UNSW SYDNEY | Australia's Global University

Water Research Laboratory
Memorandum

To: OzFish
Date: 15/10/2018
From: Will Glamore & Duncan Rayner
Subject: Conceptual Understanding and Prioritisation of Tuckean Swamp
WRL Ref: 2014129 M20181115

Background

Tuckean Swamp is part of the lower Richmond River Catchment and the floodplains covers an area of over 6,000 ha. Historically, Tuckean Swamp was predominantly a freshwater wetland system, with some tidal influence in the lower swamp (Price, 2015). Since European settlement, Tuckean has been subject to significant agricultural development (Baldwin, 1996). Agricultural canals were constructed to improve the drainage in the central region of the swamp and involved considerable realignment of the natural creeks (shown in Figure 1). In 1971, the Bagotville Barrage was constructed which effectively isolated Tuckean Swamp from tidal flushing of the Richmond River.

The agricultural drainage efficiently conveys natural rainfall and runoff off the floodplain. Areas that were once almost always underwater are typically dry expect during flood events (shown in Figure 2). While this results in agricultural benefit, it also results the lowering of the groundwater table, the extensive exposure of Acid Sulfate Soils (ASS), and chronic environmental degradation due to the consistent acidification of groundwater and surface water across the swamp.

The Richmond River is subject to large fish kills after flood events. In January 2008, a flood event killed over 30 tonnes of fish and aquatic organisms and similar events are well documented (Wong, 2008). Water discharging from the Tuckean floodplain is a contributor to poor water quality in the Richmond River after floods (Wong, 2010, Moore, 2007). Observations in 2018 indicate that pH in Hendersons Drain, the main drain through Tuckean Swamp, is commonly between pH 3 to pH 4, about the same as vinegar. pH levels as low as 2 were recorded in June 2018, well below levels sustainable for fish habitats. Large volumes of iron, which is also detrimental to the environment, were also observed across the length of Hendersons Drain. As a result, there was limited aquatic life observed during the 2018 WRL field investigations around the Tuckean floodplain and there is evidence of acid scalding throughout the low lying areas of the swamp.

While the topography is varied, the substantial areas of the floodplain within half a metre of mean sea level. As such, drainage off these areas of the swamp can be very slow. This, coupled with acid scalding prohibiting the growth of appropriate vegetation and very poor surface water quality, can make viable agricultural use of the area difficult in some of the lowest lying sections of the swamp.

This document provides a brief overview of what acid sulfate soils are, and a conceptual understanding how these soils contribute to poor water quality during dry and wet conditions. Using this understanding, and the substantial field data available, the floodplain has been sub-divided into preliminary management areas which are outlined in the final section of this memorandum. Each section has been prioritised based on its contribution to poor water quality in the region and a brief justification has been provided on each area.

