DRAFT SEDIMENTATION REPORT:

The Laloki River catchment

June 2019

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Author/s	Alex Sen Misko Ivezich
Checked	Rohan Lucas
Approved	Misko Ivezich

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1 Introduction

Alluvium Consulting has been engaged by the United Nations Development Programme (UNDP) and the Conservation and Environment Protection Authority (CEPA) to undertake an assessment of sedimentation processes to provide an empirical baseline understanding of the existing sources and extent of sedimentation within the Sirinumu Dam and the downstream Laloki River catchment. The work will inform the development of the Sirinumu Dam Integrated Land Use Plan.

Port Moresby water supply and hydro power generation relies on flows in the Laloki River (Figure 1), which are unregulated flows from the Sogeri Plateau and releases from Sirinumu Dam. In general, water supply to the Eda Ranu treatment plant comes from Rouna 2 power station, relatively high in the catchment. If adequate flows are not present in the upper catchment, water is drawn from the Laloki River at Bomana pump station near the river's confluence with the Goldie River. The quality of water at Bomana is likely to be far poorer than at Rouna 2 due to increasing land use pressure in the lower catchment (human and agricultural effluent, sediment, solid waste, etc).

With increasing land use activity in the catchment particularly for agriculture, the quality and quantity of available water in the catchment is likely to change. This study aims to provide an assessment of the existing catchment condition and the processes that impact sediment generation, transport and storage within Sirinumu Dam and the broader Laloki River catchment.

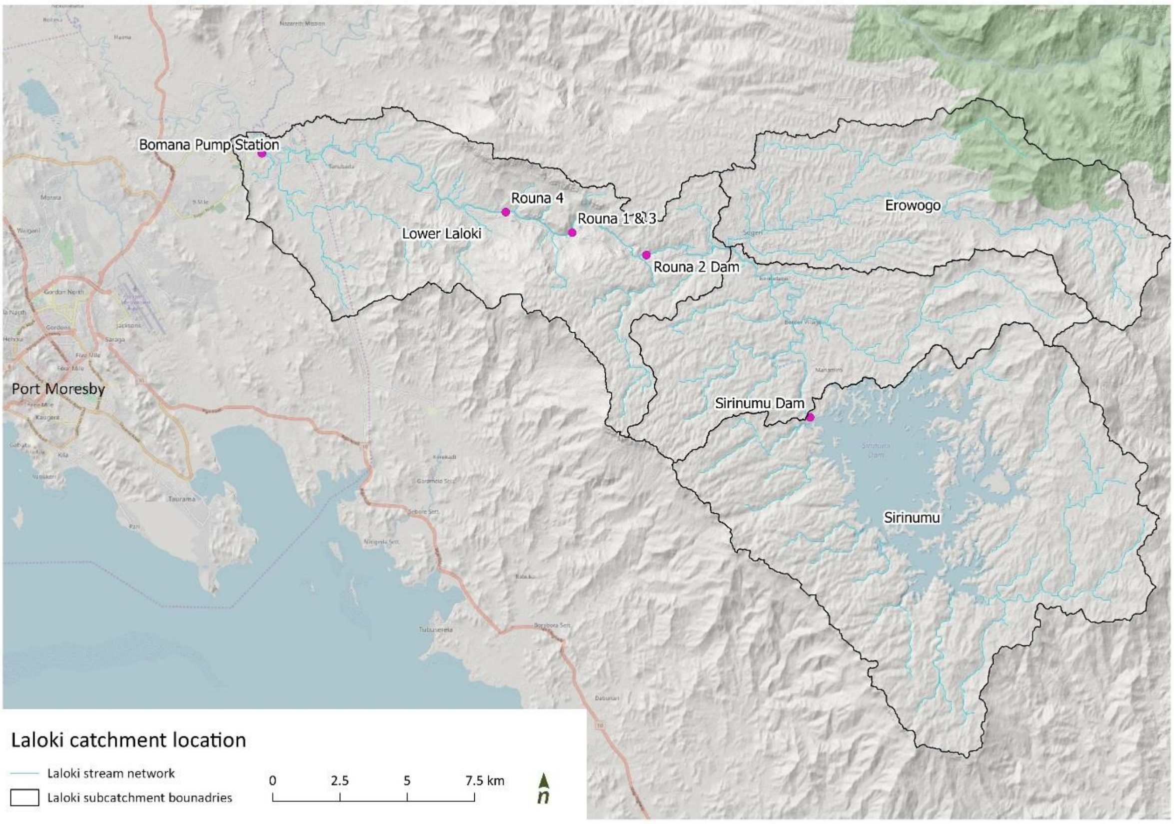

Figure 1. *An overview of the Laloki River catchment in relation of the capital city – Port Moresby. Base map courtesy of Google Earth.*

1.1 Study objectives

This study has the following objectives:

- Understand the existing catchment condition including geology, topography, rainfall and land use
- Determine the catchment sediment generation processes
- Assess waterway condition and sediment transport and storage processes
- Assess the environmental and social impacts of sedimentation on Sirinumu Dam and the Laloki River catchment
- Predict the potential impacts of unmitigated land use change within the catchment
- Provide recommendations for the future management of the catchment

1.2 Report structure

This sedimentation study report has the following structure:

- **Section 2** – Provides an overview of the catchment and existing studies
- **Section 3** – Outlines the methods using for the RUSLE assessment, geomorphic assessment sediment sampling and Hydraulic modelling.
- **Section 4** - Presents the findings of the field visits, assessments and monitoring.
- **Section 5** – Outlines the likely impacts of future land use change, the recommended monitoring regime and management practices moving forward.

2 Background

2.1 Overview

The Laloki River drains an area of 406 km² within the Eastern Highlands of Papua New Guinea. The upper catchment comprises of the Sogeri Plateau which is drained primarily by the Laloki River and Eilogo Creek which converge at Sogeri before dropping approximately 100 m at Rouna Falls. Below the falls, the Laloki River runs through Rouna Gorge before widening and meandering across lowland alluvial plains upstream of its confluence with the Goldie River at Bomana.

The Sirinumu Dam is the largest impoundment on the Laloki River. Located on the upper Sogeri Plateau, the dam was built in 1962 to secure a source of water and hydroelectricity for Port Moresby 40 km downstream. In 1999, the capacity of the dam was considered insufficient for the rapidly increasing population, which was expected to reach half a million by 2020 (UNESCO 2001). In 2007, a bathymetric study revealed that sedimentation risk into the reservoir is perceived to be low, with sources of potential sedimentation likely to derive from lake side cultivation and deforestation from within the catchment (Smith 2007).

Sedimentation within the hydroelectric retention ponds along the downstream Laloki River has increased in recent years, leading to an increase in the frequency by which the ponds are desilted. The increase has been attributed to land use intensification within the Sogeri Plateau upstream of the ponds. Consequently, the sedimentary and erosional processes within the plateau require further analysis to inform responsible land use management planning and actions that manages key erosion risks.

2.2 Topography and rainfall

The upper Loloki River catchment consists of the Sogeri Plateau which generally has an elevation of between 600 -1500 m above sea level (Figure 2). In the mid catchment the Laloki River has deeply incised into the plateau creating deep gorges before moving into unconfined alluvial system upstream of the confluence with the Goldie River.

The elevation of the Sogeri Plateau gives rise to a relatively higher degree of rainfall (Figure 3). The upper catchment can experience up to 2500 mm of annual rainfall which decreases to 1500 mm in the lower catchment. Overall the region experiences an extended dry season between April and November which is broken by a late onset wet season in December, lending to tropical dryland savannah on the lower hills and rainforest caps along the upper slopes of the catchment boundary.

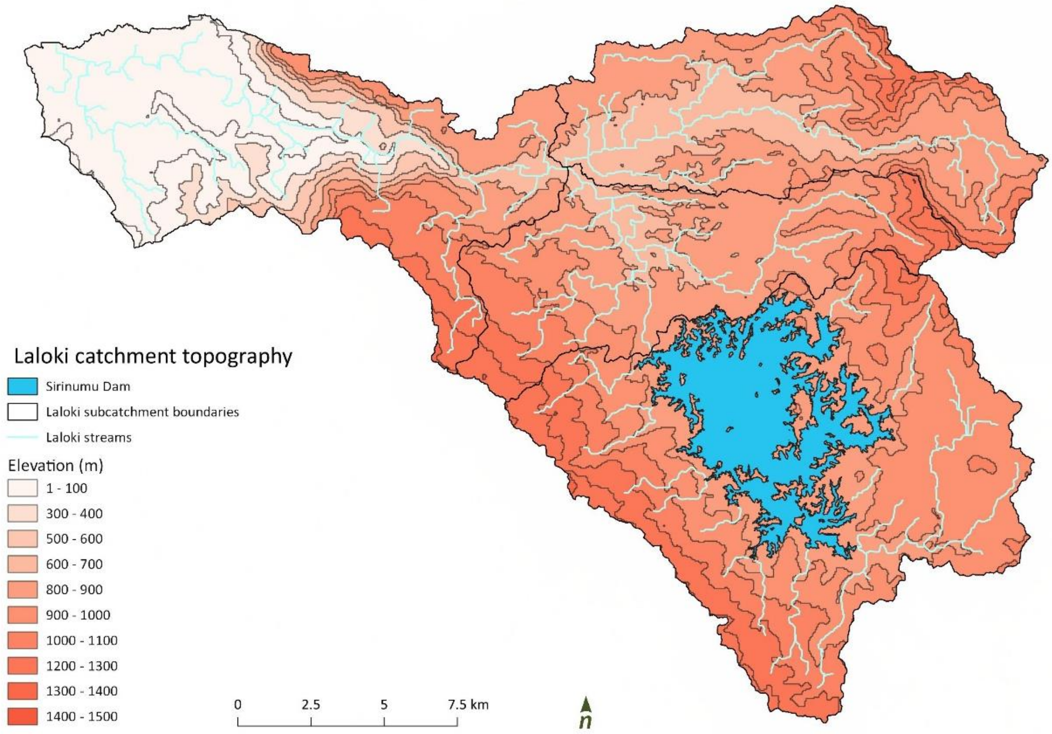

Figure 2. *The topography of the Laloki River catchment illustrating the difference in altitude between the coastal lowland and the Sogeri Plateau. Extracted from the PNGRIS database (CEPA 2018a)*

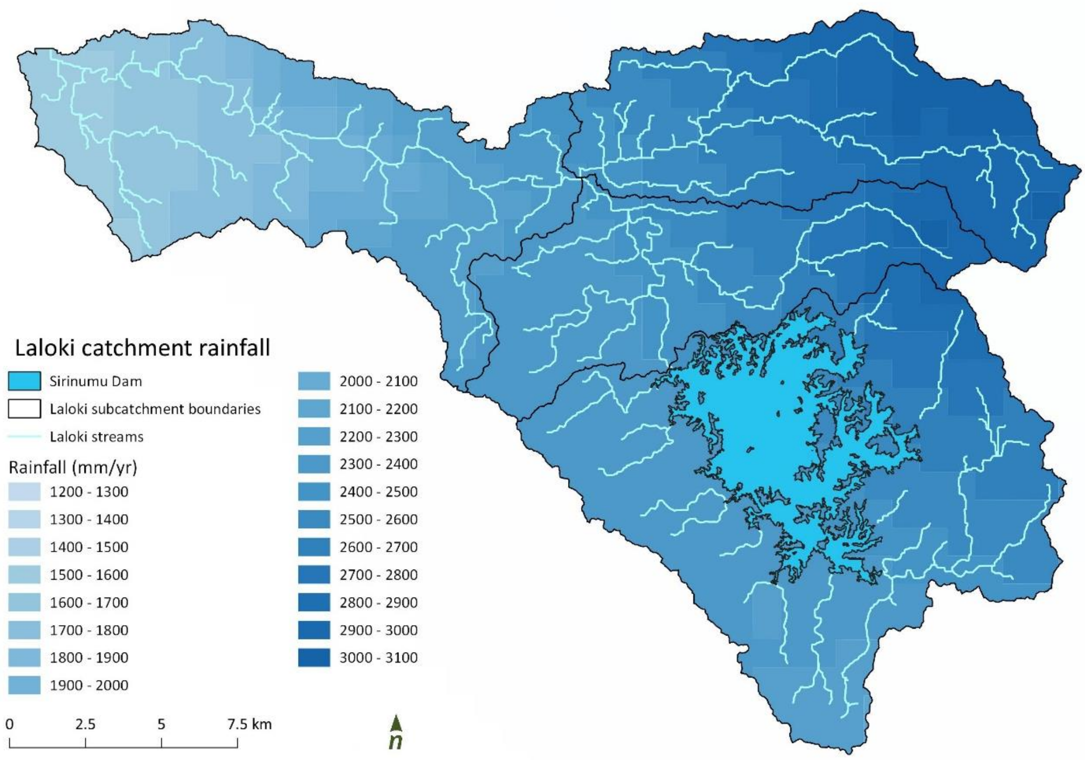

Figure 3. *Annual rainfall distribution across the catchment extracted from the PNGRIS database (CEPA 2018b)*

2.3 Geology and soils

The geology of the Sogeri Plateau consists of a broad synform of volcanic agglomerate which plunges to the north-west (Figure 4). Closely spaced, structurally controlled parallel drainage patterns begin in the upper cliff edged flanks of the catchment and give way to dense dendritic to pinnate patterns in the lower areas of broadly undulating relief (Smith 2007).

The agglomerate forms part of the Astrolabe formation, a 200-300 m thick sequence of fragmented volcanics which underlie the mid to upper Laloki River catchment. The sequence is dominated by a chaotic array of angular to sub angular boulders of basalt and andesite in a matrix of tuff with interbeds of relatively minor thin tuff deposits ranging from fine to coarse in texture. Tertiary or Cretaceous sediments and Palaeozoic metamorphic lithologies underlie the agglomerate and outcrop at the extremities of the plateau with volcanogenic massive-sulphide copper/gold deposits identified at these margins (Smith 2007).

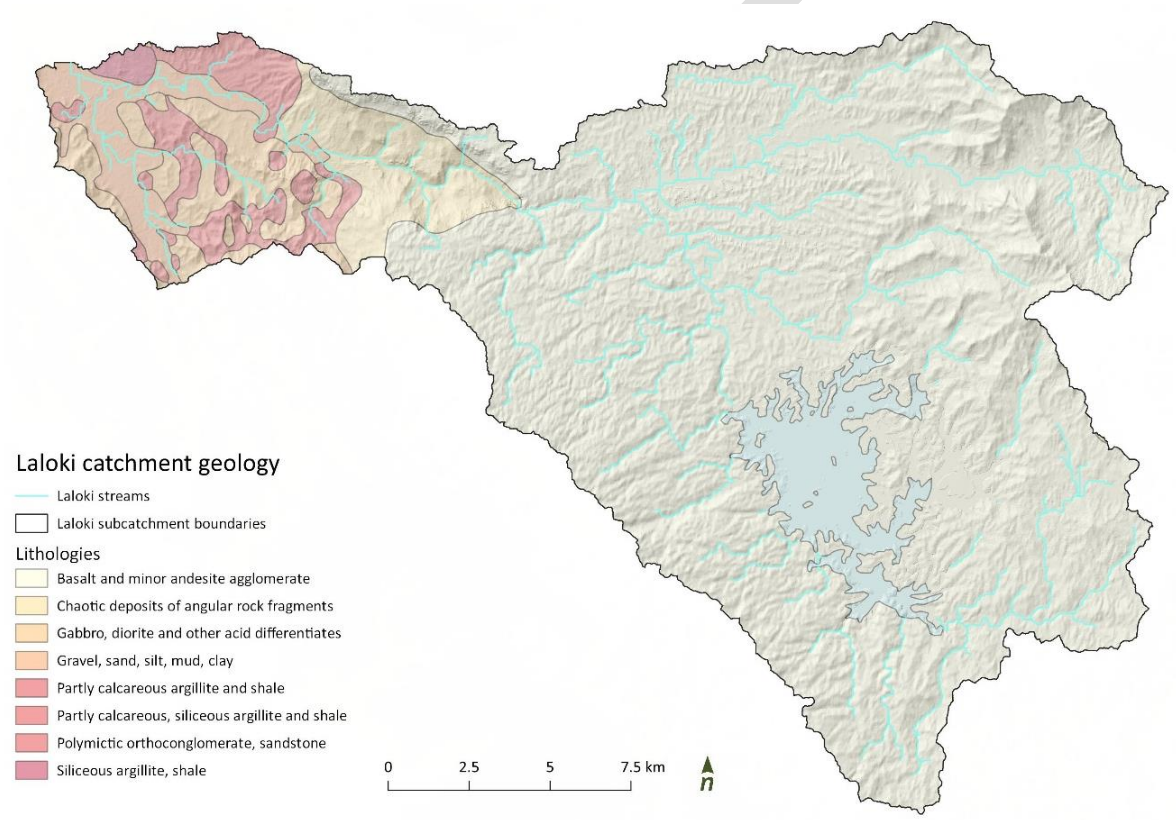

Figure 4. *Geology of the Laloki River catchment (CEPA 2018c)*

Given the climatic conditions of the region and the chemical variability of the rock, the formation is deeply weathered. The variability of the weathering profile is driven by subsurface flow through tension joints and permeable sequences. One such example of variability can be found at the Sirinumu Dam wall, where one side of the saddle yields rock exposure and the other 24 m of residual clay (Smith 2007). Smith (2007) also refers to a historical bauxite exploration report which characterised the soils of the plateau as generally 5 m to 60 m thick, weakly differentiated or not differentiated at all; friable and strongly acidic.

Downstream of Rouna Falls, the Laloki River flows through markedly different geology. Coarse materials and fine sediment are eroded from the plateau and deposited along the river's course in alluvial floodplains. The river 's depositional margin is confined by hills to the south comprising of gabbro and calcareous argillite and polymictic sandstone to the north.

The soil map in Figure 5 represents an extrapolation of very limited soils understanding across the broader region based on climate, topography and geology and is based on the USDA taxonomic classification system.

Despite being an extrapolation, the dataset provides the likely extent of key soil types, each of which will require appropriate management considering the projected intensification of land use. While the soils dataset does not identify the soil types adjacent to the banks of the Sirinumu Dam, it is likely that the adjacent soils types extend to reservoir edge. The soils associated with the key erosional features are discussed in the field observations section.

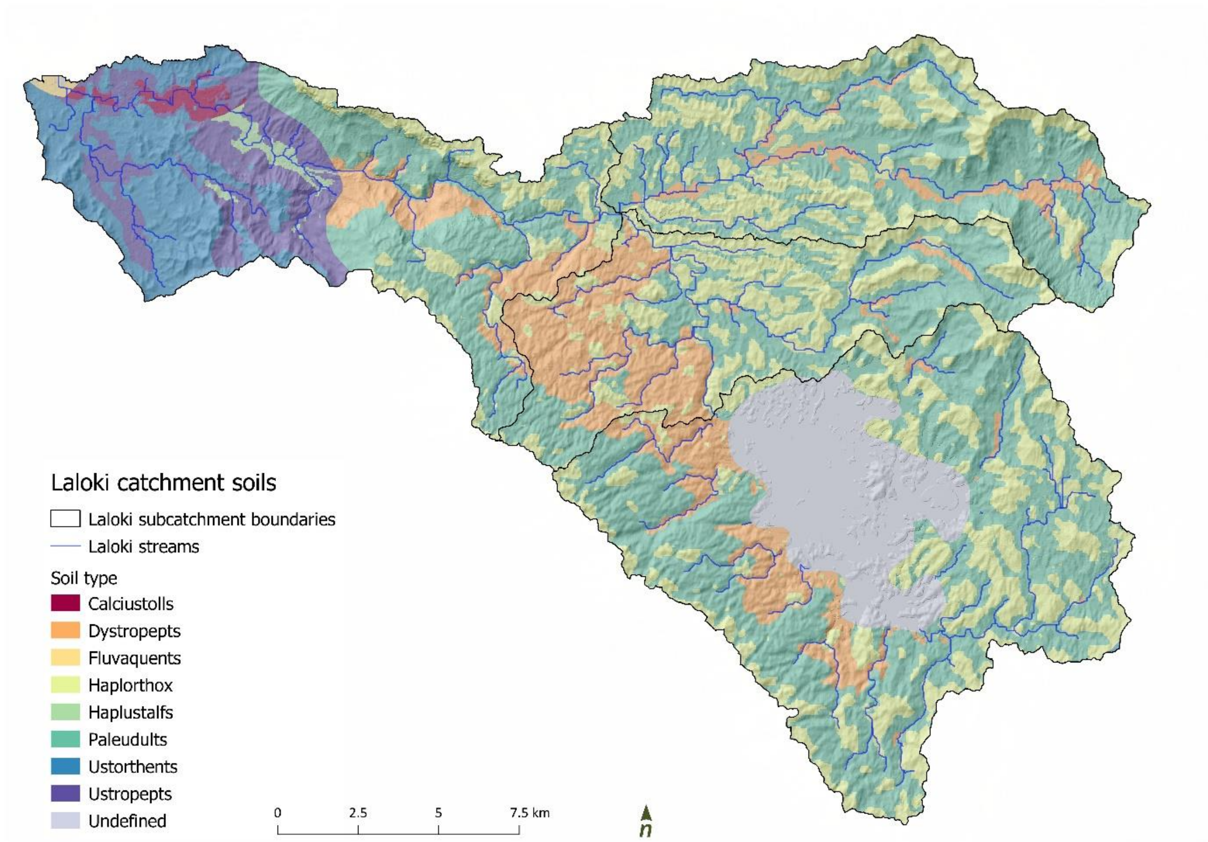

Figure 5. *Soil types across the Laloki River catchment (CEPA 2018d)*

2.4 Land use

The most recent land use dataset available is the broadscale, satellite-based microwave radar (PALSAR) analysis across much of Papua New Guinea (PNG) conducted in 2007 and 2010 (see Figure 6 and Figure 7). These data sets were provided by CEPA. Key land use observations from the two datasets, 2017 Google Earth satellite imagery and recent field notes are listed below:

- A key difference between the two PALSAR datasets appears to be a reduction of forest cover in proximity to the forest/scrub margins below Rouna Falls and within the Sirinumu Dam catchment, particularly along the southern and western flanks of the reservoir.
- The reduction in forest cover is marked by an increase in the density of Lowland Eucalypt patches within the surrounding Lower Montane Primary Forest from 2007 to 2010.
- Bare Soil/ Grass are concentrated in flatter sections of the catchment where alluvial floodplains form, particularly along the lower reaches of Eilogo Creek and the lower Laloki River.
- Areas classified as rubber plantations exist along the boundary between Forest and Bare Soil/Grass (inferred as pasture).

- While the PALSAR datasets correspond well with key features in the satellite imagery at a general level, the significant variation in the vegetation types suggests that seasonality may impact land use classification.
- Further understanding of the PALSAR dataset is necessary to draw useful conclusions at a resolution finer than at the catchment scale.
- Google earth imagery and field observations at the dam perimeter suggest that when reservoir levels recede bare lateritic soils are exposed to rill erosion.
- Significant areas of hillslope erosion were observed during recent field observations.
- Anecdotal evidence suggests that exist land slips within the catchment however the extent remains unknown.

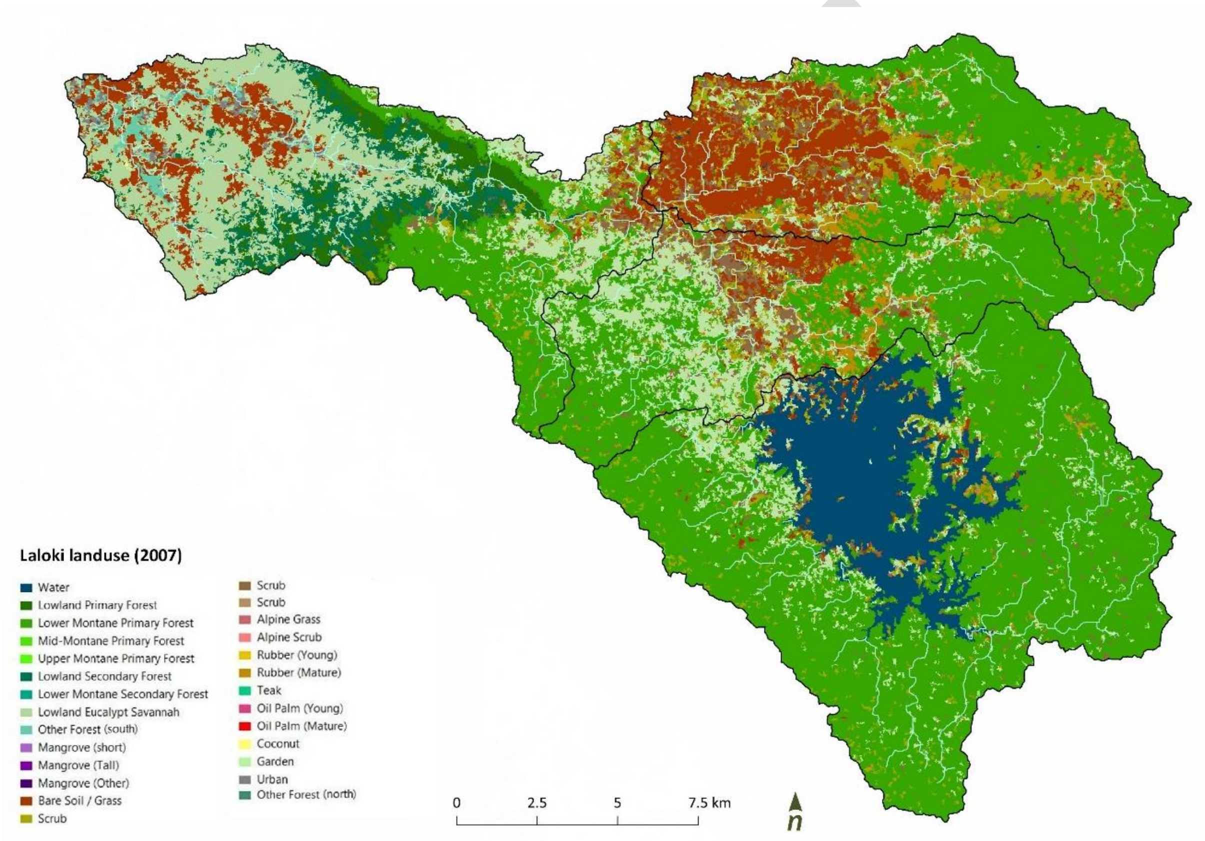

Figure 6. *Phased Array type L-band Synthetic Aperture Radar (PALSAR) analysis of land surface and inferred land use categories for the Laloki River catchment in 2007 (CEPA 2007)*

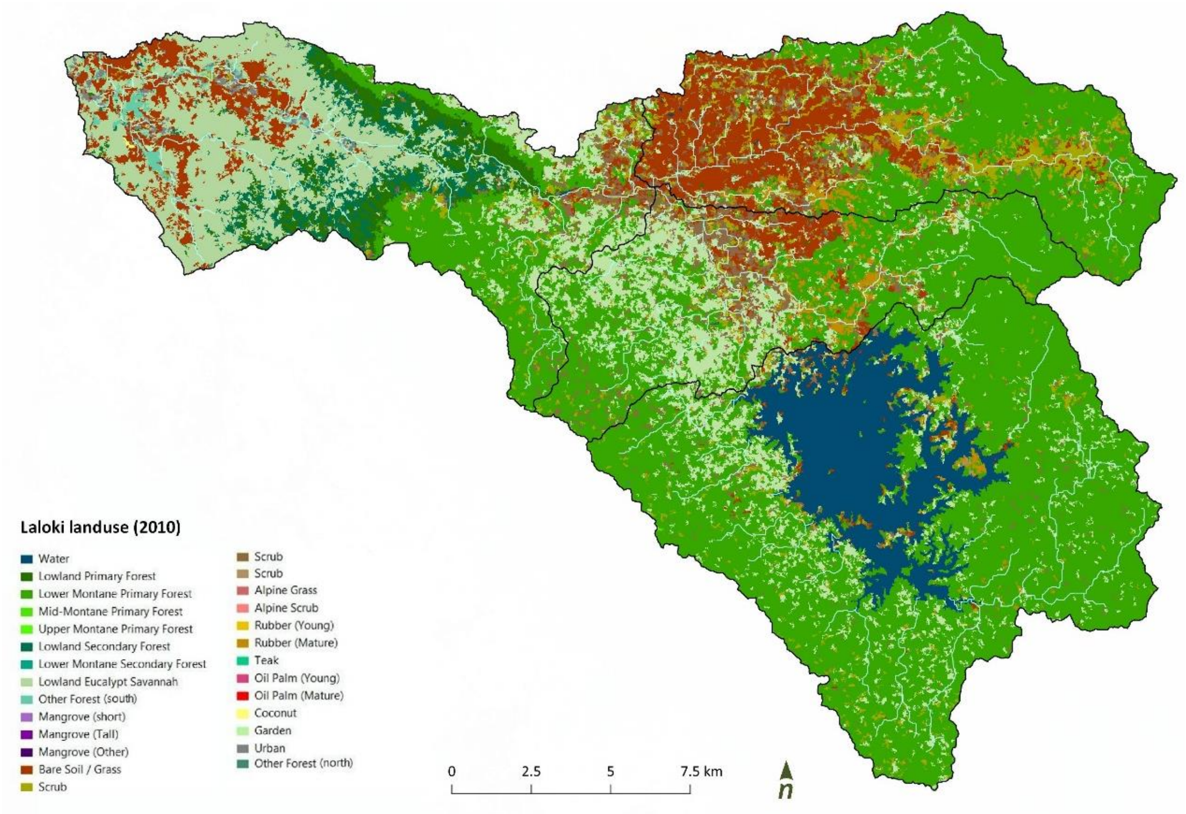

Figure 7. *Phased Array type L-band Synthetic Aperture Radar (PALSAR) analysis of land surface and inferred land use categories for the Laloki River catchment in 2007 (CEPA 2010)*

2.5 Previous studies

A bathymetric survey of the Sirinumu Dam was undertaken by the Secretariat of the Pacific Islands Applied Geoscience Commission (SOPAC) in 2007. 123 bathymetric profiles (total length 155km) of the reservoir were processed and interpolated to yield a 10m grid DTM of the reservoir (Figure 8). The dam was divided into four broad zones and a cross-section profiles analysis examined the results of the DTM in respect to the principle branch source areas feeding the reservoir. The profiles were chosen to correlate with actual bathymetric results.

