Healthy Waterways and Catchments

Keeping It In Kin Kin – Applying LiDAR Change to Identify Erosion Hotspots

Final May 2017

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Acknowledgements

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Background

Kin Kin Creek Catchment consists of confined steep headwaters and alluvial, meandering sand beds. Previous work completed for the Kin Kin Creek Rehabilitation Plan (Earth Tech, 2002) assessed and divided the creek and its tributaries into geomorphic segments.

Along the slopes of the ranges a mosaic of eucalypt and rainforest communities grow. Areas of rainforest in the middle reaches have been mostly cleared, leaving vine forest remnants along the creek. The lower reaches of the Kin Kin Creek contain the last remnant of the Kin Kin scrub mostly within the Cooloola National Park.

Previous issues and opportunities identified through local landcare meetings include the need to maintain local farming and the rural landscape. The mixed landuse of the catchment creates local diversity within the community and attracts eco-tourism. The high biodiversity and nature conservation areas of the catchment are locally valued and help towards climate change resilience.

The 2016 Report Card on waterway health noted that the environmental condition of waterways in the north subregion ranges from good to excellent, and local communities generally receive high to very high social and economic benefits from the waters. The landcover of the catchment is made up of 29% Grass-cover, 5% Cropping, 55% Forest-cover, 7% Plantation and Tree Crops, and 4% Built-up. The Noosa River is a largely intact coastal lagoon system. There are no major point sources discharging into the river, and urban areas are concentrated around the lower estuarine reaches and occupy less than 3% of the total catchment.

The Kin Kin Catchment still loses a significant amount of soil each year to erosion. This reduces the Kin Kin's available farmland and decreases water quality in the overall Noosa River Catchment. The purpose of this study is to identify and prioritise areas that contribute to this soil loss so that targeted mitigation activities can take place. The primary identification tool used is a LiDAR digital elevation model of change (the change analysis). This report outlines the methodology used to develop the change analysis for the Kin Kin Catchment. Preliminary results of the change analysis are tabled to assist with subcatchment prioritisation and to address sediment risk hotspots.

A combination of manual and automated change analysis identified 258 'Areas of Interest'. The process involved applying filters and masks to improve reliability in results, and verification using desktop high resolution aerial photography.

Areas were characterised by erosion type including Gully, Hillslope, Land Management, Mass Movement, Sheet /Rill, and Stream Bank Erosion. Additional analysis allowed the Areas of Interest to be prioritised based on soil loss (tonnes) and erosion rate (tonnes/ha) for the time interval of 2008-2015. Ground-truthing will confirm the identified Areas of

Interest, help to understand underlying catchment processes, and identify additional areas for future investigation.

This work will help program managers and research scientists determine remediation priorities to achieve the biggest water quality improvement for Kin Kin and the Noosa River, while maintaining farm productivity for the area.

Objective

The Kin Kin Catchment has been identified as a high sediment export catchment in previous scientific studies, in particular the Lake Cootharaba Sediment and Nutrient Study (Grinham, 2012). There is the need to focus attention on key areas to maximise the impact that limited financial investment can make.

In most catchments, 60-80% of sediment export comes from 20% of the catchment area, hence it is critical to identify priority areas for rehabilitation works to ensure resources are utilised efficiently. (Brodie et al., 2003)

Historically, sediment and nutrient area prioritisation was undertaken using multi-criteria spatial tools including 'Confluence of Issues' and the 'Catchment Rehabilitation Planner'. Technologically advanced spatial analysis methods and techniques now exist that allow additional evidence-based prioritisation exercises to occur.

Light Detection and Ranging (LiDAR) topographic change data is now being utilised in government and landcare projects as a means of identifying areas of past and current soil movement. LiDAR change analysis is the calculation of elevation differences between LiDAR imagery runs undertaken at different times.

The Kin Kin Creek change analysis compared latest capture (2015) against baseline data (2008), resulting in the generation of a LiDAR Topographic Change map. The change analysis identified erosion sites and areas of soil deposition for the time interval. It is hoped that this work will support subcatchment remediation efforts and inform priority investment for landscape erosion and sediment control.

Application

All relevant and available scientific information and data was assessed for use as part of the prioritisation process. This included existing land erosion risk mapping for the Kin Kin area.

Information developed from the change analysis will inform the Keeping it in the Kin Kin Project including:

- Phase 1 – Area prioritisation, Engagement and Selection of Demonstration / On-ground Activities
- Phase 2 – Full implementation of the 'Keeping it in Kin Kin Action Plan'.

Other uses of the information may include informing waterways strategies /action plans and integrated catchment management activities (property planning, weed control and creek restoration).

The change analysis provides a current baseline and snapshot of erosion/deposition rates in the Kin Kin Creek catchment for the time interval.

Outputs

The change analysis outputs include:

- A digital elevation model change map
- Areas of interest identified as having significant erosion and deposition
- 'Erosion Hot Spots' map of priority areas showing high erosion rates
- Kin Kin Waterbodies

General Approach

The change analysis was carried out following methodologies developed by the Healthy Country Program, Department of Science, Information Technology and Innovation (DSITI), and the Australian Rivers Institute (ARI). Training in Geomorphic Change Detection Software further refined our application of LiDAR digital elevation models and assisted in separating out the changes between the surveys that are due to geomorphic changes as opposed to noise in the survey data (Wheaton, 2015). This was to ensure that the analysis took advantage of the significant work already completed in this field and that it was consistent with similar assessments across the state.

The two raster digital elevation models (2008 and 2015) were standardised and analysed to:

- account for sources of uncertainty
- identify and classify changes to generate 'areas of interest'
- verify 'areas of interest'

- broadly classify erosion types within 'areas of interest'
- calculate the volumetric rates of change within 'areas of interest'

Overview of Steps

The main objective is to *establish an annual sediment load (tonne/y) entering the Noosa River and Lakes system from the Kin Kin Creek catchment, and to identify those parts of the Kin Kin catchment that contribute the bulk of this (soil erosion 'hot spots')*.

This included the following components:

- Verification and standardization of LiDAR digital elevation models
- Generate change analysis
- Identify areas of high elevation change based on change analysis
- Select areas of elevation loss for identification of 'Erosion Hot Spots'
- Preliminary prioritisation of erosion hot spots based on soil loss / erosion rate.

Post work to validate and further inform erosion hot spots include:

- Workshop with project contributors and partners for discussion and general consensus
- Prioritise areas based on multiple criteria and other factors (e.g. erosion material volume, treatment viability, landuse, soils)
- Ground-truthing workshop with Noosa Landcare and Kin Kin landholders
- Generate Keeping it in Kin Kin Action Plan for implementation Works
- Independent academic scientific review before and during the prioritisation process.

Repeat topographic surveys are often used to monitor geomorphic change in rivers. These yield digital elevation models (DEMS), which are differenced against each other to produce spatially distributed maps of elevation changes called DEMS of difference (DoD). Both area and volumetric budgets of erosion and deposition can be calculated from DoDs. (Wheaton 2008, 2015; Geomorphic Change Detection Software and Training)

The methodology of generating LiDAR DEM Change Maps removes field-observer bias and creates a repeatable approach for identifying and mapping topographic change which can be further strengthened and validated through ground-truthing. (Wyrick and Pasternack, 2015)

LiDAR Change Analysis

LiDAR is a remote sensing method where a pulsed laser is used to measure the distance from the laser sensor to the earth, to create accurate digital elevation and canopy height models. LiDAR DEM Change or DEMS of difference (Croke et al, 2012) allows the calculation of elevation differences between LiDAR imagery capture projects. This modelling provides elevation gain/loss values for the whole of Kin Kin Creek Catchment, allowing properties and areas suffering the highest erosion rates to be determined. (Parker, 2015)

DEMs collected at different times are compared by subtracting, or 'differencing', oldest from most recent (for example, 2015 DEM less 2008 DEM) to identify whether a loss or gain in elevation has occurred. Areas showing an increase in elevation could be areas of deposition, where a decrease in elevation generally indicates that erosion has occurred during the time interval. The results of the DoD were cross referenced with high resolution aerial photography to validate identified erosion hot spots. (Wyrick and Pasternack, 2015)

Once erosion hot spots are identified, the high resolution of the LiDAR elevation data (+ or – 0.15m) allows the calculation of the net volume change (m3) and the amount of sediment lost or mobilized during the time series. DEM differencing provides an accurate estimate of volumetric change and the development of sediment budgets for an area.

The resulting change file identifies spatial patterns of 'cut and fill' often presented as red to blue maps. LiDAR generated slope maps and high resolution aerial photography used in conjunction with the LiDAR DEM Change Map helped with further verifying identified and active change.

Waterbodies visible in the change map were often represented as loss in elevation. It was noted that 2015 was a dry year for rainfall, with 2008 having high rainfall levels, hence waterbodies showing a negative change in elevation. (elevation is now low, elevation was higher).

For this time interval of LiDAR images, slope analysis revealed waterbodies having a value of '0' (no slope), and areas with this value were selected and re-classified as LiDAR generated waterbodies. Further manual analysis captured additional waterbodies with a total waterbody count in excess of 504. This mostly represented farm dams and natural waterbodies, and also identified stretches of instream and open waterways.

Waterbodies were then masked / removed from the final LiDAR DEM Change Map to provide a more accurate representation of volumetric change.

In line with geomorphic change detection principles and accounting for uncertainties in digital elevation models, low pass filters were applied to the individual elevation models to reduce any noise and errors in the LiDAR DEM Change map. This action traverses a

low pass 3 by 3 filter (9 m2) over the raster and smooths the entire elevation model reducing the significance of anomalous cells and overall 'bumpiness' of the local topography. (ESRI Arc Map Toolbox)

A spatial neighbourhood analysis was also undertaken, which assesses the likelihood that changes are real based on the changes in nearby cells. A 250 m search was applied to the DoD with elevation values of -0.5 to -5.0 m less water bodies and the sum of values calculated. The output map was cross referenced with erosion hot spots to provide multiple lines of evidence.

Other spatial maps used to reduce uncertainty in DoD included a Landcover Forest mask. These areas weren't removed from the assessment, but allowed focus to be given to areas of change that could be verified using high resolution aerial photography.

A slope map was generated from the 2015 digital elevation model which was also used to confirm the DoD showing slope patterns of disturbance and altered land surfaces.

For the final LiDAR DEM Change Map, any differences +/- 0.5 m were considered within the bounds of uncertainty and labelled as 'no detectable change'. This is consistent with the +/- 0.4 m vertical accuracy of the 2015 LiDAR specifications. (See Attachments – LiDAR Specifications)

The final LiDAR DEM Change Map represents the net change in topographic elevation over the 7 year period. Erosion hot spots or 'Areas of Interest' were selected based on the final LiDAR DEM Change Map using automated and manual selection techniques in GIS.

Summary of Methodology

LiDAR Collation and Processing

- 2008 LiDAR elevation tiles compiled to establish baseline elevation model for Kin Kin Catchment

Mosaic of tiles developed, including digital elevation model, slope degrees and relative slope

- 2015 LiDAR elevation tiles sourced and compiled to establish most current elevation model for Kin Kin Catchment
- Mosaic of tiles developed, including digital elevation model, slope degrees and relative slope.
- A low pass filter was also applied to smooth the DEMs and reduce the significance of anomalous cells.

Geomorphic Change Detection

- A Geomorphic Change file was developed for Kin Kin Catchment based on 2015 Mosaic DEM less 2008 Mosaic DEM
- Water bodies were identified in the change file as having a loss in elevation and manually exported as a separate layer (assumption is 2008 was wetter and 2015 a dry year for rainfall).
- Water bodies were also extracted through automation based on LiDAR Slope 2015 and how the data was processed (value = 0). This has provided an accurate baseline of bio-available water during a dry year.

Applying filters to confirm losses and gains (Wheaton et al, 2010)

- Landcover Forest mask was used to target change within cleared areas
- 2015 LiDAR slope was used to confirm change / disturbance within forested areas and non-forested areas
- High resolution aerial photography for 2015 (10cm) and 2009 (50cm) was used to confirm change and disturbance

Erosion Hotspots

- Areas of Interest were selected based on the LiDAR analysis support files previously mentioned. Identified areas were showing erosion values, verified through desktop high resolution aerial photography and were captured at a landscape level averaging 3 – 7 ha in size. (See Table 1)
- Areas of Interest were classified by erosion type and used as a mask to select from the geomorphic change file (LiDAR DEM Change Map)
- Erosion and deposition rates were calculated within Areas of Interest for the catchment, with higher confidence given to sediment loss.

Findings

Based on the change analysis for Kin Kin, erosion and general land management is a catchment wide issue and opportunity. At a catchment overview, there is a clear distinction of higher levels of erosion occurring in the mid to upper catchment areas upstream of the Kin Kin Creek - Wahpunga Pass. Higher levels of deposition were observed in the lower catchment areas, with areas of natural levee banks forming along lower Kin Kin Creek from reduced velocities and sediment drop-out. Ground-truthing of results would confirm these initial findings.

Higher levels of disturbance were noted on the slopes even though forests were showing signs of recovery from previous land uses. Old landslips were also picked up on the forested slopes, with ground-truthing required to verify whether these are still active or prone to further erosion.

Areas with numerous tracks were identified along the western range / Woondum Range presenting a high risk of erosion. Some of these valleys presented signs of heavy weed infestations (e.g. lantana) and unstable conditions.

On the cleared slopes, areas of mass movement and gullies were noted. Across the catchment, many sediment inputs were identified that could become mobilised during rainfall events due to the presence of low ground cover and visible areas of bare earth from high resolution aerial photography.

There were areas with high erosion risk that showed signs of remediation effort through the construction of contour banks.

Stream bank erosion was mostly confined to the mid to upper reaches of the study area. Lower Kin Kin Creek does have riparian / creek vegetation in good condition although in some reaches the overall width is quite narrow. Based on community feedback and anecdotal evidence across the region, recent rainfall events and increased flows is placing further pressure on outside creek bends and riparian zones. Ground-truthing in the Kin Kin Creek catchment would confirm if this is occurring.

Waterways with riparian vegetation showed signs of greater stability with the LiDAR Change Map confirming areas of deposition and less erosion. Some mapping interference was observed coming from the instream water within the riparian zone, mostly as a loss of elevation. This may be from reduced water levels between the two LiDAR captures, 2015 – 2008. Analysis within the riparian zone focussed on creek banks with higher slope, large clusters of erosion and un-vegetated waterways.

Slopes currently supporting weeds (e.g. lantana) and regrowth are showing signs of erosion, with drainage and track management required.

The Areas of interest represent sites showing current erosion based on the LiDAR Change Map. High resolution aerial photography was used to confirm areas at a desktop level for greater confidence in the process. It is recommended that ground-truthing be undertaken and local feedback received to advance this work.

Types of erosion classified included Gully Erosion, Stream Bank Erosion and Mass Movement / Landslips. Erosion associated with land management through ground disturbance and weeds was also included as was found to be a significant factor. Table 1 summarises the erosion classification with a total of 258 sites identified.

Table 1: Areas of Interest identified for Kin Kin Creek Catchment

Erosion Type	Areas Identified (number)	Area (ha) based on 'Area of Interest'	Mean Area (ha)
Gully Erosion	96	274	3
Land Management – Disturbance and Weeds	72	480	7
Mass Movement	35	223	6
Sheet and Rill Erosion	1	1	-
Stream Bank Erosion	54	173	3
Total	258	1,151	4

The LiDAR Change was further analysed based on the identified Areas of Interest, applying filters and masks. Further corrections were applied through removing errors associated with water bodies. Greater confidence was also assigned to elevation changes between the ranges of 0.5 – 2.0 m both for gain and loss.

