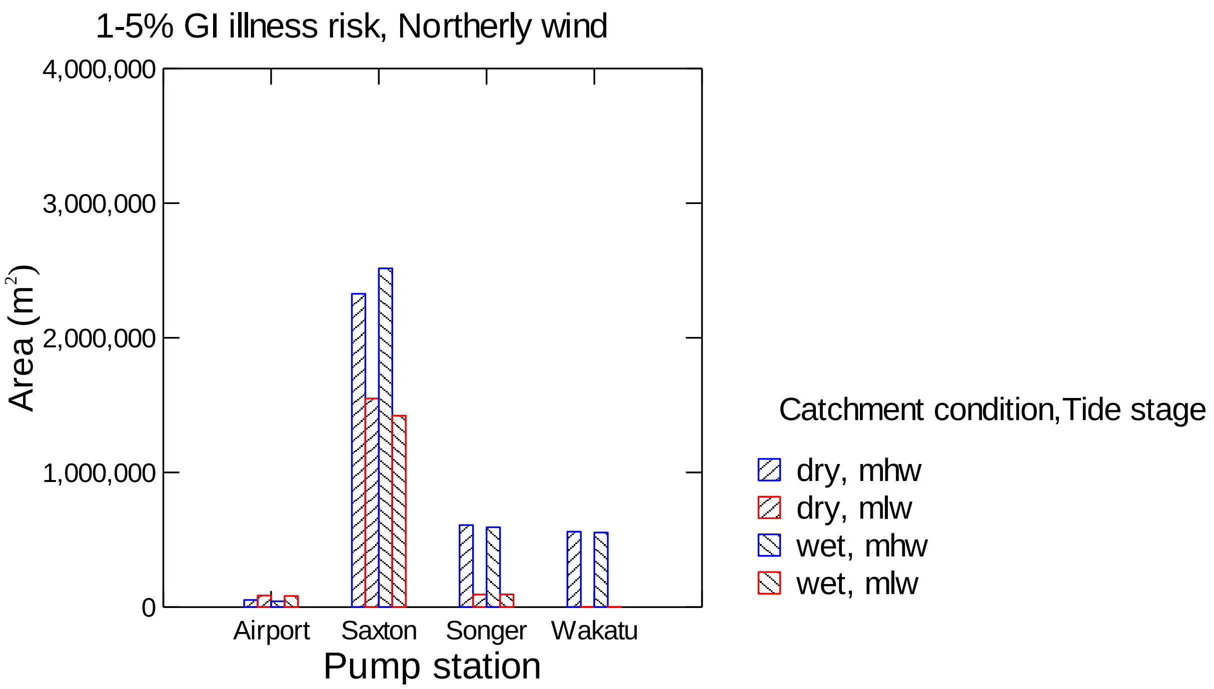
wet, mlw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Area (m2)
Airport
Saxton
Songer
Wakatu
Pump station
Catchment condition,Tide stage
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dry, mlw
wet, mhw
wet, mlw