No pre-dam topography was available to compare with the 2007 survey. However, interpretation of the morphology of the bathymetry profiles indicated the widespread presence of former, well defined channels on the reservoir floor. The fact that these former channels had not been infilled indicated that sedimentation in the dam since 1967 is very low.

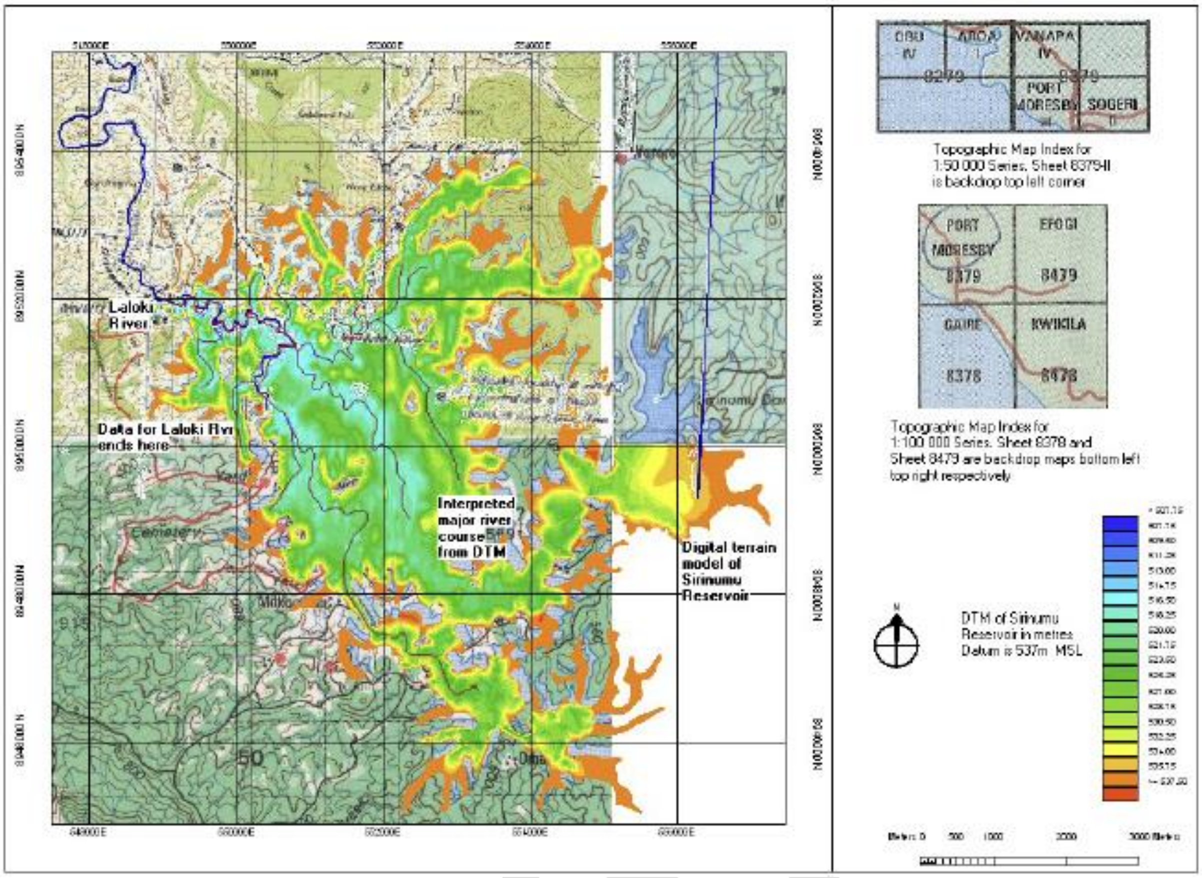

Figure 8 *The digital terrain model (DTM) produced as part of SOPAC's 2007 study*

In 2018 additional bathymetry and sub-bottom profiling was undertaken as part of this study (See Attachment A). The 2018 data provided the opportunity for a comparative analysis of the 2007 survey results. The analysis confirmed that minimal sedimentation has occurred within Sirinumu Dam since construction. The evidence to support this conclusion includes:

- The bathymetric survey comparisons did not identify significant channel fill or change in channel reservoir floor morphology. This indicates that rates of sedimentation are very low.
- The only noted change was possible slumping of reservoir margins, which does not impact overall reservoir capacity as it is a redistribution of floor sediment.
- The ground penetrating radar survey revealed well defined reservoir floor features across most sections of the dam. This suggests that rates of sedimentation are very low.
- Suspended sediment samples suggest that turbidity levels are at a minimum within the reservoir.
- The two successful bed sediment samples contained gravels. This indicates that the sample contains in situ sediments prior to dam construction. This suggests that rates of sedimentation are very low.
- The lack of soft sediment available for sampling by the dredge suggests that post inundation sedimentation is minimal across the other sections of the dam.

From these observations, the analysis concluded that the reservoir is currently experiencing low levels of sedimentation, however this may increase in the future if there is extensive land clearing.

3 Method

3.1 Overview

The following sections provide an overview of the methods and tools used for this investigation. This includes the approach adopted for the hillslope erosion assessment, waterway classifications and assessments, field investigation and hydraulic modelling.

3.2 RUSLE assessments

A commonly used method to assess catchment scale hillslope sediment generation processes is the Revised Universal Soil Loss Equation (RUSLE). Benefits of using RUSLE include the requirement of a modest amount of parameters that can be derived from commonly available datasets, it has been employed in PNG studies (Samanta et al, 2016) and its factor-based nature allows for individual contributing factors to be easily analysed (Lu et al, 2011). The RUSLE determines mean annual soil loss (A, t/ha/yr) as a product of six factors as shown below:

$$A = RKLSCP$$

Where:

- A is the annual average soil loss per unit of area (ton per hectare per year),
- R is the rainfall erosivity factor,
- K is the soil erodibility factor,
- L is the slope length factor,
- S is the slope steepness factor,
- C is the cover management factor and
- P is the erosion control practice factor.

The equation helps determine areas within the catchment with high hillslope erosion risks.

Methods to calculate each of the RUSLE factors across the Laloki River catchment are shown in Table 1 and discussed in detail below. There is some uncertainty in the RUSLE factors, particularly the site-specific nature of soil erodibility and erosion control practice (Doyle et al., 2015). Therefore, without a rigorous field validation of these conditions the results should be used with some caution.

Table 1. RUSLE parameters used in the Laloki River catchment hillslope erosion assessment

Factor	Method
Rainfall erosivity (R)	Calculated with a regression model and rainfall records from PNGRIS
Soil erodibility (K)	Calculated from national soils layer PNGRIS
Slope length (L)	LS layer generated from a 5m DEM
Slope steepness (S)	
Cover management (C)	C factors applied to land use layer
Erosion control practice (P)	1 (assuming no erosion control)

Rainfall Erosivity (R)

Rainfall Erosivity is a function of the rainfall intensity and kinetic energy of all storms occurring throughout a year (Wischmeier and Smith, 1965). It is defined as:

$$R = \frac{1}{n}\sum_{j=1}^{n}\left[\sum_{k=1}^{m}(E)(I_{30})_k\right]$$

Where R is the rainfall erosivity factor (MJ.mm/ha.hr.yr), n is the number of storm events in a given year, E is a total kinetic energy in a single storm (MJ/ha) and I_{30} is maximum 30-minute rainfall intensity (mm/hr) of that storm. Given that pluviograph data was not available for the purposes of this study, the empirical relationship observed between rainfall erosivity and mean annual rainfall in India by Parveen & Kumar (2012) was employed. The derived relationship is given below

$$R = 79 + 0.363R_N$$

(Where R_N is the average annual rainfall in mm)

This relationship was employed by Samanta et al. 2016 in the estimation of rainfall erosivity values for the Markham River catchment, which is the fourth largest catchment in PNG and is located to the north-west of the Laloki River catchment. While the relationship is not based on rainfall intensity data from PNG, it is considered appropriate for developing a relative understanding of hillslope erosion risk within the catchment. The final R values across the catchment are illustrated in Figure 9 below.

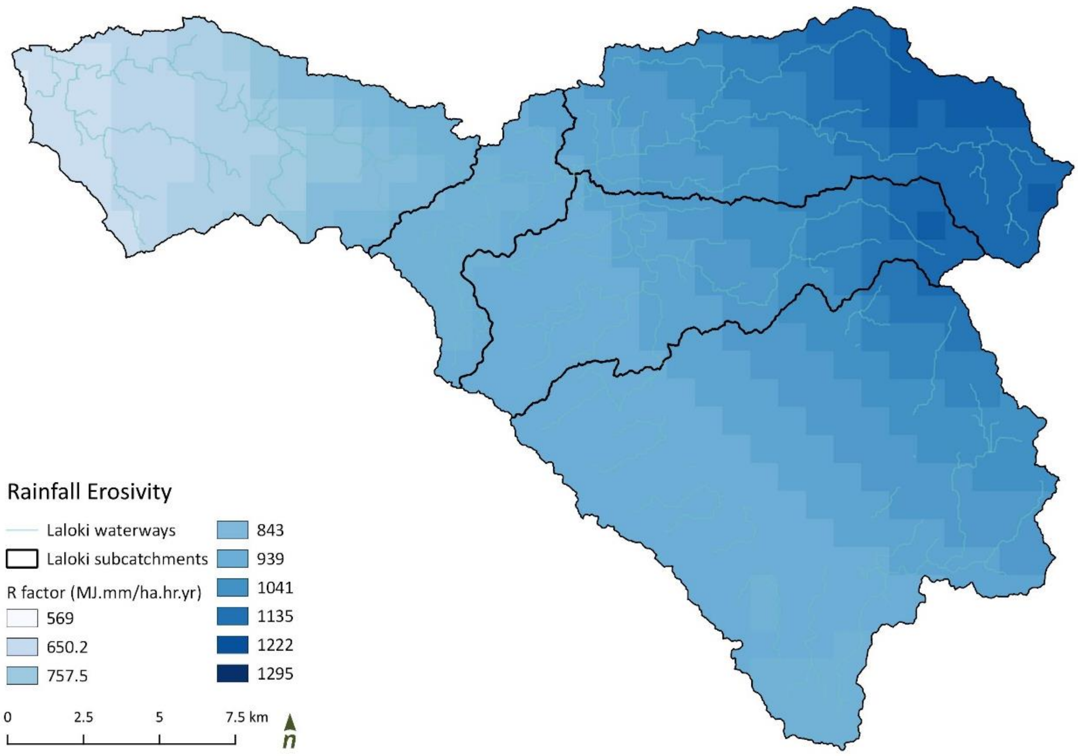

Figure 9. *Derived rainfall erosivity across the Laloki River catchment*

Soil erodibility factor (K)

The PNGRIS soils dataset provides a broad categorisation of soil erodibility across the study area. Four erodibility values are provided which range from 'Very Low' to 'High'. A review of this dataset revealed that it is highly interpolated and generated from sparse and often spatially inaccurate on ground observations (Doyle 2015).

Given that any improvement of the soils data set would require extensive ground-truthing of soil textures across the catchment, the approach by Samanta et al, (2016) was considered suitable for the purposes of this study (Table 2). This method applies K values to soils types based on textural similarity based on Stone (2012).

The area soils layer immediately adjacent to Sirinumu Dam did not contain erodibility data, for this reason, a median erodibility value of 0.22 was applied.

Table 2. Corresponding K factor values assigned to the soil erodibility code of the provided soils layer (after Samanta et al, 2016).

Code	Soil Erodibility	Description	K factor
1	Very low	Soils with high to very high organic matter content and moderate to rapid permeability	0.07
2	Low	Except for sandy Entisols, these soils have moderate organic matter content and moderate permeability	0.17
3	Moderate	Generally, slowly permeable soils with moderate organic matter content; the alluvial Entisols have low to moderate organic matter content	0.27
4	High	Poorly structured topsoils	0.37

The distribution of the soil erodibility (K) factor across the Laloki River catchment as applied in the RUSLE calculations are shown in Figure 10.

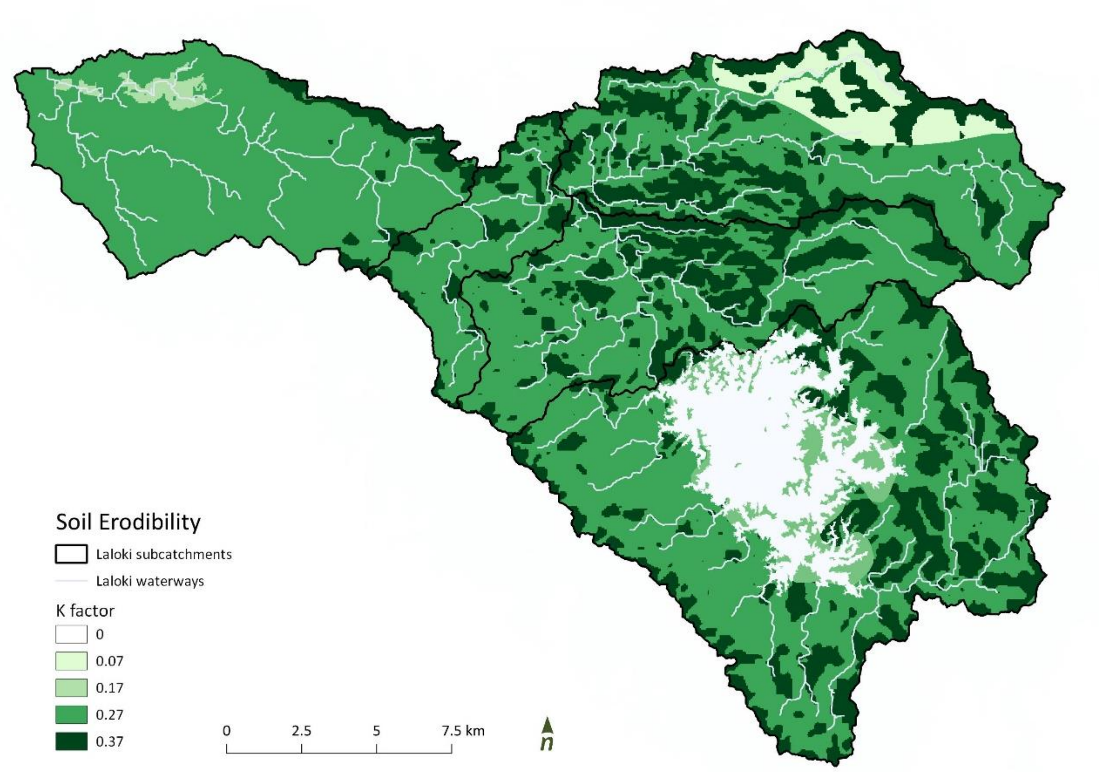

Figure 10. *The Laloki River catchment soil erodibility (K) factor*

Slope length and slope steepness factor (LS)

The L factor (slope length) and S factor (steepness) are often combined as LS to represent the effect of topography on hillslope erosion rates (Zhang 2017).

Various GIS based algorithms have been developed for calculating a combined LS factor using high resolution Digital Elevation Models (DEMs). The combined LS factor in RUSLE represents the ratio of soil loss on a given slope length and steepness to the soil loss from a unit slope that has a length of 22.13m and a steepness of 9%, where all other conditions are the same (Yang 2015).

Five metre resolution elevation data is available for the entire Laloki River catchment, however the accuracy and resolution of this data is significantly reduced within low lying areas. Given that this is the best information available, the LS factor was calculated from this data using the SAGA LS factor tool, which requires a layer of contributing area for each point in the grid, and a layer of slope. These layers were developed using TauDEM (Terrain Analysis Using Digital Elevation Models), a set of tools developed by Utah State University for the analysis of terrain using the DEM. The tools can be used as a plug-in to most mapping software.

The following steps were undertaken to develop the LS factor layer:

1. TauDEM: Pit removal of the 5m DEM to ensure hydraulic connectivity within the watershed
2. TauDEM: Computation of flow directions and slopes using the D8 method which selects which adjacent grid cell water will flow to for each cell in the grid
3. TauDEM: Contributing area using the D8 flow direction method
4. SAGA: LS factor tool in Terrain>Hydrology to convert slope and contributing area layers to the LS factor layer

The distribution of LS values for the whole of the Laloki River catchment and a magnified area are presented in Figure 11 and Figure 12 respectively.

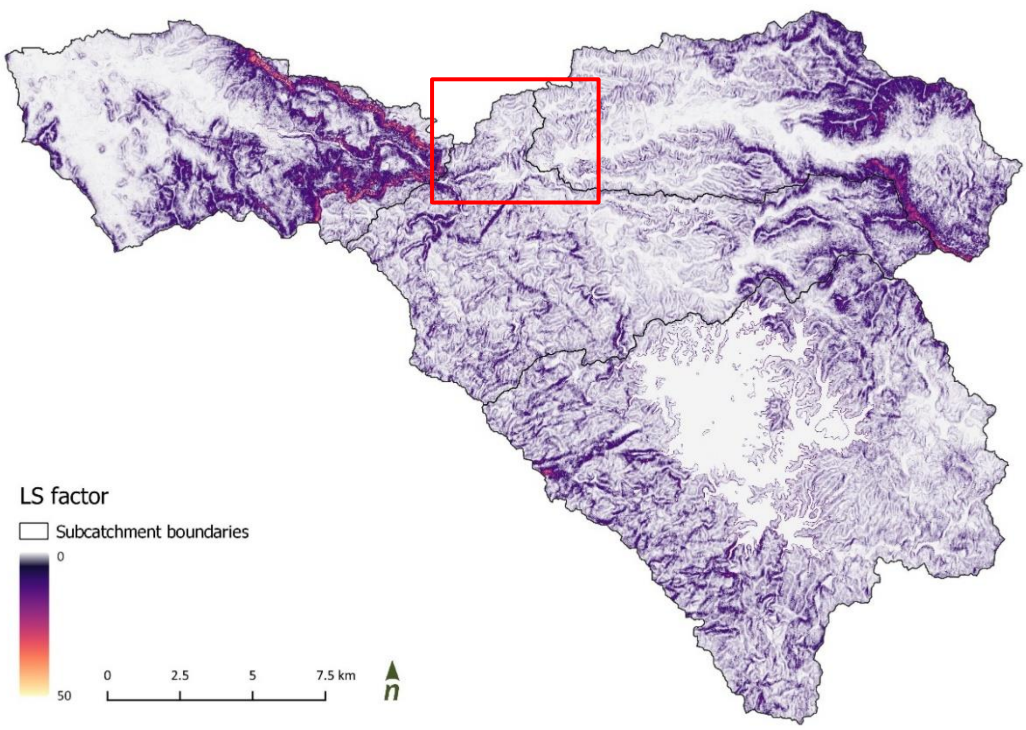

Figure 11. *The Laloki River catchment Slope length (LS) factor, with the highlighted area magnified in Figure 12 below*

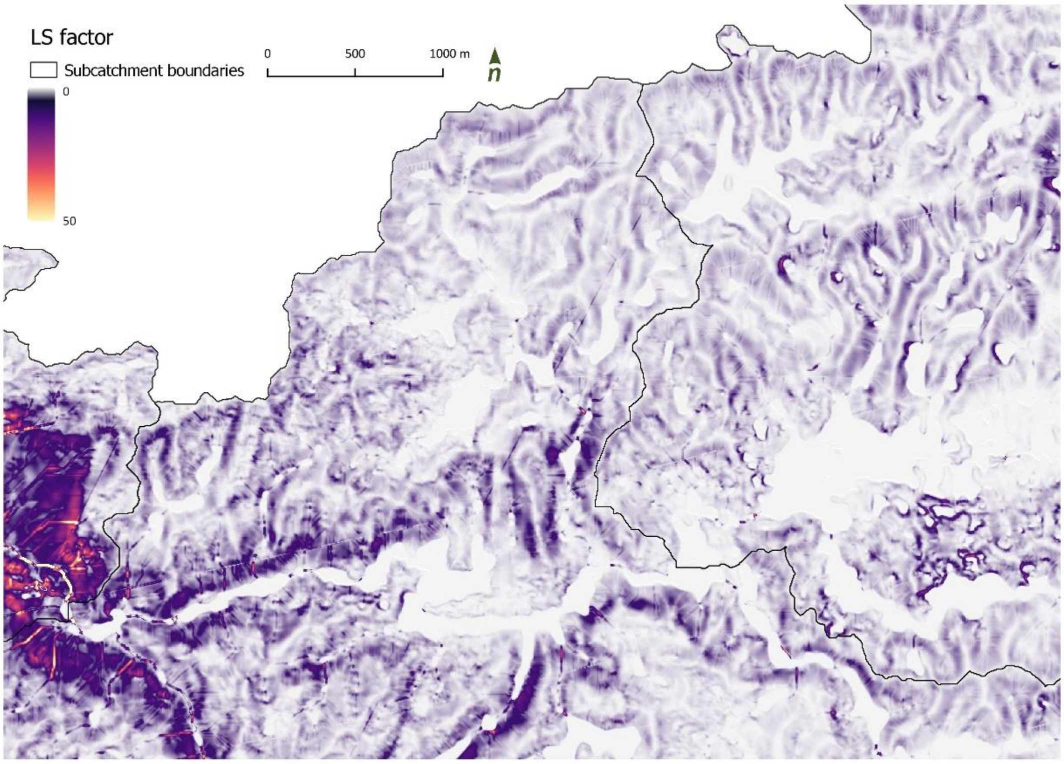

Figure 12. *A close up of the Laloki River catchment's slope length (LS) factor as indicted in Figure 11*

Cover management factor (C)
There are number of methods currently used to estimate the cover management (C) factor based on ground cover estimates or land use layers. Previous studies have determined C factor values which can be applied to various land use types (Pal and Samanta 2012). Land use for the Laloki River catchment has been mapped based on a Phased Array type L-band Synthetic Aperture Radar (PALSAR) analysis of land surface imagery mapped between 2000-2012. This PALSAR analysis was produced by the Papua New Guinea Forest Authority (PNGFA).

C factor values derived from Pal and Samanta (2012) were applied to similar land use categories for the Laloki River catchment. Table 3 provides the C factor values and Figure 13 represents the final cover management layer used for the RUSLE analysis. It is important to note that this current land-use layer does not account for the extent of dirt road surfaces within the catchment which are a likely source of and conduit for sediment.

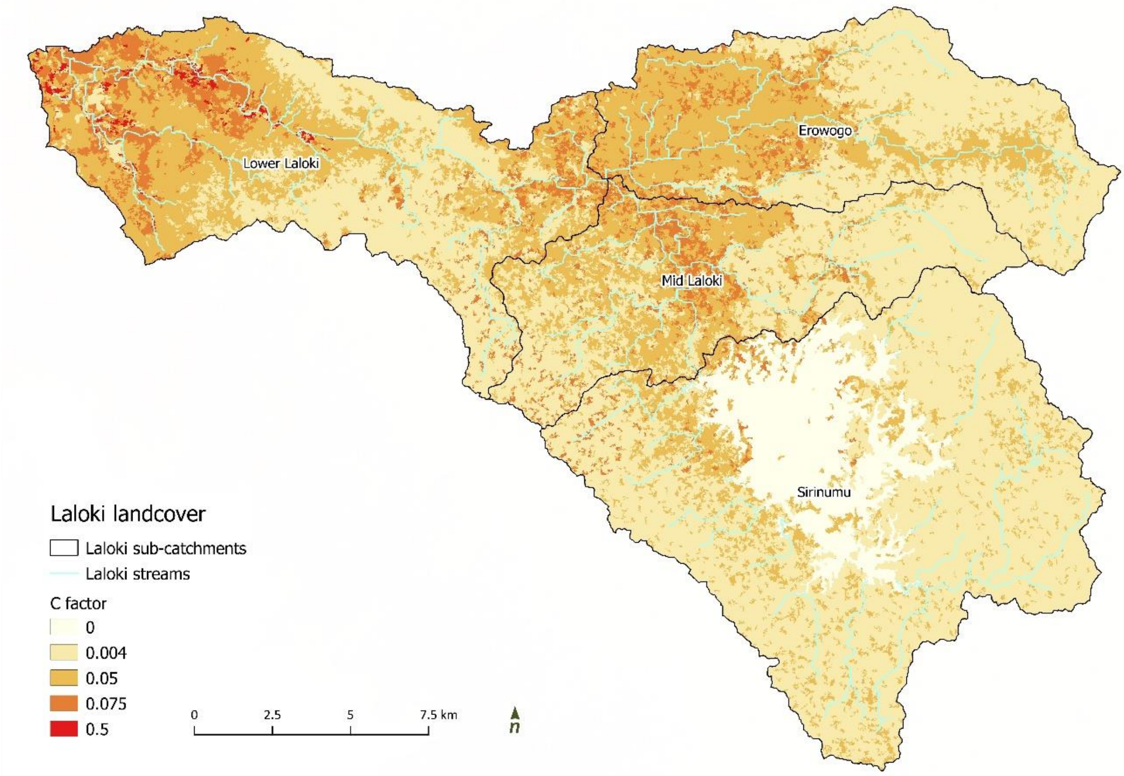

Figure 13. *Cover management factor values applied to the Laloki River catchment land use categories.*

Table 3 Cover management factor values applied to land use categories as found in the PNGFA (2012) land use layer.

Land use category	C factor
Water	0
Forest	0.004
Lower montane primary forest	0.004
Lower montane secondary forest	0.004
Lower montane secondary forest	0.004
Lowland primary forest	0.004
Mangrove (tall)	0.004
Mangrove short	0.004
Other forest (north)	0.004
Other forest (South)	0.004
Rubber (mature)	0.004
Teak	0.004
Upper montane primary forest	0.004
Coconut	0.05
Lowland eucalypt savannah	0.05
Scrub	0.05
Scrub/pasture	0.075
Garden	0.125
Urban/settlement	0.5

A future land use layer was developed by modifying the C-factor values in Table 3 to account for three forms of land-use change within the catchment, namely deforestation, agricultural intensification and urbanisation (Figure 14). Details of the changes are summarised in the following points:

- All forested areas that fell within a slope between zero and seven percent had their C-factor modified from 0.004 to 0.03 to reflect the preferential clearing of accessible slopes for agriculture
- All land use areas categorised as 'Scrub/pasture', which were predominantly on the plateau, were modified from a C-factor of 0.075 to 0.085 to reflect intensified cattle production.
- Urban areas (Red) were expanded along the Lower Laloki River and in developed areas within the Sogeri Plateau.