Table 2 presents the findings from the DoD and an estimate of the change in storage terms over the time step between the LiDAR surveys. Over 90% of observed LiDAR Change values were within the 0.5 - 2.0 m range and in terms of erosion rates for the Noosa River Catchment are more realistic. This range was rated as high confidence.

Cut and fill activities for housing and infrastructure, and topographic features (steep embankments and waterfalls) were observed through aerial photography in the 2.0 - 5.0 m and > 5.0 m LiDAR Change ranges. A moderate confidence level was given to the 2.0 – 5.0 m range.

The total observed range was slightly higher for elevation loss and this need further investigation. These higher ranges represent less than 2% of the totals. Based on the statistical analysis of the LiDAR Change Map values, total observed range, and the spatially variable elevation uncertainties in individual DEM surface representations, we would estimate an uncertainty on mass sediment eroded to be + / - 20 %.

Table 2: Total Soil Loss and Gain from Geomorphic Change Analysis for '**Areas of Interest**' (based on LiDAR DEM Change Map) **Actual values quoted may be +/- 20% accurate.**

Soil Loss	**Values***	**Soil Gain**	**Values***
Total Observed Range			
Volumetric change for elevation -0.5 to -9.0 m	1,912,839 m3	Volumetric Change for elevation 0.5 to 7.0 m	277,444 m3
Sediment mobilized** Soil loss (7 year average)	2,486,691 t 355,241 t/yr	Sediment deposited	~ 360,678 t
Area of loss	208 ha	Area of gain	26 ha
Higher Confidence Range			
Volumetric change for elevation -0.5 to -2.0 m	1,800,015 m3	Volumetric change for elevation 0.5-2.0 m	212,197 m3
Sediment mobilised Soil loss (7 year average)	2,340,020 t 334,288 t/yr	Sediment deposited	~ 275,856
Area of loss	204 ha	Area of gain	23 ha
Moderate Confidence Range			
Volumetric change for elevation -2.0 to -5.0 m	110,024 m3	Volumetric change for elevation -2.0 to -5.0 m	60,698 m3
Sediment mobilised Soil loss (7 year average)	143,031 t 20,433 t/yr	Sediment deposited	~ 78,908 t
Area of loss	4 ha	Area of gain	2 ha

*Actual values quoted may be +/- 20% accurate

**Tonnes of sediment mobilised / deposited = Volumetric Change x Soil Bulk Density (average of 1.3 applied in this case)

Area of Loss is the observed erosion / deposition extent

See table in Attachment that lists all counts and values for range -0.5 to -2.0 m loss

Within the high confidence range of 0.5 – 2.0 m for elevation gain / loss, the data showed that up to 2.3 million tonnes of sediment was mobilised during 2008 - 2015. Based on average soil replacement costs of $30 / tonne[1], soil productivity decline from the catchment or paddock is estimated to exceed $6 million for the seven year period.

Over 250,000 tonnes of sediment was found to be deposited. We have less confidence in the 'Soil Gain' estimates compared to 'Soil Loss' estimates using the approach outlined. Deposition generally occurs as narrow layers (i.e. less than 0.5 m) across floodplains, hill slopes and within channels. As a result, they will not be identified using the method outlined.

Summary

Soil erosion control for maintaining productive farmland and waterway health requires a catchment wide approach and focus. The LiDAR DEM Change Map has provided evidence of where in the landscape soil erosion has occurred during the time interval of 2008-2015.

The LiDAR assessment and DoD has provided a morphological sediment budget for the Kin Kin Creek Catchment for the time interval. Additional information of where sediment buffers and barriers exist within the landscape would improve the accuracy of this work and provide an estimate of the total soil loss from Areas of Interest that actually leaves the Kin Kin Creek catchment.

The additional work of ground-truthing of the results, assessment of geomorphic condition, active process and trajectory is recommended and may occur through other components and phases of 'Keeping it in Kin Kin Project'. This exercise does provide enough data to start ground-truthing and to work towards project development and improved land management activities e.g. ground cover management. Other catchment information including geomorphic condition and land use will help inform strategic priorities and actions to be undertaken.

[1] Trade garden soil cost for bulk purchase

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Attachments

LiDAR Specifications

Queensland LiDAR Data – Sunshine Coast LGA 2008 Re-Classified Project

http://qldspatial.information.qld.gov.au/catalogueadmin/catalog/search/resource/details.page?uuid=%7B1C053805-289E-40F5-8211-992555905EE1%7D

Date: 2008-10-31

Abstract: This LiDAR dataset covers the entire Sunshine Coast Local Government Area including areas within the current Noosa Shire. In 2012, the original LiDAR dataset was reclassified to C2 and C3 level of classification, under a Queensland Government project.

Coordinate System

Projection: MGA56

Horizontal Datum: GDA94

Vertical Datum: AHD

Data Quality

Vertical Accuracy: 0.15m

Horizontal Accuracy: 0.2m

Acquisition

Airborne Laser Scanning (ALS) data was acquired for the Sunshine Coast project from a fixed wing aircraft between October 2008 and July 2009.

Ground control points were used as check points against the remotely sensed data. These points were measured using Rapid Static GPS methodologies and consisted of approximately 105 locations throughout the project area.

Flying Height: 1000m

Swath Width: 924m

Side Overlap: 30%

Average Point Separation: 1m

Queensland LiDAR Data – Noosa Gympie 2015 Project

http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=noosa+2015+lidar

Date: 2016-05-12

Abstract: This project captured high resolution elevation data using LiDAR technology over the entire Local Government Area of Noosa and the town of Gympie and the surrounding urban area within the Gympie Regional Council.

Coordinate System

Projection: MGA56

Horizontal Datum: GDA94

Vertical Datum: AHD

Data Quality

Vertical Accuracy: +/- 0.4m

Horizontal Accuracy: +/- 0.15m

Acquisition

Airborne Laser Scanning (ALS) data was acquired from a fixed wing aircraft between August 18th and 24th 2015. Areas under tidal influence were captured at two hours either side of low tide.

Ground support GPS base station support was provided by the client without incident. The ground check points acquired by the company allowed an assessment of the accuracy of the ALS data.

GIS Processing Notes

- Create Mosaic Dataset
  GDA_1994_MGA_Zone_56
  UNIT ['Meter',1.0]
  Add Rasters To Mosaic Dataset
  Build Pyramids and Statistics

- Copy Raster lidar 2008 Mosaic
  Copy Raster lidar 2015 Mosaic

- Filter kinkin_lidar2008.img
  LOW DATA
  kinkin_lidar_2008_lowpass.img
  Filter kinkin_lidar2015.img
  LOW DATA
  kinkin_lidar_2015_lowpass.img

- Raster Calculator
  Minus kinkin_lidar2015.img - kinkin_lidar2008.img
  KinKin_dem_change15_08_v1.img
  kinkin_lidar_2015_lowpass.img - kinkin_lidar_2008_lowpass.img
  KinKin_dem_change15_08_vLowpass.img

- Slope kinkin_lidar2015.img
  Focal Statistics kinkin_lidar2015_slope.img
  Rectangle 10 10 CELL
  MEAN DATA
  kinkin_lidar2015_slope_avg10m.img
  Relative Slope
  Minus kinkin_lidar2015_slope.img - kinkin_lidar2015_slope_avg10m.img
  kinkin_lidar2015_relslope10m.img

- Slope kinkin_lidar2008.img
  Focal Statistics kinkin_lidar2008_slope.img
  Rectangle 10 10 CELL
  MEAN DATA
  kinkin_lidar2008_slope_avg10m.img

- Intergerise dem change to calculate loss and gain
  x10
  Raster Calculator Int("N:\Projects\Kin_Kin\KinKin_dem_change15_08_v1.img" * 10)
  KinKin_dem_change15_08_v1_x10_int.img
  Extract By Attributes
  KinKin_dem_change15_08_v1_x10_int.img ""Value" <= -10" (-1.0m)

- Areas of Interest manual identification up to 1:3,000
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  Extract By Mask
  KinKin_dem_change_15_08_lt1m_AoI.img
  KinKin_dem_change_15_08_lt1m_AoIv2.img
  KinKin_dem_change_15_08_lt1m_AoIv3.img
  KinKin_dem_change_15_08_lt1m_AoIv4.img
  KinKin_dem_change_15_08_lt1m_AoIv5.img

- Waterbodies to raster
  Polygon To Raster
  CELL_CENTER NONE 10
  kin_kin_waterbodies_1m.img
  Reclassify
  kin_kin_waterbodies_1m_rc.img
  kin_kin_waterbodies_1m_rc_inverse.img
  Raster Calculator
  KinKin_dem_change_15_08_lt1m_AoIv4.img *
  kin_kin_waterbodies_1m_rc_inverse.img
  Raster Calculator
  Int("N:\Projects\Kin_Kin\KinKin_dem_change_15_08_lt1m_AoIv4_revised.img" * 1000)
  KinKin_dem_change_15_08_lt1m_AoIv4_revisedInt.img

Types of Erosion – Definitions

Source: Taken from https://www.qld.gov.au/environment/land/soil/erosion/types/

Gully Erosion: Gully erosion happens when runoff concentrates and flows strongly enough to detach and move soil particles. A small waterfall may form, with runoff picking up energy as it plunges over the gully head. Splashback at the base of the gully head erodes the subsoil and the gully eats its way up the slope. Gullies may develop in watercourses or other places where runoff concentrates.

Land Management – Disturbance and Weeds: This category was included to capture erosion processes caused by disturbance and weeds. The LiDAR DEM Change Map was showing soil loss associated with tracks, general land disturbance and areas infested with weeds. Further ground-truthing required to classify into other erosion type categories.

Mass Movement: Mass movement occurs on cleared slopes in coastal and hinterland areas. Gravity moves earth, rock and soil material downslope both slowly and suddenly generally associated with rainfall events.

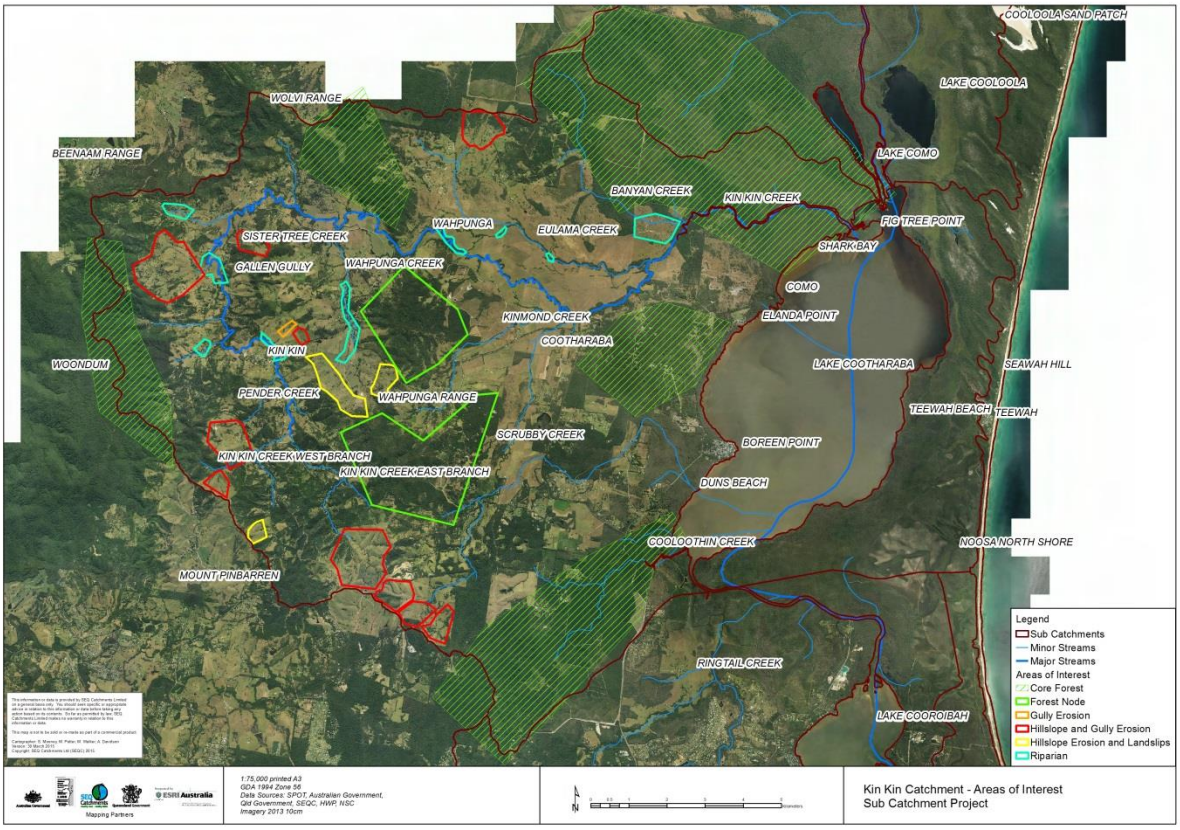
During periods of prolonged and heavy rainfall, water entering permeable soils can be stopped by a barrier as bedrock or a clay-rich soil horizon. The heavy weight of this saturated soil can slide downslope if it is sitting on a rock surface loosened by the build-up of water in the soil.

Sheet and Rill Erosion: Hill-slopes are prone to sheet and rill erosion. The amount of hill slope erosion largely depends on how the land is used. Sheet erosion occurs when a thin layer of topsoil is removed over a whole hillside paddock. Rill erosion occurs when runoff forms small channels as it concentrates down a slope. These rills can be up to 0.3 m deep, and if they become deeper they are referred to as gully erosion.