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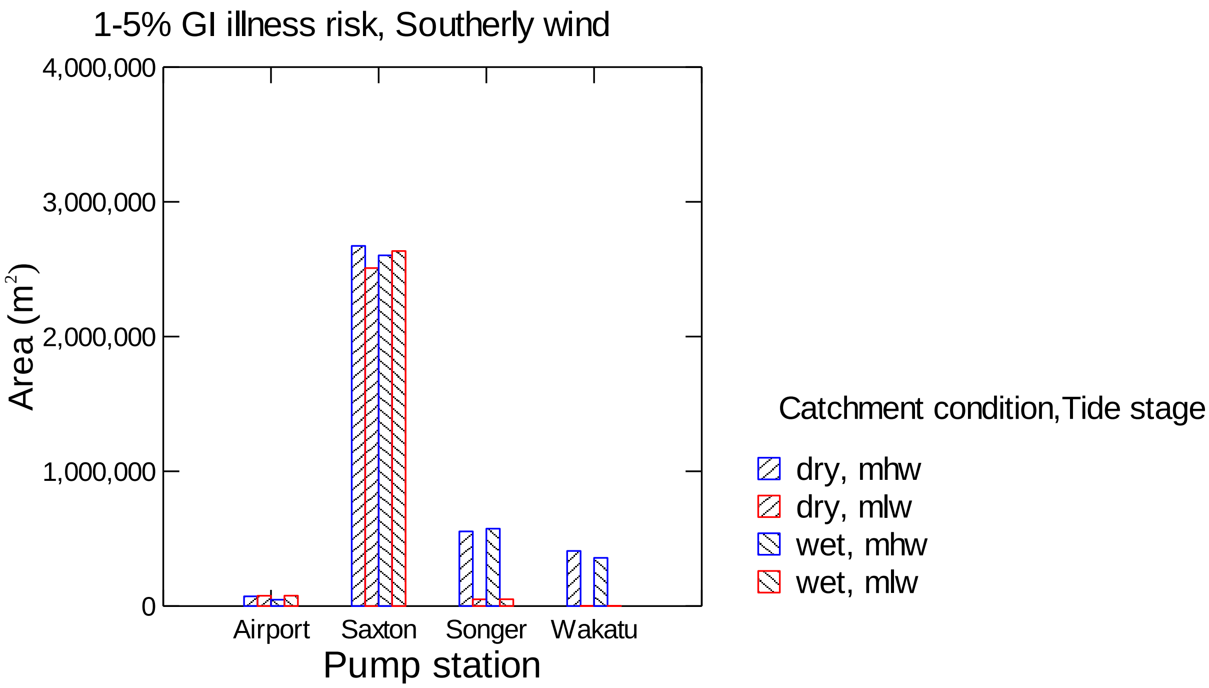
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0
Area (m²)
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Saxton
Songer
Wakatu
Pump station
Catchment condition,Tide stage
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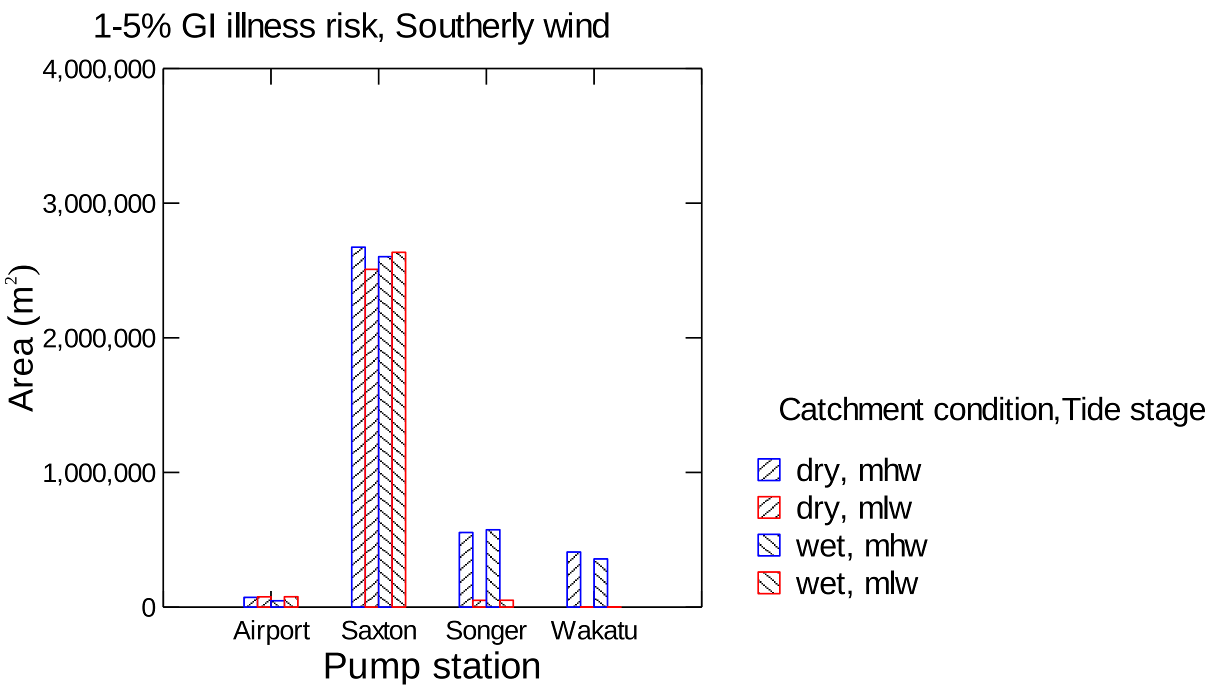
dry, mlw
wet, mhw
wet, mlw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Area (m²)
Airport
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Wakatu
Pump station
Catchment condition,Tide stage
dry, mhw
dry, mlw
wet, mhw
wet, mlw