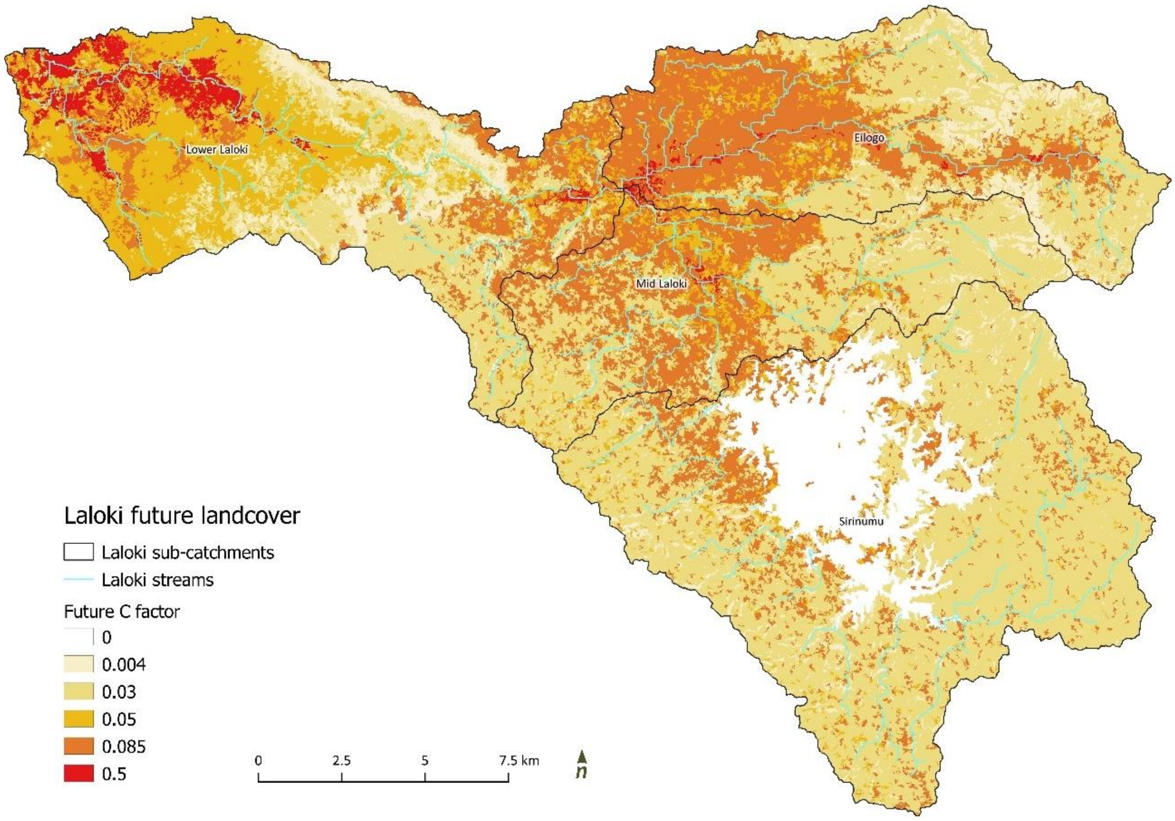

Figure 14 *Future landcover layer reflecting potential broadscale changes to the catchment in the next 25 to 50 years.*

Erosion control practice factor (P)
No adjustment has been applied to account for erosion control practices.

Assessment of sediment delivery ratio
Not all sediment generated from hillslope erosion processes will enter waterways, or discharge at catchment outlets. In Fu et al (2010) an assessment of the delivery of sediments from unsealed roads in forested catchments showed that the distance of the source of sediment to the stream was a critical measure of delivery ratio. Based on this research and similar studies, it was assumed that the delivery ratio for sediment generated within 10 m, 30 m and greater than 30 m of a waterway is 100%, 35% and 10% respectively.

Summary
The analysis described above shows that there are various assumptions and multiple levels of uncertainty involved in the estimation of hillslope erosion generation and delivery rates. The estimates provide an indication of the relative loads (see Section 4.1) and can be used as a tool to support the identification of sites with potentially high risk of hillslope erosion.

3.3 Field investigations

Overview

Several field assessments were made within the catchment during this study. This includes assessments on the 25th-26th of April 2018, the 11th-12th of December 2018 and the 21st-22nd of March 2019 (Figure 15). These assessments focussed on the assessment of geomorphic characteristics and processes as outlined in Section 3.4. A water quality monitoring program was also incorporated into the last two field programs to compliment the overall catchment assessment. The three field programs are summarised below.

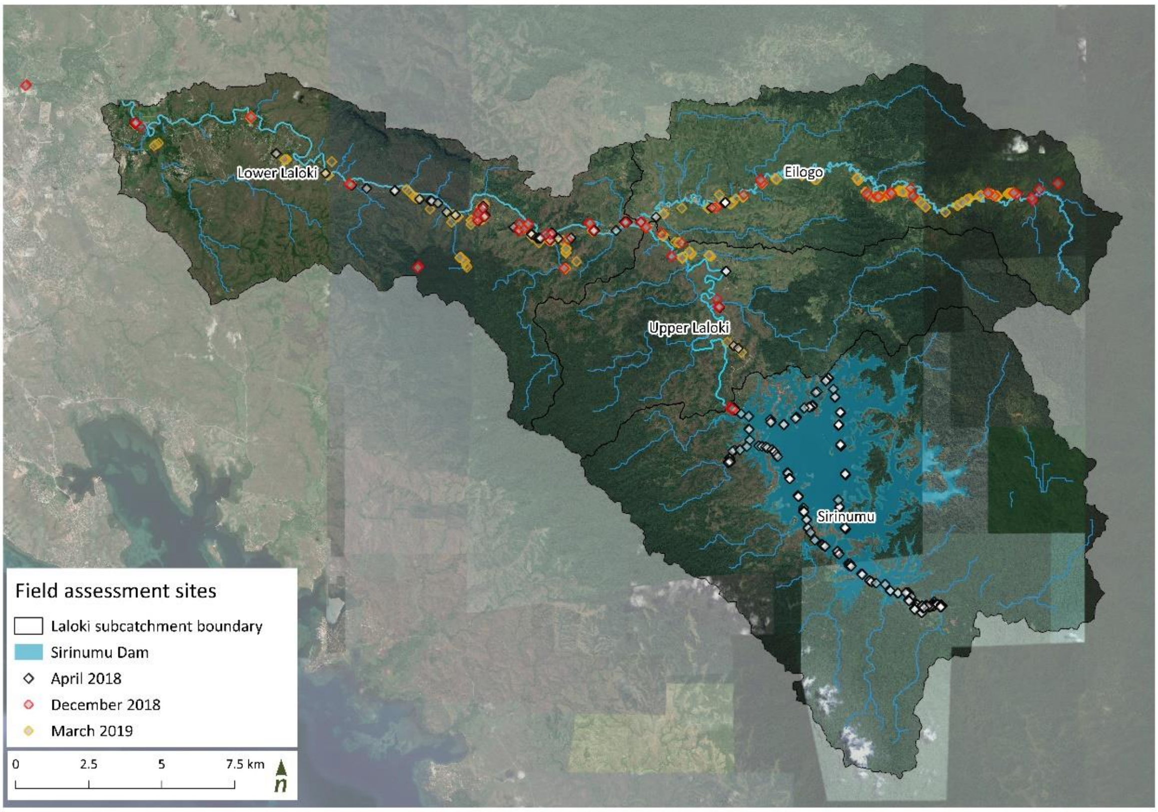

Figure 15 *An overview of the data/photo collection points for both the April and December field assessments.*

On the afternoon of the 25th of April 2018, a rapid catchment assessment was undertaken visiting several sites along the Laloki River and on the Sogeri Plateau. On the 26th of April 2018 a boat was employed to support a shoreline assessment of Sirinumu Dam and inspect key tributary inflows points.

The second field investigation of the Laloki River catchment was undertaken over the 11th and 12th of December 2018 during the dry season (Figure 16). It included the sampling and monitoring for total suspended sediment analysis and turbidity respectively.

The third and final field assessment was undertaken on the 21st-22nd of March 2019 during the wet season (Figure 16). This assessment entailed follow up sampling and monitoring of the same parameters at previously established monitoring points. Follow up sampling was also planned to take place across the Sirinumu Dam at this time, however local landholder protests on the 22nd of March 2019 restricted access. The reservoir sampling was aimed to confirm the findings of the previous dam monitoring which was undertaken as part of the collection of bathymetric survey (see Attachment A).

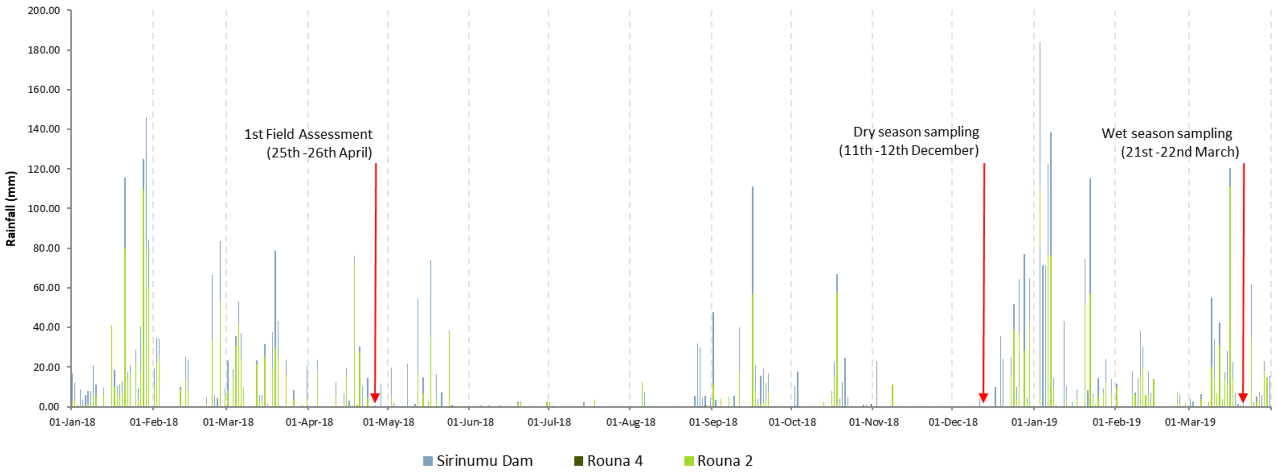

Figure 16. *Daily rainfall data for three rain gauges across the Laloki River catchment and the dates for each of the field assessments.*

3.4 Sediment sampling

The water sampling and monitoring program was undertaken during December 2018 and March 2019 to determine the Total Suspended Sediment (TSS) concentrations and Turbidity. Samples were collected for TSS analysis along accessible sections of Eilogo Creek and the Laloki River (Figure 17). Turbidity levels (NTU) were also recorded at these sampling points by means of a WP88 turbidity meter. Care was taken at each sample site to ensure sediment and aquatic vegetation was not disturbed during sample collection and monitoring. Each 500ml unfiltered sample was stored on ice and delivered to Australian Laboratory Services (ALS) Brisbane for processing within seven days of collection.

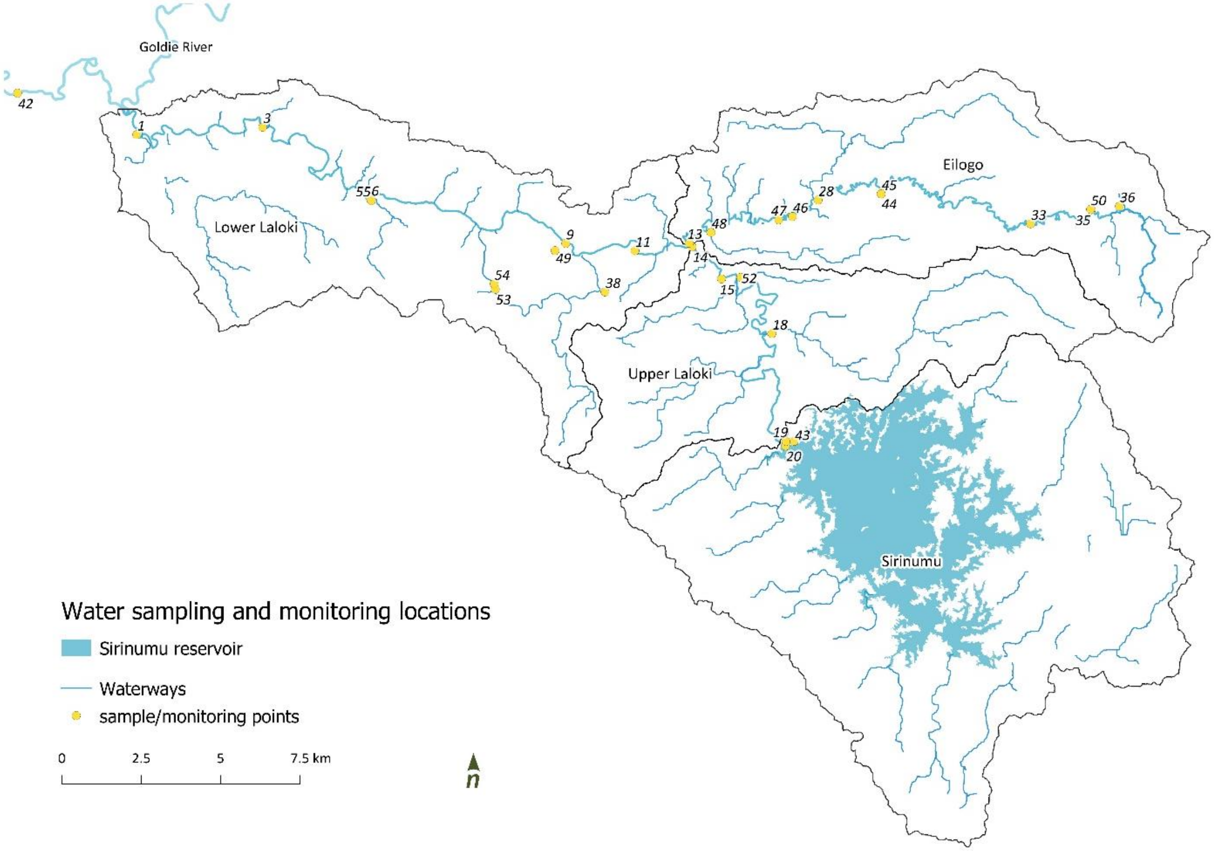

Figure 17. *The sampling locations within the Laloki River catchment and Goldie River*

3.5 Geomorphic assessment

Overview

The current geomorphic character and behaviour of a waterway is influenced by a complex and multi-faceted collection of environmental and anthropogenic factors. These factors have been well discussed in the scientific literature and classified and grouped in a variety of ways. Examples include the classification by Kochel (1988) and Cook and Schneider (2006), whose classifications align well with the River Styles® framework (presented below). Based on these systems, the factors that influence the geomorphic character and behaviour of waterways can be classified as:

- Drainage basin factors — controls on the waterway that are external to the channel and floodplain; and
- River channel factors—internal controls on the river resulting from the physical characteristics of the channel, floodplain and flow.

Table 4 lists a range of geomorphic controls on channel form and processes, for each of these factor groups. These factors control the geomorphic character and behaviour, and therefore physical form of each reach.

Table 4. List of factors that influence geomorphic characteristics of waterways (adapted from Kochel 1988, and Cook and Schneider (2006)).

Group	Drainage basin factors	River channel factors
Landscape morphology	• Valley cross-section shape and slope • Valley width	• Longitudinal channel gradient • Floodplain width • Bank slopes

Group	Drainage basin factors	River channel factors
Climate	• Rainfall • Temperature range • Humidity	• None
Geology and soils	• Geological units • Soil erodibility (e.g. cohesion, permeability, dispersion, structure, chemistry, organic matter content) • Bedrock outcrops and lithology • Nature of upstream/upslope sources (catchment slopes, gullies, tributaries, channel stores etc.) • Mass movement (where external to fluvial processes, e.g. rockslides)	• Substrate particle size, shape and cohesion • Bank sediment particle size, shape and cohesion • Bedrock outcrops and lithology
Hydrology (discharge)	• Frequency and season of flooding • Regulation by dam/weir operation • Duration of floods and duration between floods • Rates of rise and fall • Tributary/trunk timing relationships • Groundwater seepage	• None
Land use and physical interventions	• Land use, e.g. urban development, cropping, stocking, feral animals, mining, roads • Drains, channels, diversions and levees	• Erosion control works (bed and bank) • Large woody debris removal or reinstallation • Sand and gravel extraction or dredging • Crossings or bank cuttings
Vegetation	• Vegetation cover, species, structure, bushfires • Catchment/floodplain channel clearing or revegetation	• Vegetation species, tractive stress tolerance and structure • Riparian channel clearing or revegetation • Large woody debris loading

An objective of the geomorphic assessment undertaken for this study aimed to understand how key factors in Table 4 influence the geomorphic characteristics of waterways in the study area. Once the geomorphic characteristics and processes of a waterway are understood, the implications on sedimentation, ecology and communities can also be assessed.

The below section describes the field and desktop methods used in the geomorphic assessment.

Field assessments
For multiple sites across the catchment, several observations were made relating to the geomorphic condition and processes to inform this study, these included:

- Landscape setting (e.g. degree of valley confinement)
- Adjacent land use
- Channel planform (i.e. low sinuosity, meandering etc.)
- Bank morphology (i.e. convex, vertical, undercut etc.)
- Bank substrate (i.e. fine grained, cobbles, bedrock)
- Bank stability (i.e. eroding bank, channel expansion/contraction)
- Bed stability (i.e. aggradation, knickpoints etc.)

- Instream features (i.e. bars, riffles, large wood, pools, undercut banks etc.)
- Sediment regime (i.e. source, transfer, accumulation)
- Sediment transport capacity (supply limited, transport limited).

These observations helped inform the RiverStyle® assessment and sub catchment assessment of geomorphic condition and processes.

River Style® assessment

The River Styles® framework was developed by Gary Brierley and Kirstie Fryirs (2000) to provide a rigorous geomorphic approach for examining river character, behaviour, condition and recovery potential. A River Styles assessment was undertaken for all waterways within the study area. The River Styles framework describes a set of procedures for identifying river character and behaviour based on a geomorphic understanding of river forms, processes and linkages and provides valuable insight for evaluating geomorphic condition and predicting recovery potential.

River Styles® are identified at the reach scale and framed in the context of valley setting. The valley setting is distinguished by the nature of the floodplain: a confined valley setting (CVS) has no floodplain, a partly-confined valley setting (PCVS) has a discontinuous floodplain and a laterally unconfined valley setting (LUVS) has a continuous floodplain. Once the valley setting has been established, each River Style® is identified based on the stream's planform, assemblage of geomorphic units and bed material texture.

Desktop based assessments of River Style® were undertaken using aerial imagery and available GIS spatial data, such as waterways, topography and infrastructure. The data from the site inspections was used to supplement and refine the desktop assessments (both classification and delineation).

The procedure used for River Style® assessments across the study area is based on the River Styles® procedural tree method (Figure 18). The River Style® framework also provides an understanding of river character and behaviour such that sediment source, transport and storage processes can be understood.

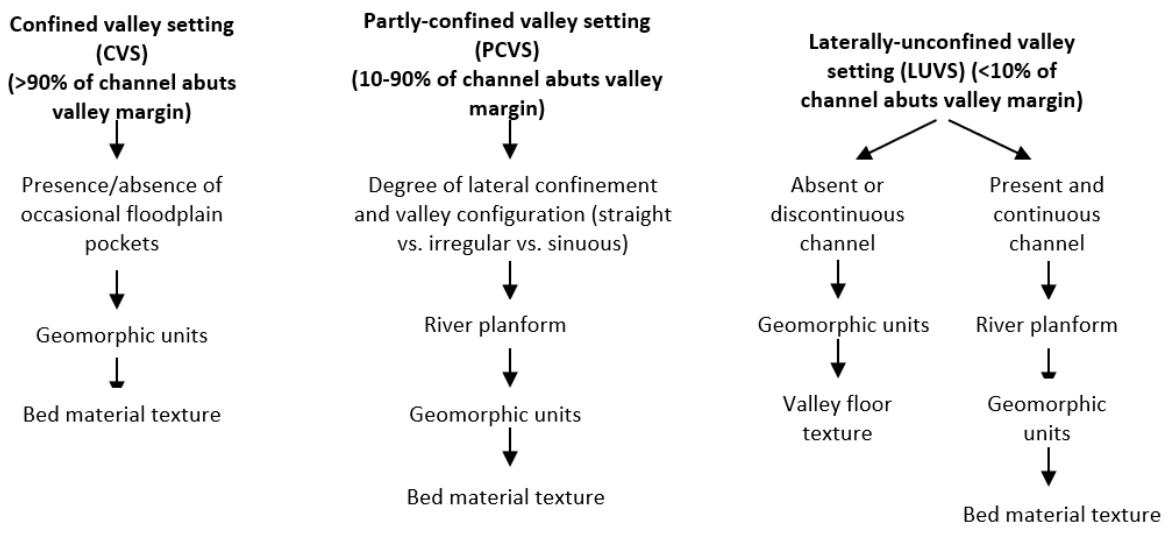

Figure 18 *River Styles procedural tree (Brierley and Fryirs 2005, p. 264)*

3.6 Hydraulic modelling

Overview

A broadscale one dimensional hydraulic model (HEC-RAS model) of the Laloki River and Eilogo Creek was developed to provide an indication of the variation in stream power experienced throughout the catchment (Figure 19). An understanding of how stream power is distributed in the catchment can help pinpoint which areas are most susceptible to both sediment mobilisation and deposition.

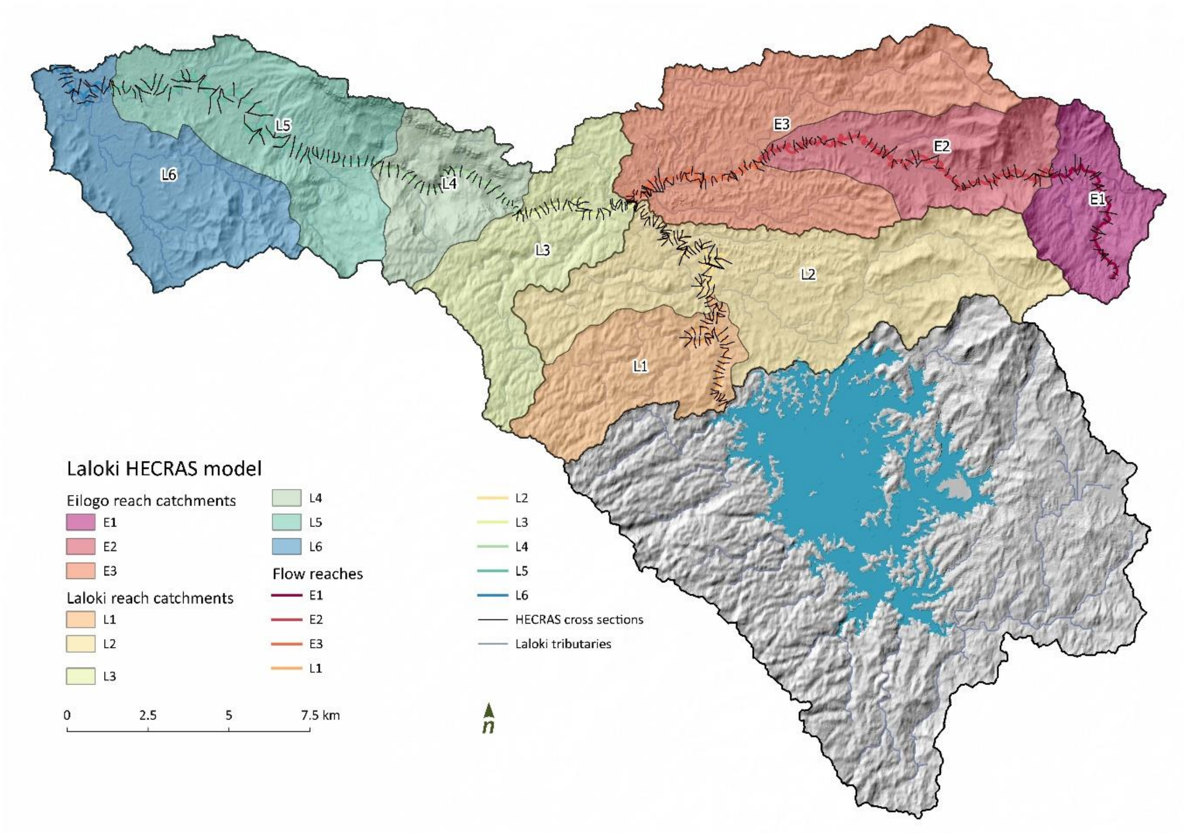

Figure 19 *An overview of the HECRAS model set up, illustrating the DEM (grayscale), cross sections, flow reaches and colour matching reach catchments*

The model was developed from the 5 m DEM provided by CEPA. The DEM is based on 2.5 m ASCII point data which were gridded to a mosaic of 5 m using ArcGIS 3D Analyst (Doyle 2015). While this DEM provides a more accurate and higher resolution representation of the local topography than the publicly available 90 metre SRTM data for the study area, details of low-lying areas and channels are obscured, thus severely limiting the accuracy of the model. This is exemplified in Figure 20, where the DEM represents the Sogeri urban area as one completely flat surface without any channel definition of the adjacent creek.

The flat sections within the DEM create artificial stepwise reductions in valley floor elevation, which are more prominent in the lower floodplains of both the Eilogo Creek sub catchment and the lower Laloki River sub catchment. These steps are likely to influence the model by artificially increasing channel gradient in particular sections, leading to an increase in the calculated stream power.

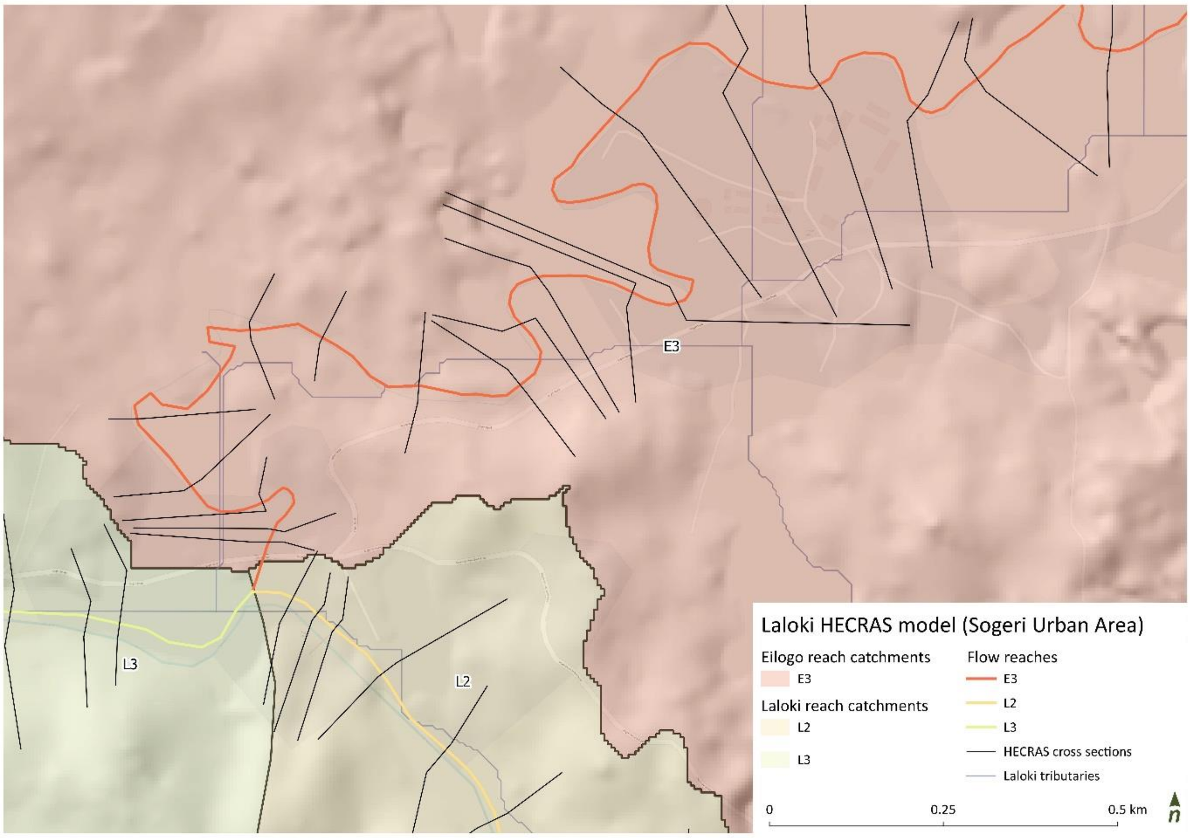

Figure 20 *A close-up of the DEM, the HECRAS cross sections, traced stream pathways (reaches) and generated stream pathways (tributaries) in relation to the confluence and the Sogeri urban area.*

Due to the lack of channel morphology present in the DEM, artificial channels were inserted at each cross section according to channel width derived from aerial imagery and a depth/width ratio of 1:10. This ratio was considered representative given the stream types present and observations made in the field. Values for the channel widths are provided in Table 5 below and correspond to each of the reaches depicted previously in Figure 19.