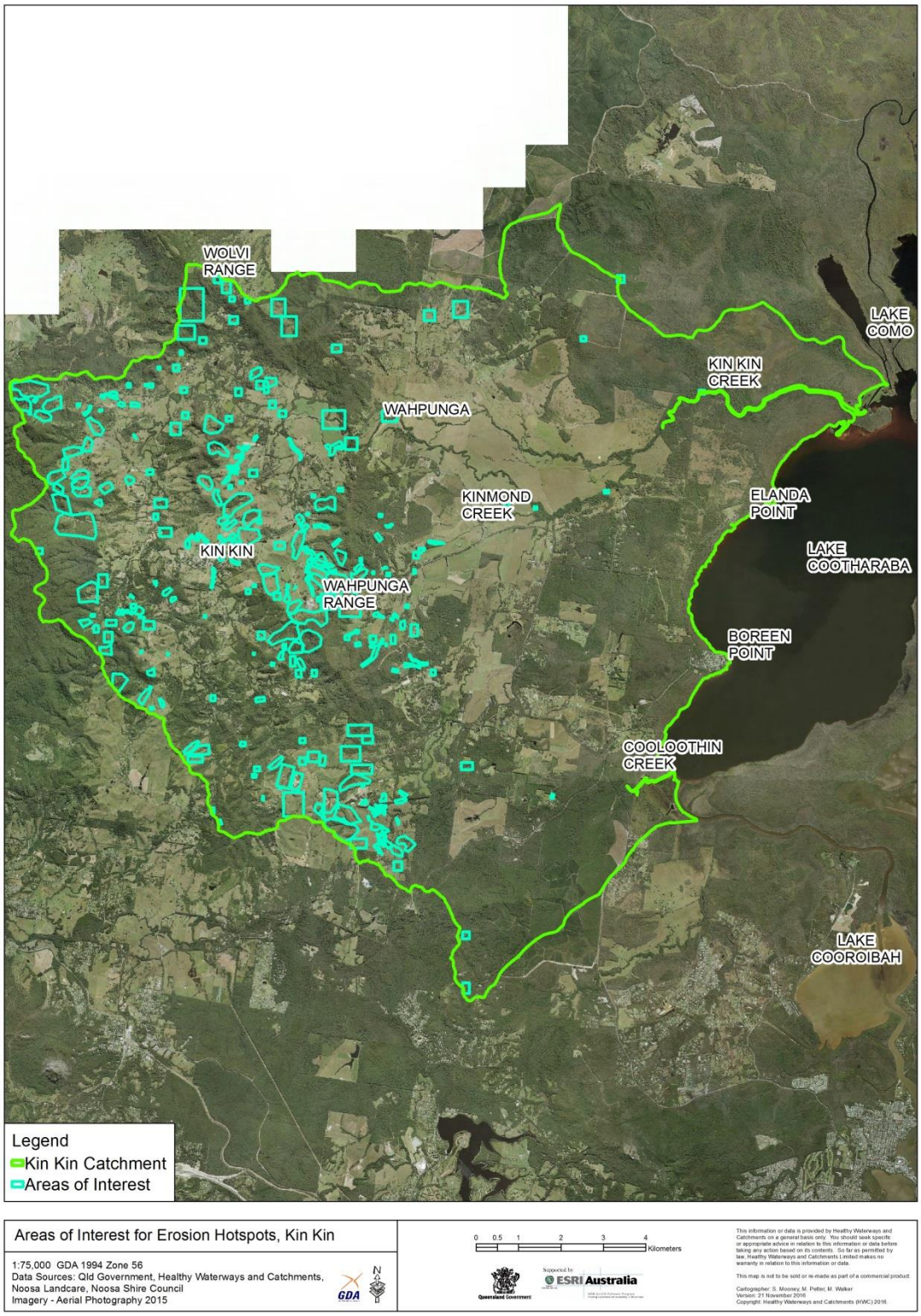
Stream Bank Erosion: Stream bank erosion generally happens during floods and rainfall events. The major cause of stream bank erosion is the removal of vegetation on river banks and the removal of sand and gravel from the stream bed.

Supporting Maps

Map 1: 2015 Preliminary Erosion Investigation Areas



Map 2: Identified Areas of Interest and Erosion Hotspots (LiDAR derived)



Map 3: Cut and Fill example showing loss of elevation where soil has been removed on slope and then used as fill as gain in elevation to create a level pad for shed/house.

Map 4a: Aerial photography 2015 showing Erosion Type of "gully erosion" (not visible)

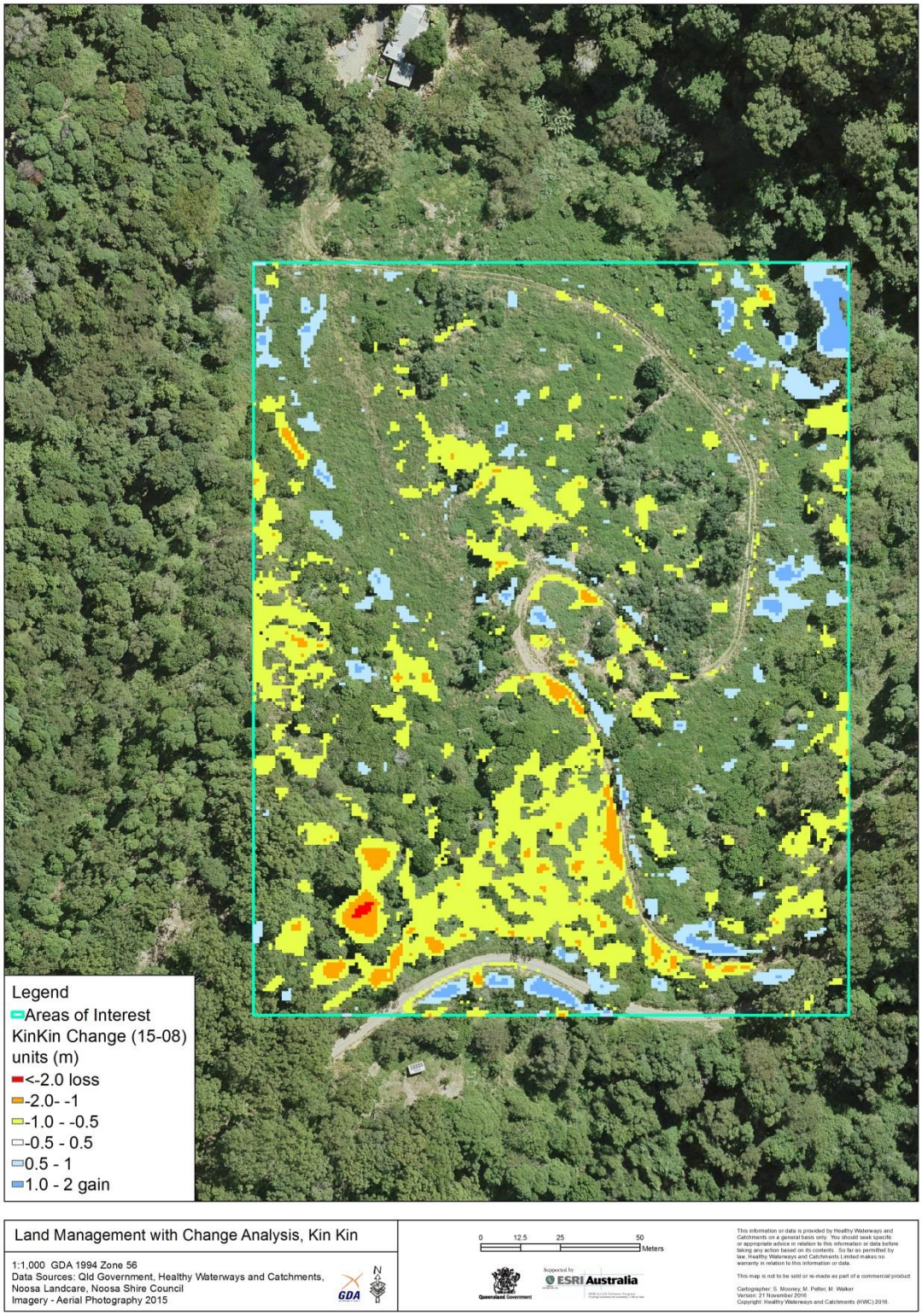
Map 4b: LiDAR slope showing Erosion Type of "gully erosion" where dark slope represents steeper areas and light slope are flatter areas

Map 4c: Change analysis over Erosion Type of "gully erosion" showing loss in elevation (active erosion) mostly at the head of the gully system

Map 5a: Aerial photography 2015 of Erosion Type "Land Management" (disturbance and weeds)

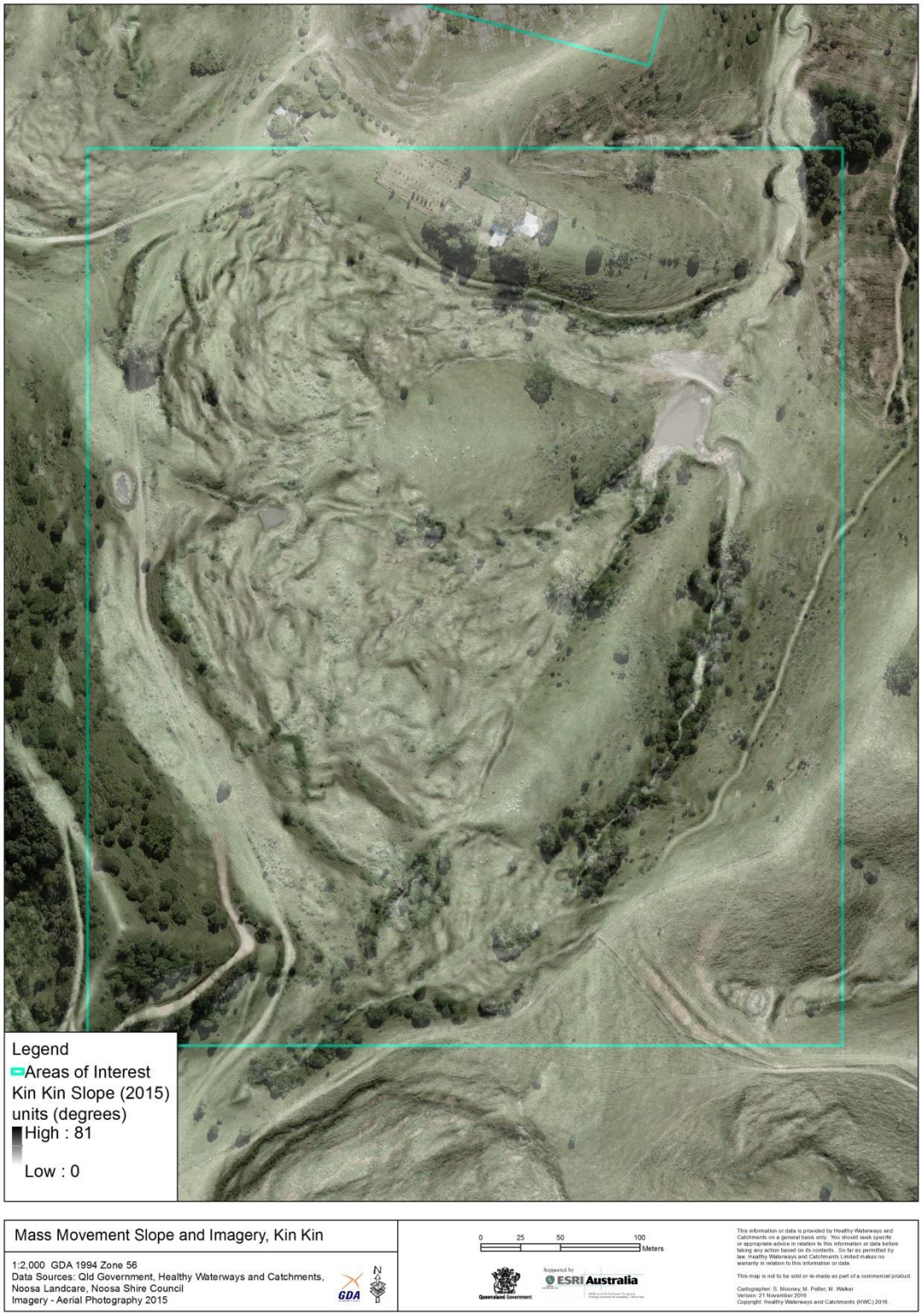
Map 5b: LiDAR slope showing Erosion Type of "Land Management" highlighting tracks and general disturbance on steeper slopes. The lidar slope is generally showing unstable conditions on previously cleared lands with potential weeds as regrowth

Map 5c: Change analysis over Erosion Type of "Land Management" showing higher loss in elevation (active erosion) along track and in steeper southern area

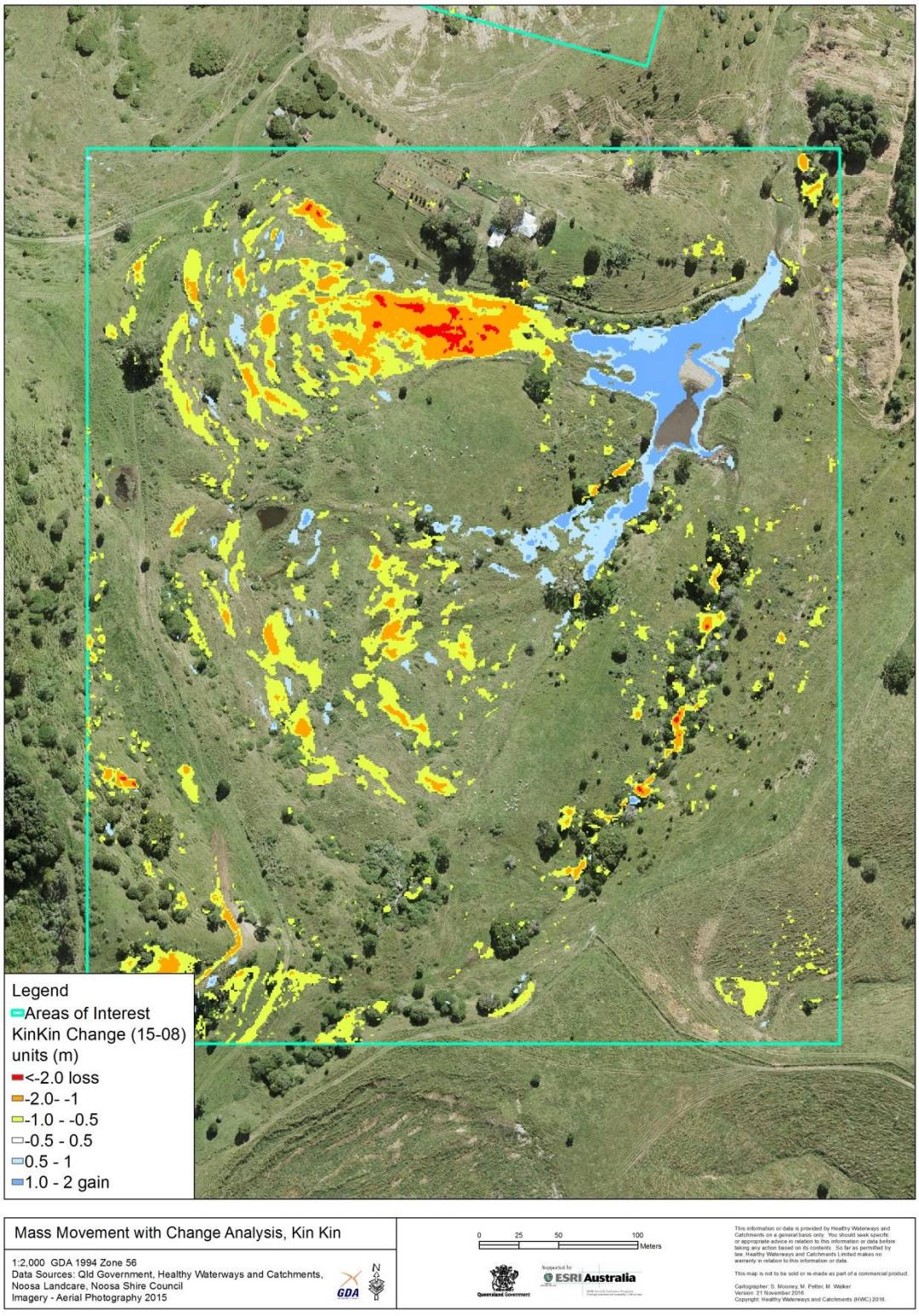


Map 6a: Aerial photography 2015 of Erosion Type "Mass Movement" – landslip

Map 6b: LiDAR slope showing 2 distinct areas of Erosion Type "Mass Movement" highlighting rippling affect as soil slumps down the slope