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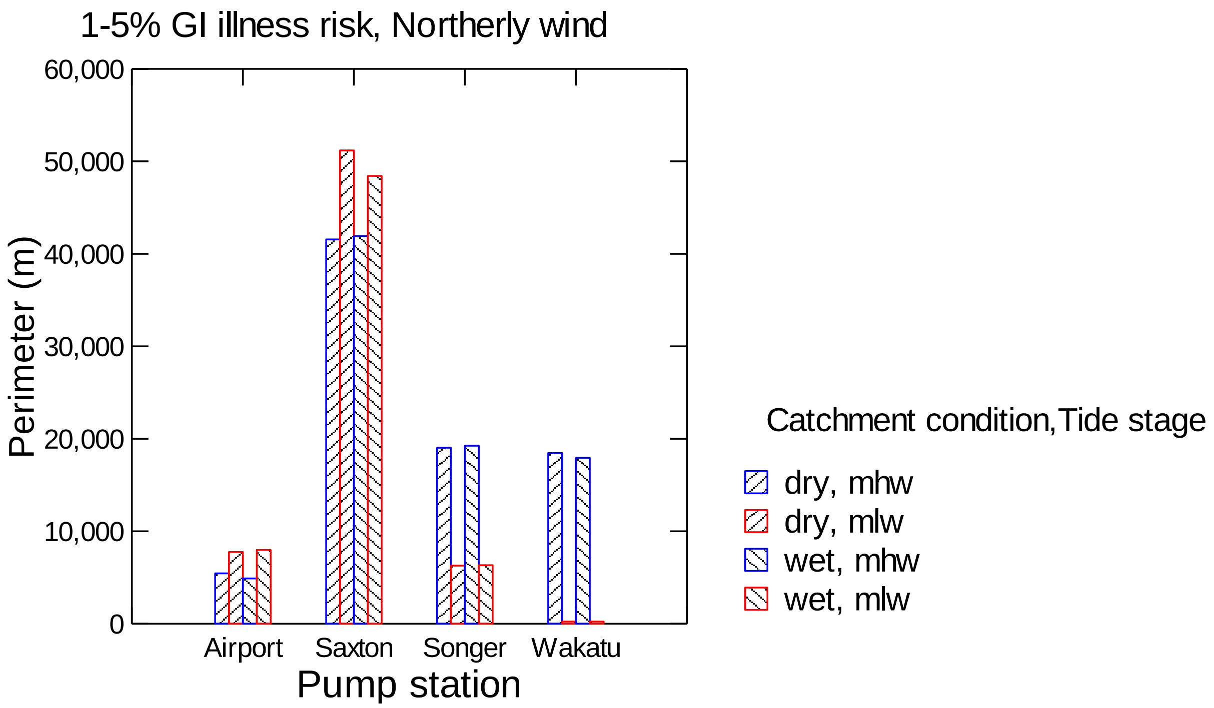
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Perimeter (m)
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30,000
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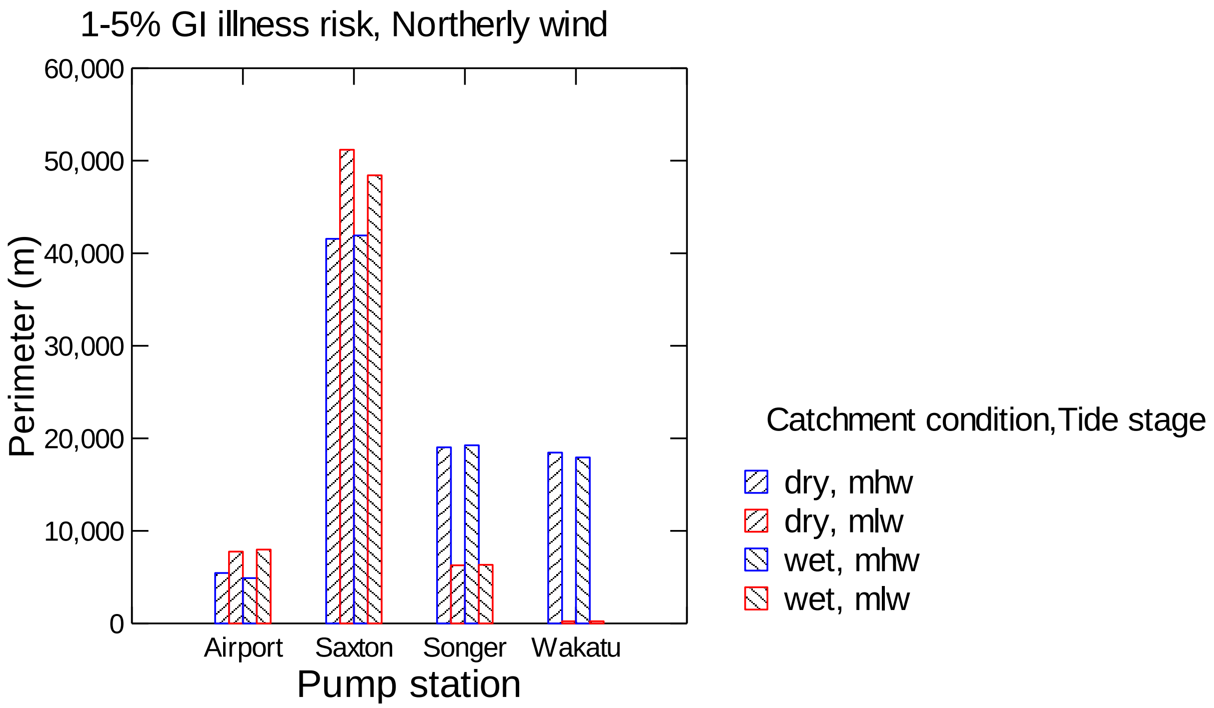
10,000
0
Airport
Saxton
Songer
Wakatu
Pump station
Catchment condition,Tide stage
dry, mhw
dry, mlw
wet, mhw
wet, mlw


1-5% GI illness risk, Northerly wind
Perimeter (m)
60,000
50,000
40,000
30,000
20,000
10,000
0
Airport
Saxton
Songer
Wakatu
Pump station
Catchment condition,Tide stage
dry, mhw
dry, mlw
wet, mhw
wet, mlw

.