Table 5 Channel parameters applied to reaches within the model

Reaches	Chainage from	Chainage to	Channel depth (m)	Top width (m)	Bottom width (m)	Manning's n Value
E1	34122	31261	0.7	7	6.3	0.03
E1	30900	24515	0.8	8	7.2	0.03
E2	24225	14922	0.85	8.5	7.65	0.03
E2	14662	8583	0.9	9	8.1	0.03
E3	8320	75	1	10	9	0.03
L1	43019	34516	1	10	9	0.03
L2	34118	31178	1.2	12	10.8	0.03
L2	31078	28045	1.9	19	17.1	0.03
L3	27749	26181	2.3	23	20.7	0.03
L3	25961	23518	2.9	29	26.1	0.035
L4	23366	23051	1.8	18	16.2	0.035

L4	22895	17520	1.3	13	11.7	0.04
L5	17353	12680	1.8	18	16.2	0.35
L5	12401	4205	2.3	23	20.7	0.03
L6	3979	87	2.5	25	22.5	0.03

Peak flow estimation

Design peak flows for the catchment were estimated through the Regional Flood-Frequency Estimation method for Papua New Guinea (SMEC 1990). The method is based on a regression analysis of 66 flood records and various catchment and rainfall parameters. Catchment areas ranged from $5km^2$ to $40,900km^2$.

The method utilised three parameters for the estimation of floods: Area, daily rainfall intensity (P_2) and equal area slope. Two other factors used to determine the 'normality' of the catchments were calculated. These were the percentage of karstic landscape (K) (of which there was zero) and the catchment shape index (S).

The P_2, Area and Slope of the Laloki River and Eilogo Creek reach catchments were checked to sit within the limits used to derive the regression model. Overall, the catchments were a good fit (Figure 21), however the smaller catchments in the upper reaches (L1, E1 and E2) fell beyond the envelope for the model and required a slightly different method in order to calculate peak flows which is outlined in the method by SMEC (1990).

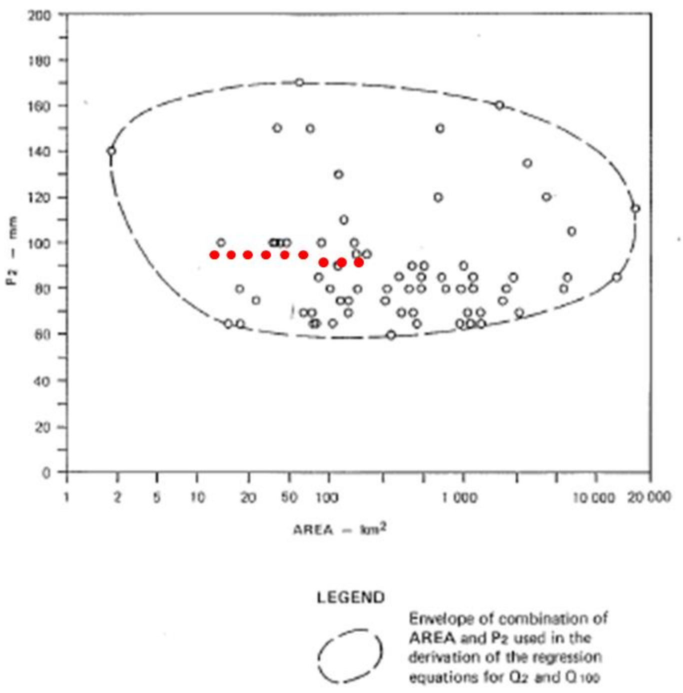

Figure 21 *Envelope of combination of area and daily rainfall intensity used in regression equation with the Laloki River and Eilogo Creek reach catchment areas plotted in red (SMEC 1990).*

For all reach catchments that fell within the envelope, the 2 to 100-year return period for peak floods was estimated using the formulae listed below (SMEC 1990):

$$Q_2 = 0.028*AREA^{0.70}*P_2^{1.12}*KS$$

For the upper catchments (E1, E2 and L1), a slightly different formula was used:

$$Q_2 = 4*AREA^{0.71}*KS$$

$$Q_{100} = 0.095*AREA^{0.61}*P_2^{1.12}* SLOPE^{0.11}* KS$$

The flood discharges for the other return periods (T) were calculated using the following:

$$Q_T = Q_2 + KQ_T*(Q_{100}-Q_2)$$

Where $KQ_5 = 0.27$

$KQ_{10} = 0.45$

$KQ_{20} = 0.62$

$KQ_{25} = 0.67$

$KQ_{50} = 0.83$

Peak flow estimations were calculated for the outlets for each of the reach catchments and are displayed in Table 6 below.

Table 6 Estimated peak flow calculations for each of the reach outlets

Reach outlet	Area km^2	Q2	Q5	Q10	Q20	Q25	Q50	Q100
E1	15	32	46	56	64	67	76	85
E2	37	60	83	99	114	118	132	147
E3	79	102	124	139	153	157	170	185
L1	20	39	56	67	77	80	90	101
L2	70	93	116	132	147	151	165	180
L3	174	176	215	240	265	272	295	319
L4	190	183	243	283	321	333	368	406
L5	223	205	266	306	344	355	391	430
L6	251	223	286	328	368	380	417	457

4 Findings

4.1 Hillslope erosion

RUSLE assessment
The RUSLE assessment provides an estimation of the hillslope erosion rates for the Laloki River catchment which are illustrated in Figure 22 and Figure 23 summarised in Table 7. The results indicate that 408,200 tonnes of sediment is mobilised due to hillslope erosion per year. Of this amount, approximately 60,000 tonnes per year is estimated to make its way into to the stream network. These results do not consider additional sediment derived from gully and stream bank erosion processes.

Table 7 Summary of RUSLE derived sediment yield for each of the Laloki River and Eilogo Creek sub catchments

Sub catchment	Area (Ha)	% catchment area	Mean sediment generation t/ha/yr	Mean sediment delivery (t/ha/yr)	Catchment yield (t/yr)	Delivered to waterway (t/yr)	Proportion of Laloki delivered
Upper Laloki	6996	17%	10.9	1.5	75,900	10,700	18%
Lower Laloki	10224	25%	13.9	2.4	141,900	24,200	40%
Eilogo Creek	7931	20%	12.0	1.7	95,200	13,400	22%
Sirinumu	15516	38%	6.1	0.8	95,200	11,700	20%
Total	**40,667**	**100%**			**408,200**	**60,000**	

The results suggest that each of the sub catchments within the plateau deliver a similar proportion of sediment generated by hillslope erosion of approximately 10,000 to 13,000 tonnes/year. Contrastingly, the Lower Laloki sub catchment is estimated to deliver almost double of what the Eilogo Creek or the upper Laloki sub catchments provide. This difference between the plateau sub catchments and the lower Laloki sub catchment is likely due the combination of steep escarpments which border the lower valley, the reduced vegetation cover and increased concentration of intensified land use across the floodplain.

Most of the high hillslope erosion zones in the lower Laloki sub catchment are situated along the upper escarpment adjacent to the Rouna hydroelectric plants. These streams however are downstream of the uptake and therefore do not pose a sedimentation risk to the retention basins. They may however indicate a greater likelihood of rock-fall or land slip, which may pose a risk to adjacent infrastructure, including the pipeline (Figure 24). They will also impact water quality at the Bomana Pump Station. High erosion rates are also predicted within steep stream channels near Rouna Falls within the lower area of the upper Laloki sub catchment. The proximity of these streams to the Rouna 1 and 3 uptake highlights them as potential contributor of sediment.

The results also illustrate the effects of broadscale clearance of vegetation. This is seen particularly well in the Eilogo Creek sub catchment, where within the perimeter of the grazing paddocks, relatively higher hillslope erosion values are found when contrasted against the forested areas further upstream. In addition, high hillslope values along the upper escarpment indicate that if clearance of the upper catchment should occur, just as has been done in the mid to lower catchment, that broader scale erosion is likely to follow (Figure 25).

Furthermore, as outlined in Section 3.1; the RUSLE factor which corresponds with the land use data for the catchment was modified to reflect potential future broad scale changes in land use within the next 25 to 50 years. The results of this analysis are presented discussed in Section 5.

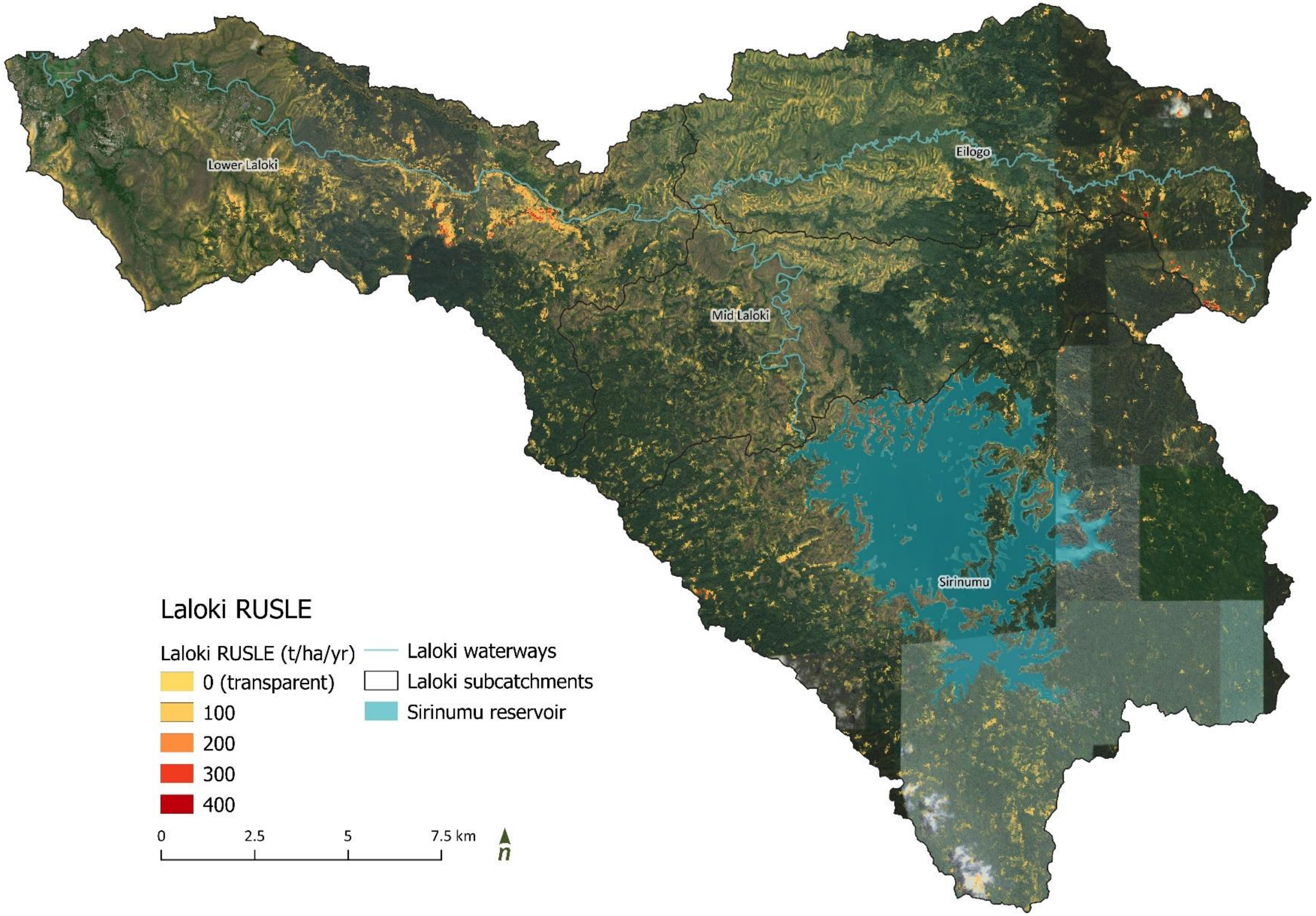

Figure 22 *RUSLE hillslope erosion analysis for the Laloki River catchment*

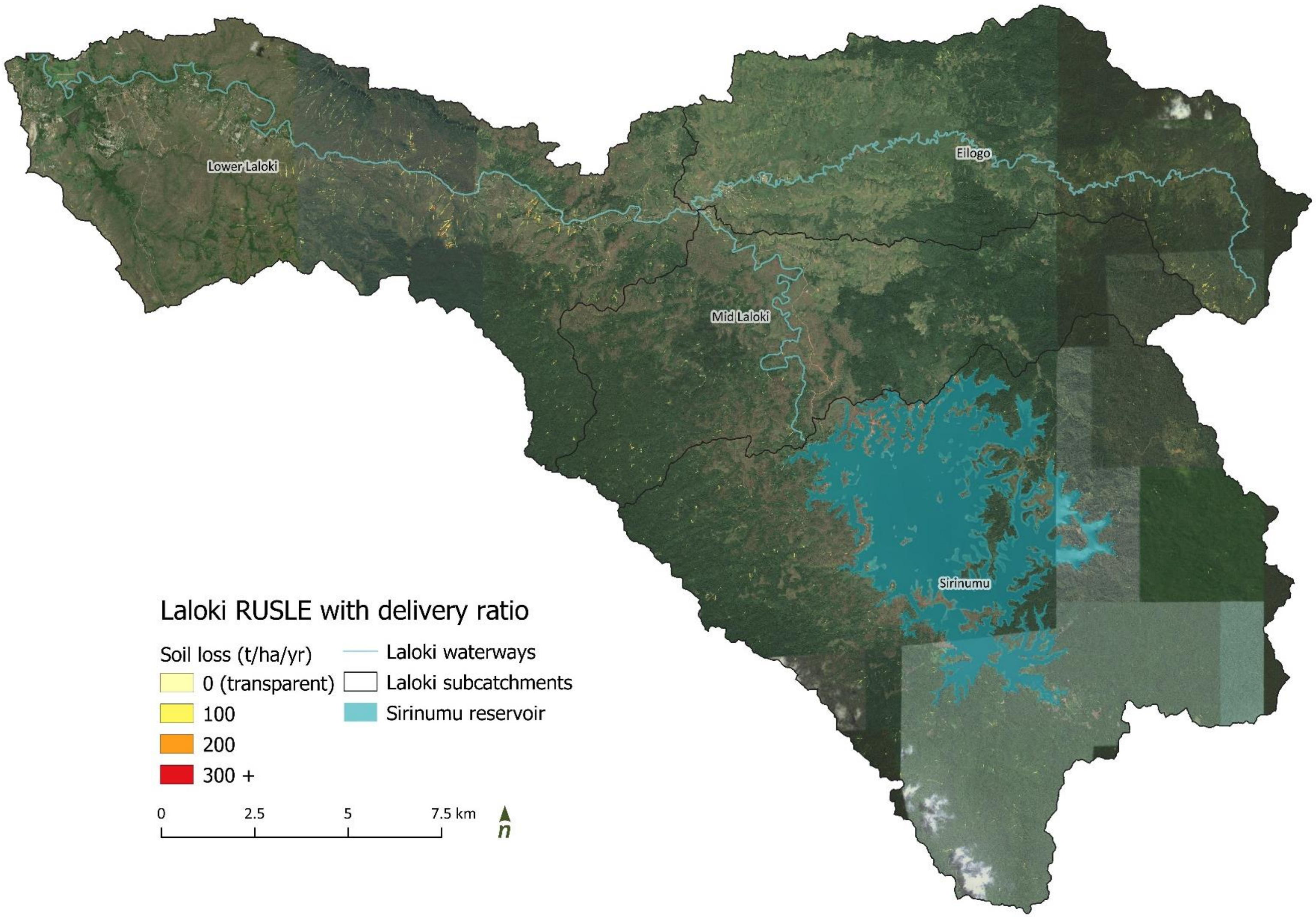

Figure 23 *RUSLE hillslope erosion analysis for the Laloki River catchment with delivery ratio applied*

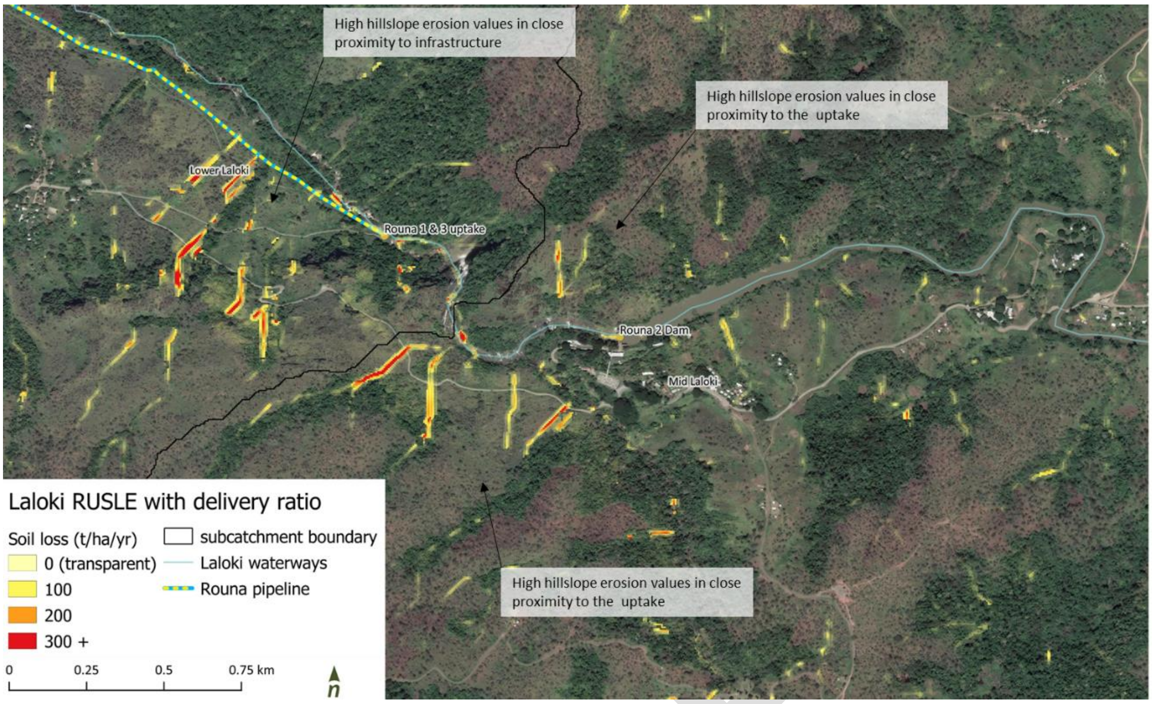

Figure 24 Areas highlighted by the RUSLE analysis which are likely to deliver hillslope derived sediment into the Laloki River

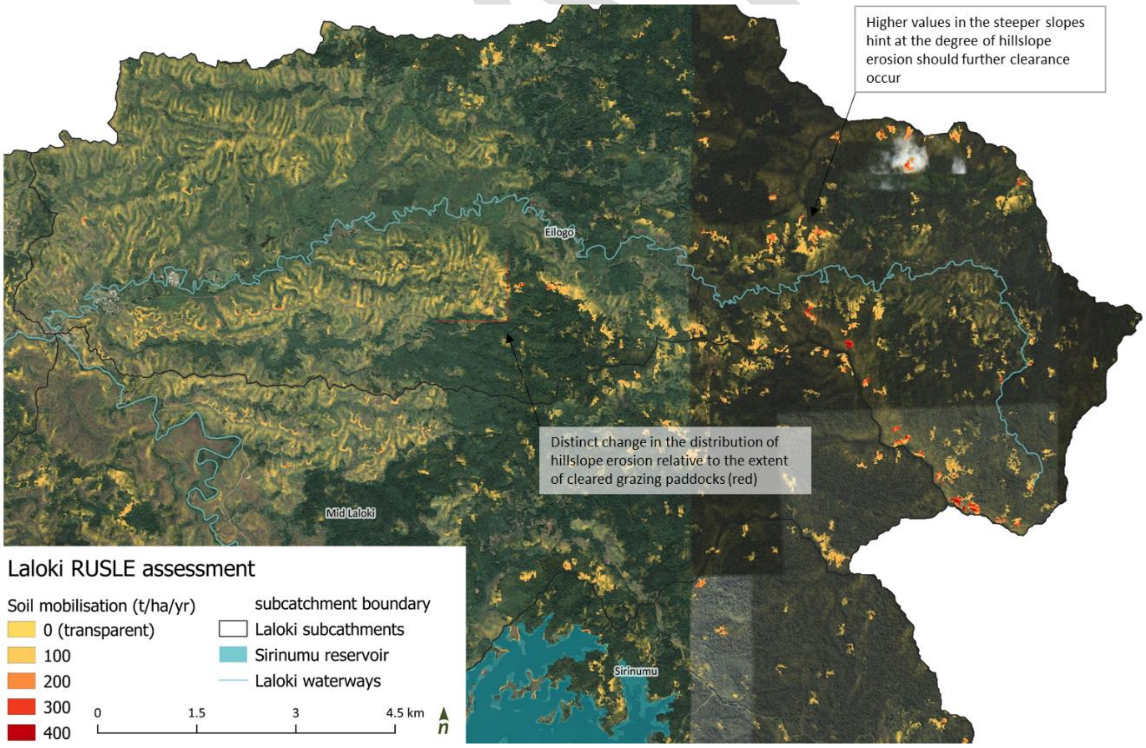

Figure 25 *The cleared lower half of the Eilogo Creek sub catchment exhibits broader scale hillslope erosion due to reduced cover.*

Field observations

Eilogo Creek catchment

The upper section of the Eilogo Creek catchment features small creek-side villages which have developed after logging made way for the establishment of rubber plantations and cattle stations. In this upper section, the creek is bordered by dense riparian zones which give way to rainforest upon cohesive volcanic clays (Figure 26). Small (~1Ha) portions of steeply sloping land are burnt/cleared for intensive horticulture; primarily peanuts, beans and sweet potato (Figure 27). This highland farming style can lead to large losses of the A-ce of up to 70 cm in two years. Similar sized portions of land within flat floodplain margin swamps have also been cleared for intensive horticulture, which in times of flood are likely to lead to further sediment losses. These swampy areas of the valley floor are a major sediment/nutrient sink, which lend to intensive agriculture (Figure 27).

Figure 26 *Multiple road cuttings along the Eilogo Creek catchment expose cohesive volcanic clays, leading to sediment slumping and transport along the road during runoff events*

Figure 27 *The main access road cuts across multiple floodplain margin swamps which remain sodden even during the dry season. Note the cleared upper slopes in the background, which are burnt to make way for vegetable gardens*

Figure 28 *Intensive horticulture on the floodplain*

An inactive cattle station upstream of Sogeri comprises the majority of the mid Eilogo Creek catchment and is largely cleared of native vegetation on its floodplains and lower hills. Thin sections of riparian rainforest line the creek as it meanders across the floodplain and adjacent swamps. On the rises, stands of eucalypt woodland regrowth and the odd rainforest tree standout amidst grass regrowth which is periodically burnt. These sections feature areas of exposed bare earth including gullies and treefall scars (Figure 29). While some have revegetated, temporal Google Earth imagery analysis indicates that many have remained exposed for years. This is likely a result of a combination of factors, including prolonged cattle activity, tree fall, burning prior to high rainfall intensities and unfavourable soil structure and chemistry.

Figure 29 *Exposed gullies on low hills are prevalent within the perimeter of the cattle station particularly where vehicle or animal traffic has concentrated overland flow in steeper sections (March 2019)*

A major tributary of Eilogo Creek drains a significant portion of the northern escarpment which includes the cattle station, gardens and burnt areas exposed to hillslope erosion (Figure 30 and Figure 33). Proposals for upgrading the beginnings of the Kokoda trail (which is accessed via Sogeri) and the renewal of the vacant cattle station into a world class agricultural food park are likely to lead to further disturbance of the Eilogo Creek catchment, particularly the unsealed access roads, which cut across the floodplain swamps (Figure 32).

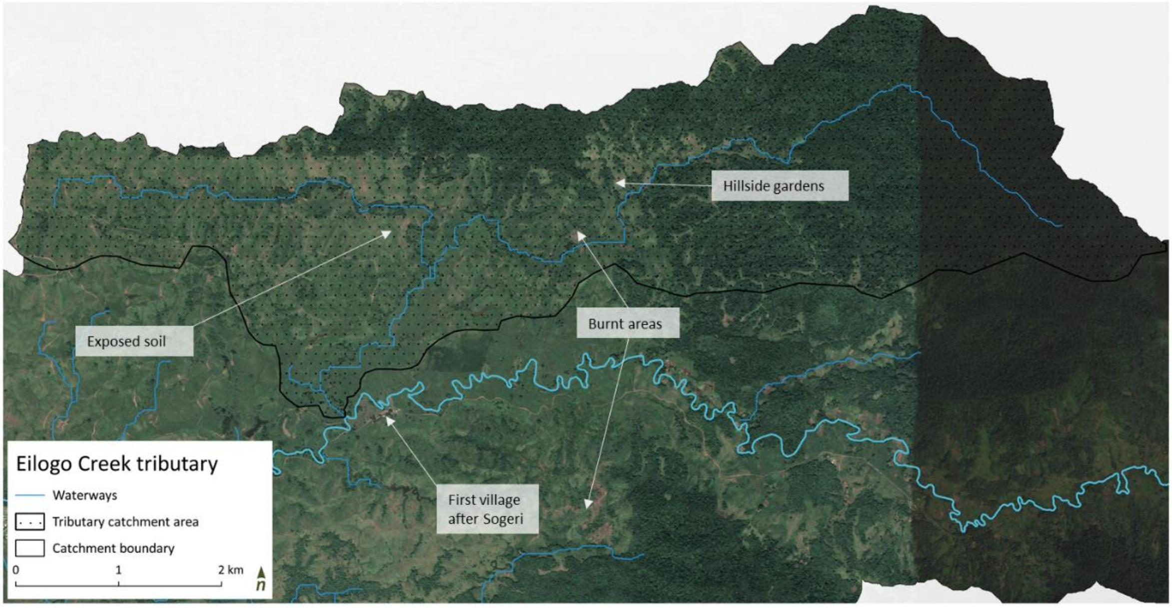

Figure 30 *The catchment boundary of the tributary which drains a significant portion of the Eilogo Creek sub catchment*

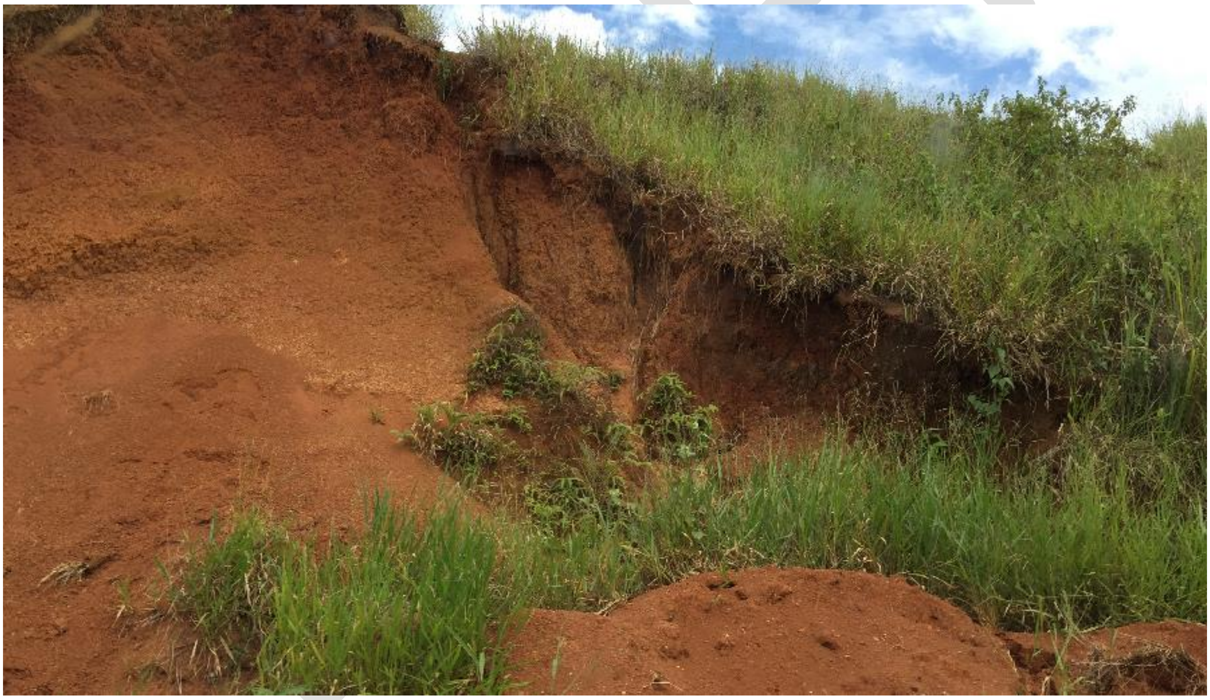

Figure 31 *While relatively cohesive, the exposed laterite clay soils are susceptible to mass failure when saturated (March 2019)*

Figure 32 *Eilogo Creek road crosses multiple floodplain swamps which are often impassable during the wet season, note the exposed hillslope scalds highlighted in the red box (March 2019)*

Figure 33 *Hillslope burning in the dry season further exposes scalds to rain splash during the wet season, delivering fine sediment into floodplain swamps (Dec 2018)*

The introduced giant African snail is a major pest in parts of the Central Region in PNG. While the snail was not observed during the field assessment, it is possible that the widespread burning of the catchment is a measure for its control (Sowi & Allen 2003).