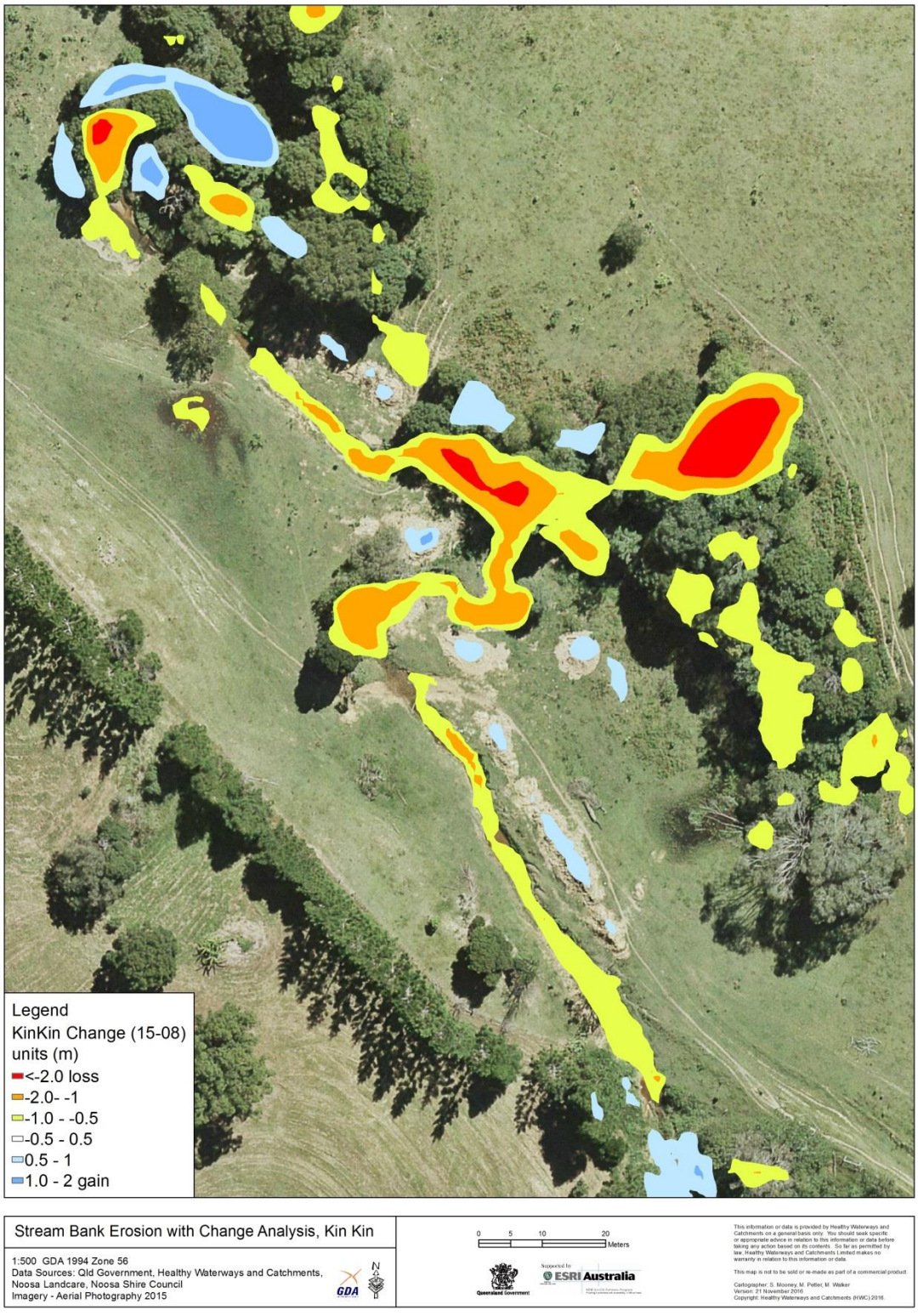
Map 6c: Change analysis over Erosion Type "Mass Movement" showing northern landslip being more active with higher rates of soil loss. High levels of deposition observed in the valley and entering waterway.



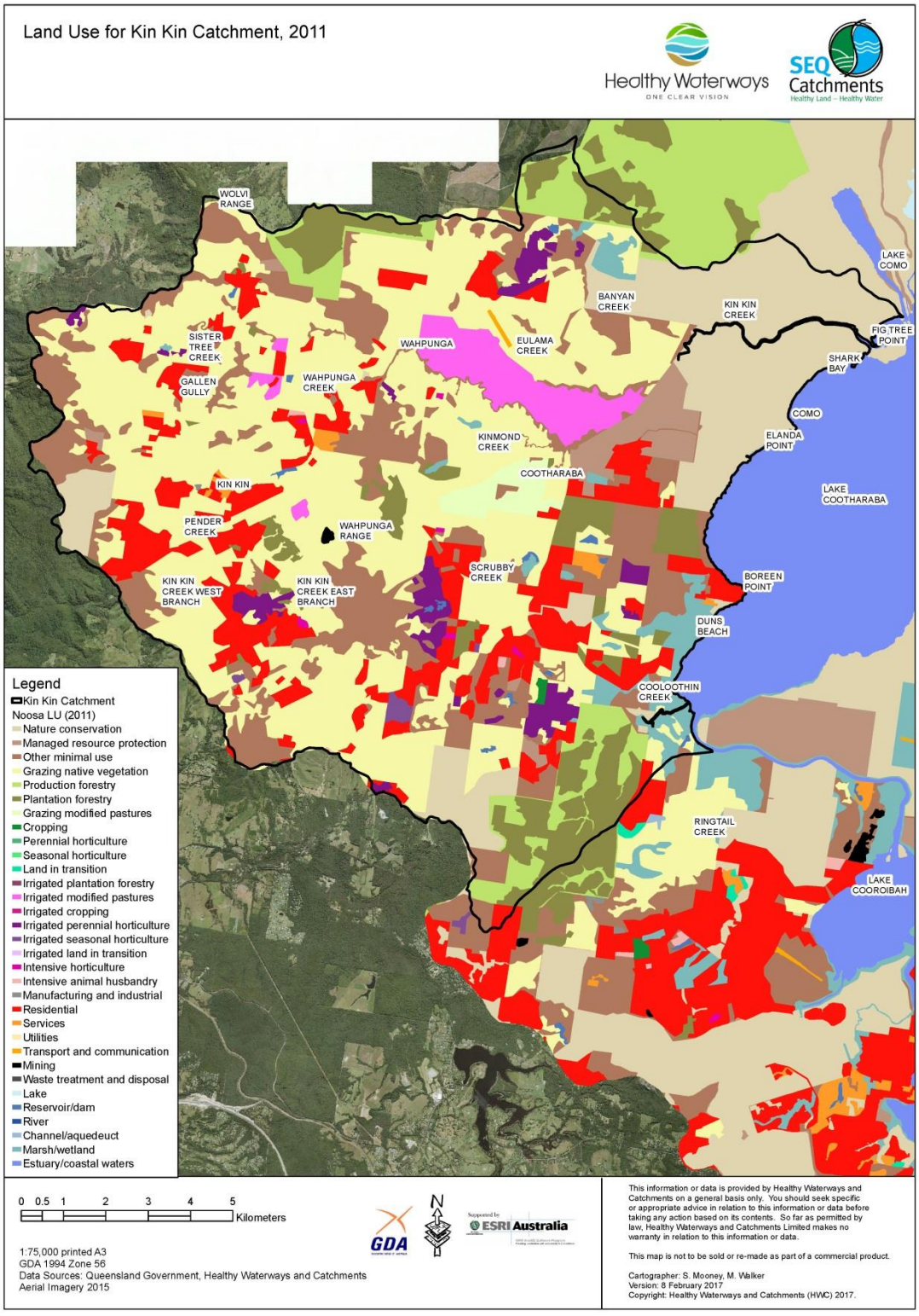
Map 7a: Aerial photography 2015 showing Erosion Type "stream bank erosion"

Map 7b: LiDAR slope showing Erosion Type "stream bank erosion" with steeper creek banks and high slope as dark colour with a steep gully on the eastern side of the waterway

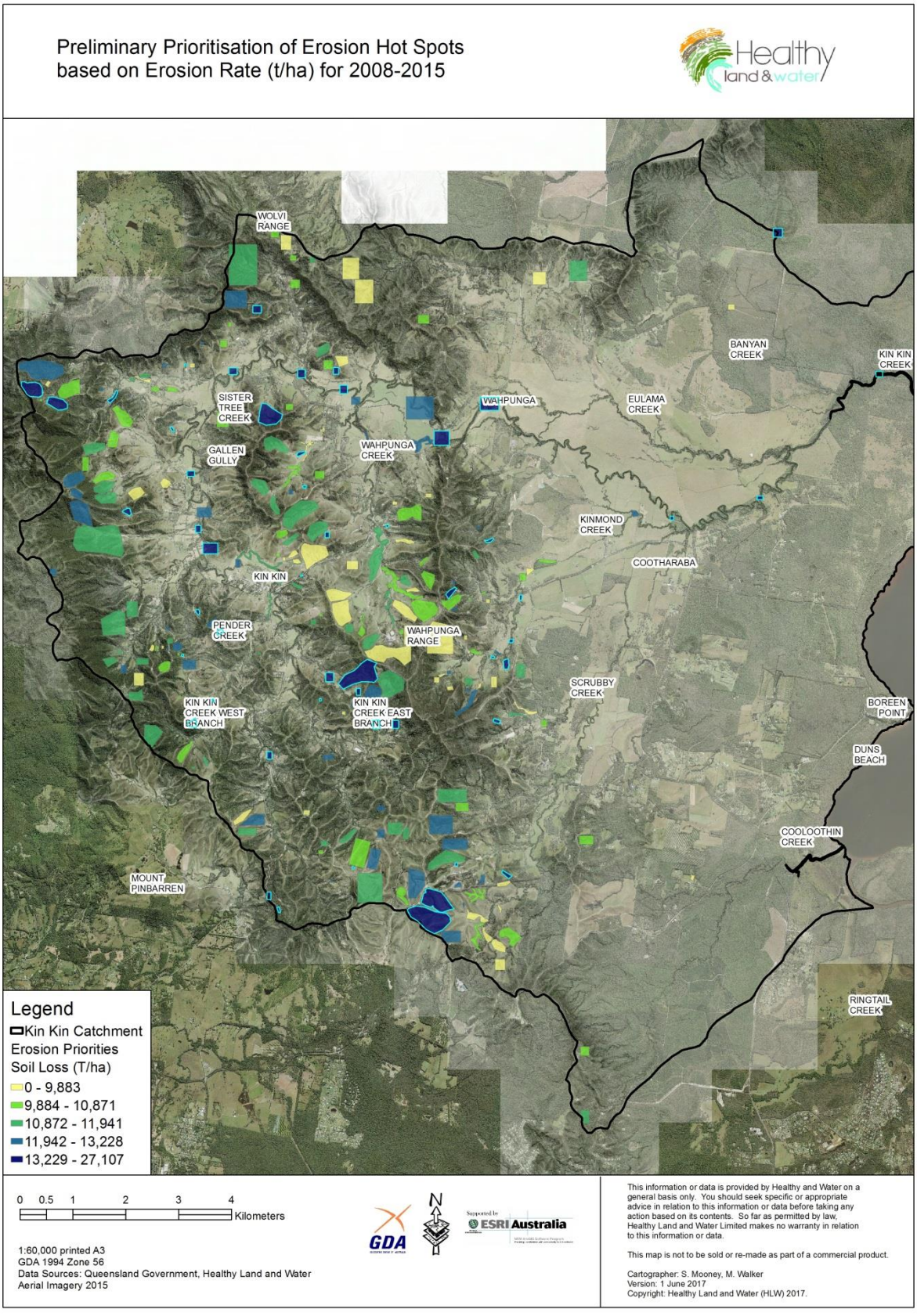
Map 7c: Change analysis over Erosion Type "stream bank erosion" showing areas of erosion and deposition along the waterway. Steep gully on eastern side also showing signs of erosion.



Map 8: Land Use Support Map for Kin Kin



Map 9: Preliminary Prioritisation of Erosion Hot Spots (t/ha)



Volumetric Change from DoD (-0.5 to -2.0 m)

Count	Elevation	Value
105.0	-2.000	-210.000
115.0	-1.999	-229.885
100.0	-1.998	-199.800
109.0	-1.997	-217.673
106.0	-1.996	-211.576
120.0	-1.995	-239.400
121.0	-1.994	-241.274
120.0	-1.993	-239.160
114.0	-1.992	-227.088
114.0	-1.991	-226.974
127.0	-1.990	-252.730
121.0	-1.989	-240.669
111.0	-1.988	-220.668
110.0	-1.987	-218.570
127.0	-1.986	-252.222
154.0	-1.985	-305.690
122.0	-1.984	-242.048
117.0	-1.983	-232.011
143.0	-1.982	-283.426
104.0	-1.981	-206.024
123.0	-1.980	-243.540
117.0	-1.979	-231.543
112.0	-1.978	-221.536
128.0	-1.977	-253.056
99.0	-1.976	-195.624
132.0	-1.975	-260.700
118.0	-1.974	-232.932
134.0	-1.973	-264.382
124.0	-1.972	-244.528
117.0	-1.971	-230.607
130.0	-1.970	-256.100
120.0	-1.969	-236.280
121.0	-1.968	-238.128
131.0	-1.967	-257.677
132.0	-1.966	-259.512
123.0	-1.965	-241.695
143.0	-1.964	-280.852
126.0	-1.963	-247.338
112.0	-1.962	-219.744
118.0	-1.961	-231.398
116.0	-1.960	-227.360
128.0	-1.959	-250.752
129.0	-1.958	-252.582
128.0	-1.957	-250.496
131.0	-1.956	-256.236
144.0	-1.955	-281.520
136.0	-1.954	-265.744
119.0	-1.953	-232.407
128.0	-1.952	-249.856
136.0	-1.951	-265.336
132.0	-1.950	-257.400
133.0	-1.949	-259.217
111.0	-1.948	-216.228
145.0	-1.947	-282.315
132.0	-1.946	-256.872
133.0	-1.945	-258.685
144.0	-1.944	-279.936
120.0	-1.943	-233.160
161.0	-1.942	-312.662
126.0	-1.941	-244.566
136.0	-1.940	-263.840
112.0	-1.939	-217.168
133.0	-1.938	-257.754
144.0	-1.937	-278.928
159.0	-1.936	-307.824
150.0	-1.935	-290.250
127.0	-1.934	-245.618
138.0	-1.933	-266.754
123.0	-1.932	-237.636
102.0	-1.931	-196.962
150.0	-1.930	-289.500
134.0	-1.929	-258.486
136.0	-1.928	-262.208
112.0	-1.927	-215.824
125.0	-1.926	-240.750
129.0	-1.925	-248.325
125.0	-1.924	-240.500
154.0	-1.923	-296.142
122.0	-1.922	-234.484
150.0	-1.921	-288.150
141.0	-1.920	-270.720
126.0	-1.919	-241.794
144.0	-1.918	-276.192
143.0	-1.917	-274.131
182.0	-1.916	-348.712
149.0	-1.915	-285.335
126.0	-1.914	-241.164
146.0	-1.913	-279.298
150.0	-1.912	-286.800
155.0	-1.911	-296.205
160.0	-1.910	-305.600
138.0	-1.909	-263.442
139.0	-1.908	-265.212
152.0	-1.907	-289.864
150.0	-1.906	-285.900
166.0	-1.905	-316.230
151.0	-1.904	-287.504
147.0	-1.903	-279.741
154.0	-1.902	-292.908
162.0	-1.901	-307.962
134.0	-1.900	-254.600
166.0	-1.899	-315.234
138.0	-1.898	-261.924
157.0	-1.897	-297.829
143.0	-1.896	-271.128
149.0	-1.895	-282.355
181.0	-1.894	-342.814
154.0	-1.893	-291.522
142.0	-1.892	-268.664
161.0	-1.891	-304.451
171.0	-1.890	-323.190
162.0	-1.889	-306.018
150.0	-1.888	-283.200
145.0	-1.887	-273.615
173.0	-1.886	-326.278
161.0	-1.885	-303.485
160.0	-1.884	-301.440
165.0	-1.883	-310.695
157.0	-1.882	-295.474
153.0	-1.881	-287.793
167.0	-1.880	-313.960
153.0	-1.879	-287.487
172.0	-1.878	-323.016
177.0	-1.877	-332.229
161.0	-1.876	-302.036
154.0	-1.875	-288.750
163.0	-1.874	-305.462
179.0	-1.873	-335.267