Extent of impact of aberrant discharges expressed in terms of perimeter and area of contours defined by human health risk. "Catchment" indicates state of catchment (wet or dry), "mhw" and "mlw" indicate tidal stage at time of discharge (mean high water and mean low water respectively), and S, N and C represent southerly, northerly and calm wind conditions at time of discharge.

Model output arranged in terms of "Pump station", "Illness risk" and "Length". These results represent the total length and total area of impact over the 11 hour to 21 hour period of simulation. (10,000 m^2 = 1 ha, and 1,000,000 m^2 = 100 ha = 1 km^2).

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Airport	>10% GI	wet	mhw	S	d0-800	1710	44900
Airport	>10% GI	dry	mhw	C	d0-800	1710	47175
Airport	>10% GI	dry	mhw	N	d0-800	1740	45000
Airport	>10% GI	dry	mhw	S	d0-800	1740	46600
Airport	>10% GI	wet	mhw	C	d0-800	1740	47150
Airport	>10% GI	wet	mhw	N	d0-800	1750	44975
Airport	>10% GI	wet	mlw	C	d0-800	1750	42425
Airport	>10% GI	dry	mlw	C	d0-800	1760	42600
Airport	>10% GI	wet	mlw	S	d0-800	3250	87025
Airport	>10% GI	dry	mlw	S	d0-800	3360	89200
Airport	>10% GI	wet	mlw	N	d0-800	3520	93725
Airport	>10% GI	dry	mlw	N	d0-800	3610	97075
Airport	5-10% GI	dry	mlw	C	d800-2500	2250	12375
Airport	5-10% GI	wet	mlw	C	d800-2500	2250	12325
Airport	5-10% GI	dry	mhw	N	d800-2500	3290	32800
Airport	5-10% GI	wet	mhw	S	d800-2500	3340	32900
Airport	5-10% GI	wet	mhw	N	d800-2500	3380	30475
Airport	5-10% GI	dry	mhw	S	d800-2500	3910	39925
Airport	5-10% GI	dry	mhw	C	d800-2500	4210	29475
Airport	5-10% GI	wet	mhw	C	d800-2500	4270	29050
Airport	5-10% GI	wet	mlw	S	d800-2500	5110	49125
Airport	5-10% GI	dry	mlw	N	d800-2500	5160	41200
Airport	5-10% GI	dry	mlw	S	d800-2500	5290	48525

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Airport	5-10% GI	wet	mlw	N	d800-2500	5370	44825
Airport	1-5% GI	wet	mlw	C	d2500-15000	3600	30925
Airport	1-5% GI	dry	mlw	C	d2500-15000	3630	31275
Airport	1-5% GI	wet	mhw	N	d2500-15000	4890	43000
Airport	1-5% GI	wet	mhw	S	d2500-15000	5230	46600
Airport	1-5% GI	dry	mhw	N	d2500-15000	5440	52300
Airport	1-5% GI	dry	mhw	S	d2500-15000	6190	71550
Airport	1-5% GI	wet	mhw	C	d2500-15000	7260	99050
Airport	1-5% GI	dry	mhw	C	d2500-15000	7610	115950
Airport	1-5% GI	wet	mlw	S	d2500-15000	7700	76675
Airport	1-5% GI	dry	mlw	N	d2500-15000	7760	85825
Airport	1-5% GI	dry	mlw	S	d2500-15000	7780	75900
Airport	1-5% GI	wet	mlw	N	d2500-15000	7970	82425
Songer	>10% GI	dry	mlw	C	d0-800	210	1225
Songer	>10% GI	wet	mlw	C	d0-800	210	1200
Songer	>10% GI	dry	mhw	C	d0-800	250	1525
Songer	>10% GI	wet	mhw	C	d0-800	250	1525
Songer	>10% GI	wet	mlw	S	d0-800	2410	49450
Songer	>10% GI	dry	mlw	S	d0-800	2420	50300
Songer	>10% GI	wet	mlw	N	d0-800	2500	62700
Songer	>10% GI	dry	mlw	N	d0-800	2600	60950
Songer	>10% GI	dry	mhw	S	d0-800	3010	109125
Songer	>10% GI	wet	mhw	S	d0-800	4240	122725
Songer	>10% GI	dry	mhw	N	d0-800	5220	158000
Songer	>10% GI	wet	mhw	N	d0-800	5230	159950
Songer	5-10% GI	dry	mlw	C	d800-2500	350	1150
Songer	5-10% GI	wet	mlw	C	d800-2500	350	1200
Songer	5-10% GI	dry	mhw	C	d800-2500	380	1625
Songer	5-10% GI	wet	mhw	C	d800-2500	380	1650