Sirinumu Dam
Comprising the upper extent of the Laloki River, the dam catchment is of strategic interest as the primary source of water and hydroelectric power for Port Moresby. Field visits to the catchment did not extend across its forested perimeter but were mainly restricted to vessel-based assessments from within the dam and along the dam wall (Figure 34). The risk of sedimentation within the dam was assessed in 2007 and more recently confirmed to be low (Smith 2007, Alluvium 2018). Sediment sources are likely to derive from lake side cultivation and deforestation from within the catchment in proximity to lakeside settlements (Figure 35).

Sedimentation within the dam may increase in the future if extensive land clearing continues. Evidence of wind-driven, wave derived erosion along the dam shoreline does not have an impact on the overall capacity as it is only a redistribution of sediment within the dam itself (Figure 36). It was also observed that the saddle dams to the north of the main wall leak into tributaries of the Laloki River below.

Figure 34 *Sirinumu Dam on the 21/3/2019, exhibiting good water clarity during the wet season*

Figure 35 *Lake-side cultivation involves the clearing burning of adjacent land*

Figure 36 *Evidence of active erosion within the dam most likely due to wind driven wave action*

Upper Laloki

The upper Laloki River catchment (below the Sirinumu Dam wall) generally features cohesive volcanic clays which consist of more colluvium when compared to the Eilogo Creek catchment. The river is predominantly basally controlled by bedrock, which restricts the opportunity for floodplain development and erosion (Figure 37).

Figure 37 *Multiple bedrock exposures along the Laloki River restrict the opportunity for the erosion of floodplain pockets*

Much of the low-lying areas have been cleared, and regrowth is burnt periodically. Regrowth consists of open eucalypt woodland regrowth which gives way to dense rainforest on the upper slopes. The proportion of pineapple farming has significantly increased along the slopes of the sub catchment since April 2018, with large swathes of land being burnt prior to the onset of the wet season, exposing more soil to hillslope erosion (Figure 38). Ongoing construction of the Sirinumu Dam access road from Sogeri is a likely sediment source and conduit for its delivery into the Laloki River.

Figure 38 *Steep grassy slopes are periodically burnt late in the dry season, exposing soil to wet season rainfall.*

At the lower end of the plateau, the final weir before Rouna Falls collects a large proportion of the fine sediment which is periodically released. The timing and degree of release may influence deposition in the Rouna holding ponds downstream.

Lower Laloki

This section of the catchment begins at Sogeri, at the confluence of the Laloki River and Eilogo Creek. Between Sogeri and Rouna Falls lies Rouna 2 Dam, the first hydroelectric impoundment, which is periodically flushed to release accreted bedload. Below lies Rouna Falls, over which the Laloki River flows into Rouna Gorge (Figure 39), from which an intake delivers river water to the holding ponds of the Rouna hydroelectric system (Figure 40). The deposits which accumulate within these holding ponds are not dispersive, which is to be expected given the young volcanic soils from which they derive.

Figure 39 *The confined valley setting of Rouna Gorge lends itself to high sediment transport potential with little to no opportunity for deposition within the valley*

Figure 40 *Removal of sediment from the first of two holding ponds along Rouna Gorge (Dec 2018).*

The upper streams running off Varirata National Park into the lower Laloki are relatively undisturbed, confined and contain minimal alluvial deposits. Below Rouna Gorge, sandier alluvial soils predominate in conjunction with larger stores of sands across the floodplain. Untreated effluent from a commercial piggery flows directly into the lower Laloki River 4.7km upstream of the Bomana pump station (Figure 41). A dairy farm with extensive areas of exposed soil, is situated directly opposite the station along the northern bank of the river.

Figure 41 *The back fence of the piggery in the background, from where the effluent in the drain pictured, flows into the Laloki River*

Evidence of bank erosion at the pump station weir was observed during the field investigation with the bank being vertical with exposed clays (Figure 44). Imagery from all three field visits indicates that there wasn't a large degree of change in streambank condition during this period, despite significant floodwaters which swept through the catchment during the December to March wet season in mid-February.

Figure 42. *Three consecutive visits over 12 months illustrate the cohesive nature of the stream bank at Bomana pump station, where the circled tree remains insitu despite an extensive flood event in mid-February 2019.*

Summary
The surficial geology of the region, which comprises largely of the volcaniclastic basalt and tuff deposits, have laterised to form deep, iron oxide dominated clayey soils, otherwise known as ferrosols (see Figure 4 and Figure 31). Being relatively young in age, these clays are cohesive (resistant to mobilisation) and when undisturbed, provide for the dense vegetation growth, such as that seen in the upper bounds of the Sirinumu Dam catchment.

Once disturbed vegetation does not readily re-establish, as shown by the exposed gullies, tree fall scars and land slumps across low lying/cleared areas. Interannual aerial imagery analysis confirms that many of these exposed features (in the Eilogo Creek sub catchment particularly) have not revegetated over a five to ten-year period. A reason for this is likely to be metal toxicity (namely aluminium and manganese) associated with the known low pH of these lateritic soils (Doyle et al., 2015).

Land use across the catchment is a mix between forested area and areas cleared for agriculture (i.e. grazing, vegetables, fruits etc.) and minor urban/village settlement. Cleared areas are often quite small (i.e. less than 1 hectare) but also consist of large areas which are periodically burnt. Burnt areas are often situated on steep slopes, which often corresponded with slumped and exposed subsoil (Figure 33 and Figure 38).

The RUSLE analysis generally correlates with these field-based observations yet is limited in its ability to reflect finer scale erosional features due to the accuracy and resolution of the datasets involved. For example, the RULSE analysis does well to reflect how the Eilogo and upper Laloki catchments host significantly more hillslope erosion when compared with the relatively forested Sirinumu catchment (Table 7), yet it does not capture the localised sediment mobilisation that has been observed to occur in hillslope gardens, gullies and some burnt areas. Furthermore, the RUSLE analysis does not capture the impact of roads, which are a significant conduit for sediment, particularly in the Eilogo Creek catchment.

While not directly related to erosional issues, the field assessment also identified effluent draining into the lower Laloki River from a river-side piggery (Figure 41). Such practices directly upstream of the Bomana Pump Station present a risk to water quality.

Combined, the field and RUSLE assessments provide a strong understanding the landform and its erosional processes; which will be used to support the overall assessment of the catchment and the consequent recommendations in Section 5.

4.2 Waterways

Geomorphic assessment
The River Style® assessment for the Laloki River catchment is illustrated by Figure 43, which provides a breakdown of style categories that characterise reaches of the Laloki River and Eilogo Creek. The assessment

identifies key geomorphological features relevant to understanding the nature of waterway sedimentation and erosion.

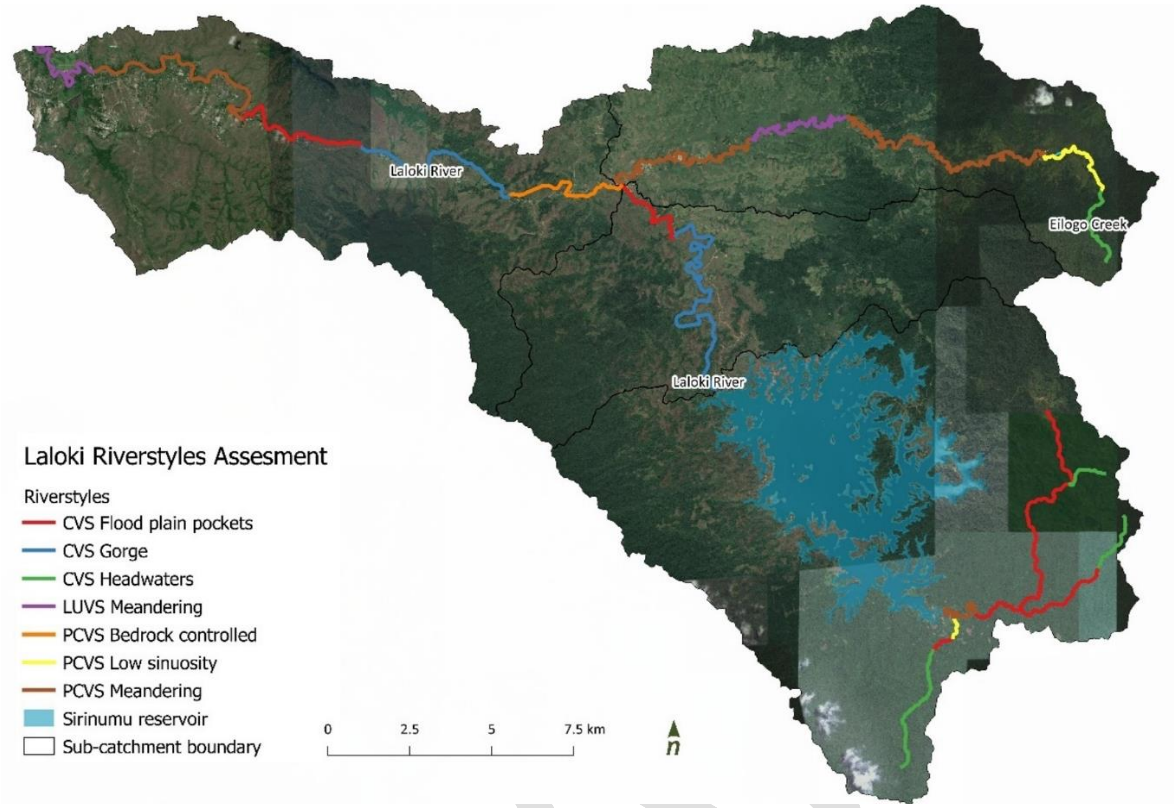

Figure 43 *Riverstyles assessment for all major streams within the Laloki River catchment*

Sirinumu

Upstream of Sirinumu Dam exists three main converging streams which drain the largest of all the catchments flowing into the dam (Figure 44). A significant proportion of these streams are confined with numerous floodplain pockets before becoming less confined in proximity to the dam shore. The floodplain pockets are largely forested; however, some clearance has occurred near proximal settlements. Should clearance continue, increased runoff and loss of floodplain resistance may expose floodplain pockets to increased erosion risk and downstream sediment delivery.

Stream clarity and a visible cobbles/boulders bed suggest that the present rates of sedimentation are not excessive (Figure 50 and Figure 52). There was good water clarity, no observed deltas or sediment deposits at inflow points and limited fine sediment attached to submerged vegetation or instream timber/trees which is often observed in water bodies with high suspended sediment loads.

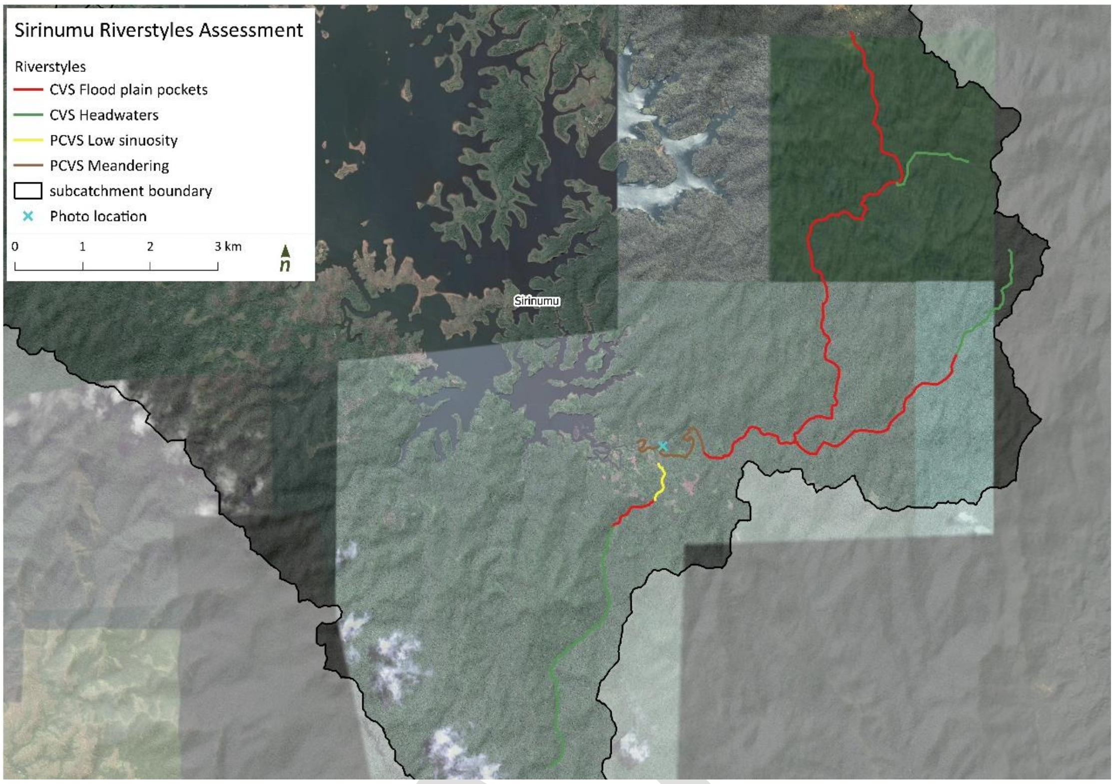

Figure 44 *The Riverstyle classification for the main tributaries of the Laloki River flowing into Sirinumu Dam. Blue cross marks the location of Figure 50 below*

Figure 45. *Upstream of Sirinumu Dam (April 2018)*

Figure 46. *Cobbles and boulders in the bedload and the clarity of the water are shown in the upper most reaches of the dam inlet (April 2018)*

Wind generated wave erosion occurs in locations within the dam where there is a large fetch or on islands subject to variable inundation depths without vegetation cover. However, the impact of this sediment mobilisation on overall storage capacity is likely to be negligible as it is only re-distributing sediment within the dam. It was also observed that regulated releases from the dam wall late in the dry season exhibited low turbidity but a strong sulphurous odour, indicative of anoxic conditions when dam levels are low.

Eilogo Creek

The upper reaches of the Eilogo Creek consist of confined to partly confined gravel to cobble bed streams with a diversity of riffles and runs with well vegetated riparian zones. These upper reaches have the capacity to transport sediment derived from rill and hillslope erosion along adjacent hillslope gardens.

Figure 47. *At the confluence of a minor tributary and upper Eilogo Creek, with a bedload comprised of primarily cobbles and gravels and some boulders amidst a sandy to fine matrix. Photo located by the blue cross in Figure 52*

Streambank scouring and mass failure is occurring along the mid to upper sections of Eilogo Creek (Figure 53). While the clay banks are relatively cohesive, the increased stream power due to further land clearance upstream may exacerbate these processes. The processes were observed particularly in areas devoid of perennial riparian vegetation.

Figure 48. *An example mass failure at an outer bend of Eilogo Creek, contributing to the meander development*

Further downstream Eilogo Creek is predominantly partly confined, where meander development and migration of the main channel across the floodplain is likely to generate and mobilise sediment downstream (Figure 49). Approximately mid-way along the catchment, the creek is unconfined where broader sections of floodplain margin swamp line tributaries which run off the bordering escarpment. Evidence of pig disturbance was noted within this section, left unchecked, such activity can lead to increased erosion and altered hydrology (Strauch et al., 2016).

Figure 49 *A view from the road looking across the floodplain and margin swamp land, through which the Eilogo Creek meanders. Photo located by the green cross in Figure 48*

Eilogo Creek experiences increasing bedrock controls as it makes it way to Sogeri before its confluence with the Laloki River, with a bedload comprising of fines, gravels and sands with rockier sections where bedrock becomes exposed at hillslope abutments (Figure 50). At Sogeri, local landholders practice erosion control measures through the staking of susceptible banks with live branches to establish riparian vegetation (Figure 51).

Figure 50. *The hillslope rises in the background are expressions of the bedrock controls which guide lower Eilogo Creek toward its confluence with the Laloki River at Sogeri. Photo located by the yellow cross in Figure 48.*

Figure 51. *Staking of an eroding bank with live branches as an erosion control measure by local landholders in Sogeri.*

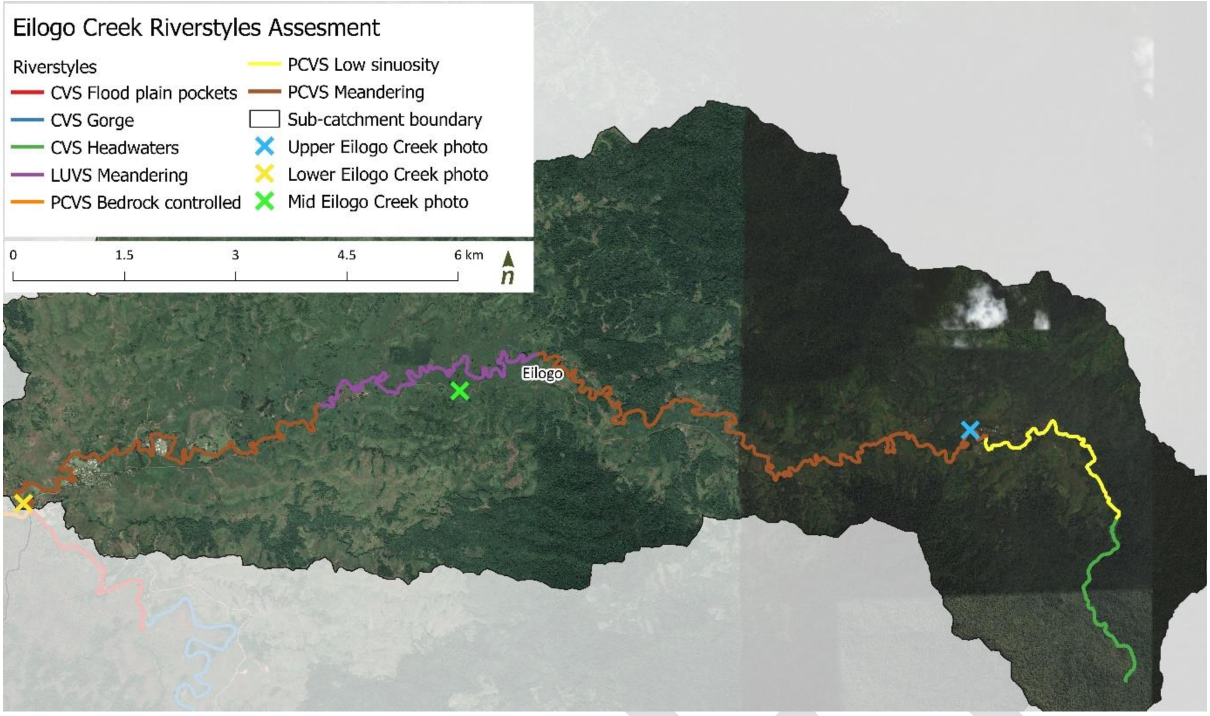

Figure 52 *An overview of the Riverstyles classification for the Eilogo Creek catchment with figure locations marked.*

Upper Laloki

Flowing from the Sirinumu Dam wall to Sogeri, the Upper Laloki River comprises of two reaches. For the most part, it is confined in a gorge, which widens near Crystal Rapids before its confluence with Eilogo Creek at Sogeri (Figure 54). The predominance of bedrock controls through the upper and mid sections of the catchment provide relatively fewer sediment stores when compared to Eilogo Creek or the Laloki River further downstream near Sogeri (Figure 53). Towards the confluence, the bedload consists of cobbles gravels and sands with floodplain pockets comprised of fine sands and clays.

Figure 53 *As shown above, the Laloki River downstream of Sirinumu Dam features prominent bedrock controls. Riparian vegetation has been cleared in sections to support river-side settlement.*

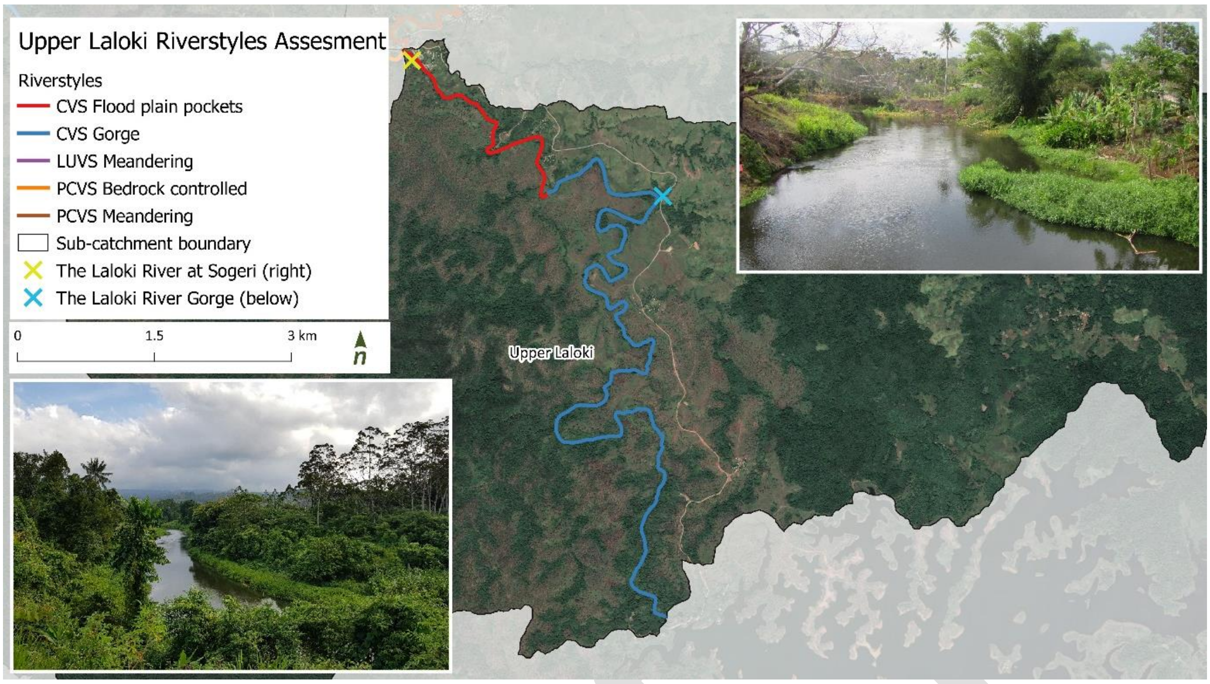

Figure 54 *An overview of the Riverstyles for the upper Laloki River catchment, with inset images of the gorge (bottom left) and the banks at Sogeri (top right).*

Lower Laloki

The lower Laloki River flows through a range of valley settings as shown in Figure 62. At its confluence with Eilogo Creek, there was a distinct difference in the colour of the water between both streams during the wet season (March 2019), suggesting a relatively higher contribution of suspended sediment by Eilogo Creek during this time (Figure 55). From this initial confluence, the Laloki River bears isolated zones of discontinuous floodplain deposits where sediments are stored (and eroded). Confining exposures of Astrolabe Agglomerate (Figure 56) increase in frequency as the river reaches Rouna Dam, near Rouna Falls.

Figure 55 *A distinct difference in the stream colour in March 2019 post rainfall, with Eilogo Creek brown in the background and the Laloki River in the foreground with a clearer green.*

Figure 56 *The partly confined Laloki downstream of Sogeri.*

Below Rouna Dam, the river bed is scoured, leaving only minor deposits of sand amdist bedrock and boulders (Figure 57). Below the falls, the confined and steep gorge conditions provide for high sediment transport capacity, as indicated by the lack of sand, gravel and cobble deposits (Figure 58).

Figure 57 *Exposed bedrock above Rouna Falls downstream of Rouna Dam.*

Figure 58 *Large boulders within Rouna Gorge with very little opportunity for sedimentation*

Downstream of the gorge, the Laloki River becomes less confined. Floodplain pockets have formed where the valley floor widens, allowing for the deposition of sands and gravels and cobbles (Figure 59). As the valley floor continues to widen downstream, the floodplain deposits broaden and comprise of finer alluvial sands and clays (Figure 60) and eventually other, lighter coloured clays and sands along the Goldie River (Figure 61).

Figure 59 *Alluvial gravels cobbles comprise much of the bedload along the lower Laloki River downstream of Rouna Gorge*

Figure 60 *Expansive floodplain deposits of fine alluvial sands and clays flank the lower Laloki River valley at Bomana*

Figure 61. *The Goldie River a few kilometres downstream of its confluence with the Laloki River*

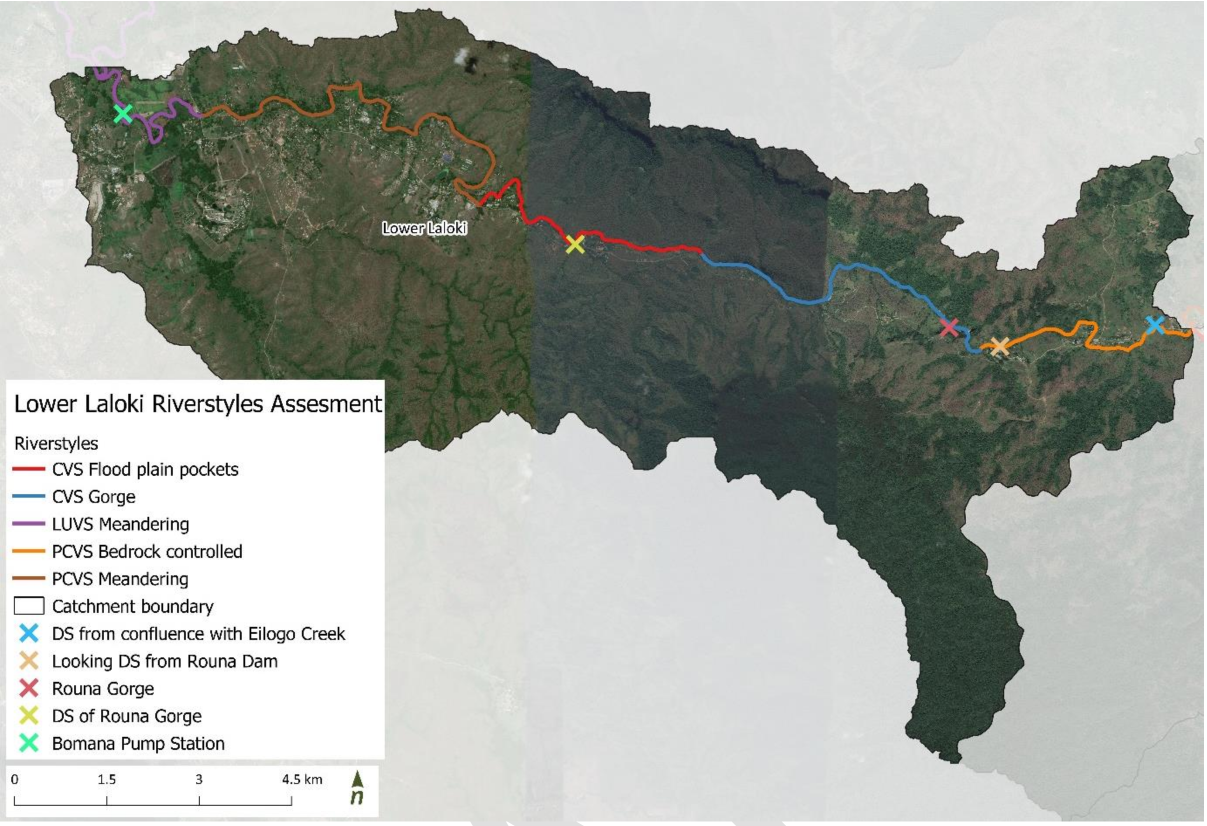

Figure 62. *An overview of the Lower Laloki Riverstyles assessment*

Summary

The waterways within the Laloki River catchment are suspended load dominated streams. The majority of the sediment is fine grained and is periodically stored in alluvial floodplain deposits. Disturbance of these areas due to removal of bank and floodplain vegetation has increase the supply of fine sediments to the waterways. Furthermore, the slope and morphology of the streams indicates there is minimal capacity to store sediments within the channel. As a result a large portion of sediments delivered to the streams will be transported to downstream receiving waters.