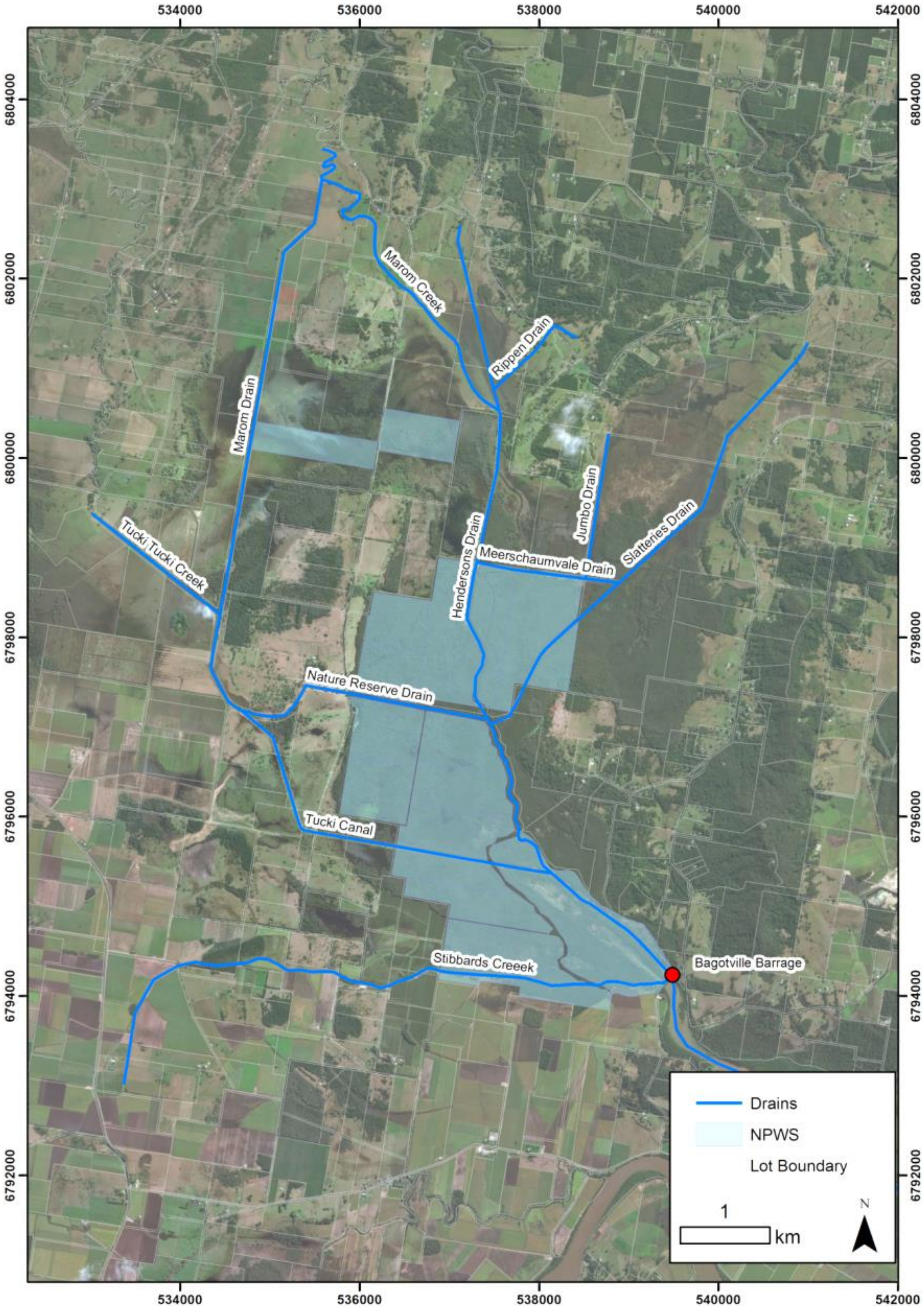


Figure 1: Major drains and creeks throughout Tuckean Swamp

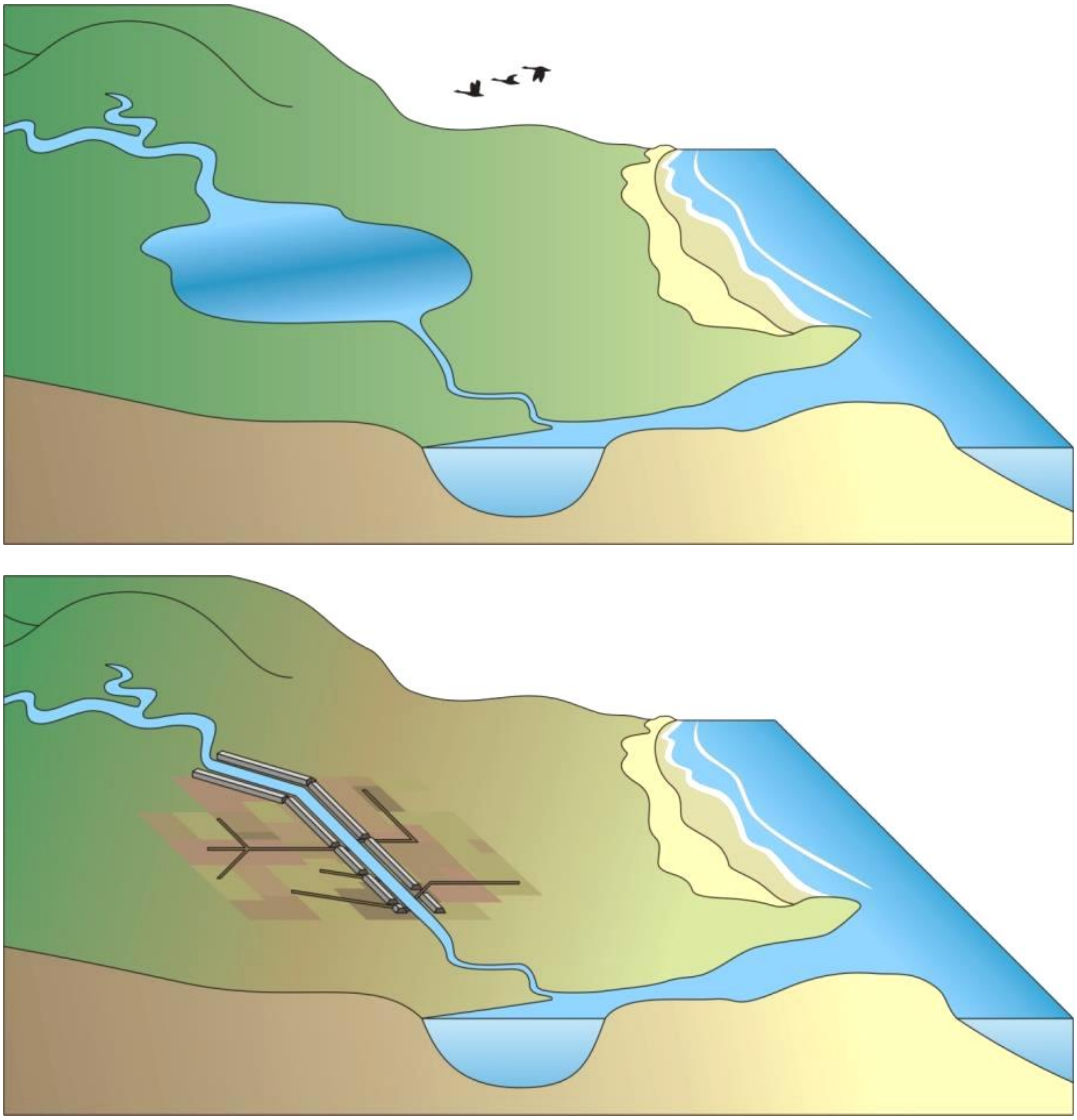
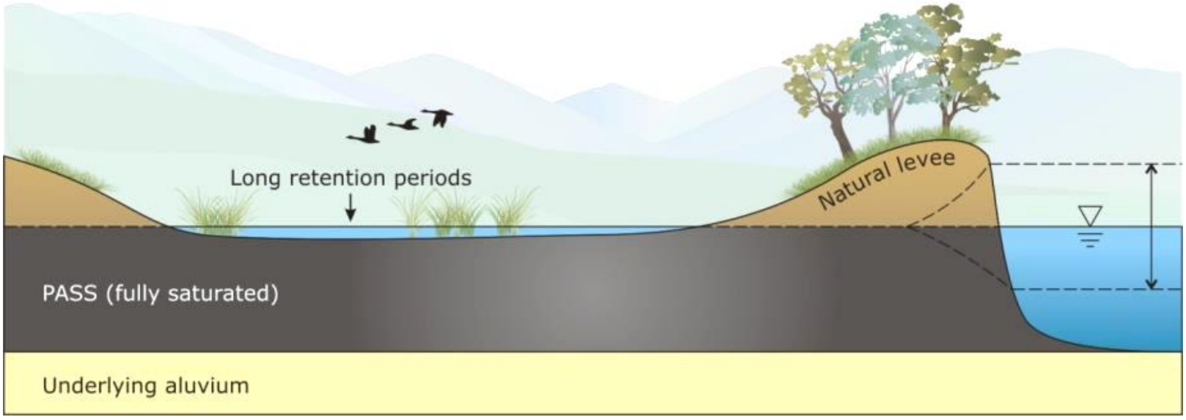


Figure 2: Schematic of Floodplain Evolution Following European Settlement

What are Acid Sulfate Soils

Acid Sulfate Soils (ASS) is the common name given to soils containing iron sulfides, which are common along the NSW east coast. ASS are inactive when they are not exposed to oxygen, such as when they are permanently underwater. However, when these soils are exposed to the air and atmospheric oxygen, a chemical process occurs, called oxidation, which results of the production of sulfuric acid. This process commonly occurs when naturally inundated floodplains are drained, as shown in Figure 3.

Undisturbed Environment



Drained Paddock

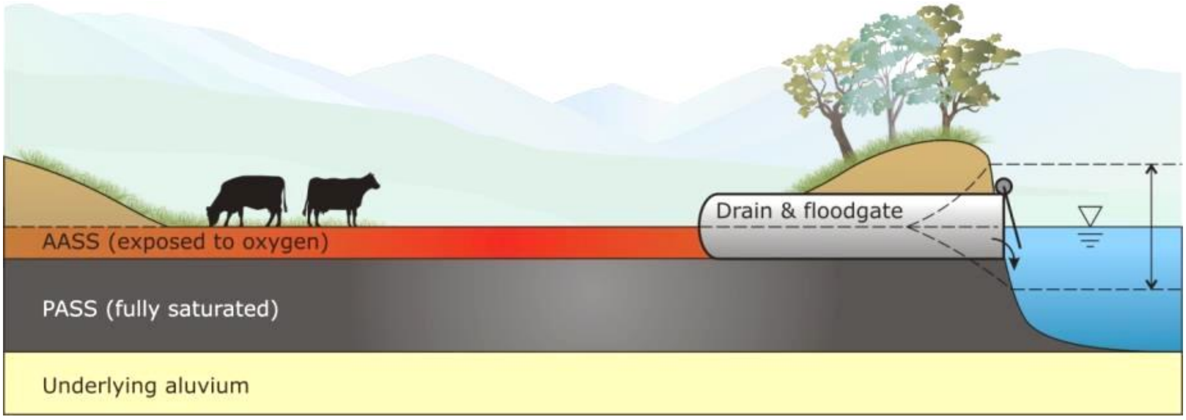


Figure 3: Soil Acidification through drainage schemes and lowering the groundwater table

ASS acidify the groundwater, which impacts the vegetation that is able to grow on affected land. However, the acid also drains and leaches into the surrounding surface waters as shown in Figure 4. During large rain events, the groundwater table rises as rainfall infiltrates the sediments. In areas which are heavily drained, surface water recedes considerably quicker than the groundwater which has to make its way through porous soils. This results in a flow of groundwater feeding into the surface water drains and acidification of the surface waters. High concentration of aluminium and iron are a by-product of acid production, which is also detrimental to the environment.

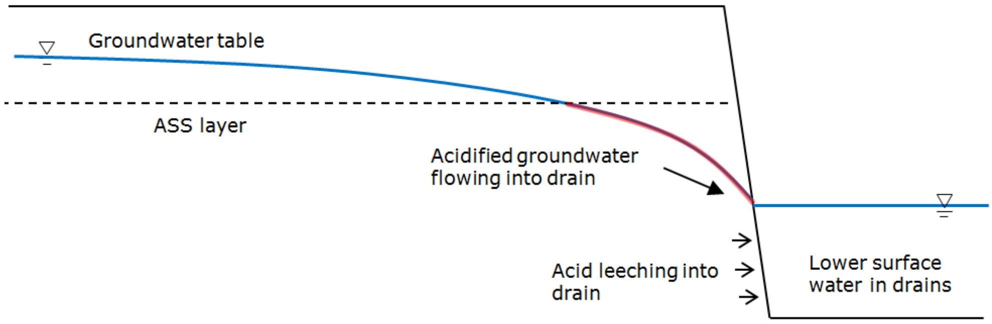


Figure 4: Pathways for acid transport into surface waters

Why does the acidity in wetlands, like Tuckean swamp, vary?

Surface water in Tuckean has been observed to be acidic during dry periods. However, the major fish kill events in the Richmond River tend to occur after a period of heavy rainfall and flooding. This is typical of ASS affected areas. While the water in drains on ASS-affected coastal floodplains can be highly acidic on a day-to-day basis, large plumes of acidic discharge are not typically recorded within estuaries during day to say conditions. Conversely, large quantities of acid are often discharged following significant rainfall events. This typically occurs in the 5 to 14 days following the peak of a flood event. During other periods, acidic water continues to drain but the impact may be reduced (depending on dilution capacity).

The pH scale (Figure 5) is used to grade acidity and is a measure of the hydrogen ion (H^+) concentration. The pH scale is logarithmic, ranging from 0 (strongly acidic) to 14 (strongly alkaline). Due to the logarithmic scale, a soil with a pH of 4 is 10 times more acidic than a soil with a pH of 5, and 1,000 times more acidic than a soil with a pH of 7. Oxidised ASS soils typically have a pH of below 4.5. pH values at Tuckean Swamp is regularly below 4 and can get below 3 at times.