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Songer	5-10% GI	dry	mlw	S	d800-2500	3260	35125
Songer	5-10% GI	wet	mlw	S	d800-2500	3410	36775
Songer	5-10% GI	wet	mlw	N	d800-2500	3570	32600
Songer	5-10% GI	dry	mlw	N	d800-2500	3650	33675
Songer	5-10% GI	dry	mhw	S	d800-2500	11690	158700
Songer	5-10% GI	wet	mhw	S	d800-2500	12010	165350
Songer	5-10% GI	dry	mhw	N	d800-2500	12340	118300
Songer	5-10% GI	wet	mhw	N	d800-2500	12490	117050
Songer	1-5% GI	dry	mhw	C	d2500-15000	460	3225
Songer	1-5% GI	dry	mlw	C	d2500-15000	470	2550
Songer	1-5% GI	wet	mhw	C	d2500-15000	470	3200
Songer	1-5% GI	wet	mlw	C	d2500-15000	490	2475
Songer	1-5% GI	dry	mlw	S	d2500-15000	3980	49675
Songer	1-5% GI	wet	mlw	S	d2500-15000	4010	50500
Songer	1-5% GI	dry	mlw	N	d2500-15000	6280	93250
Songer	1-5% GI	wet	mlw	N	d2500-15000	6330	94300
Songer	1-5% GI	wet	mhw	S	d2500-15000	18760	573750
Songer	1-5% GI	dry	mhw	S	d2500-15000	18880	553525
Songer	1-5% GI	dry	mhw	N	d2500-15000	19030	608825
Songer	1-5% GI	wet	mhw	N	d2500-15000	19250	592725
Saxton	>10% GI	wet	mlw	C	d0-800	8540	300375
Saxton	>10% GI	dry	mlw	C	d0-800	8700	325275
Saxton	>10% GI	dry	mhw	N	d0-800	11200	373525
Saxton	>10% GI	wet	mhw	S	d0-800	11580	382400
Saxton	>10% GI	wet	mhw	N	d0-800	11770	393275
Saxton	>10% GI	dry	mhw	S	d0-800	11960	391300
Saxton	>10% GI	dry	mhw	C	d0-800	13330	438525
Saxton	>10% GI	wet	mhw	C	d0-800	13900	441950
Saxton	>10% GI	wet	mlw	N	d0-800	17180	915000
Saxton	>10% GI	dry	mlw	N	d0-800	17600	950700

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Saxton	>10% GI	dry	mlw	S	d0-800	17980	901200
Saxton	>10% GI	wet	mlw	S	d0-800	18030	903700
Saxton	5-10% GI	dry	mlw	C	d800-2500	13680	196900
Saxton	5-10% GI	wet	mlw	C	d800-2500	13920	200550
Saxton	5-10% GI	dry	mhw	N	d800-2500	29350	547575
Saxton	5-10% GI	dry	mhw	S	d800-2500	30780	559075
Saxton	5-10% GI	wet	mhw	S	d800-2500	30810	539250
Saxton	5-10% GI	wet	mhw	N	d800-2500	30910	598575
Saxton	5-10% GI	dry	mhw	C	d800-2500	34390	669875
Saxton	5-10% GI	wet	mhw	C	d800-2500	35650	705050
Saxton	5-10% GI	wet	mlw	N	d800-2500	38260	708525
Saxton	5-10% GI	dry	mlw	N	d800-2500	38970	741875
Saxton	5-10% GI	dry	mlw	S	d800-2500	39450	762025
Saxton	5-10% GI	wet	mlw	S	d800-2500	39720	763500
Saxton	1-5% GI	wet	mlw	C	d2500-15000	16610	304750
Saxton	1-5% GI	dry	mlw	C	d2500-15000	18210	337750
Saxton	1-5% GI	wet	mhw	C	d2500-15000	40750	3018925
Saxton	1-5% GI	dry	mhw	N	d2500-15000	41560	2326450
Saxton	1-5% GI	wet	mhw	N	d2500-15000	41920	2515600
Saxton	1-5% GI	dry	mhw	C	d2500-15000	44070	2946400
Saxton	1-5% GI	wet	mhw	S	d2500-15000	45340	2602525
Saxton	1-5% GI	dry	mhw	S	d2500-15000	46400	2672625
Saxton	1-5% GI	wet	mlw	N	d2500-15000	48420	1421675
Saxton	1-5% GI	dry	mlw	N	d2500-15000	51180	1548650
Saxton	1-5% GI	dry	mlw	S	d2500-15000	57510	2508075
Saxton	1-5% GI	wet	mlw	S	d2500-15000	58870	2634525
Wakatu	>10% GI	dry	mhw	C	d0-800	220	925
Wakatu	>10% GI	dry	mlw	C	d0-800	220	925
Wakatu	>10% GI	dry	mlw	N	d0-800	220	925