4.3 Sediment transport

Sediment transport modelling

As stream power is the rate of energy dissipation against the bed and banks of a channel, it can be a good indicator of the sediment transport capacity of a stream. The higher the stream power, the higher the capacity of the stream to transport sediment supplied to the channel and mobilise sediments contained within the channel. Despite the data limitations associated with the DEM resolution, the modelled stream power across the Laloki River catchment provides a good high-level indication of the sediment delivery dynamics in the system.

The two and ten year ARI stream power profiles for the Laloki River catchment (excluding the Sirinumu impoundment) are presented in Figure 63 to Figure 68. These figures present stream power in relation to the stream bed profile and river form, illustrating how stream power increases with increasing gradient. River form and sediment transport capacity are interrelated. Confined sections typically have high transport capacity, and partly confined or unconfined sections bearing a lower transport capacity. It is the lower transport capacity in these reaches which leads to floodplain development within the valley.

While these broadscale relationships are evident across all three modelled reaches within the Laloki Rover catchment, the stepwise reductions in the DEM limit finer scale interpretation of stream power within the floodplain reaches.

As discussed above the majority of sediment supplied to the streams within the Laloki River catchment is fine sediment. The stream power throughout all reaches is sufficiently high to mobilise and transport the sediment load in suspension. There is likely to be limited instream sediment storages within the modelled reaches. Some sediment is likely to be deposited and stored within floodplain deposits throughout the system while the majority is transported in suspension into the Goldie River.

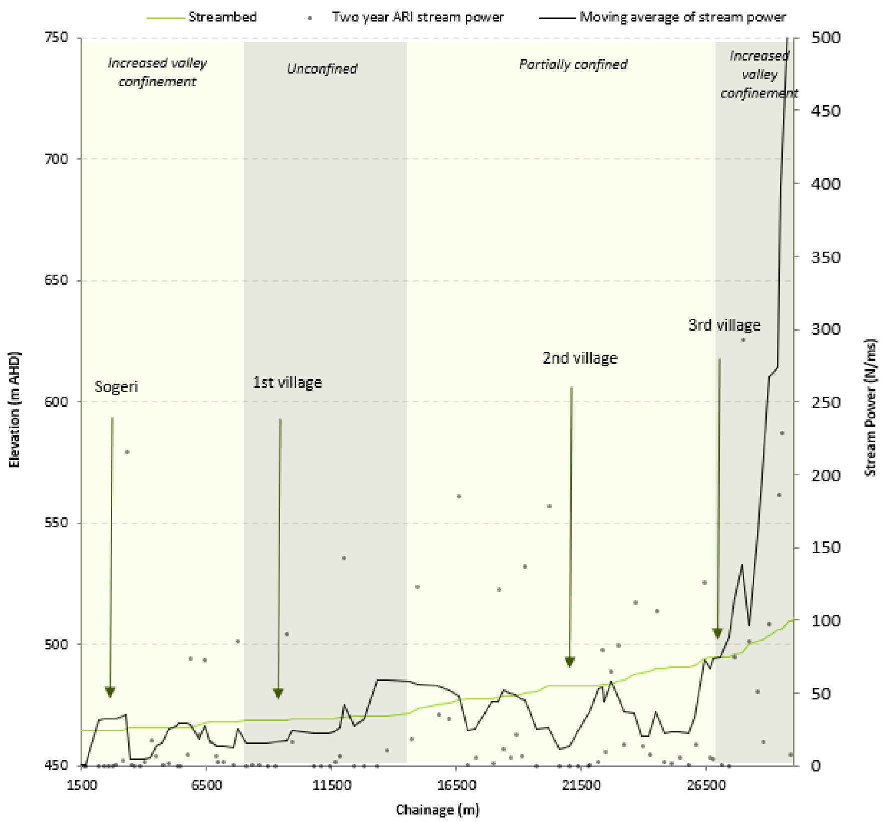

Figure 63 *Two-year ARI stream power and the moving average plotted on the right axis along Eilogo Creek. The figure also shows key locations and the streambed plotted on the left axis.*

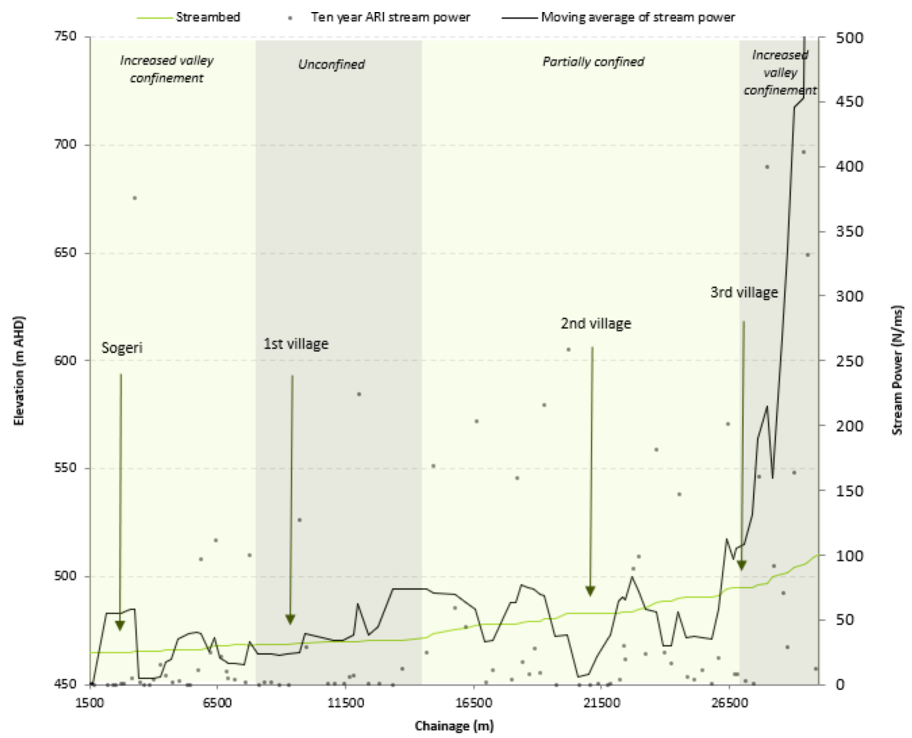

Figure 64 *Ten-year ARI stream power and the moving average plotted on the right axis along Eilogo Creek. The figure also shows key locations and the streambed plotted on the left axis.*

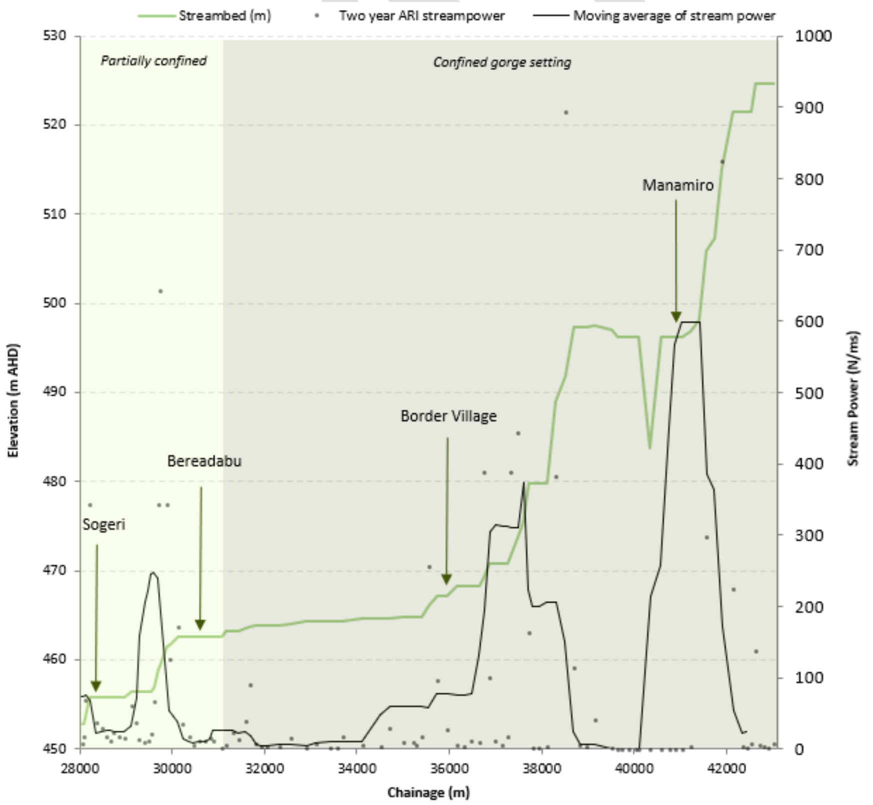

Figure 65 *Two-year ARI stream power and the moving average plotted on the right axis along the Upper Laloki River from Sirinumu Dam to Sogeri. The figure also shows key locations and the streambed plotted on the left axis.*

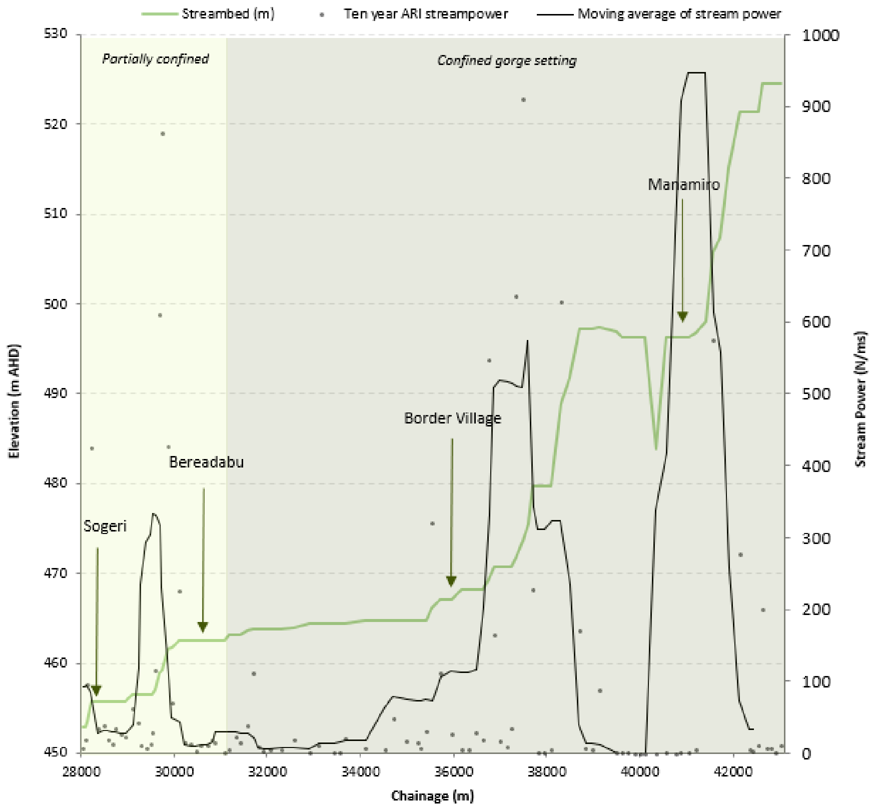

Figure 66 *Ten-year ARI stream power and the moving average plotted on the right axis along the Upper Laloki River from Sirinumu Dam to Sogeri. The figure also shows key locations and the streambed plotted on the left axis.*

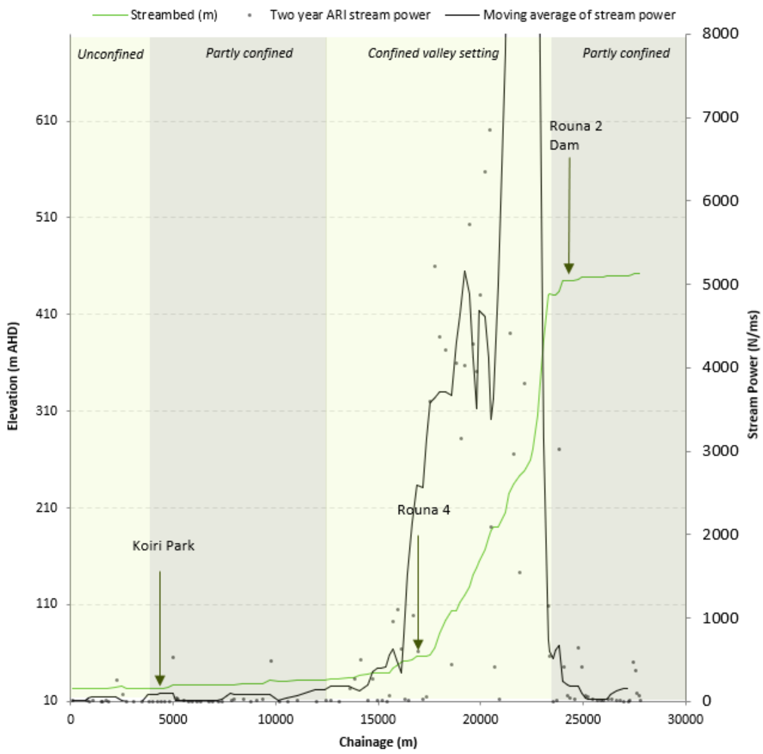

Figure 67 *Two-year ARI stream power and the moving average plotted on the right axis along the lower Laloki River. The figure also shows key locations and the streambed plotted on the left axis.*

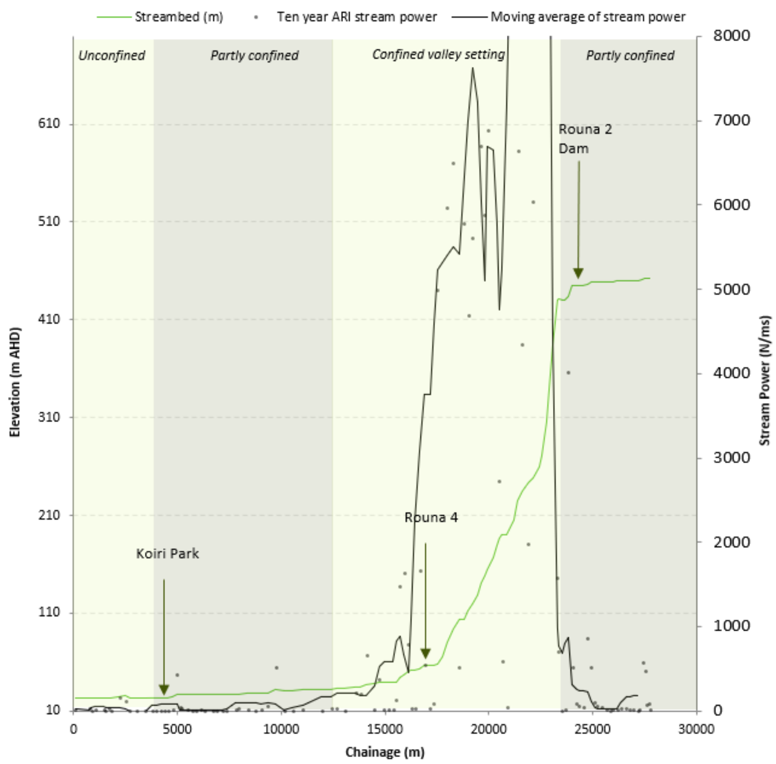

Figure 68 *Ten-year ARI stream power and the moving average plotted on the right axis along the lower Laloki. The figure also shows key locations and the streambed plotted on the left axis.*

Sediment sampling and water monitoring

Overview

Water sampling for TSS and field analysis for turbidity across the catchment for both the wet and dry seasons yielded variable results. While both sampling periods provide only a snapshot into the sediment delivery dynamics of the catchment, the results indicate the potential sources of sediment as well as sediment transport behaviour post runoff events.

Dry season

The dry season sampling yielded relatively low NTU and TSS values respectively for all sites (

Table 8). The three TSS samples which did yield values above the detection limit were sites 6, 13 and 42. The higher values at these three sites are likely to relate to the intensified land use within their respective catchments:

- Site 6 is located at the beginnings of development within the lower Laloki sub catchment, where a major tributary which runs off the slopes below Varirata National Park joins the Laloki River. This area is subject to hillslope gardening and the location itself which is also a popular swimming location.
- Site 13 is located within the Sogeri urban area prior to the confluence with the Laloki River. Development within this area extends to the creek edge, with little to no riparian zone in parts.
- Site 42 is located at a major road crossing of the Goldie River 6.5 km downstream of its confluence with the Laloki.

In most cases, the NTU values correlate with the TSS results except for site 28, where turbidity is relatively high yet the TSS sample did not exceed the <5mg/l detection limit. This site is located downstream of the confluence of the major tributary which drains much of the northern escarpment of the Eilogo Creek catchment (Figure 69), which is a likely source of sediment given the scalds visible from aerial imagery. However, the discrepancy suggests that the relatively high NTU reading is a consequence of increased coloured dissolved organic matter

(CDOM) within the main of the Laloki River (LUVS Meandering reach in Figure 69), which is unconfined, highly sinuous and dominated by floodplain swamp margins.

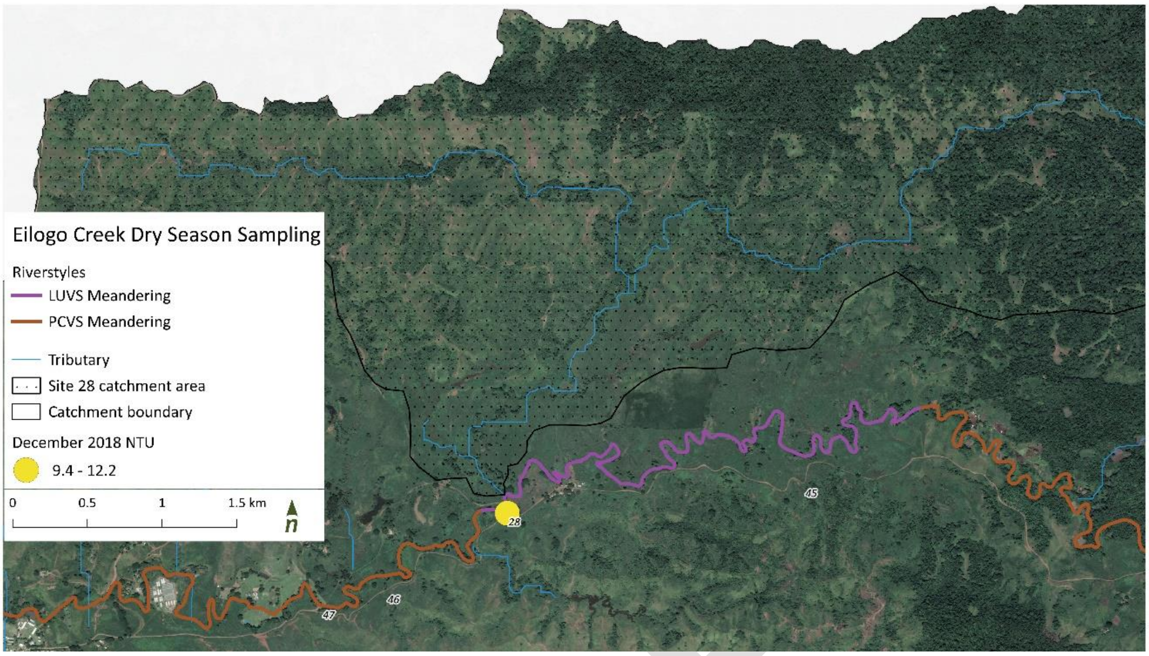

Figure 69 *The major tributary catchment area is host to large number of scalds as indicated by the brown earth exposures in the aerial image.*

Table 8 TSS and NTU values for all 17 samples collected between the 11th and 12th of December (WGS 84, UTM Z55S).

Collection date	Easting	Northing	Description	Site ID	TSS (mg/l)	NTU
11/12/2018	543278	8956907	Tributary	38	< 5	2
11/12/2018	559492	8959608	Tributary	36	< 5	5
11/12/2018	558605	8959493	Main stem	35	< 5	7
11/12/2018	556693	8959053	Main stem	33	< 5	3
11/12/2018	549995	8959799	Main stem	28	< 5	12
11/12/2018	548972	8952061	Sirinumu Dam	20	< 5	1
11/12/2018	548986	8952202	Sirinumu Dam (DS)	19	< 5	3
11/12/2018	548542	8955597	Tributary	18	< 5	6
11/12/2018	546952	8957318	Main stem	15	< 5	4
11/12/2018	546027	8958327	Main stem	14	< 5	3
11/12/2018	545933	8958444	Main stem	13	5	12
12/12/2018	544224	8958204	Main stem	11	< 5	4
12/12/2018	542043	8958434	Main stem	9	< 5	8
12/12/2018	535873	8959796	Main stem	6	6	12
12/12/2018	532494	8962097	Main stem	3	9	9
12/12/2018	528523	8961863	Main stem	1	< 5	7
12/12/2018	524767	8963164	Goldie River	42	9	15

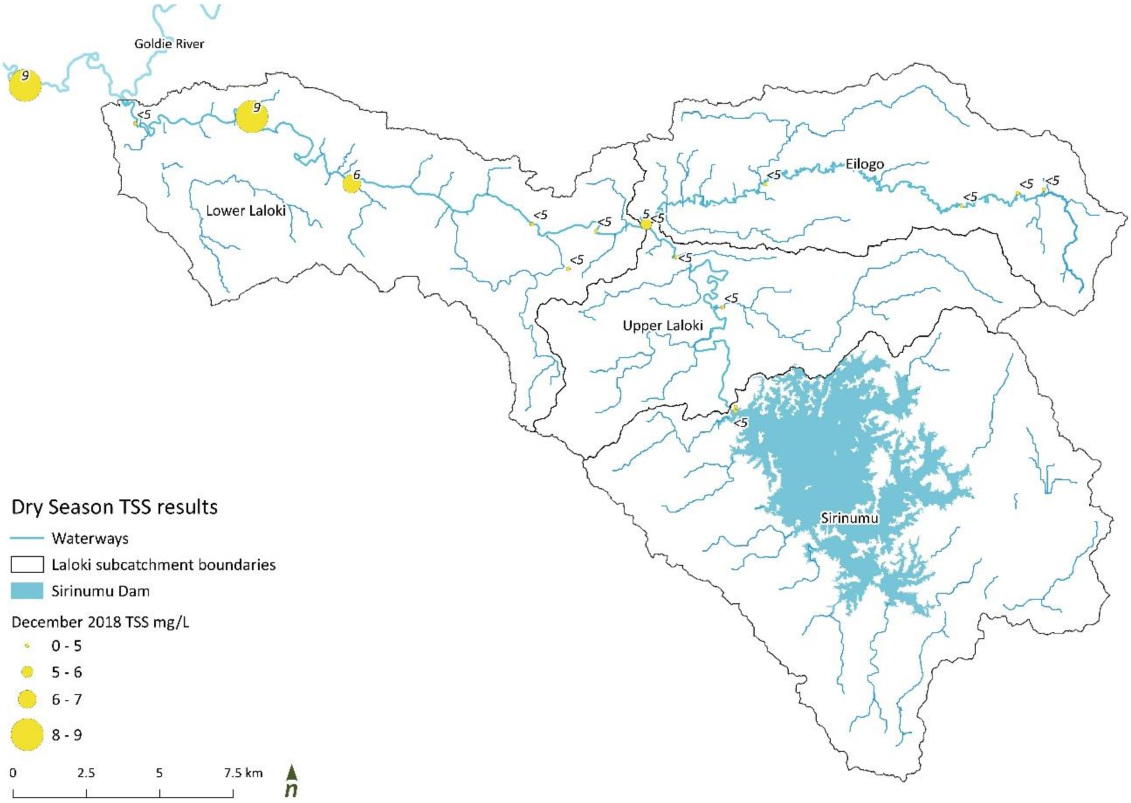

Figure 70 *Geographic distribution of TSS results from samples taken from the main stem and tributaries on the 11th to the 12th of December 2018*

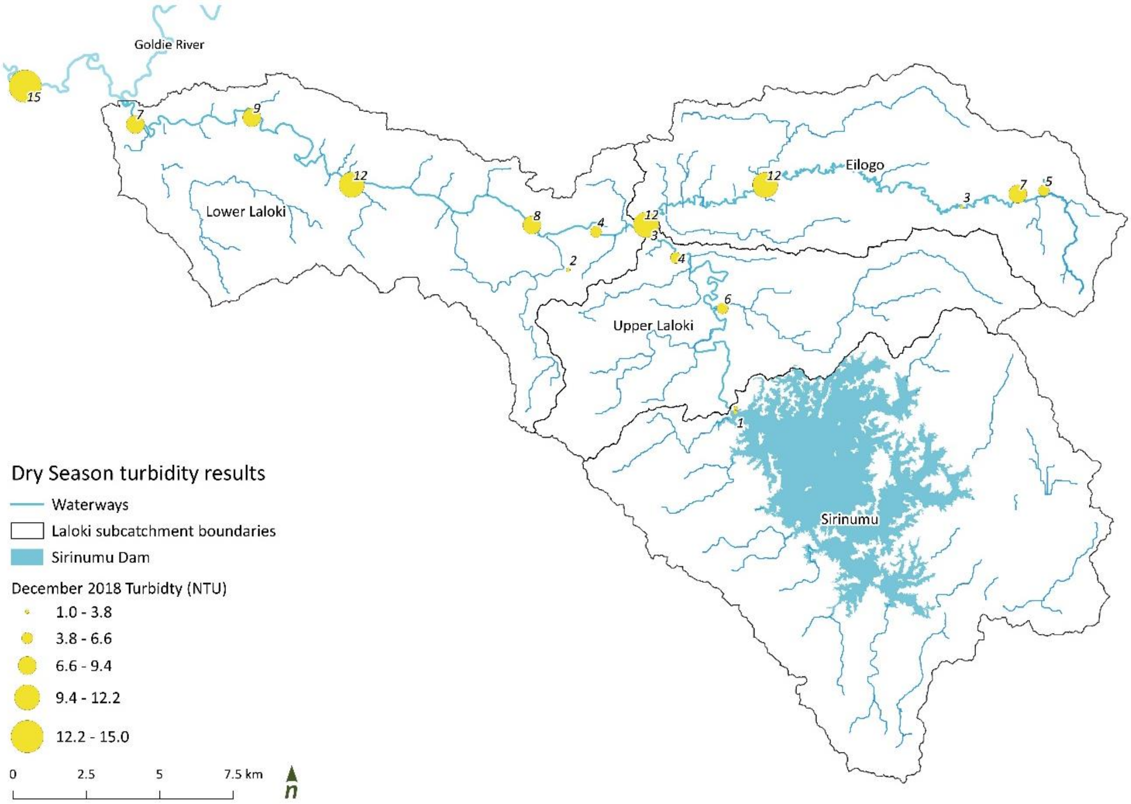

Figure 71 *Geographic distribution of turbidity readings from sites along the main stem and tributaries from the 11th to the 12th of December 2018*

Wet season
The wet season sampling period yielded higher results to those gathered during the dry season (Table 9). These higher values however are not catchment-wide but at specific areas, providing the opportunity to infer the areas which may be contributing to sediment delivery to the waterways (Figure 72 and Figure 73).