Figure 6 depicts an ASS affected floodplain during a dry period. Surface water drains in the low-lying floodplain can remain acidic, however the groundwater table is typically low which reduces the acid export from the site. At Tuckean, immediately downstream of the Bagotville Barrage, the Tuckean Broadwater is tidal – water levels go up and down with the ocean tide. During dry periods, saltwater from the ocean penetrates upstream and salinity in the Broadwater increases. Sea water contains a natural acid buffering agent which helps to neutralize any persistent acid discharge from the swamp. The barrage effectively prevents the upstream infiltration of seawater, so this neutralising capacity is not experienced upstream of the structure.

Figure 7 depicts a period immediately following a flood event when coastal floodplains are inundated with fresh floodwaters. The large volumes of freshwater from runoff off the upper catchment are sufficient to dilute any acid being produced. As the floodwaters recede, large volumes of freshwater drain from the floodplain into the estuary. This process, in conjunction with large freshwater flows in the main river channel, reduces estuarine salinity. At the Tuckean Broadwater salinity can flushed from the system even after a relatively small rain event.

Figure 8 depicts the floodplain as the floodwaters recede. During this period, floodplain pastures are saturated and groundwater levels remain elevated, resulting in a steep gradient between drain water levels and the surrounding groundwater. This process mobilises acid from the soil towards drainage channels and downstream water bodies (see Figure 4). As the natural buffering capacity of the estuary has been removed by the fresh floodwaters, acidic plumes comprised of low pH water and high soluble metal concentration remain in the open estuary. In the Richmond River, large scale fish kills have been observed as a result of acid drainage from the Tuckean after significant rain events. These events have broad ranging ecological, environmental, social and economic implications on the broader estuary.

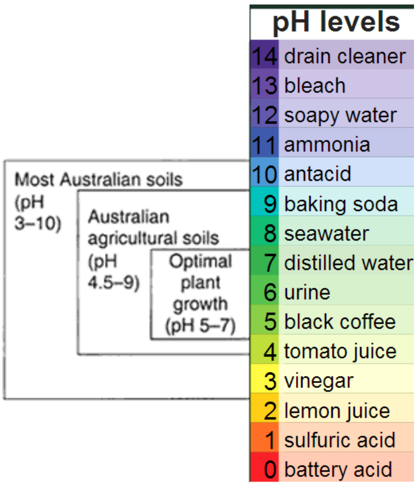


Figure 5: pH Scale (NRM, 2011)