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Wakatu	>10% GI	dry	mlw	S	d0-800	220	925
Wakatu	>10% GI	wet	mhw	C	d0-800	220	925
Wakatu	>10% GI	wet	mlw	C	d0-800	220	925
Wakatu	>10% GI	wet	mlw	N	d0-800	220	925
Wakatu	>10% GI	wet	mlw	S	d0-800	220	925
Wakatu	>10% GI	wet	mhw	S	d0-800	1870	40375
Wakatu	>10% GI	dry	mhw	S	d0-800	1880	45325
Wakatu	>10% GI	wet	mhw	N	d0-800	2500	76275
Wakatu	>10% GI	dry	mhw	N	d0-800	2560	79400
Wakatu	5-10% GI	dry	mhw	C	d800-2500	90	325
Wakatu	5-10% GI	wet	mhw	C	d800-2500	120	400
Wakatu	5-10% GI	dry	mlw	N	d800-2500	130	375
Wakatu	5-10% GI	wet	mlw	N	d800-2500	130	375
Wakatu	5-10% GI	dry	mlw	S	d800-2500	150	375
Wakatu	5-10% GI	wet	mlw	S	d800-2500	150	350
Wakatu	5-10% GI	dry	mlw	C	d800-2500	160	425
Wakatu	5-10% GI	wet	mlw	C	d800-2500	160	425
Wakatu	5-10% GI	wet	mhw	S	d800-2500	5130	73600
Wakatu	5-10% GI	dry	mhw	S	d800-2500	5410	72450
Wakatu	5-10% GI	wet	mhw	N	d800-2500	6690	78925
Wakatu	5-10% GI	dry	mhw	N	d800-2500	6810	80350
Wakatu	1-5% GI	dry	mlw	C	d2500-15000	120	225
Wakatu	1-5% GI	wet	mlw	C	d2500-15000	120	225
Wakatu	1-5% GI	dry	mlw	N	d2500-15000	220	650
Wakatu	1-5% GI	dry	mlw	S	d2500-15000	220	650
Wakatu	1-5% GI	wet	mlw	N	d2500-15000	220	650
Wakatu	1-5% GI	wet	mlw	S	d2500-15000	220	650
Wakatu	1-5% GI	dry	mhw	C	d2500-15000	260	1125
Wakatu	1-5% GI	wet	mhw	C	d2500-15000	260	1125
Wakatu	1-5% GI	wet	mhw	S	d2500-15000	12930	357300

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Wakatu	1-5% GI	dry	mhw	S	d2500-15000	14460	408550
Wakatu	1-5% GI	wet	mhw	N	d2500-15000	17930	553825
Wakatu	1-5% GI	dry	mhw	N	d2500-15000	18450	559850

Extent of impact of aberrant discharges expressed in terms of perimeter and area of contours defined by human health risk. "Catchment" indicates state of catchment (wet or dry), "mhw" and "mlw" indicate tidal stage at time of discharge (mean high water and mean low water respectively), and S, N and C represent southerly, northerly and calm wind conditions at time of discharge.

Model output arranged in terms of "Illness risk", "Length" and "Pump station". These results represent the total length and total area of impact over the 11 hour to 21 hour period of simulation. (10,000 m^2 = 1 ha, and 1,000,000 m^2 = 100 ha = 1 km^2).

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Songer	>10% GI	dry	mlw	C	d0-800	210	1225
Songer	>10% GI	wet	mlw	C	d0-800	210	1200
Wakatu	>10% GI	dry	mhw	C	d0-800	220	925
Wakatu	>10% GI	dry	mlw	C	d0-800	220	925
Wakatu	>10% GI	dry	mlw	N	d0-800	220	925
Wakatu	>10% GI	dry	mlw	S	d0-800	220	925
Wakatu	>10% GI	wet	mhw	C	d0-800	220	925
Wakatu	>10% GI	wet	mlw	C	d0-800	220	925
Wakatu	>10% GI	wet	mlw	N	d0-800	220	925
Wakatu	>10% GI	wet	mlw	S	d0-800	220	925
Songer	>10% GI	dry	mhw	C	d0-800	250	1525
Songer	>10% GI	wet	mhw	C	d0-800	250	1525
Airport	>10% GI	wet	mhw	S	d0-800	1710	44900
Airport	>10% GI	dry	mhw	C	d0-800	1710	47175
Airport	>10% GI	dry	mhw	N	d0-800	1740	45000
Airport	>10% GI	dry	mhw	S	d0-800	1740	46600
Airport	>10% GI	wet	mhw	C	d0-800	1740	47150