The Eilogo Creek catchment was sampled at five sites along the main trunk and at four tributaries running of the southern side of the valley. The highest four values ranged from 22 to 15mg/L and were concentrated at the lower end of the catchment whereas as the lower values were in the upper reaches. The results suggest that sediment is generated within the lower three quarters of the catchment. The highest TSS reading at the upstream end was taken at site 28 (see Figure 69 previously).

Table 9 TSS and NTU values for all 27 samples collected between the 21st and 22nd of March (WGS 84, UTM Z55S).

Collection date	Easting	Northing	Description	Site ID	TSS (mg/l)	NTU
21/03/2019	549241	8952206	Tributary	43	20	25
21/03/2019	548972	8952061	Sirinumu Dam	20	8	2
21/03/2019	548986	8952202	DS Sirinumu Dam	19	<5	10
21/03/2019	548542	8955597	Tributary	18	<5	5
21/03/2019	546952	8957318	Main stem	15	<5	5
21/03/2019	547561	8957363	Tributary	52	NS	1.8
21/03/2019	546027	8958327	Main stem	14	<5	5.3
21/03/2019	545933	8958444	Main stem	13	22	50
21/03/2019	549995	8959799	Main stem	28	15	38
21/03/2019	551986	8960006	Road	44	167000	exceedance
21/03/2019	551983	8959991	Tributary	45	<5	2.3
21/03/2019	549187	8959280	Tributary	46	<5	3.2
21/03/2019	548753	8959176	Main stem	47	23	37.5
21/03/2019	546621	8958778	Tributary	48	22	8
21/03/2019	544224	8958204	Main stem	11	6	22
21/03/2019	543278	8956907	Tributary	38	<5	5.2
21/03/2019	539823	8956993	Tributary	53	NS	10.4
21/03/2019	539787	8957162	Tributary	54	NS	24
21/03/2019	541708	8958209	Tributary	49	<5	20.1
21/03/2019	535873	8959796	Main stem	6	6	21.1
21/03/2019	535919	8959786	Tributary	55	NS	6.2
21/03/2019	532494	8962097	Main stem	3	6	15
21/03/2019	528523	8961863	Main stem	1	11	21
21/03/2019	524767	8963164	Goldie River	42	34	47
22/03/2019	556693	8959053	Main stem	33	<5	2.8
22/03/2019	558605	8959493	Main stem	35	<5	2.5
22/03/2019	558583	8959507	Tributary	50	<5	1

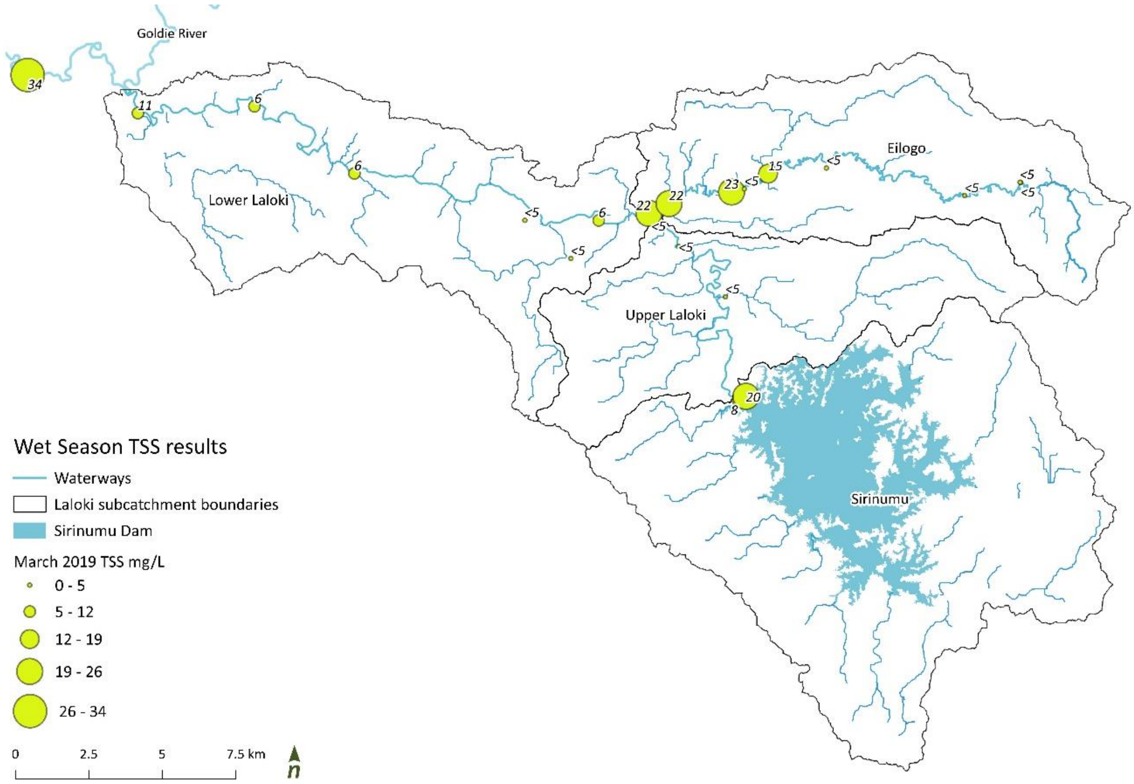

Figure 72 *Geographic distribution of TSS results from samples taken from the 21st to the 22nd of March 2019*

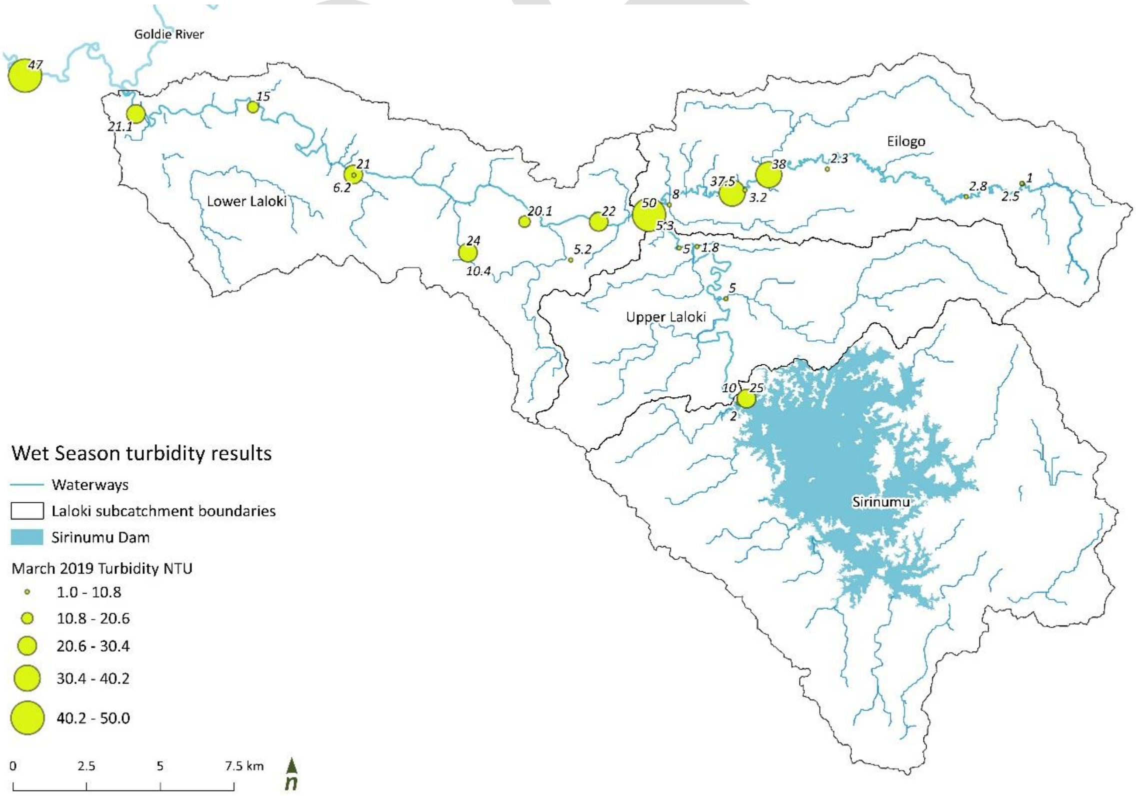

Figure 73. *Geographic distribution of Turbidity readings from sites along the main stem and tributaries from the 21st to the 22nd of March 2019*

The sampling period covered two days after a significant rainfall period (see section 3.4 Figure 16). The basic time series shown in Table 10 indicate that the Laloki River minimal variation in turbidity post rainfall in comparison to Eilogo Creek which dropped by almost 75% within 30 hours of the first reading. Downstream of the Eilogo Creek and Laloki River confluence, the turbidity dropped by 50% within 20 hours of the first reading. Another 6 hours later there was no change, suggesting turbidity had stabilised.

Table 10 Turbidity values for three sites which were visited on multiple occasions during the sampling period

Site	Location	Ist reading	2nd reading (20-30 hours later)	3rd reading (6 hours later)
14	Laloki River, 200m upstream of confluence	5.3	5.3	n/a
28	Eilogo Creek near Country Club	38	10	n/a
11	Laloki River 2km downstream of confluence at Sogeri	22	10.5	10.5

Anomalous TSS and NTU readings were observed at sites 43, 44 and 54 (Table 9). Site 43 consisted of a minor dam with a small catchment of disturbed land near the Sirinumu Dam wall. Site 44 was along the Eilogo Creek access road itself, where the road cut through floodplain margin swamp and site 54 is located within Varirata National Park, where the two lakes run into the creek near the cultural centre. The values recorded at Site 43 are of relatively minor significance as they are likely to relate to localised activity such as road runoff, washing, pig activity or the tipping of rubbish.

The anomalous values in Varirata National Park are likely to be a result of runoff from the access road which runs alongside the lake, these values are well attenuated by the park itself, as indicated by the low TSS and NTU values further downstream at site 38. Site 44 produced extremely high results as it was a highly disturbed section of the road, which was still experiencing incoming runoff from the adjacent slope at the time of sampling. This site is indicative of the degree to which sediment is mobilised in these sections of road.

Furthermore, it was observed during this sampling period that each of these swampy, floodplain margin sections which the road cut through was recently drained in order to facilitate vehicle passage (Figure 74). In many instances, these drains extended for tens of metres towards Eilogo Creek in order to ensure removal of excess water and mud. It is highly likely that these drains contribute high sediment loads to the waterway.

Figure 74 *A sample of the multiple drains dug in order to facilitate road drainage*

Close inspection of the roadside drains indicates that the fine clays are not dispersive and drop out relatively quickly. This observation is supported by the monitoring results which highlighted the rapid attenuation of turbidity post rainfall (Table 10).

Regression analysis
A regression analysis of the TSS and turbidity data revealed that data collected to date are insufficient to support the use of NTU readings as a proxy for TSS values (Figure 75). One issue with the analysis is that the TSS analysis detection range is limited to >5mg/l. This renders all values below 5mg/L as zero on the graph below, thus reducing number of data points available to identify if a statistically significant relationship exists. A sensitivity analysis allocating all TSS values less than 5mg/L to 0, 2.5 and 5mg/L yielded r^2 values of 0.68, 0.66 and 0.61 respectively, indicating that the modification of these values within their realistic bounds does not necessarily increase the ability to identify a strong relationship between the two datasets.

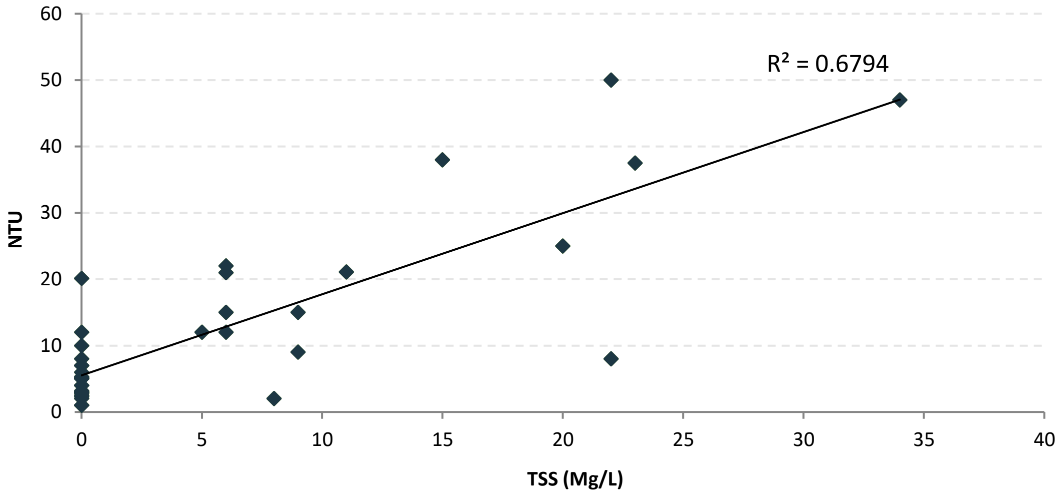

Figure 75 *All comparable TSS and NTU values collected within the Laloki River catchment are plotted with the line of best fit.*

4.4 Summary and conclusions

The assessments undertaken in this study provide for a good understanding of the sediment delivery dynamics within the catchment. Hillslope erosion is widespread across the cleared, burnt and agricultural areas, particular in the Eilogo Creek and lower Laloki sub-catchments. The fine sediments are likely to be transported in suspension to downstream receiving waters during high flow event. However, during overbank events the cohesive properties of the volcanic clays allows for a proportion of the hillslope derived sediments to drop out on the floodplain. These floodplain sediments however are susceptible to further mobilisation, through land clearing and increases in stream power generated by upstream landscape disturbance and drainage works (Figure 74).

Upstream of the confluence at Sogeri, the results indicate that the Laloki River is delivering significantly less sediment than Eilogo Creek. This can be attributed to several factors, namely that the upper Laloki River catchment bears significant bedrock controls and that the main road (Sirinumu Dam Rd) runs along the ridgeline. This is in stark contrast to the Eilogo Creek catchment, which bears less bedrock controls, steeper valley tributaries, a higher proportion of cleared area and extensive floodplain swamp which is traversed by the main (unsealed) road on multiple occasions.

The attenuation of turbidity observed across Varirata National Park provides a good example of how well protected riparian vegetation can improve water quality, namely suspended sediment loads. Protection and enhancement of riparian vegetation in critical areas is likely to yield similar effects. Vulnerable sections include the Eilogo Creek and the lower Laloki River, upstream of Bomana pump station.

5 Socio-economic impacts

5.1 Introduction

As part of this study community and stakeholder consultation has been undertaken with the Koiari people of the Sogeri Plateau and other interested parties. A detailed overview of the assessment is provided in Attachment B. A brief summary of the processes and outcomes are provided in this section.

5.2 Approach

The purpose of this consultation was to determine the socio-economic impacts of sedimentation within the Laloki River catchment. The consultation aimed to discuss the following issues on communities:

- Water quality and associated impacts on community livelihoods.
- Water and power supply issues that affect communities.
- Land use practices, both current and proposed, and
- Future opportunities for community based economic development and conservation.

The fundamental principle applied to the consultation process was for all discussions to preference local landowners, clan leaders, communities and Ward councillors. Over the term of the consultation process eight organised meetings and discussions were held with representatives of the 33 Koiari clans that occupy the area. Other interested parties (i.e. Ward councillors, members of the Sirinumu Development Company Limited etc.) were also either briefed or consulted.

5.3 Findings

Water quality

There is a general view that water quality throughout the greater catchment has significantly deteriorated since the dam was constructed but become dire over more recent years. Many people also expressed disappointment with the level of water and power supply services claiming their frustrations are further compounded knowing that Edu Ranu and PNG Power are 'resourced' from Koairi water and they receive little (if any) benefit.

Communities are reluctant to use water sourced from 'stagnant' reserves, often affected by effluent flows and containing sediments at varying levels depending on season. A routine practice across communities is to collect water 'in pots' and let it stand prior to using it for cooking and drinking.

Communities claim that water quality related health issues are common. Irresponsible domestic practices (i.e. using the creeks and rivers to dump wastes, and poor public services and facilities, lack of waste management services, non-existent or unreliable sewerage facilities) contribute heavily to poor water quality. There was a general level of acceptance that community 'behaviour' is a contributor to poor water quality and a desire to change was often advocated.

Land use

While hunting and gathering is commonly practiced subsistence farming is the main means of providing communities with food. Some suggested that community gardens are becoming less productive (even under 10 year rotations) and that it's often necessary to prepare new ground through clearing and burning the forest. Savanah grasslands are also considered poorer in nutrients than forest soils which further encourages communities to clear forest. Diminished native fish stocks and access to other aquatic resources which is affecting community nutrition security and cultural practices, is of concern.

Village economies throughout the greater catchment were once complimented through local (mainly Port Moresby) tourist activities however over recent decades this has significantly slowed and is now limited to trekking the Kokoda track (which commences at Owers corner) and some activities on Lake Sirinumu. This decline is partly due to loss of tourism related services (i.e. tour operators and facilities, poor road conditions beyond Sogeri and limited marketing and promotion capability). Lack of maintenance of the main roads (i.e. Sogeri to Sirinumu and Depo junction to Owers Corner) is also regarded as a contributor to sedimentation during heavy rain events.

Essential service
Social and cultural well-being in general terms is of key concern among all communities. A reliable supply of quality water, power to households and improved regional sanitation services were regarded as major constraints to advancing other socio-economic initiatives. It was claimed that improving these services would have an immediate effect on community health, the quality of water in rivers and creeks and consequently the natural environment. These services were also considered integral to advancing a tourism industry.

Cultural
The Koiari people remain aggrieved with the loss of access to customary lands, particularly places of traditional and historical significance, and the subsequent affect this has had on their culture. Communities struggled with differentiating between 'environment' and the physical 'cultural landscape' referring to impacts on environment as an impact on culture. This is evidenced through concerns with the loss of the traditional food sources (i.e. aquatic plant, 'tumutumu' and other native aquatic species). There is substantial interest in people reconnecting with the natural/cultural landscape to serve environmental/conservation outcomes and to reinvigorate community integrity and improve health and well-being.

Future opportunities
The Sogeri Plateau offers significant tourism potential through its unique landscape, diverse environmental setting and the cultural values of the area. A number of products are on offer however patronage is random and insufficient as a reliable income for business. A barramundi restocking program for Sirinumu Dam is considered of primary importance to compliment the range of tourism products (adventure fishing) but to also provide improved protein for communities. Proximity to PNG's capital city, an international airport and other tourism support services are also additional 'tourism' assets for the region.

Concern was expressed on the lack of environmental stewardship within communities and across all clans. The concept of a Koiari Community Ranger program as a way of improving social, cultural and environment outcomes within the greater catchment was flagged. This is of particular interest to the Sirinumu community who suggested Rangers would work closely with local tourist operators and landowners and undertake compliance monitoring and awareness once the barramundi program is introduced.

It is common knowledge and evident that there is a diverse range of produce grown and harvested within the area. While this is primarily for the local market there is a strong appetite within communities to increase yields to service an extended market.

While communities (and individuals within) were limited in capacity to change current land use practices there was considerable discussion on improving local economies through a focus on communities specialising in produce and/or certain services. It was agreed that this 'regional approach' would not only 'grow the market, consolidate and/or develop specialist skill and knowledge but would potentially draw 'buyers' to the region mitigating the logistical constraints of transporting produce. It was agreed across communities that there is potential within the area to accommodate the concept - with an appropriate level of support. This would also contribute to regional tourism.

A series of community development initiatives will make an immediate difference to livelihoods and community well-being however it is generally agreed to ensure these initiatives are sustained and to achieve an acceptable standard of living a foundation community empowerment program is required.

5.4 Summary

The socio-economic assessment outlined in Attachment B advocates for strategic implementation of the recommendations to not only improve the socio-economic status of the catchment communities but importantly build capacity within the Koiari people of the plateau through the empowerment/leadership program. If this can be achieved there is a high likelihood that social, economic, cultural and environmental values will be better observed across the greater catchment and as a consequence significant advances made toward sustainable development within the region.

6 Future trajectory and management

Impacts of future land use change

Ongoing land clearing and land use intensification is a significant threat to the social and cultural values, water quality and ecosystems. The most fertile soils within the catchment underly the forested areas. Following clearing these soils are highly erodible and the fertile topsoil is lost over time. The underlying soil tends to have poor soil chemistry which inhibits vegetation growth. This forces communities to clear more forested areas. As a result, increasing areas of the catchment become poorly covered and vulnerable to hillslope erosion processes.

The mid to upper reaches of Eilogo Creek present the highest streambank erosion risk. Within these sections the creek is actively migrating across the floodplain. Further changes to the catchment upstream, such as the clearance of forested areas, are likely to increase rates of lateral channel erosion resulting in the mobilisation of sediment downstream. Ongoing floodplain clearing also increases avulsion risks which would mobilise large volumes of sediment from the floodplain.

Gully erosion, ad hoc drainage works and poor road design and maintenance are also likely to be an ongoing sedimentation risks associated with land use intensification. The sediment generated from these processes, along with hillslope and channel erosion, will predominately be fine sediment that will result in the ongoing deterioration of the ecosystem services provided by the Laloki River and catchment to the local community and broader Port Moresby population.

Revised RUSLE

The cover crop component of the RUSLE model used to assess hillslope erosion rates has been modified to reflect potential land use intensification within the next 25 to 50 years. The results reflect these changes through widespread increases in sediment mobilisation and delivery across all sub-catchments (see Figure 76, Figure 77, Table 11 and Table 12). Sediment delivery from sub-catchments on the plateau is doubled. While land use intensification has the potential to triple sediment loads entering Sirinumu Dam.

Such vast increases in sediment delivery highlight the risk that further clearance poses to the catchment without mitigation measures. Increases in sediment delivery of the proportions estimated would impact water quality in Sirinumu Dam and Bomana Pump Station and increase sedimentation of the Rouna holding ponds. This estimate however does not take into account streambank erosion and gully erosion processes that would occur under such land use changes. Stream bank and gully erosion associated with land clearing would also result in extensive sediment loads entering the waterways.

Table 11 Summary of RUSLE derived potential sediment yields under intensified land use within the Laloki River catchment.

Sub catchment name	Area (Ha)	% area of Laloki	Potential Mean sediment generation t/ha/yr	Potential Mean sediment delivery (t/ha/yr)	Potential Catchment yield (t/yr)	Potential Delivered to waterway (t/yr)	Proportion of Laloki delivered
Upper Laloki	6996	17%	21.8	3.3	152,500	23,100	18%
Lower Laloki	10224	25%	19.9	3.6	203,500	36,800	28%
Eilogo Creek	7931	20%	23.3	3.5	184,800	27,800	21%
Sirinumu	15516	38%	17.9	2.8	277,700	43,400	33%
Total	**40667**	**100%**			**818,5000**	**131,100**	

Table 12 Summary of the difference RUSLE derived sediment yield for current (Table 7) and future scenarios (Table 11).

Sub catchment name	Sediment generation (existing) t/ha/yr	Sediment delivery (existing) t/ha/yr	Sediment generation (future) t/ha/yr	Sediment delivery (future) t/ha/yr	% Increase generation	% Increase delivery
Upper Laloki	10.9	1.5	21.8	3.3	101%	115%
Lower Laloki	13.9	2.4	19.9	3.6	43%	52%
Eilogo Creek	12.0	1.7	23.3	3.5	94%	107%
Sirinumu	6.1	0.8	17.9	2.8	192%	270%

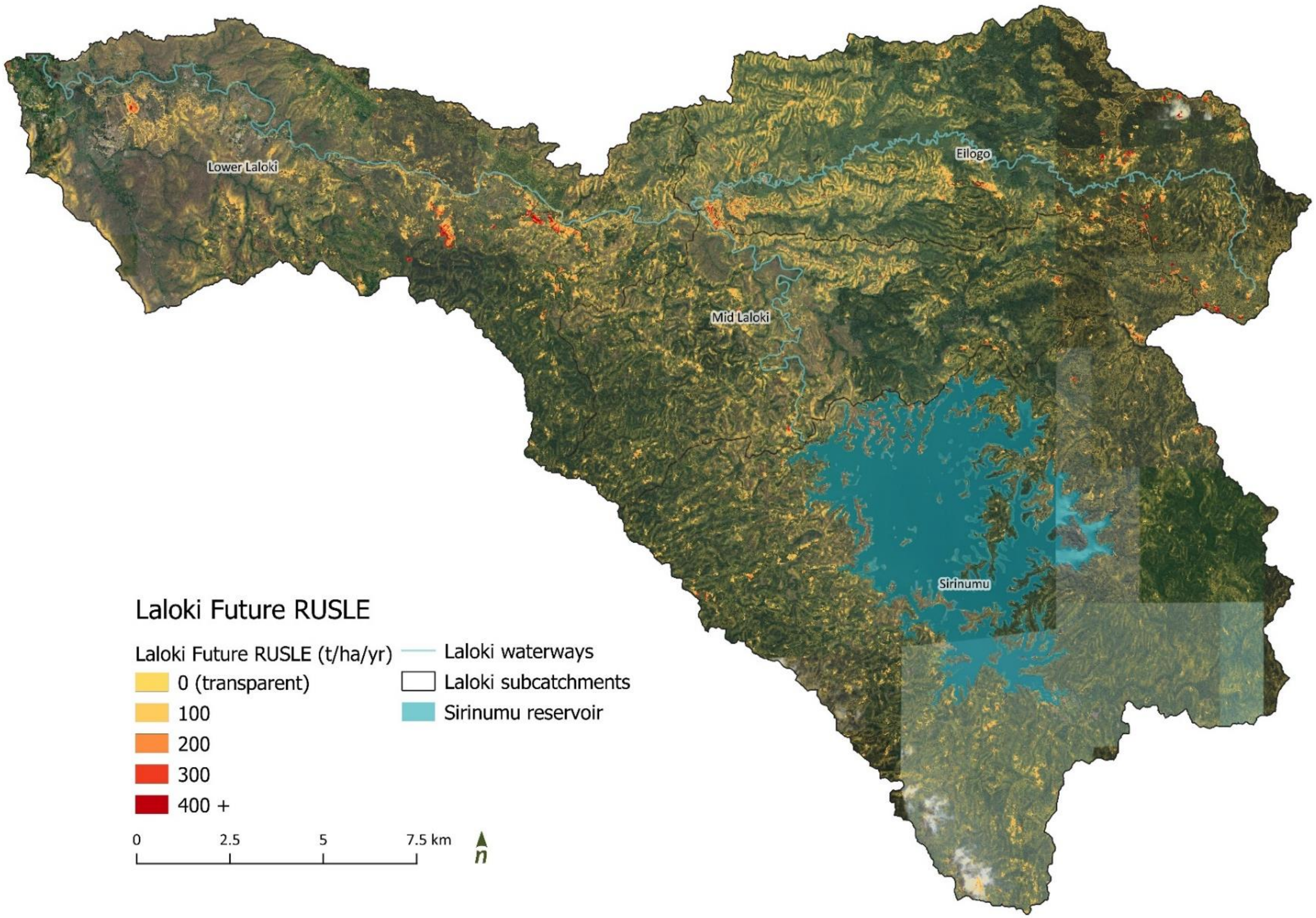

Figure 76 *Future RUSLE hillslope erosion analysis for the Laloki River catchment*

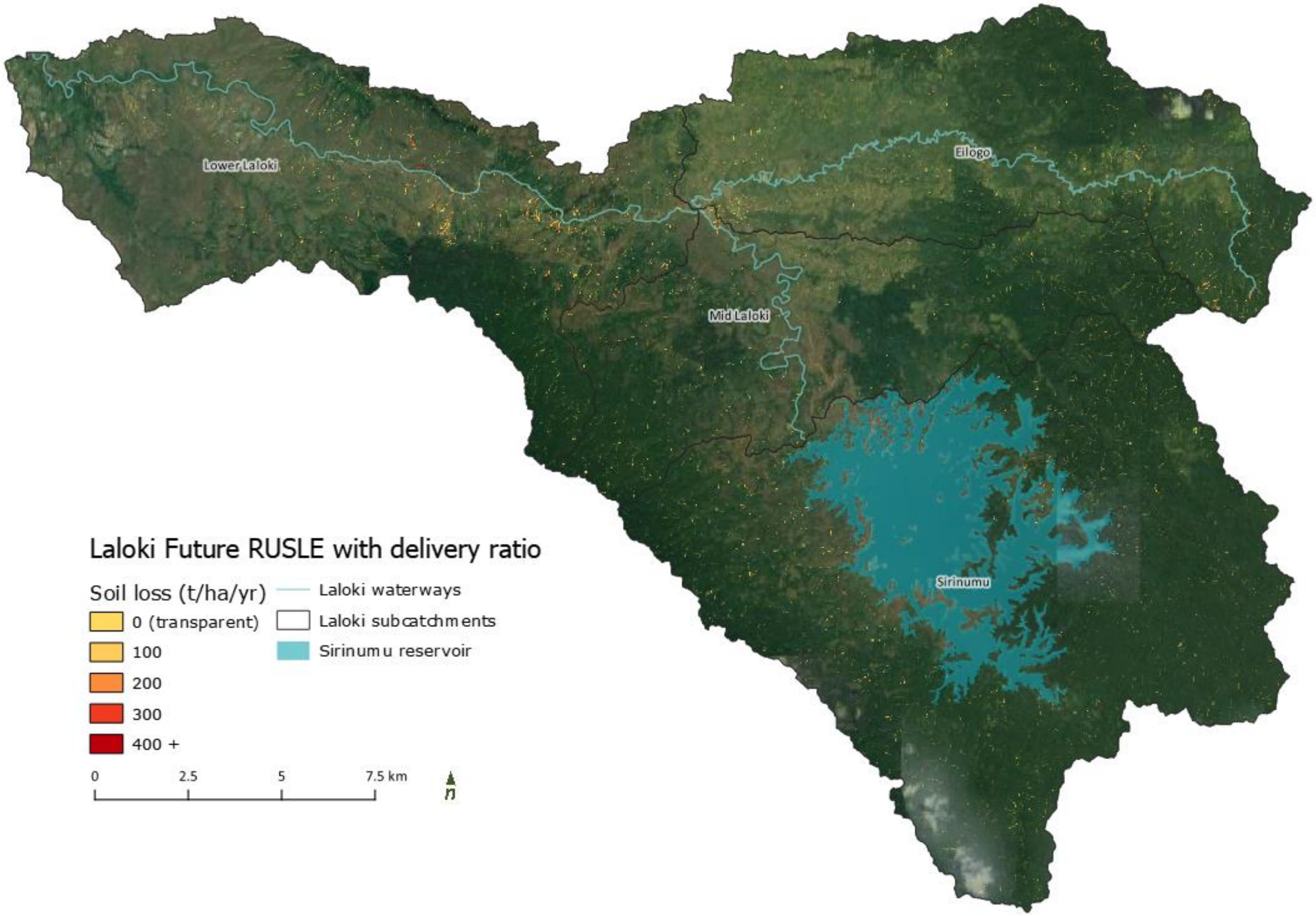

Figure 77 *Future RUSLE hillslope erosion analysis for the Laloki River catchment with delivery ratio applied*

Recommended monitoring regime

Ongoing regular monitoring of water quality is recommended given the importance of the Laloki River to the local community and broader Port Moresby population. Land use intensification within the catchment are likely to lead to key changes which will affect water quality and hydro-power generation. A well-designed monitoring regime can inform how these changes in land use are impacting and likely to impact key interests, providing metrics which can be used to support future land-use management decisions An outline of which parameters should be considered for issues facing the catchment in the foreseeable future is provided in Table 13 below.