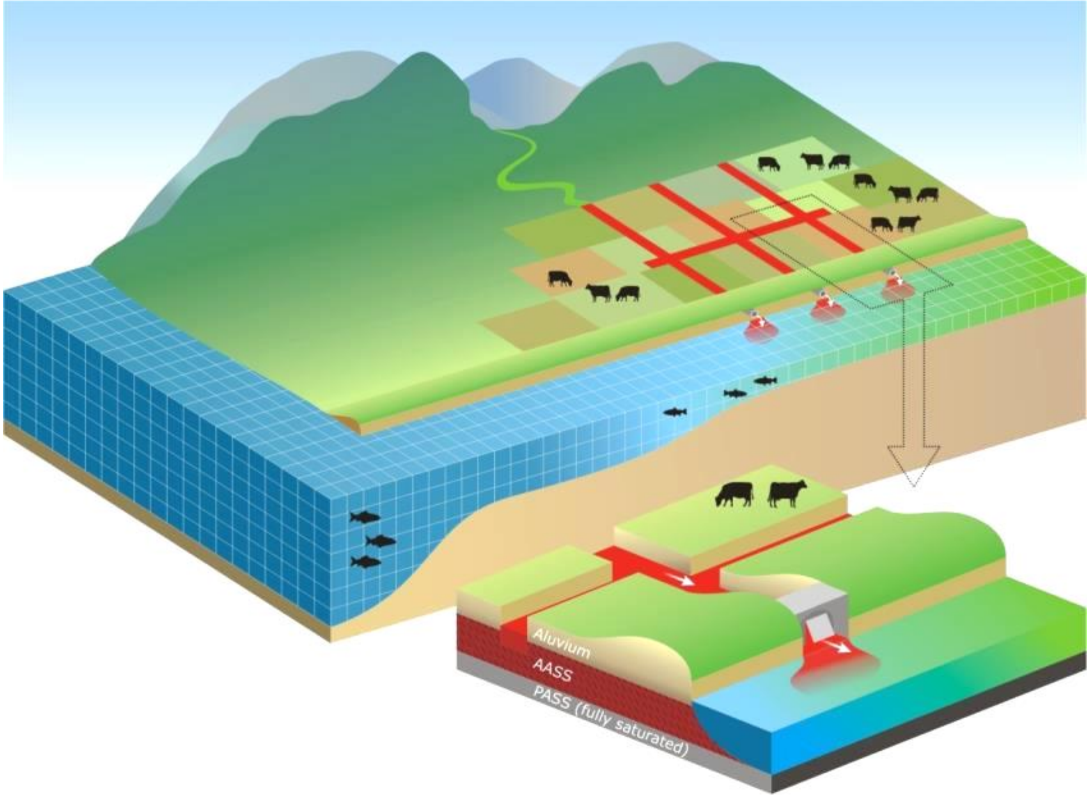


Figure 6:ASS affected floodplains during dry periods

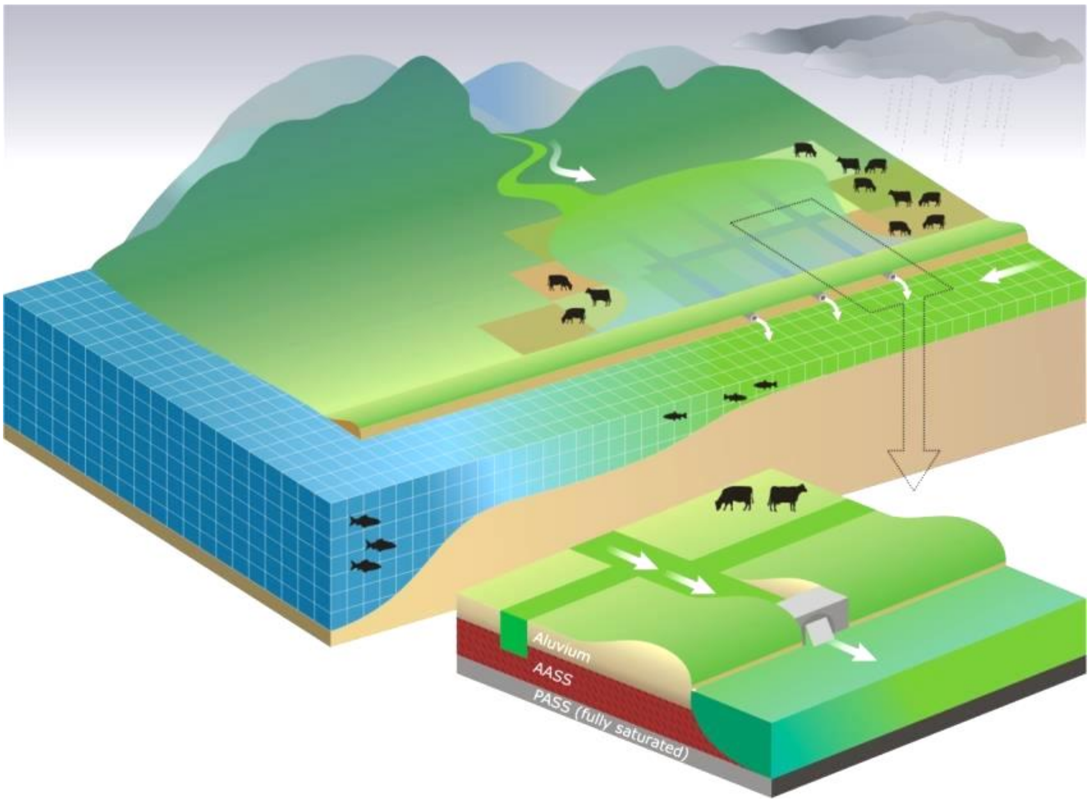


Figure 7: Freshwater inundation during and immediately following a flood event

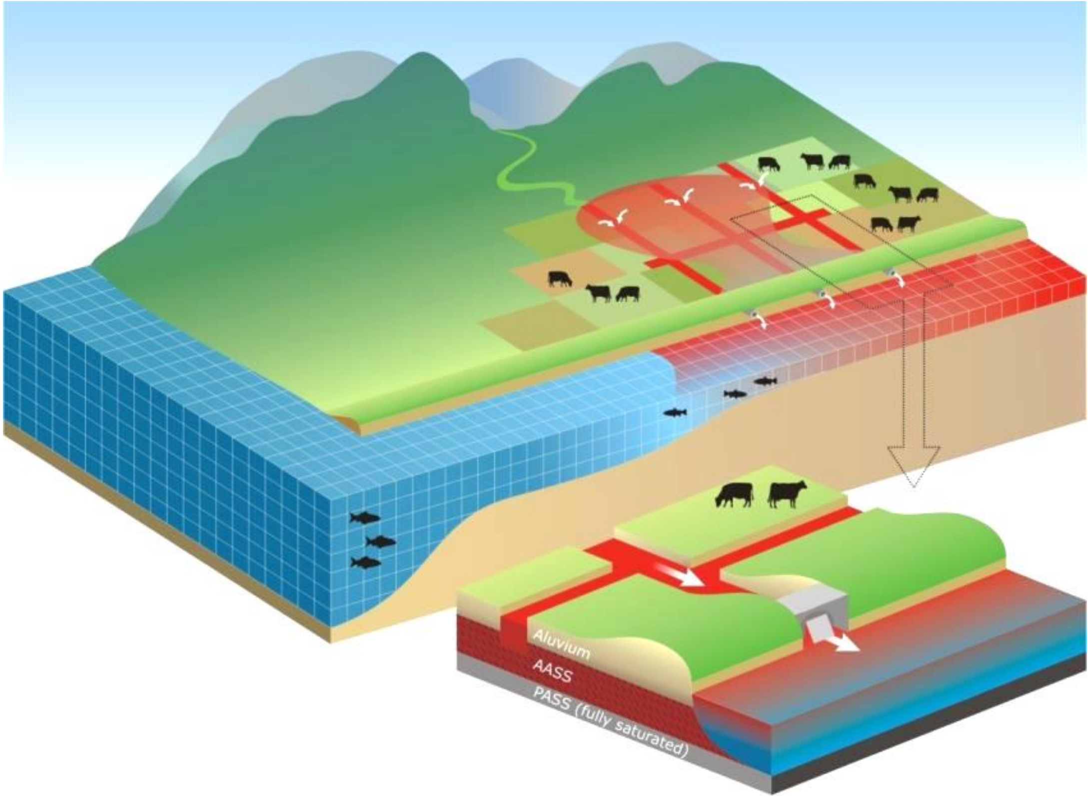


Figure 8: Period of Acid Impact Following Rainfall Event

Prioritising the Tuckean

Tuckean Swamp is a large coastal floodplain with significant ASS issues. Due to the size of the floodplain, nature of the land use and extensive drainage, it is not practical to return the swamp to a pre-European natural condition. However, water quality in the Tuckean region is, at times, extremely poor which has implications for the environment and for the viability of farming and agriculture in the region. As such, it is necessary to split the floodplain into management sub-areas and to prioritise which areas should be targeted to improve water quality throughout the region.

There are a number of factors which are considered when prioritising the remediation of ASS affected areas, some of which are summarized in Figure 9. In general, low-lying land with deep drains below the ASS layer and observations of high levels of soil and surface water acidity results in a greater environmental risk for ASS discharges.

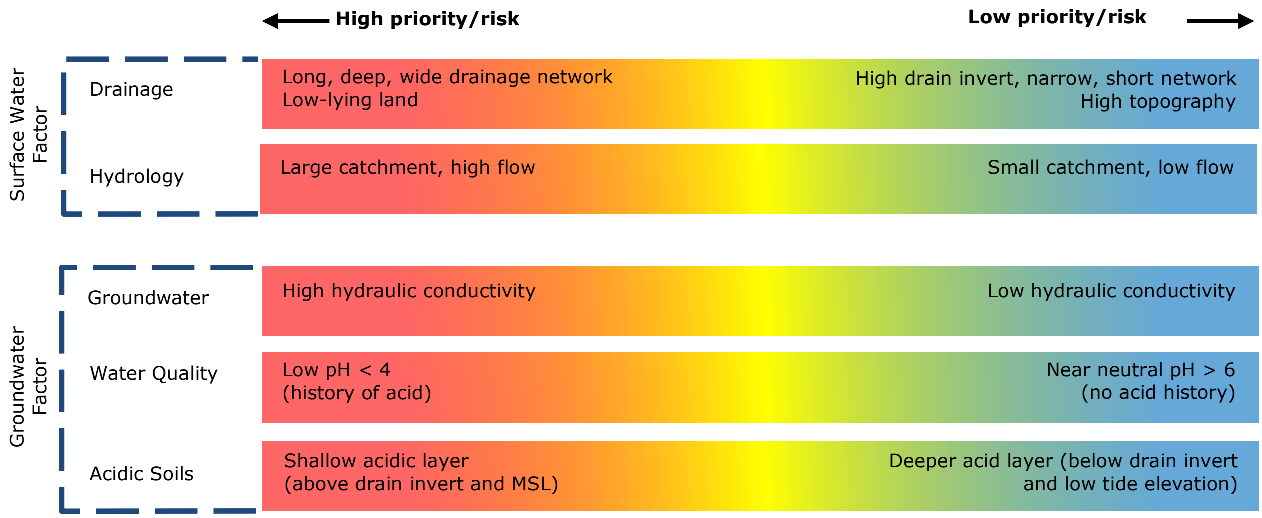


Figure 9: Environmental factors influencing the risk of impacts from ASS discharge (adapted from Glamore et al. 2016)

While there has been substantial work undertaken at the Tuckean before, extensive field investigations have been undertaken throughout 2018 to assess the highest risk areas in the Tuckean. Data collected includes:

- Spot measurements of ground elevations have been used to correct aerial measurements of topography and produce an elevation map of the low lying floodplain (see Figure 10);
- Surveys of most of the major drains throughout the lower floodplain (see Figure 11);
- Spot measurements of water quality throughout the major drainage paths (see Figure 12); and
- Installation of water level loggers throughout the floodplain (see Figure 14 and Figure 15) which assisted in understanding the relative flow magnitudes throughout the drainage system (see Figure 16).

In addition to the data collected by WRL in 2018, soil profiles from the NSW SALIS (Soil and Land Information Systems) have also been obtained to map soil acidity and permeability. Data of from the 1995 Acid Sulfate Soil Survey (Smith, 1995) have also been considered. Observed pH/percentage sulfur (an alternative measure of the presence of ASS in soils) from the available soil profiles is shown Figure 15.