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Airport	>10% GI	wet	mhw	N	d0-800	1750	44975
Airport	>10% GI	wet	mlw	C	d0-800	1750	42425
Airport	>10% GI	dry	mlw	C	d0-800	1760	42600
Wakatu	>10% GI	wet	mhw	S	d0-800	1870	40375
Wakatu	>10% GI	dry	mhw	S	d0-800	1880	45325
Songer	>10% GI	wet	mlw	S	d0-800	2410	49450
Songer	>10% GI	dry	mlw	S	d0-800	2420	50300
Wakatu	>10% GI	wet	mhw	N	d0-800	2500	76275
Songer	>10% GI	wet	mlw	N	d0-800	2500	62700
Wakatu	>10% GI	dry	mhw	N	d0-800	2560	79400
Songer	>10% GI	dry	mlw	N	d0-800	2600	60950
Songer	>10% GI	dry	mhw	S	d0-800	3010	109125
Airport	>10% GI	wet	mlw	S	d0-800	3250	87025
Airport	>10% GI	dry	mlw	S	d0-800	3360	89200
Airport	>10% GI	wet	mlw	N	d0-800	3520	93725
Airport	>10% GI	dry	mlw	N	d0-800	3610	97075
Songer	>10% GI	wet	mhw	S	d0-800	4240	122725
Songer	>10% GI	dry	mhw	N	d0-800	5220	158000
Songer	>10% GI	wet	mhw	N	d0-800	5230	159950
Saxton	>10% GI	wet	mlw	C	d0-800	8540	300375
Saxton	>10% GI	dry	mlw	C	d0-800	8700	325275
Saxton	>10% GI	dry	mhw	N	d0-800	11200	373525
Saxton	>10% GI	wet	mhw	S	d0-800	11580	382400
Saxton	>10% GI	wet	mhw	N	d0-800	11770	393275
Saxton	>10% GI	dry	mhw	S	d0-800	11960	391300
Saxton	>10% GI	dry	mhw	C	d0-800	13330	438525
Saxton	>10% GI	wet	mhw	C	d0-800	13900	441950
Saxton	>10% GI	wet	mlw	N	d0-800	17180	915000
Saxton	>10% GI	dry	mlw	N	d0-800	17600	950700
Saxton	>10% GI	dry	mlw	S	d0-800	17980	901200

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Saxton	>10% GI	wet	mlw	S	d0-800	18030	903700
Wakatu	5-10% GI	dry	mhw	C	d800-2500	90	325
Wakatu	5-10% GI	wet	mhw	C	d800-2500	120	400
Wakatu	5-10% GI	dry	mlw	N	d800-2500	130	375
Wakatu	5-10% GI	wet	mlw	N	d800-2500	130	375
Wakatu	5-10% GI	dry	mlw	S	d800-2500	150	375
Wakatu	5-10% GI	wet	mlw	S	d800-2500	150	350
Wakatu	5-10% GI	dry	mlw	C	d800-2500	160	425
Wakatu	5-10% GI	wet	mlw	C	d800-2500	160	425
Songer	5-10% GI	dry	mlw	C	d800-2500	350	1150
Songer	5-10% GI	wet	mlw	C	d800-2500	350	1200
Songer	5-10% GI	dry	mhw	C	d800-2500	380	1625
Songer	5-10% GI	wet	mhw	C	d800-2500	380	1650
Airport	5-10% GI	dry	mlw	C	d800-2500	2250	12375
Airport	5-10% GI	wet	mlw	C	d800-2500	2250	12325
Songer	5-10% GI	dry	mlw	S	d800-2500	3260	35125
Airport	5-10% GI	dry	mhw	N	d800-2500	3290	32800
Airport	5-10% GI	wet	mhw	S	d800-2500	3340	32900
Airport	5-10% GI	wet	mhw	N	d800-2500	3380	30475
Songer	5-10% GI	wet	mlw	S	d800-2500	3410	36775
Songer	5-10% GI	wet	mlw	N	d800-2500	3570	32600
Songer	5-10% GI	dry	mlw	N	d800-2500	3650	33675
Airport	5-10% GI	dry	mhw	S	d800-2500	3910	39925
Airport	5-10% GI	dry	mhw	C	d800-2500	4210	29475
Airport	5-10% GI	wet	mhw	C	d800-2500	4270	29050
Airport	5-10% GI	wet	mlw	S	d800-2500	5110	49125
Wakatu	5-10% GI	wet	mhw	S	d800-2500	5130	73600
Airport	5-10% GI	dry	mlw	N	d800-2500	5160	41200
Airport	5-10% GI	dry	mlw	S	d800-2500	5290	48525
Airport	5-10% GI	wet	mlw	N	d800-2500	5370	44825