Count	Elevation	Value
154.0	-1.872	-288.288
156.0	-1.871	-291.876
154.0	-1.870	-287.980
179.0	-1.869	-334.551
168.0	-1.868	-313.824
176.0	-1.867	-328.592
189.0	-1.866	-352.674
163.0	-1.865	-303.995
140.0	-1.864	-260.960
177.0	-1.863	-329.751
166.0	-1.862	-309.092
186.0	-1.861	-346.146
198.0	-1.860	-368.280
163.0	-1.859	-303.017
180.0	-1.858	-334.440
180.0	-1.857	-334.260
187.0	-1.856	-347.072
183.0	-1.855	-339.465
167.0	-1.854	-309.618
180.0	-1.853	-333.540
198.0	-1.852	-366.696
189.0	-1.851	-349.839
186.0	-1.850	-344.100
189.0	-1.849	-349.461
203.0	-1.848	-375.144
219.0	-1.847	-404.493
178.0	-1.846	-328.588
179.0	-1.845	-330.255
182.0	-1.844	-335.608
173.0	-1.843	-318.839
198.0	-1.842	-364.716
191.0	-1.841	-351.631
188.0	-1.840	-345.920
221.0	-1.839	-406.419
195.0	-1.838	-358.410
217.0	-1.837	-398.629
172.0	-1.836	-315.792
207.0	-1.835	-379.845
199.0	-1.834	-364.966
207.0	-1.833	-379.431
208.0	-1.832	-381.056
194.0	-1.831	-355.214
214.0	-1.830	-391.620
185.0	-1.829	-338.365

Count	Elevation	Value
181.0	-1.828	-330.868
180.0	-1.827	-328.860
187.0	-1.826	-341.462
196.0	-1.825	-357.700
189.0	-1.824	-344.736
193.0	-1.823	-351.839
205.0	-1.822	-373.510
187.0	-1.821	-340.527
188.0	-1.820	-342.160
226.0	-1.819	-411.094
195.0	-1.818	-354.510
216.0	-1.817	-392.472
207.0	-1.816	-375.912
198.0	-1.815	-359.370
214.0	-1.814	-388.196
188.0	-1.813	-340.844
213.0	-1.812	-385.956
200.0	-1.811	-362.200
186.0	-1.810	-336.660
205.0	-1.809	-370.845
215.0	-1.808	-388.720
208.0	-1.807	-375.856
226.0	-1.806	-408.156
213.0	-1.805	-384.465
219.0	-1.804	-395.076
196.0	-1.803	-353.388
234.0	-1.802	-421.668
211.0	-1.801	-380.011
218.0	-1.800	-392.400
212.0	-1.799	-381.388
224.0	-1.798	-402.752
223.0	-1.797	-400.731
216.0	-1.796	-387.936
228.0	-1.795	-409.260
205.0	-1.794	-367.770
221.0	-1.793	-396.253
222.0	-1.792	-397.824
224.0	-1.791	-401.184
224.0	-1.790	-400.960
224.0	-1.789	-400.736
207.0	-1.788	-370.116
244.0	-1.787	-436.028
219.0	-1.786	-391.134
222.0	-1.785	-396.270

Count	Elevation	Value
196.0	-1.784	-349.664
221.0	-1.783	-394.043
237.0	-1.782	-422.334
226.0	-1.781	-402.506
237.0	-1.780	-421.860
251.0	-1.779	-446.529
213.0	-1.778	-378.714
251.0	-1.777	-446.027
222.0	-1.776	-394.272
229.0	-1.775	-406.475
250.0	-1.774	-443.500
245.0	-1.773	-434.385
223.0	-1.772	-395.156
263.0	-1.771	-465.773
203.0	-1.770	-359.310
239.0	-1.769	-422.791
251.0	-1.768	-443.768
241.0	-1.767	-425.847
229.0	-1.766	-404.414
243.0	-1.765	-428.895
250.0	-1.764	-441.000
239.0	-1.763	-421.357
227.0	-1.762	-399.974
255.0	-1.761	-449.055
231.0	-1.760	-406.560
273.0	-1.759	-480.207
253.0	-1.758	-444.774
249.0	-1.757	-437.493
220.0	-1.756	-386.320
245.0	-1.755	-429.975
264.0	-1.754	-463.056
237.0	-1.753	-415.461
228.0	-1.752	-399.456
223.0	-1.751	-390.473
258.0	-1.750	-451.500
249.0	-1.749	-435.501
258.0	-1.748	-450.984
257.0	-1.747	-448.979
267.0	-1.746	-466.182
244.0	-1.745	-425.780
256.0	-1.744	-446.464
253.0	-1.743	-440.979
274.0	-1.742	-477.308
259.0	-1.741	-450.919

Count	Elevation	Value
290.0	-1.740	-504.600
235.0	-1.739	-408.665
270.0	-1.738	-469.260
273.0	-1.737	-474.201
250.0	-1.736	-434.000
265.0	-1.735	-459.775
252.0	-1.734	-436.968
257.0	-1.733	-445.381
265.0	-1.732	-458.980
275.0	-1.731	-476.025
251.0	-1.730	-434.230
271.0	-1.729	-468.559
268.0	-1.728	-463.104
252.0	-1.727	-435.204
306.0	-1.726	-528.156
285.0	-1.725	-491.625
268.0	-1.724	-462.032
311.0	-1.723	-535.853
290.0	-1.722	-499.380
248.0	-1.721	-426.808
269.0	-1.720	-462.680
240.0	-1.719	-412.560
305.0	-1.718	-523.990
263.0	-1.717	-451.571
297.0	-1.716	-509.652
259.0	-1.715	-444.185
281.0	-1.714	-481.634
268.0	-1.713	-459.084
304.0	-1.712	-520.448
284.0	-1.711	-485.924
308.0	-1.710	-526.680
266.0	-1.709	-454.594
291.0	-1.708	-497.028
293.0	-1.707	-500.151
257.0	-1.706	-438.442
299.0	-1.705	-509.795
262.0	-1.704	-446.448
316.0	-1.703	-538.148
320.0	-1.702	-544.640
304.0	-1.701	-517.104
271.0	-1.700	-460.700
288.0	-1.699	-489.312
283.0	-1.698	-480.534
286.0	-1.697	-485.342

Count	Elevation	Value
299.0	-1.696	-507.104
312.0	-1.695	-528.840
284.0	-1.694	-481.096
287.0	-1.693	-485.891
287.0	-1.692	-485.604
304.0	-1.691	-514.064
274.0	-1.690	-463.060
304.0	-1.689	-513.456
302.0	-1.688	-509.776
293.0	-1.687	-494.291
313.0	-1.686	-527.718
288.0	-1.685	-485.280
277.0	-1.684	-466.468
294.0	-1.683	-494.802
335.0	-1.682	-563.470
315.0	-1.681	-529.515
330.0	-1.680	-554.400
290.0	-1.679	-486.910
333.0	-1.678	-558.774
294.0	-1.677	-493.038
312.0	-1.676	-522.912
321.0	-1.675	-537.675
305.0	-1.674	-510.570
316.0	-1.673	-528.668
302.0	-1.672	-504.944
326.0	-1.671	-544.746
357.0	-1.670	-596.190
301.0	-1.669	-502.369
319.0	-1.668	-532.092
321.0	-1.667	-535.107
320.0	-1.666	-533.120
305.0	-1.665	-507.825
328.0	-1.664	-545.792
294.0	-1.663	-488.922
323.0	-1.662	-536.826
304.0	-1.661	-504.944
341.0	-1.660	-566.060
296.0	-1.659	-491.064
305.0	-1.658	-505.690
335.0	-1.657	-555.095
343.0	-1.656	-568.008
298.0	-1.655	-493.190
345.0	-1.654	-570.630
364.0	-1.653	-601.692

Count	Elevation	Value
332.0	-1.652	-548.464
326.0	-1.651	-538.226
320.0	-1.650	-528.000
344.0	-1.649	-567.256
355.0	-1.648	-585.040
309.0	-1.647	-508.923
358.0	-1.646	-589.268
387.0	-1.645	-636.615
358.0	-1.644	-588.552
367.0	-1.643	-602.981
335.0	-1.642	-550.070
333.0	-1.641	-546.453
366.0	-1.640	-600.240
327.0	-1.639	-535.953
340.0	-1.638	-556.920
338.0	-1.637	-553.306
357.0	-1.636	-584.052
365.0	-1.635	-596.775
346.0	-1.634	-565.364
350.0	-1.633	-571.550
369.0	-1.632	-602.208
384.0	-1.631	-626.304
368.0	-1.630	-599.840
333.0	-1.629	-542.457
343.0	-1.628	-558.404
331.0	-1.627	-538.537
407.0	-1.626	-661.782
365.0	-1.625	-593.125
357.0	-1.624	-579.768
386.0	-1.623	-626.478
375.0	-1.622	-608.250
388.0	-1.621	-628.948
343.0	-1.620	-555.660
390.0	-1.619	-631.410
336.0	-1.618	-543.648
381.0	-1.617	-616.077
367.0	-1.616	-593.072
403.0	-1.615	-650.845
364.0	-1.614	-587.496
408.0	-1.613	-658.104
349.0	-1.612	-562.588
356.0	-1.611	-573.516
393.0	-1.610	-632.730
387.0	-1.609	-622.683

Count	Elevation	Value
391.0	-1.608	-628.728
351.0	-1.607	-564.057
386.0	-1.606	-619.916
370.0	-1.605	-593.850
384.0	-1.604	-615.936
407.0	-1.603	-652.421
382.0	-1.602	-611.964
384.0	-1.601	-614.784
398.0	-1.600	-636.800
365.0	-1.599	-583.635
421.0	-1.598	-672.758
417.0	-1.597	-665.949
426.0	-1.596	-679.896
417.0	-1.595	-665.115
392.0	-1.594	-624.848
390.0	-1.593	-621.270
373.0	-1.592	-593.816
392.0	-1.591	-623.672
377.0	-1.590	-599.430
424.0	-1.589	-673.736
404.0	-1.588	-641.552
422.0	-1.587	-669.714
376.0	-1.586	-596.336
425.0	-1.585	-673.625
413.0	-1.584	-654.192
412.0	-1.583	-652.196
418.0	-1.582	-661.276
401.0	-1.581	-633.981
416.0	-1.580	-657.280
390.0	-1.579	-615.810
426.0	-1.578	-672.228
433.0	-1.577	-682.841
443.0	-1.576	-698.168
393.0	-1.575	-618.975
415.0	-1.574	-653.210
405.0	-1.573	-637.065
431.0	-1.572	-677.532
420.0	-1.571	-659.820
449.0	-1.570	-704.930
472.0	-1.569	-740.568
421.0	-1.568	-660.128
432.0	-1.567	-676.944
421.0	-1.566	-659.286
448.0	-1.565	-701.120

Count	Elevation	Value
426.0	-1.564	-666.264
434.0	-1.563	-678.342
384.0	-1.562	-599.808
454.0	-1.561	-708.694
379.0	-1.560	-591.240
423.0	-1.559	-659.457
442.0	-1.558	-688.636
464.0	-1.557	-722.448
393.0	-1.556	-611.508
450.0	-1.555	-699.750
453.0	-1.554	-703.962
423.0	-1.553	-656.919
456.0	-1.552	-707.712
424.0	-1.551	-657.624
436.0	-1.550	-675.800
465.0	-1.549	-720.285
488.0	-1.548	-755.424
431.0	-1.547	-666.757
493.0	-1.546	-762.178
450.0	-1.545	-695.250
471.0	-1.544	-727.224
442.0	-1.543	-682.006
456.0	-1.542	-703.152
467.0	-1.541	-719.647
416.0	-1.540	-640.640
487.0	-1.539	-749.493
445.0	-1.538	-684.410
476.0	-1.537	-731.612
455.0	-1.536	-698.880
538.0	-1.535	-825.830
470.0	-1.534	-720.980
461.0	-1.533	-706.713
458.0	-1.532	-701.656
446.0	-1.531	-682.826
445.0	-1.530	-680.850
498.0	-1.529	-761.442
459.0	-1.528	-701.352
484.0	-1.527	-739.068
479.0	-1.526	-730.954
457.0	-1.525	-696.925
521.0	-1.524	-794.004
476.0	-1.523	-724.948
476.0	-1.522	-724.472
476.0	-1.521	-723.996

Count	Elevation	Value
511.0	-1.520	-776.720
470.0	-1.519	-713.930
484.0	-1.518	-734.712
470.0	-1.517	-712.990
510.0	-1.516	-773.160
509.0	-1.515	-771.135
553.0	-1.514	-837.242
471.0	-1.513	-712.623
483.0	-1.512	-730.296
505.0	-1.511	-763.055
499.0	-1.510	-753.490
539.0	-1.509	-813.351
507.0	-1.508	-764.556
547.0	-1.507	-824.329
452.0	-1.506	-680.712
513.0	-1.505	-772.065
510.0	-1.504	-767.040
541.0	-1.503	-813.123
467.0	-1.502	-701.434
545.0	-1.501	-818.045
491.0	-1.500	-736.500
464.0	-1.499	-695.536
536.0	-1.498	-802.928
512.0	-1.497	-766.464
495.0	-1.496	-740.520
493.0	-1.495	-737.035
545.0	-1.494	-814.230
478.0	-1.493	-713.654
533.0	-1.492	-795.236
455.0	-1.491	-678.405
509.0	-1.490	-758.410
548.0	-1.489	-815.972
515.0	-1.488	-766.320
564.0	-1.487	-838.668
576.0	-1.486	-855.936
544.0	-1.485	-807.840
501.0	-1.484	-743.484
535.0	-1.483	-793.405
486.0	-1.482	-720.252
532.0	-1.481	-787.892
524.0	-1.480	-775.520
565.0	-1.479	-835.635
549.0	-1.478	-811.422
578.0	-1.477	-853.706