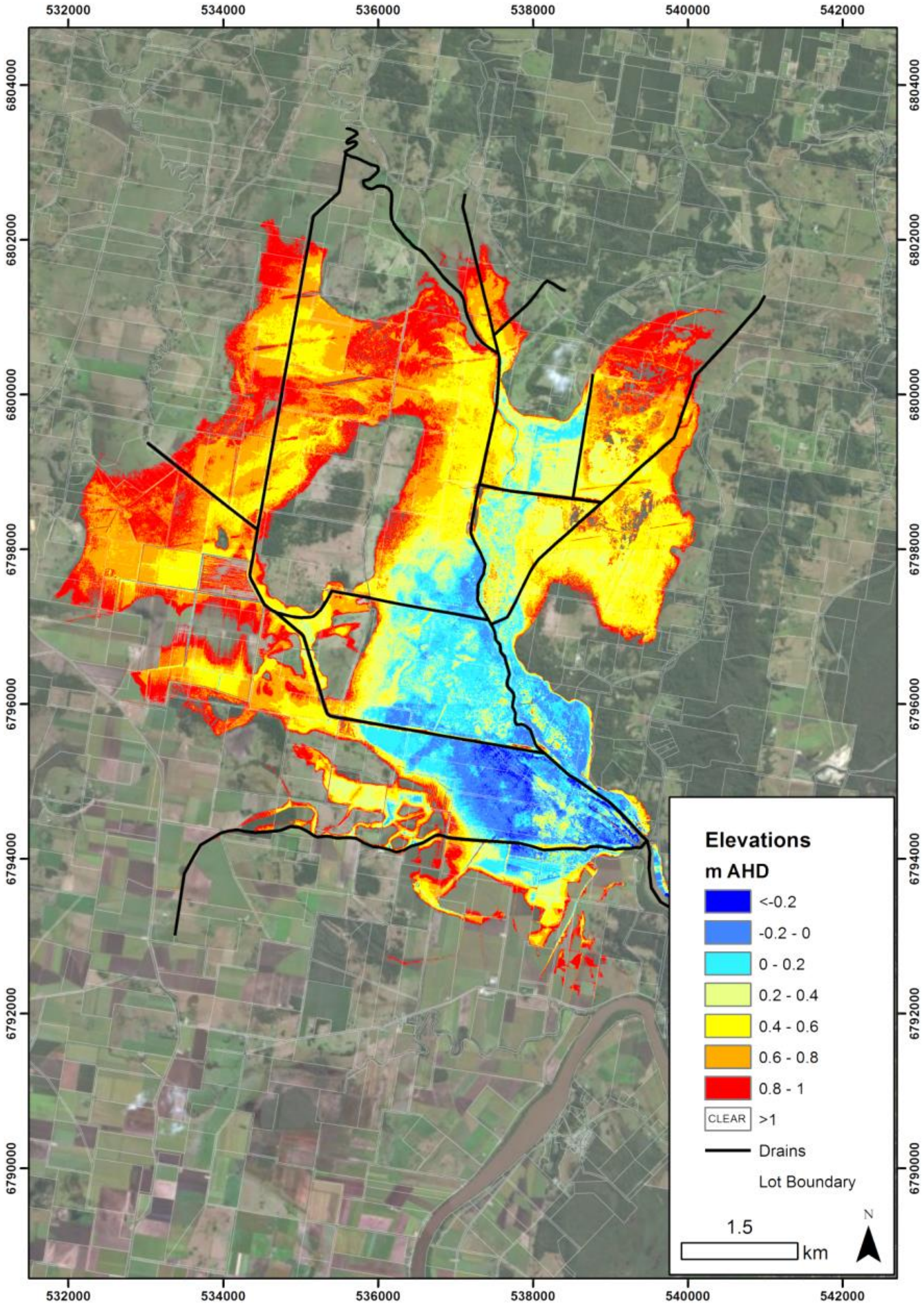


Figure 10: Digital Elevation Map (DEM) of the low lying areas of the Tuckean

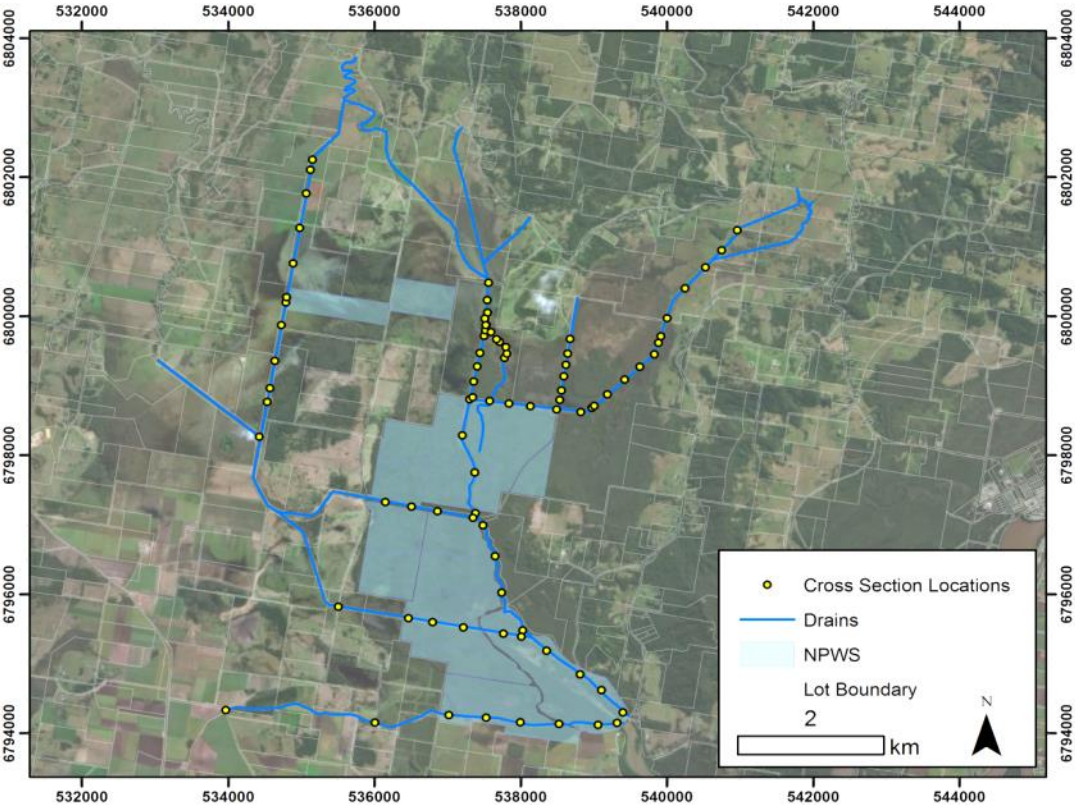


Figure 11: Location of surveyed drain cross sections

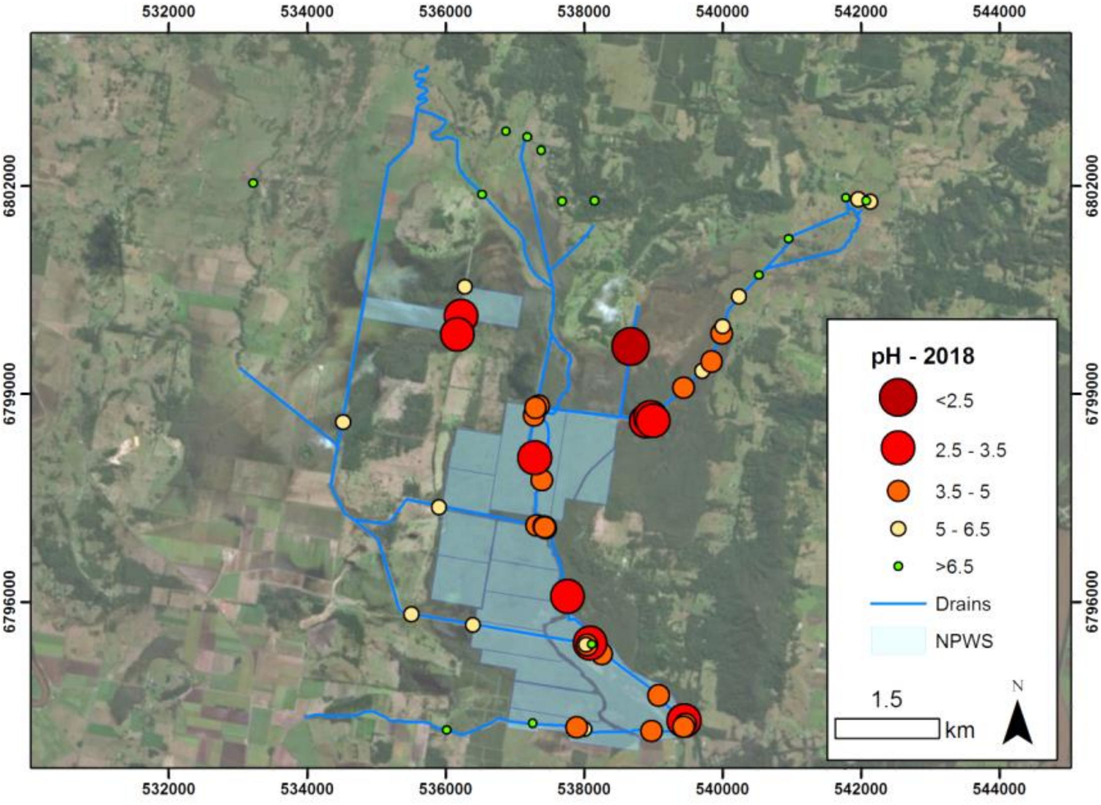


Figure 12: Surface water acidity 2018

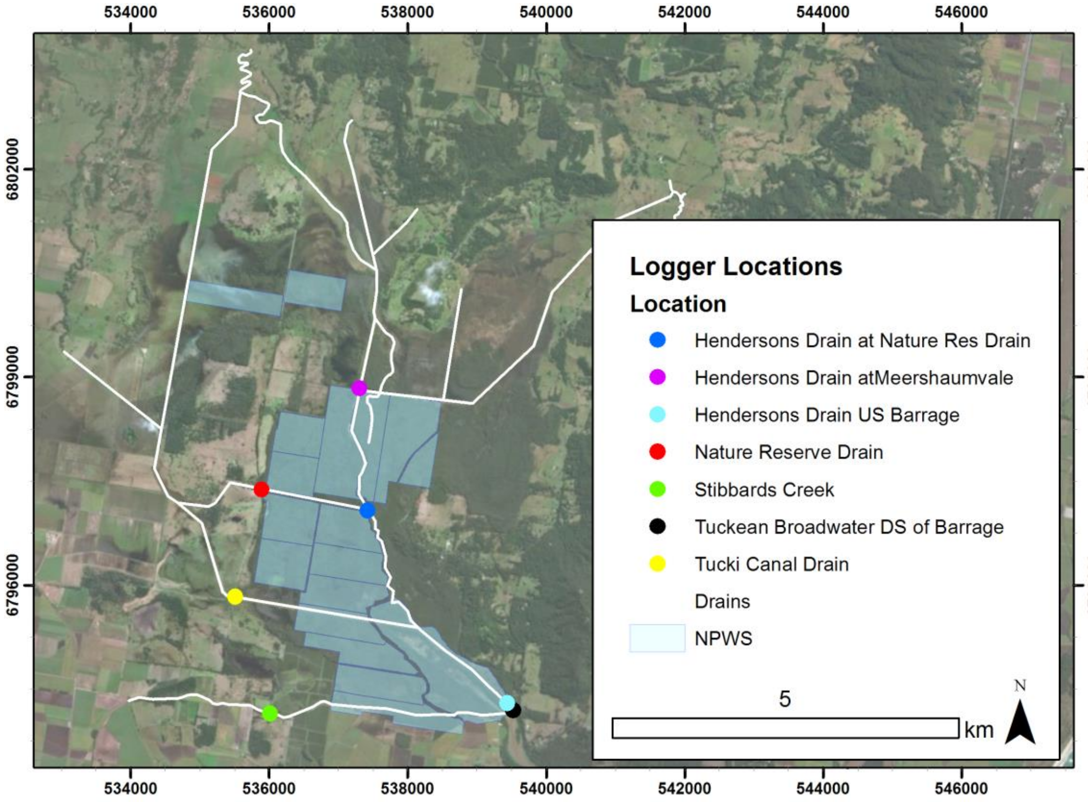


Figure 13: Water level logger locations

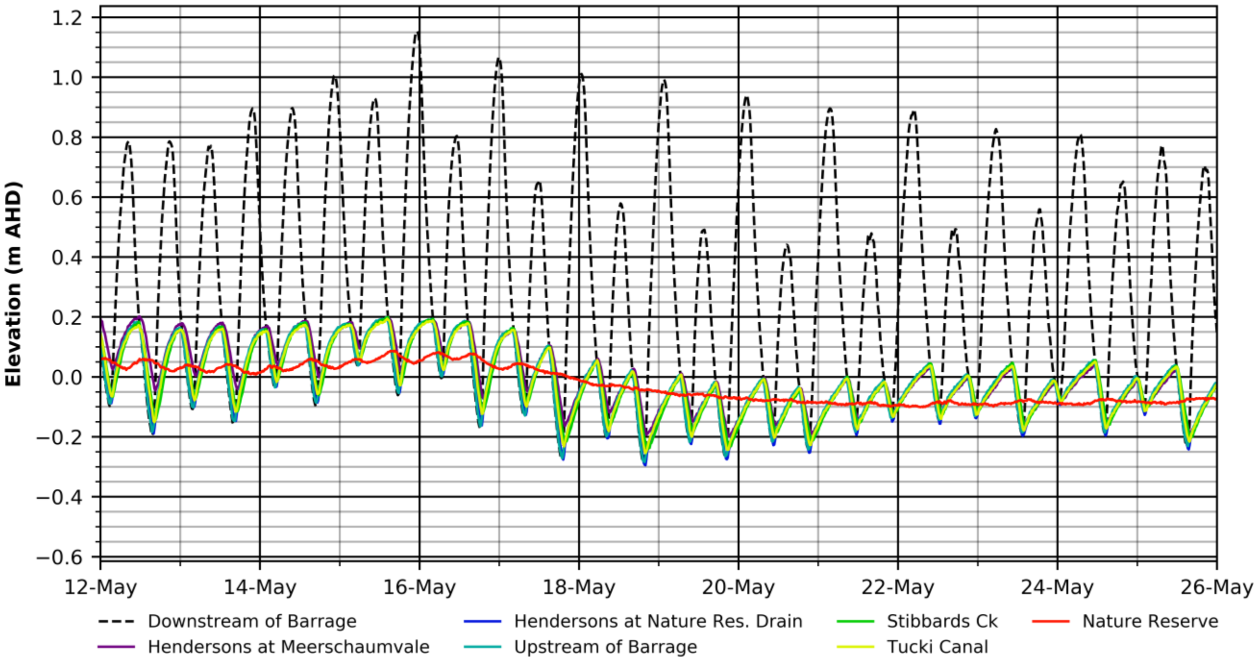


Figure 14: Observed water levels throughout May 12th – 26th

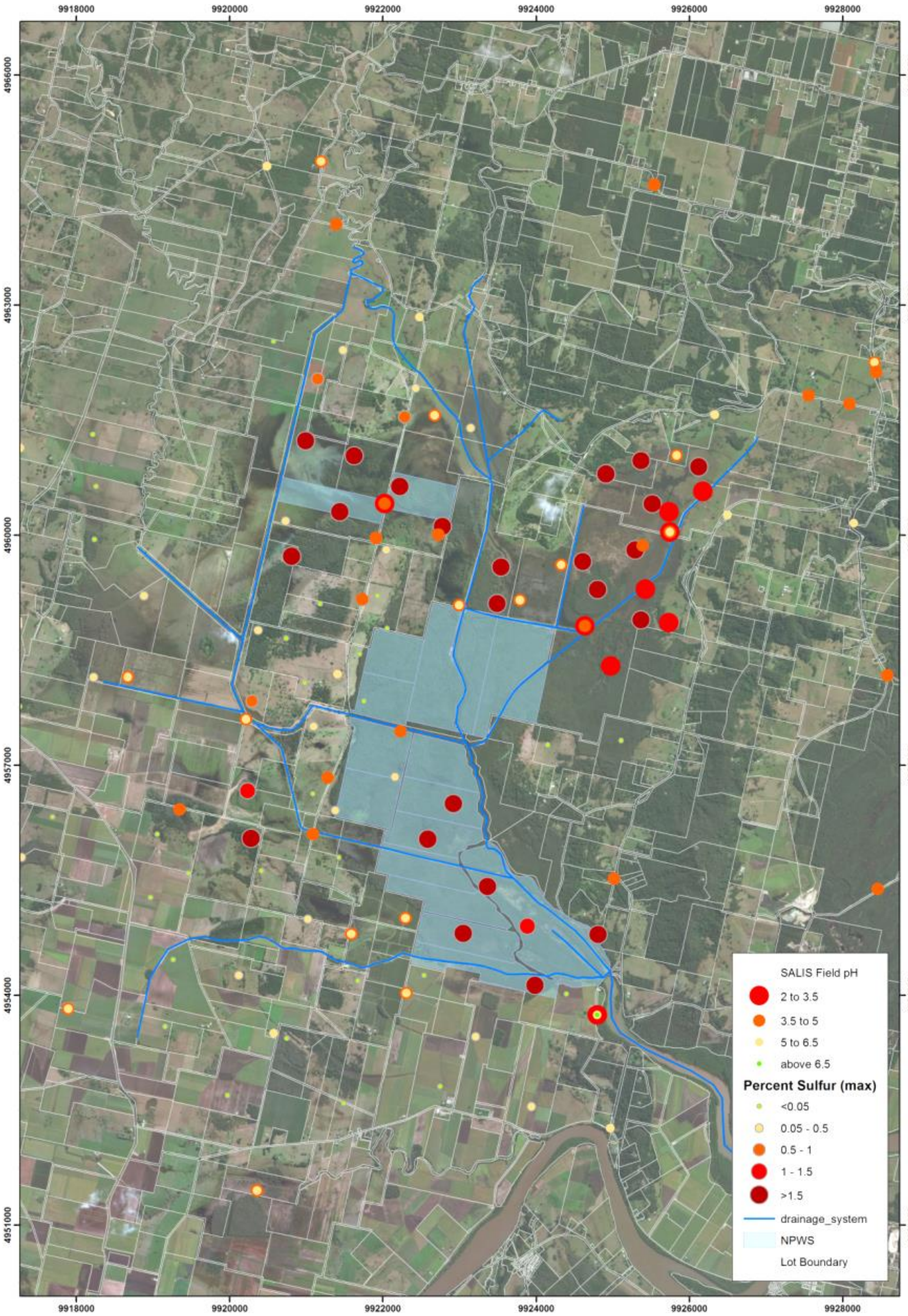


Figure 15: Soils data from Smith (1995) and SALIS database

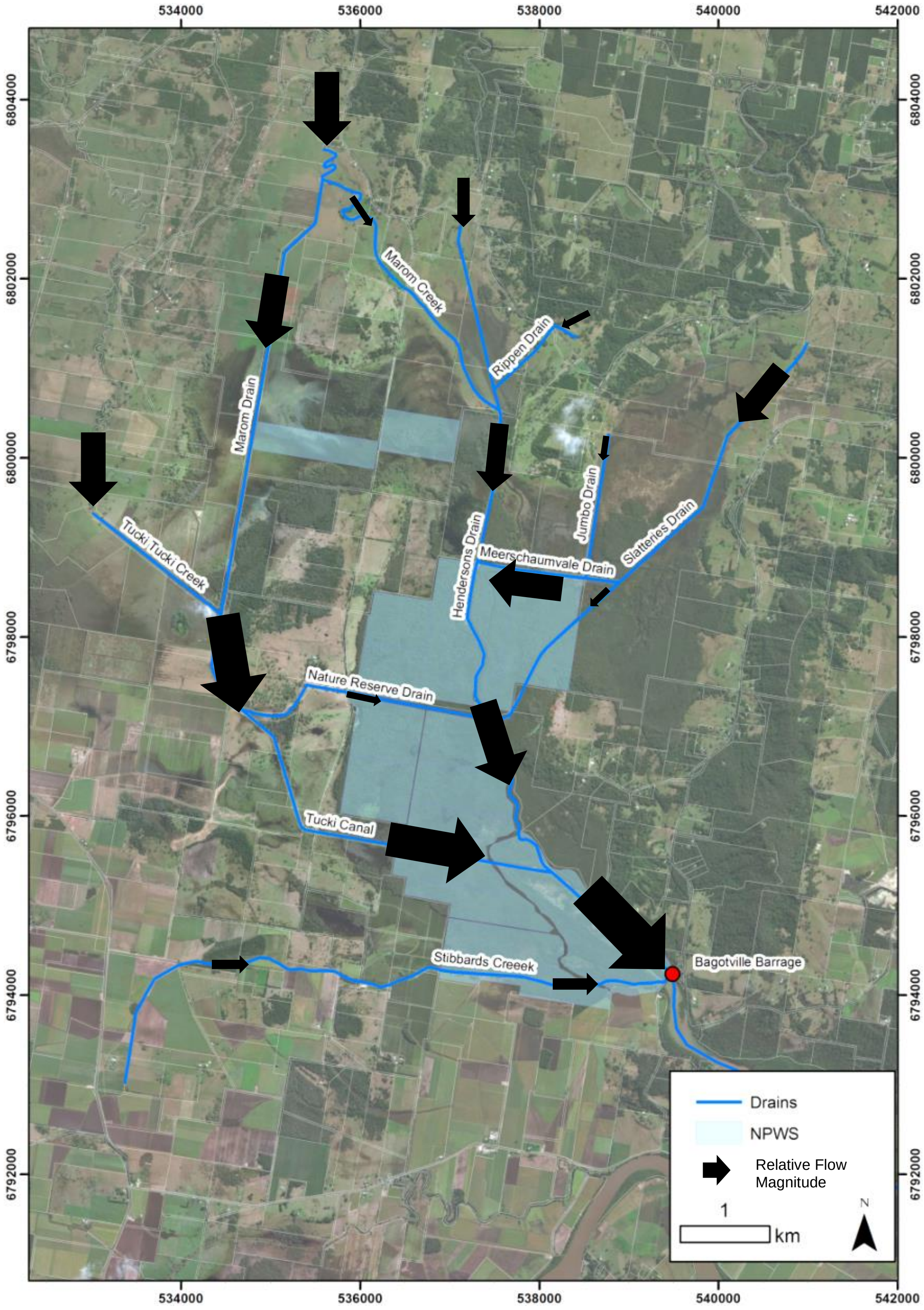


Figure 16: Relative flow magnitude throughout the Tuckean drainage system

Management Sub-Areas

Using the field data available, onsite observations by WRL engineers (some of which are depicted in photographs at the end of this document) and a conceptual understanding of how acid generation occurs in the Tuckean region during different climatic conditions, the floodplain has been split into 10 separate management areas and prioritized for remediation efforts, shown in Figure 17. Areas were separated based on the major drains and the floodplain topography. Images referred to in this table are provided at the end of this document

Area	Priority	Justification
1. Upper Slatteries	**Highest**	- Large catchment flows - High soil acidity observed - Acidic surface waters observed, particularly at the confluence with Meerschaum Vale Drain - No aquatic life observed - Significant iron floc settlement observed (see image 17) - Low lying topography (see image 20)