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Wakatu	5-10% GI	dry	mhw	S	d800-2500	5410	72450
Wakatu	5-10% GI	wet	mhw	N	d800-2500	6690	78925
Wakatu	5-10% GI	dry	mhw	N	d800-2500	6810	80350
Songer	5-10% GI	dry	mhw	S	d800-2500	11690	158700
Songer	5-10% GI	wet	mhw	S	d800-2500	12010	165350
Songer	5-10% GI	dry	mhw	N	d800-2500	12340	118300
Songer	5-10% GI	wet	mhw	N	d800-2500	12490	117050
Saxton	5-10% GI	dry	mlw	C	d800-2500	13680	196900
Saxton	5-10% GI	wet	mlw	C	d800-2500	13920	200550
Saxton	5-10% GI	dry	mhw	N	d800-2500	29350	547575
Saxton	5-10% GI	dry	mhw	S	d800-2500	30780	559075
Saxton	5-10% GI	wet	mhw	S	d800-2500	30810	539250
Saxton	5-10% GI	wet	mhw	N	d800-2500	30910	598575
Saxton	5-10% GI	dry	mhw	C	d800-2500	34390	669875
Saxton	5-10% GI	wet	mhw	C	d800-2500	35650	705050
Saxton	5-10% GI	wet	mlw	N	d800-2500	38260	708525
Saxton	5-10% GI	dry	mlw	N	d800-2500	38970	741875
Saxton	5-10% GI	dry	mlw	S	d800-2500	39450	762025
Saxton	5-10% GI	wet	mlw	S	d800-2500	39720	763500
Wakatu	1-5% GI	dry	mlw	C	d2500-15000	120	225
Wakatu	1-5% GI	wet	mlw	C	d2500-15000	120	225
Wakatu	1-5% GI	dry	mlw	N	d2500-15000	220	650
Wakatu	1-5% GI	dry	mlw	S	d2500-15000	220	650
Wakatu	1-5% GI	wet	mlw	N	d2500-15000	220	650
Wakatu	1-5% GI	wet	mlw	S	d2500-15000	220	650
Wakatu	1-5% GI	dry	mhw	C	d2500-15000	260	1125
Wakatu	1-5% GI	wet	mhw	C	d2500-15000	260	1125
Songer	1-5% GI	dry	mhw	C	d2500-15000	460	3225
Songer	1-5% GI	dry	mlw	C	d2500-15000	470	2550
Songer	1-5% GI	wet	mhw	C	d2500-15000	470	3200

.

Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Songer	1-5% GI	wet	mlw	C	d2500-15000	490	2475
Airport	1-5% GI	wet	mlw	C	d2500-15000	3600	30925
Airport	1-5% GI	dry	mlw	C	d2500-15000	3630	31275
Songer	1-5% GI	dry	mlw	S	d2500-15000	3980	49675
Songer	1-5% GI	wet	mlw	S	d2500-15000	4010	50500
Airport	1-5% GI	wet	mhw	N	d2500-15000	4890	43000
Airport	1-5% GI	wet	mhw	S	d2500-15000	5230	46600
Airport	1-5% GI	dry	mhw	N	d2500-15000	5440	52300
Airport	1-5% GI	dry	mhw	S	d2500-15000	6190	71550
Songer	1-5% GI	dry	mlw	N	d2500-15000	6280	93250
Songer	1-5% GI	wet	mlw	N	d2500-15000	6330	94300
Airport	1-5% GI	wet	mhw	C	d2500-15000	7260	99050
Airport	1-5% GI	dry	mhw	C	d2500-15000	7610	115950
Airport	1-5% GI	wet	mlw	S	d2500-15000	7700	76675
Airport	1-5% GI	dry	mlw	N	d2500-15000	7760	85825
Airport	1-5% GI	dry	mlw	S	d2500-15000	7780	75900
Airport	1-5% GI	wet	mlw	N	d2500-15000	7970	82425
Wakatu	1-5% GI	wet	mhw	S	d2500-15000	12930	357300
Wakatu	1-5% GI	dry	mhw	S	d2500-15000	14460	408550
Saxton	1-5% GI	wet	mlw	C	d2500-15000	16610	304750
Wakatu	1-5% GI	wet	mhw	N	d2500-15000	17930	553825
Saxton	1-5% GI	dry	mlw	C	d2500-15000	18210	337750
Wakatu	1-5% GI	dry	mhw	N	d2500-15000	18450	559850
Songer	1-5% GI	wet	mhw	S	d2500-15000	18760	573750
Songer	1-5% GI	dry	mhw	S	d2500-15000	18880	553525
Songer	1-5% GI	dry	mhw	N	d2500-15000	19030	608825
Songer	1-5% GI	wet	mhw	N	d2500-15000	19250	592725
Saxton	1-5% GI	wet	mhw	C	d2500-15000	40750	3018925
Saxton	1-5% GI	dry	mhw	N	d2500-15000	41560	2326450
Saxton	1-5% GI	wet	mhw	N	d2500-15000	41920	2515600

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Pump station	GI Illness risk	Catchment	Tide	Wind	Dilution (x)	Length (m)	Area (m^2)
Saxton	1-5% GI	dry	mhw	C	d2500-15000	44070	2946400
Saxton	1-5% GI	wet	mhw	S	d2500-15000	45340	2602525
Saxton	1-5% GI	dry	mhw	S	d2500-15000	46400	2672625
Saxton	1-5% GI	wet	mlw	N	d2500-15000	48420	1421675
Saxton	1-5% GI	dry	mlw	N	d2500-15000	51180	1548650
Saxton	1-5% GI	dry	mlw	S	d2500-15000	57510	2508075
Saxton	1-5% GI	wet	mlw	S	d2500-15000	58870	2634525