Count	Elevation	Value
517.0	-1.476	-763.092
571.0	-1.475	-842.225
554.0	-1.474	-816.596
540.0	-1.473	-795.420
578.0	-1.472	-850.816
477.0	-1.471	-701.667
562.0	-1.470	-826.140
514.0	-1.469	-755.066
555.0	-1.468	-814.740
514.0	-1.467	-754.038
595.0	-1.466	-872.270
528.0	-1.465	-773.520
578.0	-1.464	-846.192
526.0	-1.463	-769.538
588.0	-1.462	-859.656
517.0	-1.461	-755.337
592.0	-1.460	-864.320
553.0	-1.459	-806.827
589.0	-1.458	-858.762
598.0	-1.457	-871.286
526.0	-1.456	-765.856
555.0	-1.455	-807.525
542.0	-1.454	-788.068
573.0	-1.453	-832.569
526.0	-1.452	-763.752
608.0	-1.451	-882.208
536.0	-1.450	-777.200
583.0	-1.449	-844.767
588.0	-1.448	-851.424
620.0	-1.447	-897.140
517.0	-1.446	-747.582
624.0	-1.445	-901.680
627.0	-1.444	-905.388
587.0	-1.443	-847.041
570.0	-1.442	-821.940
585.0	-1.441	-842.985
607.0	-1.440	-874.080
598.0	-1.439	-860.522
603.0	-1.438	-867.114
599.0	-1.437	-860.763
618.0	-1.436	-887.448
565.0	-1.435	-810.775
595.0	-1.434	-853.230
609.0	-1.433	-872.697

Count	Elevation	Value
632.0	-1.432	-905.024
614.0	-1.431	-878.634
635.0	-1.430	-908.050
622.0	-1.429	-888.838
600.0	-1.428	-856.800
638.0	-1.427	-910.426
619.0	-1.426	-882.694
656.0	-1.425	-934.800
593.0	-1.424	-844.432
641.0	-1.423	-912.143
636.0	-1.422	-904.392
645.0	-1.421	-916.545
594.0	-1.420	-843.480
641.0	-1.419	-909.579
620.0	-1.418	-879.160
636.0	-1.417	-901.212
646.0	-1.416	-914.736
599.0	-1.415	-847.585
632.0	-1.414	-893.648
614.0	-1.413	-867.582
605.0	-1.412	-854.260
647.0	-1.411	-912.917
655.0	-1.410	-923.550
592.0	-1.409	-834.128
681.0	-1.408	-958.848
604.0	-1.407	-849.828
685.0	-1.406	-963.110
585.0	-1.405	-821.925
619.0	-1.404	-869.076
702.0	-1.403	-984.906
657.0	-1.402	-921.114
652.0	-1.401	-913.452
650.0	-1.400	-910.000
645.0	-1.399	-902.355
597.0	-1.398	-834.606
662.0	-1.397	-924.814
632.0	-1.396	-882.272
636.0	-1.395	-887.220
673.0	-1.394	-938.162
702.0	-1.393	-977.886
639.0	-1.392	-889.488
646.0	-1.391	-898.586
670.0	-1.390	-931.300
686.0	-1.389	-952.854

Count	Elevation	Value
641.0	-1.388	-889.708
627.0	-1.387	-869.649
658.0	-1.386	-911.988
706.0	-1.385	-977.810
704.0	-1.384	-974.336
643.0	-1.383	-889.269
716.0	-1.382	-989.512
689.0	-1.381	-951.509
675.0	-1.380	-931.500
617.0	-1.379	-850.843
707.0	-1.378	-974.246
641.0	-1.377	-882.657
723.0	-1.376	-994.848
722.0	-1.375	-992.750
706.0	-1.374	-970.044
738.0	-1.373	-1013.274
716.0	-1.372	-982.352
718.0	-1.371	-984.378
688.0	-1.370	-942.560
755.0	-1.369	-1033.595
660.0	-1.368	-902.880
735.0	-1.367	-1004.745
691.0	-1.366	-943.906
734.0	-1.365	-1001.910
735.0	-1.364	-1002.540
771.0	-1.363	-1050.873
687.0	-1.362	-935.694
791.0	-1.361	-1076.551
706.0	-1.360	-960.160
682.0	-1.359	-926.838
672.0	-1.358	-912.576
700.0	-1.357	-949.900
756.0	-1.356	-1025.136
737.0	-1.355	-998.635
720.0	-1.354	-974.880
645.0	-1.353	-872.685
747.0	-1.352	-1009.944
682.0	-1.351	-921.382
749.0	-1.350	-1011.150
713.0	-1.349	-961.837
715.0	-1.348	-963.820
757.0	-1.347	-1019.679
729.0	-1.346	-981.234
757.0	-1.345	-1018.165

Count	Elevation	Value
718.0	-1.344	-964.992
735.0	-1.343	-987.105
757.0	-1.342	-1015.894
731.0	-1.341	-980.271
687.0	-1.340	-920.580
721.0	-1.339	-965.419
779.0	-1.338	-1042.302
796.0	-1.337	-1064.252
716.0	-1.336	-956.576
773.0	-1.335	-1031.955
759.0	-1.334	-1012.506
815.0	-1.333	-1086.395
740.0	-1.332	-985.680
743.0	-1.331	-988.933
773.0	-1.330	-1028.090
712.0	-1.329	-946.248
771.0	-1.328	-1023.888
716.0	-1.327	-950.132
766.0	-1.326	-1015.716
762.0	-1.325	-1009.650
813.0	-1.324	-1076.412
805.0	-1.323	-1065.015
788.0	-1.322	-1041.736
743.0	-1.321	-981.503
791.0	-1.320	-1044.120
859.0	-1.319	-1133.021
786.0	-1.318	-1035.948
797.0	-1.317	-1049.649
801.0	-1.316	-1054.116
784.0	-1.315	-1030.960
804.0	-1.314	-1056.456
794.0	-1.313	-1042.522
790.0	-1.312	-1036.480
775.0	-1.311	-1016.025
762.0	-1.310	-998.220
854.0	-1.309	-1117.886
792.0	-1.308	-1035.936
824.0	-1.307	-1076.968
782.0	-1.306	-1021.292
848.0	-1.305	-1106.640
837.0	-1.304	-1091.448
795.0	-1.303	-1035.885
839.0	-1.302	-1092.378
790.0	-1.301	-1027.790

Count	Elevation	Value
797.0	-1.300	-1036.100
805.0	-1.299	-1045.695
788.0	-1.298	-1022.824
830.0	-1.297	-1076.510
857.0	-1.296	-1110.672
804.0	-1.295	-1041.180
832.0	-1.294	-1076.608
837.0	-1.293	-1082.241
852.0	-1.292	-1100.784
874.0	-1.291	-1128.334
833.0	-1.290	-1074.570
839.0	-1.289	-1081.471
809.0	-1.288	-1041.992
799.0	-1.287	-1028.313
857.0	-1.286	-1102.102
826.0	-1.285	-1061.410
832.0	-1.284	-1068.288
916.0	-1.283	-1175.228
860.0	-1.282	-1102.520
844.0	-1.281	-1081.164
837.0	-1.280	-1071.360
861.0	-1.279	-1101.219
871.0	-1.278	-1113.138
900.0	-1.277	-1149.300
886.0	-1.276	-1130.536
843.0	-1.275	-1074.825
909.0	-1.274	-1158.066
896.0	-1.273	-1140.608
884.0	-1.272	-1124.448
816.0	-1.271	-1037.136
967.0	-1.270	-1228.090
837.0	-1.269	-1062.153
846.0	-1.268	-1072.728
851.0	-1.267	-1078.217
895.0	-1.266	-1133.070
870.0	-1.265	-1100.550
944.0	-1.264	-1193.216
931.0	-1.263	-1175.853
822.0	-1.262	-1037.364
942.0	-1.261	-1187.862
884.0	-1.260	-1113.840
916.0	-1.259	-1153.244
867.0	-1.258	-1090.686
883.0	-1.257	-1109.931

Count	Elevation	Value
905.0	-1.256	-1136.680
957.0	-1.255	-1201.035
945.0	-1.254	-1185.030
954.0	-1.253	-1195.362
860.0	-1.252	-1076.720
886.0	-1.251	-1108.386
959.0	-1.250	-1198.750
871.0	-1.249	-1087.879
932.0	-1.248	-1163.136
914.0	-1.247	-1139.758
930.0	-1.246	-1158.780
889.0	-1.245	-1106.805
897.0	-1.244	-1115.868
938.0	-1.243	-1165.934
917.0	-1.242	-1138.914
846.0	-1.241	-1049.886
918.0	-1.240	-1138.320
955.0	-1.239	-1183.245
918.0	-1.238	-1136.484
926.0	-1.237	-1145.462
1011.0	-1.236	-1249.596
999.0	-1.235	-1233.765
897.0	-1.234	-1106.898
950.0	-1.233	-1171.350
961.0	-1.232	-1183.952
982.0	-1.231	-1208.842
938.0	-1.230	-1153.740
977.0	-1.229	-1200.733
908.0	-1.228	-1115.024
1023.0	-1.227	-1255.221
957.0	-1.226	-1173.282
986.0	-1.225	-1207.850
896.0	-1.224	-1096.704
995.0	-1.223	-1216.885
1046.0	-1.222	-1278.212
948.0	-1.221	-1157.508
1035.0	-1.220	-1262.700
924.0	-1.219	-1126.356
972.0	-1.218	-1183.896
956.0	-1.217	-1163.452
981.0	-1.216	-1192.896
950.0	-1.215	-1154.250
963.0	-1.214	-1169.082
990.0	-1.213	-1200.870

Count	Elevation	Value
959.0	-1.212	-1162.308
966.0	-1.211	-1169.826
984.0	-1.210	-1190.640
979.0	-1.209	-1183.611
1087.0	-1.208	-1313.096
1023.0	-1.207	-1234.761
934.0	-1.206	-1126.404
1003.0	-1.205	-1208.615
1022.0	-1.204	-1230.488
1011.0	-1.203	-1216.233
961.0	-1.202	-1155.122
1057.0	-1.201	-1269.457
1044.0	-1.200	-1252.800
1035.0	-1.199	-1240.965
974.0	-1.198	-1166.852
1041.0	-1.197	-1246.077
923.0	-1.196	-1103.908
1046.0	-1.195	-1249.970
1113.0	-1.194	-1328.922
943.0	-1.193	-1124.999
1022.0	-1.192	-1218.224
1006.0	-1.191	-1198.146
1065.0	-1.190	-1267.350
981.0	-1.189	-1166.409
1050.0	-1.188	-1247.400
986.0	-1.187	-1170.382
1019.0	-1.186	-1208.534
1000.0	-1.185	-1185.000
1113.0	-1.184	-1317.792
1029.0	-1.183	-1217.307
1025.0	-1.182	-1211.550
1025.0	-1.181	-1210.525
1107.0	-1.180	-1306.260
1050.0	-1.179	-1237.950
994.0	-1.178	-1170.932
1040.0	-1.177	-1224.080
1014.0	-1.176	-1192.464
1044.0	-1.175	-1226.700
1014.0	-1.174	-1190.436
1083.0	-1.173	-1270.359
1058.0	-1.172	-1239.976
1119.0	-1.171	-1310.349
1058.0	-1.170	-1237.860
1142.0	-1.169	-1334.998
1088.0	-1.168	-1270.784
1060.0	-1.167	-1237.020
1091.0	-1.166	-1272.106
1020.0	-1.165	-1188.300
1092.0	-1.164	-1271.088
1036.0	-1.163	-1204.868
1101.0	-1.162	-1279.362
1100.0	-1.161	-1277.100
1089.0	-1.160	-1263.240
1079.0	-1.159	-1250.561
1156.0	-1.158	-1338.648
1068.0	-1.157	-1235.676
1135.0	-1.156	-1312.060
1057.0	-1.155	-1220.835
1118.0	-1.154	-1290.172
1052.0	-1.153	-1212.956
1196.0	-1.152	-1377.792
1085.0	-1.151	-1248.835
1038.0	-1.150	-1193.700
1147.0	-1.149	-1317.903
1099.0	-1.148	-1261.652
1150.0	-1.147	-1319.050
1061.0	-1.146	-1215.906
1129.0	-1.145	-1292.705
1106.0	-1.144	-1265.264
1119.0	-1.143	-1279.017
1105.0	-1.142	-1261.910
1151.0	-1.141	-1313.291
1111.0	-1.140	-1266.540
1124.0	-1.139	-1280.236
1179.0	-1.138	-1341.702
1176.0	-1.137	-1337.112
1203.0	-1.136	-1366.608
1119.0	-1.135	-1270.065
1232.0	-1.134	-1397.088
1129.0	-1.133	-1279.157
1143.0	-1.132	-1293.876
1119.0	-1.131	-1265.589
1197.0	-1.130	-1352.610
1156.0	-1.129	-1305.124
1208.0	-1.128	-1362.624
1121.0	-1.127	-1263.367
1203.0	-1.126	-1354.578
1268.0	-1.125	-1426.500
1157.0	-1.124	-1300.468
1212.0	-1.123	-1361.076
1200.0	-1.122	-1346.400
1227.0	-1.121	-1375.467
1118.0	-1.120	-1252.160
1205.0	-1.119	-1348.395
1193.0	-1.118	-1333.774
1216.0	-1.117	-1358.272
1198.0	-1.116	-1336.968
1251.0	-1.115	-1394.865
1176.0	-1.114	-1310.064
1236.0	-1.113	-1375.668
1192.0	-1.112	-1325.504
1263.0	-1.111	-1403.193
1201.0	-1.110	-1333.110
1192.0	-1.109	-1321.928
1218.0	-1.108	-1349.544
1243.0	-1.107	-1376.001
1218.0	-1.106	-1347.108
1145.0	-1.105	-1265.225
1265.0	-1.104	-1396.560
1134.0	-1.103	-1250.802
1239.0	-1.102	-1365.378
1288.0	-1.101	-1418.088
1265.0	-1.100	-1391.500
1282.0	-1.099	-1408.918
1236.0	-1.098	-1357.128
1318.0	-1.097	-1445.846
1266.0	-1.096	-1387.536
1272.0	-1.095	-1392.840
1231.0	-1.094	-1346.714
1280.0	-1.093	-1399.040
1201.0	-1.092	-1311.492
1298.0	-1.091	-1416.118
1237.0	-1.090	-1348.330
1212.0	-1.089	-1319.868
1242.0	-1.088	-1351.296
1284.0	-1.087	-1395.708
1194.0	-1.086	-1296.684
1274.0	-1.085	-1382.290
1298.0	-1.084	-1407.032
1346.0	-1.083	-1457.718
1320.0	-1.082	-1428.240
1223.0	-1.081	-1322.063

Count	Elevation	Value
1302.0	-1.080	-1406.160
1276.0	-1.079	-1376.804
1285.0	-1.078	-1385.230
1182.0	-1.077	-1273.014
1281.0	-1.076	-1378.356
1282.0	-1.075	-1378.150
1373.0	-1.074	-1474.602
1231.0	-1.073	-1320.863
1362.0	-1.072	-1460.064
1271.0	-1.071	-1361.241
1410.0	-1.070	-1508.700
1440.0	-1.069	-1539.360
1278.0	-1.068	-1364.904
1365.0	-1.067	-1456.455
1326.0	-1.066	-1413.516
1359.0	-1.065	-1447.335
1293.0	-1.064	-1375.752
1359.0	-1.063	-1444.617
1257.0	-1.062	-1334.934
1367.0	-1.061	-1450.387
1299.0	-1.060	-1376.940
1336.0	-1.059	-1414.824
1276.0	-1.058	-1350.008
1379.0	-1.057	-1457.603
1330.0	-1.056	-1404.480
1450.0	-1.055	-1529.750
1366.0	-1.054	-1439.764
1317.0	-1.053	-1386.801
1387.0	-1.052	-1459.124
1293.0	-1.051	-1358.943
1425.0	-1.050	-1496.250
1312.0	-1.049	-1376.288
1337.0	-1.048	-1401.176
1335.0	-1.047	-1397.745
1396.0	-1.046	-1460.216
1376.0	-1.045	-1437.920
1409.0	-1.044	-1470.996
1465.0	-1.043	-1527.995
1441.0	-1.042	-1501.522
1372.0	-1.041	-1428.252
1278.0	-1.040	-1329.120
1375.0	-1.039	-1428.625
1386.0	-1.038	-1438.668
1433.0	-1.037	-1486.021