2. Meerschaum Vale/ Jumbo	**Highest**	- Worst surface acidity observed in 2018 in Jumbo Drain (pH of 2, approximately the same as a lemon) - High soil acidity observed at most profiles - Significant iron plumes observed discharging from Meerschaum Vale Drain into Hendersons Drain - Low lying topography, significant area between 0 – 0.2 m AHD (where 0 is approximately mean sea level) (see image 16 and 19) - No aquatic life observed
3. Nature Reserve Drain/ Central Hendersons/ NPWS Area	**High**	- Surface water pH in Hendersons Drain was typically between 3 – 4 for the length of the Nature Reserve - Extensive iron staining observed in Nature Reserve Drain and Hendersons Drain (see image 5) - Nature Reserve Drain appears to convey little flow during drier periods and appears to be infilling with soft sediments and other flow impediments (see image 12 and 23) - Low lying topography (see image 13) - No aquatic life observed
4. Tucki Canal/ Central Hendersons/ NPWS Area	**High**	- Surface water pH in Hendersons Drain was typically between 3 – 4 for the length of the Nature Reserve - Extensive iron staining observed in Hendersons Drain (however not in Tucki Canal) (see image 5) - High soil acidity observed at most profiles - Low lying topography - High catchment flows - No aquatic life observed
5. Lower Stibbards/ Lower Hendersons/ NPWS Area	**High**	- Lowest lying area of Tuckean Swamp, with significant area below 0 m AHD (mean sea level) - Surface water pH in Hendersons Drain was typically between 3 – 4 for the length of the Nature Reserve - Extensive iron staining observed in Hendersons Drain (see image 3, 4, 5 and 11) - Significant iron discharge observed in March 2018 (see image 3 and 4)

Area	Priority	Justification