Count	Elevation	Value
1398.0	-1.036	-1448.328
1470.0	-1.035	-1521.450
1382.0	-1.034	-1428.988
1476.0	-1.033	-1524.708
1387.0	-1.032	-1431.384
1435.0	-1.031	-1479.485
1413.0	-1.030	-1455.390
1464.0	-1.029	-1506.456
1363.0	-1.028	-1401.164
1490.0	-1.027	-1530.230
1464.0	-1.026	-1502.064
1357.0	-1.025	-1390.925
1436.0	-1.024	-1470.464
1478.0	-1.023	-1511.994
1431.0	-1.022	-1462.482
1459.0	-1.021	-1489.639
1477.0	-1.020	-1506.540
1403.0	-1.019	-1429.657
1426.0	-1.018	-1451.668
1426.0	-1.017	-1450.242
1491.0	-1.016	-1514.856
1395.0	-1.015	-1415.925
1519.0	-1.014	-1540.266
1534.0	-1.013	-1553.942
1498.0	-1.012	-1515.976
1489.0	-1.011	-1505.379
1465.0	-1.010	-1479.650
1422.0	-1.009	-1434.798
1472.0	-1.008	-1483.776
1511.0	-1.007	-1521.577
1379.0	-1.006	-1387.274
1578.0	-1.005	-1585.890
1512.0	-1.004	-1518.048
1477.0	-1.003	-1481.431
1480.0	-1.002	-1482.960
1573.0	-1.001	-1574.573
1576.0	-1.000	-1576.000
1448.0	-0.999	-1446.552
1576.0	-0.998	-1572.848
1509.0	-0.997	-1504.473
1512.0	-0.996	-1505.952
1489.0	-0.995	-1481.555
1514.0	-0.994	-1504.916
1517.0	-0.993	-1506.381

Count	Elevation	Value
1604.0	-0.992	-1591.168
1509.0	-0.991	-1495.419
1604.0	-0.990	-1587.960
1515.0	-0.989	-1498.335
1487.0	-0.988	-1469.156
1498.0	-0.987	-1478.526
1688.0	-0.986	-1664.368
1628.0	-0.985	-1603.580
1530.0	-0.984	-1505.520
1636.0	-0.983	-1608.188
1545.0	-0.982	-1517.190
1603.0	-0.981	-1572.543
1499.0	-0.980	-1469.020
1656.0	-0.979	-1621.224
1550.0	-0.978	-1515.900
1663.0	-0.977	-1624.751
1579.0	-0.976	-1541.104
1601.0	-0.975	-1560.975
1563.0	-0.974	-1522.362
1688.0	-0.973	-1642.424
1689.0	-0.972	-1641.708
1549.0	-0.971	-1504.079
1635.0	-0.970	-1585.950
1606.0	-0.969	-1556.214
1712.0	-0.968	-1657.216
1556.0	-0.967	-1504.652
1620.0	-0.966	-1564.920
1547.0	-0.965	-1492.855
1580.0	-0.964	-1523.120
1554.0	-0.963	-1496.502
1683.0	-0.962	-1619.046
1549.0	-0.961	-1488.589
1653.0	-0.960	-1586.880
1632.0	-0.959	-1565.088
1685.0	-0.958	-1614.230
1661.0	-0.957	-1589.577
1644.0	-0.956	-1571.664
1713.0	-0.955	-1635.915
1633.0	-0.954	-1557.882
1685.0	-0.953	-1605.805
1624.0	-0.952	-1546.048
1693.0	-0.951	-1610.043
1649.0	-0.950	-1566.550
1665.0	-0.949	-1580.085

Count	Elevation	Value
1652.0	-0.948	-1566.096
1719.0	-0.947	-1627.893
1670.0	-0.946	-1579.820
1675.0	-0.945	-1582.875
1769.0	-0.944	-1669.936
1623.0	-0.943	-1530.489
1742.0	-0.942	-1640.964
1689.0	-0.941	-1589.349
1736.0	-0.940	-1631.840
1708.0	-0.939	-1603.812
1702.0	-0.938	-1596.476
1744.0	-0.937	-1634.128
1673.0	-0.936	-1565.928
1702.0	-0.935	-1591.370
1744.0	-0.934	-1628.896
1707.0	-0.933	-1592.631
1710.0	-0.932	-1593.720
1732.0	-0.931	-1612.492
1815.0	-0.930	-1687.950
1771.0	-0.929	-1645.259
1692.0	-0.928	-1570.176
1769.0	-0.927	-1639.863
1727.0	-0.926	-1599.202
1800.0	-0.925	-1665.000
1681.0	-0.924	-1553.244
1789.0	-0.923	-1651.247
1693.0	-0.922	-1560.946
1734.0	-0.921	-1597.014
1750.0	-0.920	-1610.000
1818.0	-0.919	-1670.742
1775.0	-0.918	-1629.450
1868.0	-0.917	-1712.956
1917.0	-0.916	-1755.972
1800.0	-0.915	-1647.000
1850.0	-0.914	-1690.900
1788.0	-0.913	-1632.444
1770.0	-0.912	-1614.240
1757.0	-0.911	-1600.627
1824.0	-0.910	-1659.840
1731.0	-0.909	-1573.479
1805.0	-0.908	-1638.940
1732.0	-0.907	-1570.924
1787.0	-0.906	-1619.022
1825.0	-0.905	-1651.625

Count	Elevation	Value
1868.0	-0.904	-1688.672
1875.0	-0.903	-1693.125
1976.0	-0.902	-1782.352
1870.0	-0.901	-1684.870
1812.0	-0.900	-1630.800
1835.0	-0.899	-1649.665
1878.0	-0.898	-1686.444
1879.0	-0.897	-1685.463
1797.0	-0.896	-1610.112
1991.0	-0.895	-1781.945
1858.0	-0.894	-1661.052
1873.0	-0.893	-1672.589
1840.0	-0.892	-1641.280
1970.0	-0.891	-1755.270
1899.0	-0.890	-1690.110
1959.0	-0.889	-1741.551
1972.0	-0.888	-1751.136
1851.0	-0.887	-1641.837
2019.0	-0.886	-1788.834
1841.0	-0.885	-1629.285
1967.0	-0.884	-1738.828
1945.0	-0.883	-1717.435
1906.0	-0.882	-1681.092
1944.0	-0.881	-1712.664
1937.0	-0.880	-1704.560
1893.0	-0.879	-1663.947
1960.0	-0.878	-1720.880
1968.0	-0.877	-1725.936
1961.0	-0.876	-1717.836
2055.0	-0.875	-1798.125
1900.0	-0.874	-1660.600
2006.0	-0.873	-1751.238
1864.0	-0.872	-1625.408
2068.0	-0.871	-1801.228
1971.0	-0.870	-1714.770
2043.0	-0.869	-1775.367
2034.0	-0.868	-1765.512
2084.0	-0.867	-1806.828
1859.0	-0.866	-1609.894
2068.0	-0.865	-1788.820
1949.0	-0.864	-1683.936
2058.0	-0.863	-1776.054
1943.0	-0.862	-1674.866
2034.0	-0.861	-1751.274

Count	Elevation	Value
2092.0	-0.860	-1799.120
2024.0	-0.859	-1738.616
2070.0	-0.858	-1776.060
2058.0	-0.857	-1763.706
2093.0	-0.856	-1791.608
1941.0	-0.855	-1659.555
2121.0	-0.854	-1811.334
2043.0	-0.853	-1742.679
2240.0	-0.852	-1908.480
2008.0	-0.851	-1708.808
2205.0	-0.850	-1874.250
2032.0	-0.849	-1725.168
2096.0	-0.848	-1777.408
2168.0	-0.847	-1836.296
2093.0	-0.846	-1770.678
2128.0	-0.845	-1798.160
2003.0	-0.844	-1690.532
2192.0	-0.843	-1847.856
2035.0	-0.842	-1713.470
2171.0	-0.841	-1825.811
2047.0	-0.840	-1719.480
2147.0	-0.839	-1801.333
2141.0	-0.838	-1794.158
2121.0	-0.837	-1775.277
2162.0	-0.836	-1807.432
2155.0	-0.835	-1799.425
2084.0	-0.834	-1738.056
2234.0	-0.833	-1860.922
2234.0	-0.832	-1858.688
2062.0	-0.831	-1713.522
2228.0	-0.830	-1849.240
2202.0	-0.829	-1825.458
2211.0	-0.828	-1830.708
2098.0	-0.827	-1735.046
2238.0	-0.826	-1848.588
2149.0	-0.825	-1772.925
2254.0	-0.824	-1857.296
2141.0	-0.823	-1762.043
2219.0	-0.822	-1824.018
2125.0	-0.821	-1744.625
2166.0	-0.820	-1776.120
2377.0	-0.819	-1946.763
2218.0	-0.818	-1814.324
2339.0	-0.817	-1910.963

Count	Elevation	Value
2222.0	-0.816	-1813.152
2367.0	-0.815	-1929.105
2147.0	-0.814	-1747.658
2269.0	-0.813	-1844.697
2213.0	-0.812	-1796.956
2262.0	-0.811	-1834.482
2195.0	-0.810	-1777.950
2264.0	-0.809	-1831.576
2225.0	-0.808	-1797.800
2396.0	-0.807	-1933.572
2320.0	-0.806	-1869.920
2417.0	-0.805	-1945.685
2305.0	-0.804	-1853.220
2222.0	-0.803	-1784.266
2368.0	-0.802	-1899.136
2237.0	-0.801	-1791.837
2374.0	-0.800	-1899.200
2234.0	-0.799	-1784.966
2387.0	-0.798	-1904.826
2389.0	-0.797	-1904.033
2405.0	-0.796	-1914.380
2281.0	-0.795	-1813.395
2376.0	-0.794	-1886.544
2329.0	-0.793	-1846.897
2371.0	-0.792	-1877.832
2493.0	-0.791	-1971.963
2336.0	-0.790	-1845.440
2478.0	-0.789	-1955.142
2261.0	-0.788	-1781.668
2444.0	-0.787	-1923.428
2417.0	-0.786	-1899.762
2388.0	-0.785	-1874.580
2362.0	-0.784	-1851.808
2555.0	-0.783	-2000.565
2427.0	-0.782	-1897.914
2486.0	-0.781	-1941.566
2346.0	-0.780	-1829.880
2503.0	-0.779	-1949.837
2390.0	-0.778	-1859.420
2570.0	-0.777	-1996.890
2507.0	-0.776	-1945.432
2281.0	-0.775	-1767.775
2440.0	-0.774	-1888.560
2367.0	-0.773	-1829.691

Count	Elevation	Value
2536.0	-0.772	-1957.792
2522.0	-0.771	-1944.462
2542.0	-0.770	-1957.340
2417.0	-0.769	-1858.673
2503.0	-0.768	-1922.304
2377.0	-0.767	-1823.159
2592.0	-0.766	-1985.472
2487.0	-0.765	-1902.555
2590.0	-0.764	-1978.760
2748.0	-0.763	-2096.724
2455.0	-0.762	-1870.710
2610.0	-0.761	-1986.210
2614.0	-0.760	-1986.640
2652.0	-0.759	-2012.868
2539.0	-0.758	-1924.562
2619.0	-0.757	-1982.583
2576.0	-0.756	-1947.456
2614.0	-0.755	-1973.570
2472.0	-0.754	-1863.888
2639.0	-0.753	-1987.167
2430.0	-0.752	-1827.360
2625.0	-0.751	-1971.375
2700.0	-0.750	-2025.000
2464.0	-0.749	-1845.536
2718.0	-0.748	-2033.064
2548.0	-0.747	-1903.356
2771.0	-0.746	-2067.166
2593.0	-0.745	-1931.785
2747.0	-0.744	-2043.768
2606.0	-0.743	-1936.258
2718.0	-0.742	-2016.756
2584.0	-0.741	-1914.744
2789.0	-0.740	-2063.860
2631.0	-0.739	-1944.309
2781.0	-0.738	-2052.378
2607.0	-0.737	-1921.359
2913.0	-0.736	-2143.968
2821.0	-0.735	-2073.435
2677.0	-0.734	-1964.918
2883.0	-0.733	-2113.239
2587.0	-0.732	-1893.684
2725.0	-0.731	-1991.975
2774.0	-0.730	-2025.020
2793.0	-0.729	-2036.097

Count	Elevation	Value
2688.0	-0.728	-1956.864
2898.0	-0.727	-2106.846
2759.0	-0.726	-2003.034
2793.0	-0.725	-2024.925
2666.0	-0.724	-1930.184
2851.0	-0.723	-2061.273
2922.0	-0.722	-2109.684
2812.0	-0.721	-2027.452
2859.0	-0.720	-2058.480
2734.0	-0.719	-1965.746
2845.0	-0.718	-2042.710
2766.0	-0.717	-1983.222
2979.0	-0.716	-2132.964
2798.0	-0.715	-2000.570
2934.0	-0.714	-2094.876
2764.0	-0.713	-1970.732
2882.0	-0.712	-2051.984
2898.0	-0.711	-2060.478
2864.0	-0.710	-2033.440
2873.0	-0.709	-2036.957
3067.0	-0.708	-2171.436
2880.0	-0.707	-2036.160
2773.0	-0.706	-1957.738
2855.0	-0.705	-2012.775
2876.0	-0.704	-2024.704
2996.0	-0.703	-2106.188
2927.0	-0.702	-2054.754
3003.0	-0.701	-2105.103
2888.0	-0.700	-2021.600
3005.0	-0.699	-2100.495
3022.0	-0.698	-2109.356
3060.0	-0.697	-2132.820
3005.0	-0.696	-2091.480
3128.0	-0.695	-2173.960
3177.0	-0.694	-2204.838
2961.0	-0.693	-2051.973
3062.0	-0.692	-2118.904
3061.0	-0.691	-2115.151
3133.0	-0.690	-2161.770
2963.0	-0.689	-2041.507
3114.0	-0.688	-2142.432
3066.0	-0.687	-2106.342
3130.0	-0.686	-2147.180
3027.0	-0.685	-2073.495

Count	Elevation	Value
3116.0	-0.684	-2131.344
3045.0	-0.683	-2079.735
3175.0	-0.682	-2165.350
3035.0	-0.681	-2066.835
3287.0	-0.680	-2235.160
3246.0	-0.679	-2204.034
3096.0	-0.678	-2099.088
3266.0	-0.677	-2211.082
3067.0	-0.676	-2073.292
3284.0	-0.675	-2216.700
3168.0	-0.674	-2135.232
3417.0	-0.673	-2299.641
3088.0	-0.672	-2075.136
3181.0	-0.671	-2134.451
3124.0	-0.670	-2093.080
3316.0	-0.669	-2218.404
3083.0	-0.668	-2059.444
3388.0	-0.667	-2259.796
3424.0	-0.666	-2280.384
3189.0	-0.665	-2120.685
3350.0	-0.664	-2224.400
3158.0	-0.663	-2093.754
3380.0	-0.662	-2237.560
3310.0	-0.661	-2187.910
3289.0	-0.660	-2170.740
3375.0	-0.659	-2224.125
3364.0	-0.658	-2213.512
3351.0	-0.657	-2201.607
3520.0	-0.656	-2309.120
3182.0	-0.655	-2084.210
3559.0	-0.654	-2327.586
3375.0	-0.653	-2203.875
3504.0	-0.652	-2284.608
3454.0	-0.651	-2248.554
3306.0	-0.650	-2148.900
3507.0	-0.649	-2276.043
3349.0	-0.648	-2170.152
3484.0	-0.647	-2254.148
3374.0	-0.646	-2179.604
3597.0	-0.645	-2320.065
3342.0	-0.644	-2152.248
3527.0	-0.643	-2267.861
3411.0	-0.642	-2189.862
3534.0	-0.641	-2265.294

Count	Elevation	Value
3371.0	-0.640	-2157.440
3469.0	-0.639	-2216.691
3625.0	-0.638	-2312.750
3390.0	-0.637	-2159.430
3686.0	-0.636	-2344.296
3414.0	-0.635	-2167.890
3626.0	-0.634	-2298.884
3437.0	-0.633	-2175.621
3598.0	-0.632	-2273.936
3497.0	-0.631	-2206.607
3631.0	-0.630	-2287.530
3524.0	-0.629	-2216.596
3678.0	-0.628	-2309.784
3399.0	-0.627	-2131.173
3585.0	-0.626	-2244.210
3688.0	-0.625	-2305.000
3534.0	-0.624	-2205.216
3716.0	-0.623	-2315.068
3549.0	-0.622	-2207.478
3695.0	-0.621	-2294.595
3636.0	-0.620	-2254.320
3736.0	-0.619	-2312.584
3638.0	-0.618	-2248.284
3831.0	-0.617	-2363.727
3574.0	-0.616	-2201.584
3759.0	-0.615	-2311.785
3530.0	-0.614	-2167.420
3897.0	-0.613	-2388.861
3635.0	-0.612	-2224.620
3921.0	-0.611	-2395.731
3680.0	-0.610	-2244.800
3760.0	-0.609	-2289.840
3735.0	-0.608	-2270.880
3728.0	-0.607	-2262.896
3766.0	-0.606	-2282.196
3736.0	-0.605	-2260.280
3827.0	-0.604	-2311.508
3844.0	-0.603	-2317.932
3989.0	-0.602	-2401.378
3706.0	-0.601	-2227.306
3914.0	-0.600	-2348.400
3707.0	-0.599	-2220.493
4017.0	-0.598	-2402.166
4018.0	-0.597	-2398.746

Count	Elevation	Value
3710.0	-0.596	-2211.160
3900.0	-0.595	-2320.500
3857.0	-0.594	-2291.058
4119.0	-0.593	-2442.567
3914.0	-0.592	-2317.088
4067.0	-0.591	-2403.597
3835.0	-0.590	-2262.650
3998.0	-0.589	-2354.822
3977.0	-0.588	-2338.476
4115.0	-0.587	-2415.505
3900.0	-0.586	-2285.400
4247.0	-0.585	-2484.495
4041.0	-0.584	-2359.944
4262.0	-0.583	-2484.746
4187.0	-0.582	-2436.834
3918.0	-0.581	-2276.358
4206.0	-0.580	-2439.480
4004.0	-0.579	-2318.316
4242.0	-0.578	-2451.876
3967.0	-0.577	-2288.959
4263.0	-0.576	-2455.488
4009.0	-0.575	-2305.175
4247.0	-0.574	-2437.778
4100.0	-0.573	-2349.300
4272.0	-0.572	-2443.584
4195.0	-0.571	-2395.345
4436.0	-0.570	-2528.520
4365.0	-0.569	-2483.685
4157.0	-0.568	-2361.176
4228.0	-0.567	-2397.276
4134.0	-0.566	-2339.844
4254.0	-0.565	-2403.510
4188.0	-0.564	-2362.032
4396.0	-0.563	-2474.948
4271.0	-0.562	-2400.302
4480.0	-0.561	-2513.280
4175.0	-0.560	-2338.000
4461.0	-0.559	-2493.699
4284.0	-0.558	-2390.472
4448.0	-0.557	-2477.536
4276.0	-0.556	-2377.456
4571.0	-0.555	-2536.905
4546.0	-0.554	-2518.484
4463.0	-0.553	-2468.039

Count	Elevation	Value
4589.0	-0.552	-2533.128
4245.0	-0.551	-2338.995
4656.0	-0.550	-2560.800
4388.0	-0.549	-2409.012
4680.0	-0.548	-2564.640
4434.0	-0.547	-2425.398
4627.0	-0.546	-2526.342
4468.0	-0.545	-2435.060
4683.0	-0.544	-2547.552
4447.0	-0.543	-2414.721
4714.0	-0.542	-2554.988
4976.0	-0.541	-2692.016
4523.0	-0.540	-2442.420
4761.0	-0.539	-2566.179
4455.0	-0.538	-2396.790
4837.0	-0.537	-2597.469
4585.0	-0.536	-2457.560
4903.0	-0.535	-2623.105
4586.0	-0.534	-2448.924
4785.0	-0.533	-2550.405
4671.0	-0.532	-2484.972
4860.0	-0.531	-2580.660
4635.0	-0.530	-2456.550
4879.0	-0.529	-2580.991
4671.0	-0.528	-2466.288
5054.0	-0.527	-2663.458
4897.0	-0.526	-2575.822
4726.0	-0.525	-2481.150
5062.0	-0.524	-2652.488
4719.0	-0.523	-2468.037
5048.0	-0.522	-2635.056
4743.0	-0.521	-2471.103
4980.0	-0.520	-2589.600
4888.0	-0.519	-2536.872
5051.0	-0.518	-2616.418
4846.0	-0.517	-2505.382
5169.0	-0.516	-2667.204
4915.0	-0.515	-2531.225
5185.0	-0.514	-2665.090
5302.0	-0.513	-2719.926
5039.0	-0.512	-2579.968
5116.0	-0.511	-2614.276
5015.0	-0.510	-2557.650
5062.0	-0.509	-2576.558

Count	Elevation	Value (m3)
5086.0	-0.508	-2583.688
5348.0	-0.507	-2711.436
5071.0	-0.506	-2565.926
5204.0	-0.505	-2628.020
5028.0	-0.504	-2534.112
5308.0	-0.503	-2669.924
5187.0	-0.502	-2603.874
5419.0	-0.501	-2714.919
5548.0	-0.500	-2774.000
Total Value (m3)		1,800,015
Total x 1.3 (t)		2,340,020
Areal Count (m2)		2,042,305
Total Area (ha)		204

Scientific Peer Review and Response

An independent review of the Lidar change analysis methodology for Kin Kin Creek Erosion Hotspots was undertaken by Water Science and Alluvium. Key comments from this review and action taken is summarised in the following table.

Executive Summary from the Peer Review states that, 'the work undertaken to use two sets of LIDAR data (2008,2015) to: (a) produce a credible Change Map for the catchment, (b) use this map to identify the 'Erosion Hot Spots', and (c) to estimate the mass of sediment eroded from the catchment over the 7-year period, was effectively done.'

Reviewer Report: Hart, B.T, Ivezich, M. (2017) Review of the LIDAR Component of the Project to Identify and Manage Sediment Erosion from the Kin Kin Catchment. For Noosa and District Landcare Group Project – Keeping it in Kin Kin.

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It should be noted that this draft report only addresses on the first two components of ToR1.	4	Report changed to state that the main objective is to *establish an annual sediment load (tonne/y) entering the Noosa River and Lakes system from the Kin Kin Creek catchment*, and to *identify those parts of the Kin Kin catchment that contribute the bulk of* this (soil erosion 'hot spots').
Are the DEM change data adequately verified? Based on the information provided in the report this cannot be answered conclusively.	5	The required information has been added to this report.
It is likely the 'Erosion Hot Spots' represent the major areas of erosion within the catchment.	5	Additional information and data now included within the report verifying soil loss.
Estimates of the mass of sediment eroded are of the correct order of magnitude, but lack of detail on the method / data used prevents us for providing a more conclusive assessment.	5	Additional information and data now included within the report verifying soil loss.
The report provides no estimate of the uncertainty on mass of sediment eroded –	5	Uncertainty somewhere around + / - 20 % which has been added to the report.

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this should be included in the final report.		
The prioritisation of the 'Areas of Interest' has not been undertaken.	5	Areas of Interest have now been prioritised based on total observed erosion and mass of sediment eroded per ha (erosion rate).
Additionally, we have identified information (e.g. several maps and spreadsheets) associated with this report.	6	Additional maps and supporting spreadsheet added and integrated into this report.
The report should note the limitations of the LiDAR assessment used. The assessment of LiDAR change over time can be a valuable tool for assessing and interrupting geomorphic changes and sediment transport processes. However, it should not solely be relied upon to inform management.	6	An understanding of catchment physiography (geology, soils, land use, topography etc.) waterway condition and sediment source, transport and storage processes also needs to be identified and compiled to inform sediment management programs.
The statement in the Application section (p2) – 'The change analysis provides a current baseline and snapshot of erosion/deposition rates in the Kin Kin Creek catchment' – should include a caveat that change analysis alone provides limited understanding of active (i.e. likely to be on-going) geomorphic processes and system trajectory, although it is a valuable tool to inform these assessments.	6	Repeat topographic surveys are often used to monitor geomorphic change in rivers. These yield digital elevation models (DEMS), which are differenced against each other to produce spatially distributed maps of elevation changes called DEMS of difference (DoD). Both area and volumetric budgets of erosion and deposition can be calculated from DoDs. (Wheaton 2008, 2015; Geomorphic Change Detection Software and Training)
It is suggested that in the Background section (p1) of the report, the addition of an overview of the catchment physiography (geology, soils, landuse, topography) and waterway condition would add significant value.	6	An overview of the Kin Kin Creek catchment had been included in the report.
It is unclear why the Overview of Steps section (p3) is included.	6	To note the first 4 dot points are only being addressed in this report.
It is not clear why the statement 'Geomorphic change assessment is the	6	Removed reference why topographic change is occurring as this will become

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process of identifying why topographic change is occurring' (p3) is made. It is not clear how this geomorphic change assessment is being undertaken in this study.		more apparent through ground-truthing and additional work.
The report correctly notes that 'mapping topographic change can be further strengthened and validated through ground-truthing', however it is unclear whether any ground-truthing is to be undertaken, and whether a management action plan based on the data is to be developed.	6	This report was developed to provide a snapshot of current and potential erosion hot spots. Ground-truthing of the results will further strengthen and validate this work and help inform a catchment management action plan.
The statement (p4) 'Areas showing an increase in elevation could be areas of deposition, where a decrease in elevation generally indicates that active erosion is present' needs to be qualified. Just because erosion has occurred in the recent past done not necessarily mean it will be on-going or 'active'.	6	Statement reworded and 'active' removed. The results of the DoD were cross referenced with a time series of high resolution aerial photography to further validate identified erosion.
The statement (p4) 'In line with geomorphic change detection principles' would be strengthened if some details of the principles were provided.	6	Applying repeat LiDAR surveys to develop maps of elevation change based on DoD. Reliability factors applied reducing some noise with LiDAR surveys. Volumetric budgets of erosion and deposition calculated.
Some description of how the 2015 LiDAR slope data was used to confirm change/disturbance within forested areas and non-forested areas would be beneficial.	6	The 2015 LiDAR slope data was used to confirm the DoD showing patterns of disturbance and altered land surfaces. (See examples)
There is no detail on how the 'Areas of Interest' (Table 1) were decided or where they are located. However, we were provided with other maps and GIS output that makes this situation clearer.	6	The 'Areas of Interest' were selected based on the DoD and further quantified and refined using high resolution aerial photography and LiDAR slope data.

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There is no detail in the report on how the mass loss budget was done or what data was used. We recommend adding calculation spreadsheets in the final report.	6	Spreadsheet calculations added as tables in final report.
An estimate of the uncertainty in the final mass loss estimate (2.3 million tonne) should be provided.	7	Uncertainty somewhere around 20-40%.
There are a number of statements in the findings section (p6-10) that need clarification. 'Across the catchment, many sediment inputs were identified that could become mobilised during rainfall events' – it is not clear how these sediment inputs were identified.	7	Based on the DoD and high resolution imagery, areas of bare earth / low ground cover were identified that require groun-truthing to confirm level of erosion risk.
'With increased flows and velocities from intense rainfall events, outside creek bends will show signs of stress and erosion risk even when vegetated' – this statement is not always correct, e.g. erosion risk will vary depending on the applied energy and resistance of substrate.	7	Based on community feedback and anecdotal evidence, increased flows and rainfall events will place further pressure on outside creek bends and riparian zones.
We have less confidence in the 'Soil Gain' estimates compared to 'Soil Loss' estimates using the approach outlined. Deposition generally occurs as narrow layers (i.e. less than 0.5 m) across floodplains, hill slopes and within channels. As a result, they will not be identified using the method outlined in the report. To provide confidence / uncertainty rating in the estimates stated.	7	Report focusses mainly on erosion rates and applies confidence intervals with higher confidence given to erosion levels of -0.5 - 2.0 m.
Table 2 needs to be upgraded: • No detail provided on criteria used to separate estimates into 'high confidence' and 'moderate confidence', • No detail in the report showing how 'tonnes of sediment mobilised' and	7	Based on training and assessment with Morphological Sediment Budgeting (Wheaton, 2015), uncertainties in Digital Elevation Models and generation of DoD's were taken into consideration. This included reducing lower values of change (+ve / -ve) to account for vertical accuracy of LiDAR sensor and further verification and

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'area of loss' were calculated. We are aware that this detail is available, but it should be included in the report (perhaps as an appendix), • What are the units of the first row? • Some estimate of the uncertainty of the tonnes of sediment and area of loss should be provided, • The number of significant figures quoted need to be modified, for example quoting a figure of 360, 678 implies an accuracy of 1/360678 or 0.0003% - accuracy could not be justified.		refinement of results using high resolution aerial photography. Table 2 presents the findings from the DoD and an estimate of the change in storage terms over the time step between the LiDAR surveys. Table 2 will be updated to be more informative of results. Uncertainty somewhere around 20-40%. Table 2: Total Soil Loss and Gain from Geomorphic Change Analysis for Areas of Interest (based on LiDAR DEM Change Map) Actual values quoted may be +/- 20% accurate.
We suggest that relying only on the LiDAR assessment is insufficient to estimating budgets and management action plans. Having an understanding of where sediment buffers and barriers exist within the landscape can greatly assist in estimating the portion of the total soil loss from areas of interest that actually leaves the Kin Kin catchment.	7	This additional information requires some on-ground assessment of the catchment which will occur in Phase 2 and through Noosa and District Landcare Group.
Additional Work Ground-truthing of the results, assessment of geomorphic condition, active processes and trajectory. The assessment of trajectory needs to identify the drivers of geomorphic change (i.e. stream bank erosion, gully erosion) and assess whether these drivers are likely to be on-going or may have ceased.	8	This additional information requires some on-ground assessment of the catchment which will happen in Phase 2 and through Noosa and District Landcare Group. This current work provides a snapshot of erosion that has occurred during the time interval of 2008 – 2015. Old landslips were identified through the assessment but were found to be non-active during the time interval assessed. This exercise gives us enough data to start ground-truthing and to work towards project development and improved land management activities e.g. ground cover management. Other catchment information including geomorphic condition

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		and land use will help inform strategic priorities and actions to be undertaken.