		• High soil acidity observed at most profiles • Lower sections of Hendersons Drain are very deep (invert as low as -4 m AHD) • High flows (see image 2) • No aquatic life observed
6. Upper Hendersons/ Marom Creek	**Moderate**	• Cross sections surveyed of Hendersons Drain in the lower portion of this section is deep (drain invert around -1.5 m AHD), but narrow (see image 21) • Most of the area is below 1 m AHD • Some poor surface water quality observed in minor drains • Smaller catchment inflows • High soil acidity observed at some profiles
7. Marom Drain	**Moderate**	• Large catchment flows but a larger baseflow appears to dilute the impact of any ASS • Surface water acidity greater than 5 • Some aquatic life observed in this drain • High soil acidity observed at some profiles • Mostly of the area is above 0.6 m AHD
8. Upper Tucki Canal	**Moderate**	• Very large catchment flows from both Marom Drain and Tucki Tucki Creek but a larger baseflow appears to dilute the impact of any ASS • Low soil acidity observed at available profiles • Most of the area is above 0.6 m AHD
9. Central Tucki Canal	**Moderate**	• Very large catchment flows from both Marom Drain and Tucki Tucki Creek but a larger baseflow appears to dilute the impact of any ASS • High soil acidity observed at available profiles • Most of the area is above 0.6 m AHD
10. Stibbards Creek	**Lowest**	• Highest topography, with significant area above 1 m AHD • More natural creek line (see image 8) • Low hydraulic conductivity observed in dense clays (see image 9) • Near neutral surface water pH observed • Low soil acidity observed at available profiles • Smallest catchment inflows

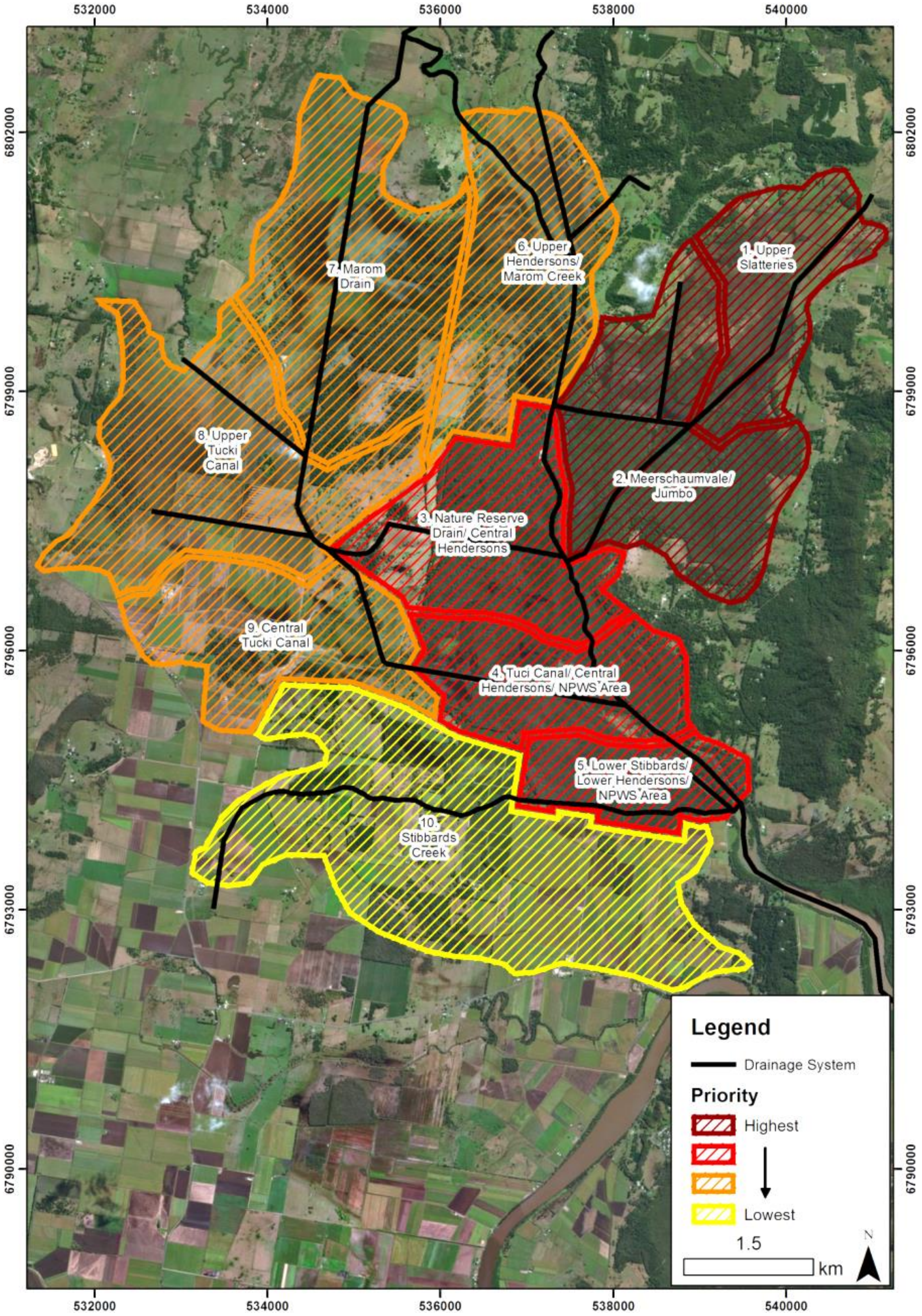


Figure 17: Prioritised management sub-areas of the Tuckean

Site Photographs

Throughout the extensive field investigations undertaken by WRL, observations of the drains and the other environmental conditions were noted. This section provides a number of photographs that show the major drains throughout Tuckean Swamp. Figure 18 is an overview of approximate locations where pictures were taken and the corresponding pictures are on the following pages.

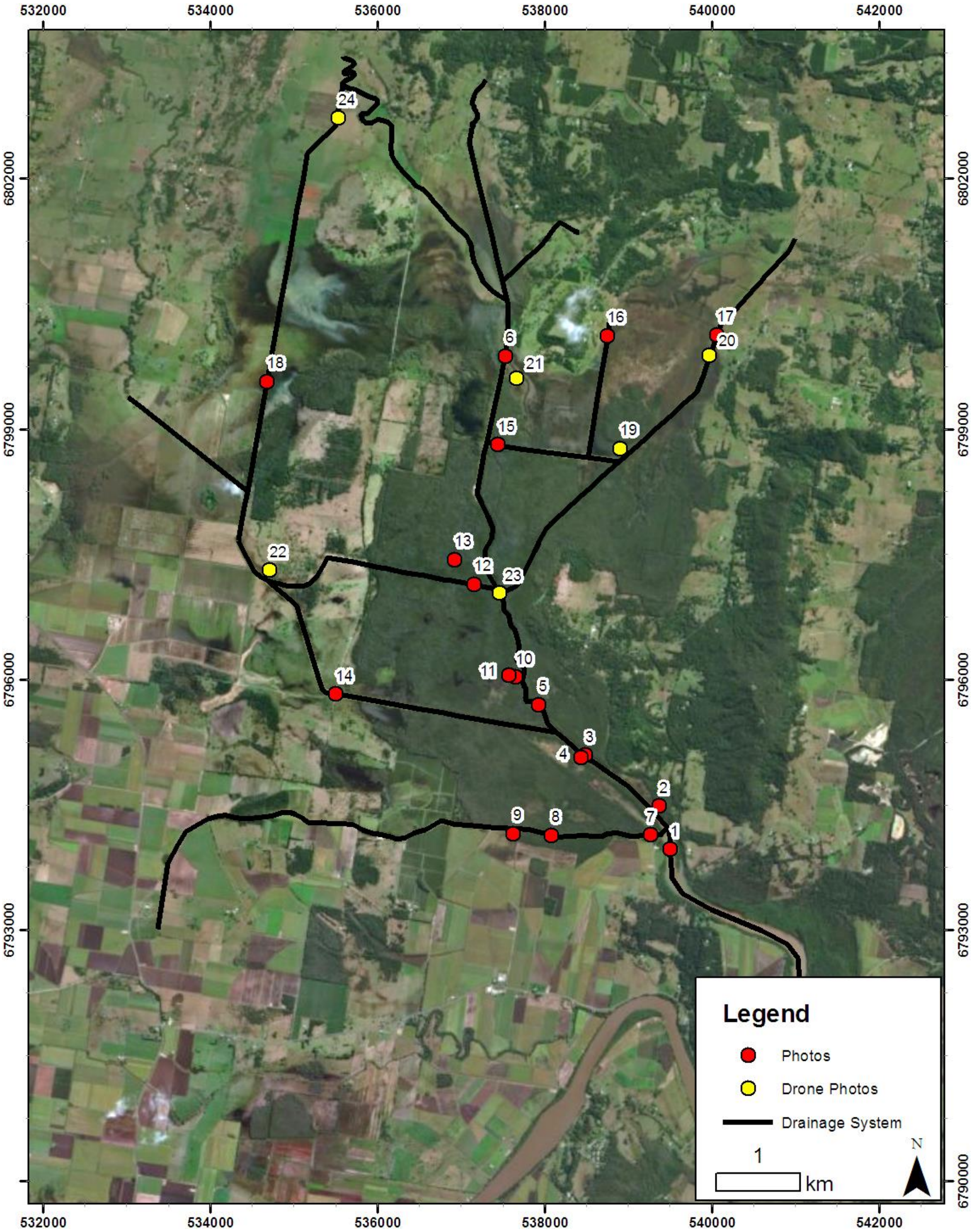


Figure 18: Overview of picture locations

1: Upstream Baggotville Barrage

2: Downstream Baggotville Barrage flowing out

3: Iron floc in water sample, Hendersons Drain

4: Extensive iron plumes, Hendersons Drain

5: Iron staining on the banks of Hendersons Drain

6: Settled iron in sediments, Hendersons Drain

7: Typical minor drain floodgate, Stibbards Creek

8: Narrow, more natural alignment of Stibbards Creek

9: Dense clays with low hydraulic conductivity near Stibbards Creek

10: Dense vegetation in the Nature Reserve

11: Iron staining throughout the Nature Reserve

12: Significant blockages of Nature Reserve Drain

13: Extensive inundation of low lying area in Nature Reserve

14: Wide, deep channel in Tucki Canal conveys most of the water from the north western section of Tuckean

15: Lily growth through Meerschaum Vale Drain

16: Jumbo Drain, where pH comparable to lemon juice (pH=2) was observed

17: Narrowing of Slatteries Drain with significant iron floc settled on bed and banks

18: Marom Drain

19: Low lying land inundation at the confluence of Slatteries and Meerschaum Vale Drain

20: Looking downstream along Slatteries Drain

21: Hendersons Drain, looking downstream.

22: Tucki Canal looking downstream (Nature Reserve Drain visible in the bottom left)

23: Confluence of Hendersons Drain (right) and Nature Reserve Drain

24: Marom Drain, looking upstream