Table 13 An overview of the recommended monitoring regime.

Issue	Monitoring Approach	Parameter
Erosion/Sedimentation	Monthly sampling catchment wide. Both parameters for the first year, then utilise NTU as a proxy for TSS if supported by a regression analysis.	TSS and NTU
Faecal pollution	Monthly sampling catchment wide	E.coli
Ecosystem health	Monthly sampling catchment wide	Key physical/chemical parameters (DO, pH, EC, Temp)

Recommended management practices

It is recommended that a catchment management plan is developed to reduce the risk posed by the issues identified in this study. Such a plan should aim to establish mechanisms which support the following risk management actions:

- A water quality monitoring program;
- Reduction of environmental hazards in potable water supply (including sewage, septic systems and piggery effluent)
- Improvement of the Eilogo Creek road at key locations where drainage is an issue;
- Protection of forested areas upstream of Sirinumu Dam and Sogeri;
- Riparian zone rehabilitation measures focussed on high-risk areas along Eilogo Creek and the Lower Laloki River;
- An extension program, working with local landholders on integrated land stewardship opportunities which address clearing of primary and secondary forest, soil conservation practices, riparian health, burning regimes, pest management (giant African snail and wild pigs);
- The development of a Source catchment model to inform future management through understanding the implications of different land use change scenarios;
- A preliminary cost benefit analysis to determine management action viability and priority.

Considering the proposed agricultural development within the Sogeri Plateau, the issues are likely to exacerbate into the future. The proposed actions should not be considered as isolated solutions but part of an integrated catchment management approach. The recommendations anticipate the complexity of conflicting land uses. For example, while improved road conditions are necessary along Eilogo Creek to reduce the sedimentation delivery downstream, improved access may facilitate further land use intensification.

The catchment management initiatives should involve improving the socio-economic status of the catchment communities. This should involve building capacity within the Koiari people of the plateau through an empowerment/leadership program and promotion of environmental and cultural advocacy roles. Management approaches that do not integrate the catchment communities as part of the solution are likely to be futile.

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Attachment A
Sirinumu Dam bathymetric survey and sediment sampling

MONITORING REPORT:

Sirinumu Dam bathymetric survey and sediment sampling

November 2018

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Contents

Figures

Tables

1 Introduction

Alluvium Consulting has been engaged by the United Nations Development Programme (UNDP) and the Conservation and Environment Protection Authority (CEPA) to undertake an assessment of sedimentation processes to provide an empirical baseline understanding of the existing sources and extent of sedimentation within the Sirinumu Dam and the downstream Laloki River. The work will inform the development of the Sirinumu Dam Integrated Land Use Plan.

Port Moresby water supply and hydro power generation relies on flows in the Laloki River (Figure 1). These are the unregulated flows from the Sogeri Plateau and releases from Sirinumu Dam. In general, water supply to the Eda Ranu treatment plant comes from Rouna 2 power station, relatively high in the catchment. In the event adequate flows are not present in the upper catchment, water is drawn from the Laloki River at Bomana pump station. The quality of water at this pump station is likely to be far poorer than at Rouna 2 due to increasing land use pressure in the lower catchment (human and agricultural effluent, sediment, solid waste, etc). With increasing land use activity in the catchment for agriculture and impacts such as burning of savannah, water quantity and quality in the catchment are likely to change. This study aims to provide an assessment of the existing catchment condition and the processes that impact sediment generation, transport and storage within Sirinumu Dam and the broader Laloki River catchment.

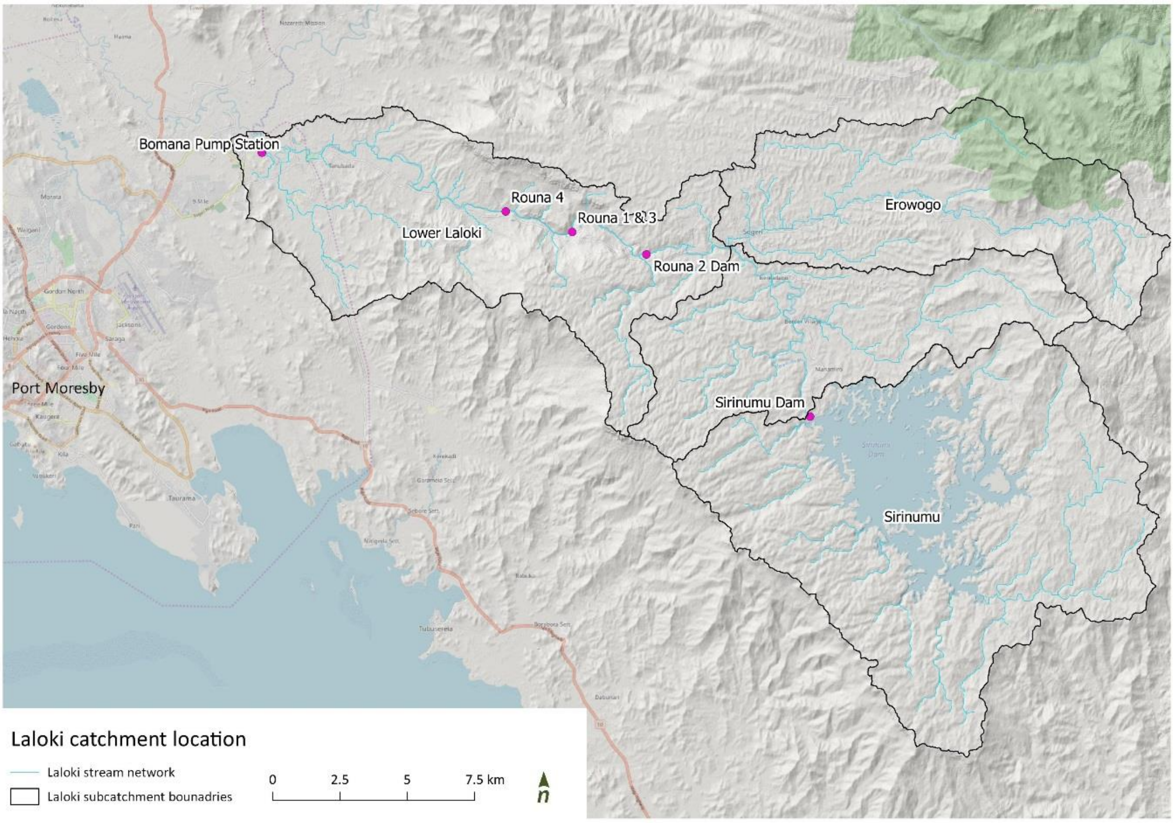


Figure 1 *An overview of the Laloki River catchment in relation of the capital city – Port Moresby. Base map courtesy of Google Earth.*

1.1 Report structure

This report outlines the outcomes of recent bathymetric survey and sediment sampling within the Sirinumu Dam and is a key deliverable in the overall sedimentation study. This report has the following structure:

- **Section 2** – Provides an overview of the catchment and existing studies
- **Section 3** – Outlines the methods using for the bathymetric survey and sediment sampling
- **Section 4** - Presents the findings of the monitoring
- **Section 5** – Provide a summary of the findings and next steps in the study

2 Background

The Laloki River drains an area of 406 km² within the Eastern Highlands of Papua New Guinea. The upper catchment comprises of the Sogeri Plateau which is drained by the Laloki River and several other streams which merge before dropping approximately 100 m at Rouna Falls. Below the falls, the Laloki River runs through Rouna Gorge before widening and meandering across lowland alluvial plains before its confluence with the Goldie River at Bomana.

The Sirinumu Dam itself is located on the Sogeri Plateau within the Owen Standley Ranges, 40 kilometres east of Port Moresby. The reservoir was impounded in 1963 to provide a water source for Port Moresby and hydroelectric power through the Rouna hydroelectric system (Smith 1997). In 1995, receding dam water levels triggered water rationing and power shedding measures which led to major environmental concerns when sewage could no longer be disposed into deep water. Further droughts during 1997-1998 and 2002 led to further rationing and power shedding across the city (Smith 2007). In 1999, UNESCO reported that the capacity of the dam was insufficient for the rapidly increasing population, which is expected to reach half a million by 2020 (UNESCO 2001). In 2007, a bathymetric study revealed that sedimentation risk into the reservoir is perceived to be low, with sources of potential sedimentation likely to derive from lake side cultivation and deforestation from within the catchment (Smith 2007).

2.1 Topography and rainfall

The upper Loloki River catchment consists of the Sogeri Plateau which generally has an elevation of between 600 -1500 m above sea level (Figure 2). In the mid catchment the Laloki River has deeply incised into the plateau creating deep gorges before moving into unconfined alluvial system upstream of the confluence with the Goldie River.

The elevation of the Sogeri Plateau gives rise to a relatively higher degree of rainfall (Figure 3). The upper catchment can experience up to 2500 mm of annual rainfall which decreases to 1500 mm in the lower catchment.

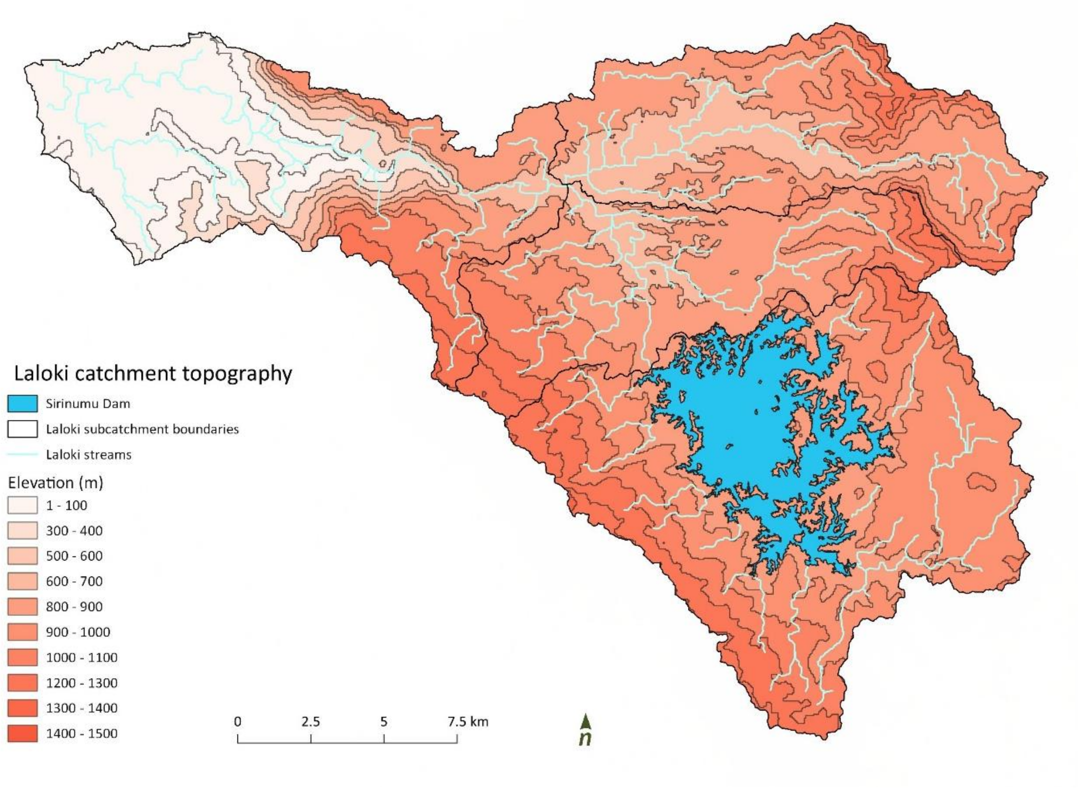


Figure 2 *The topographty of the Laloki River catchment illustrating the difference in altitude between the coastal lowland and the Sogeri Plateau. Extracted from the PNGRIS database (CEPA 2018)*

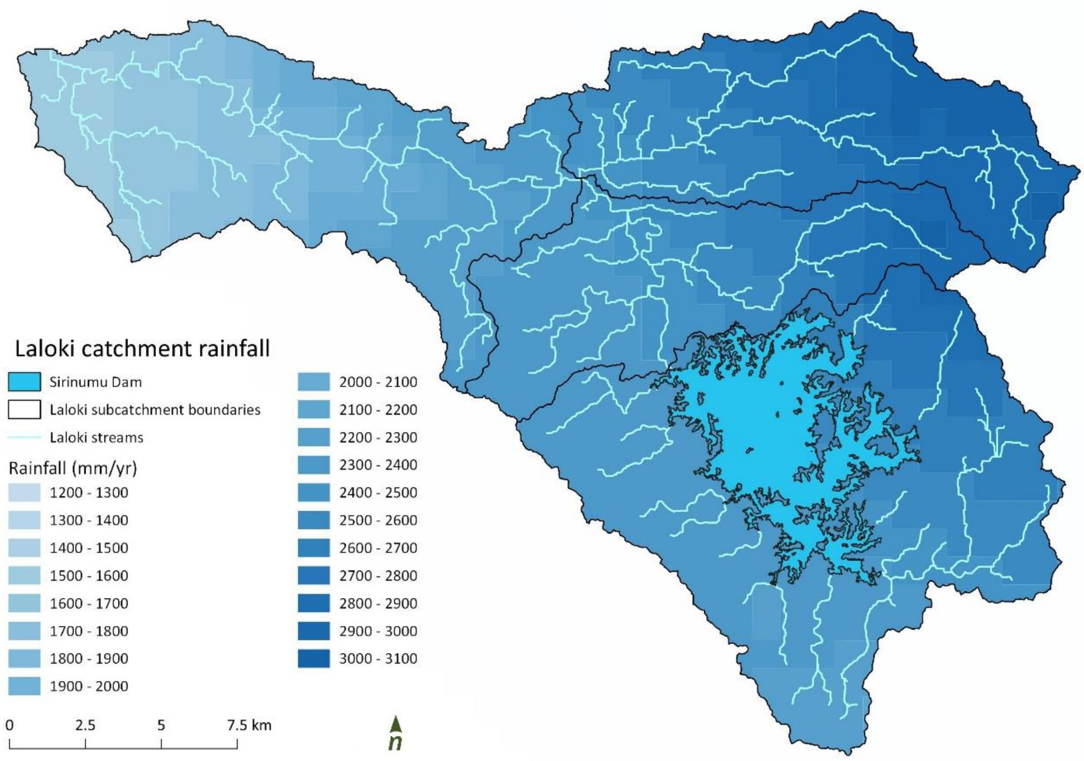


Figure 3 *Annual rainfall distribution across the catchment extracted from the PNGRIS database (CEPA2018)*

2.2 Geology and soils

The geology of the Sogeri Plateau consists of a broad synform of volcanic agglomerate which plunges to the north-west (Figure 4). Closely spaced, structurally controlled parallel drainage patterns begin in the upper cliff edged flanks of the catchment and give way to dense dendritic to pinnate patterns in the lower areas of broadly undulating relief (Smith 2007).

The agglomerate forms part of the Astrolabe formation, a 200-300m thick sequence of fragmented volcanics which underlie the mid to upper Laloki River catchment. The sequence is dominated by a chaotic array of angular to sub angular boulders of basalt and andesite in a matrix of tuff with interbeds of relatively minor thin tuff deposits ranging in fine to coarse in texture. Tertiary or Cretaceous sediments and Palaeozoic metamorphics lie beneath the agglomerate and outcrop at the extremities of the plateau with volcanogenic massive-sulphide copper/gold deposits identified at these margins (Smith 2007).

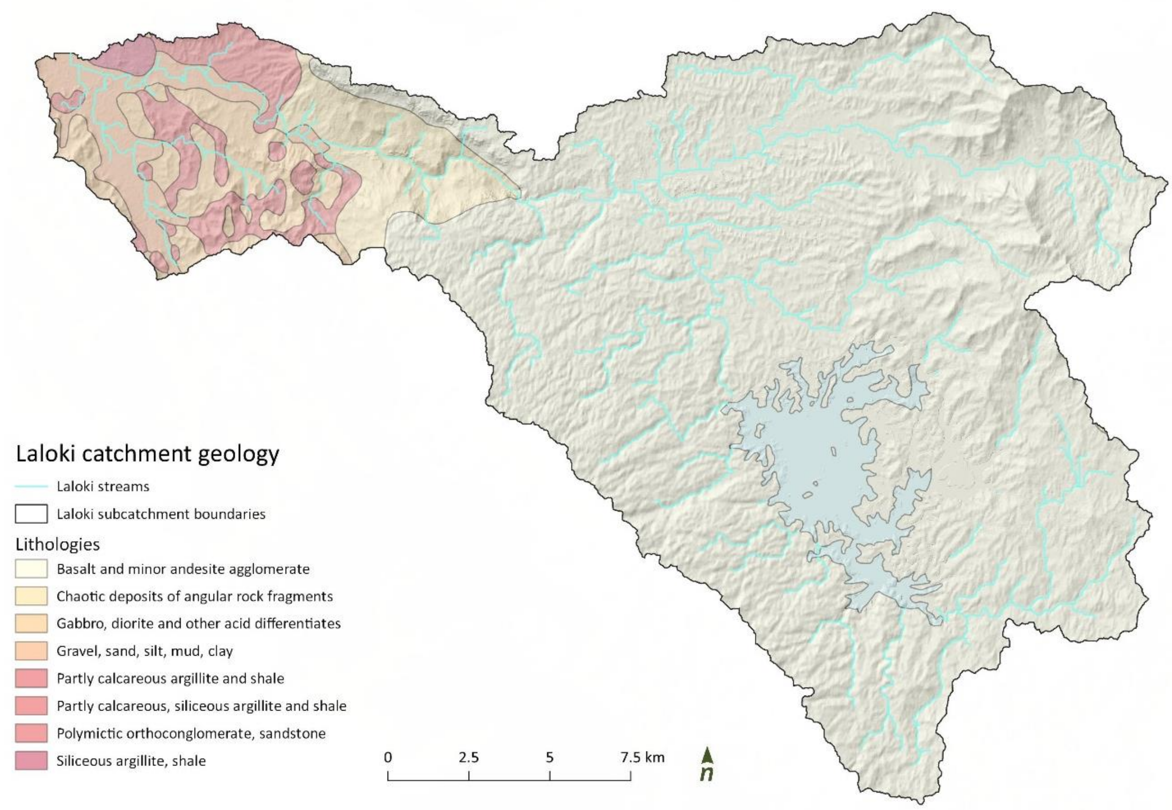


Figure 4 *Geology of the Laloki River catchment (CEPA 2018)*

Given the climatic conditions of the region and the chemical variability of the rock, the formation is deeply weathered. The variability of the weathering profile is driven by subsurface flow through tension joints and permeable sequences. One such example of variability can be found at the Sirinumu Dam wall, where one side of the saddle yields rock exposure and the other 24 m of residual clay (Smith 2007). Smith (2007) also refers to a historical exploration report (bauxite) which characterised the soils of the plateau as generally 5m to 60m thick, weakly differentiated or not differentiated at all; friable and strongly acidic.

The Laloki River flows downstream of Rouna Falls through markedly different geology. Coarse materials and fine sediment are eroded from the plateau and deposited along the river's course in alluvial floodplains. The river 's depositional margin is confined by hills to the south comprising of gabbro and calcareous argillite and polymictic sandstone to the north.

The soil map in Figure 5 represents an extrapolation of limited soils understanding across the region based on climate, topography and geology. Given the limited soil mapping in the area is inferred that the dark grey area encircling Sirinumu Dam represents soil features which have had their extrapolated dominant soil type removed due to inundation by the dam. While the outlines of the soil boundaries remain within this grey zone, their soil type is not retained in the metadata provided. Further information which identifies the soil types within these polygons would be a useful for further analysis, as the soil types at the reservoir edge have a high risk of erosion.

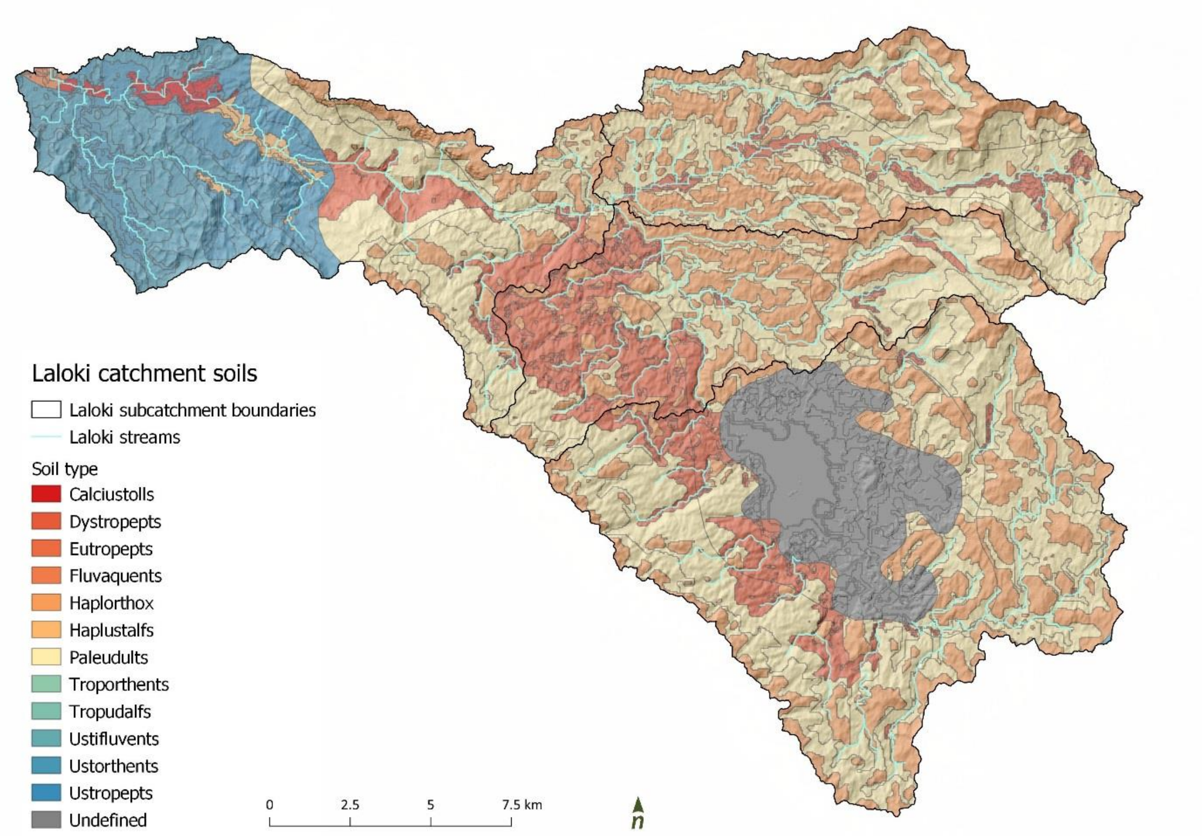


Figure 5 *Soil types across the Laloki River catchment (CEPA 2018)*

2.3 Land use

The most recent land use dataset available for the purposes of this study is the broadscale, satellite-based microwave radar (PALSAR) analysis across much of PNG conducted in 2007 and 2010 (see Figure 6 and Figure 7). These data sets were provided by CEPA. Key land use observations from the two datasets, 2017 Google Earth satellite imagery and recent field notes are listed below:

- A key difference between the two PALSAR datasets appears to be a reduction of forest cover in proximity to the forest/scrub margins below Rouna Falls and within the Sirinumu catchment, particularly along the southern and western flanks of the reservoir.
- The reduction in forest cover is marked by an increase in the density of Lowland Eucalypt patches within the surrounding Lower Montane Primary Forest from 2007 to 2010.
- Bare Soil/ Grass are concentrated in flatter sections of the catchment where alluvial floodplains form, particularly along the lower reaches of Erowogo Creek and Eilogo Creek and the lower Laloki River.
- Areas classified as rubber plantations exist along the boundary between Forest and Bare Soil/Grass (inferred as pasture).
- While the PALSAR datasets correspond well with key features in the satellite imagery at a general level, the significant variation in the vegetation types suggests that seasonality may impact land use classification.
- Further understanding of the PALSAR dataset is necessary to withdraw useful conclusions at a resolution finer than at the catchment scale.
- Google earth imagery and field observations at the dam perimeter suggests that when reservoir levels recede bare lateritic soils are exposed to rill erosion.
- Significant areas of hillslope erosion were observed during recent field observations
- Anecdotal evidence suggests that exist land slips within the catchment however the extent remains unknown.

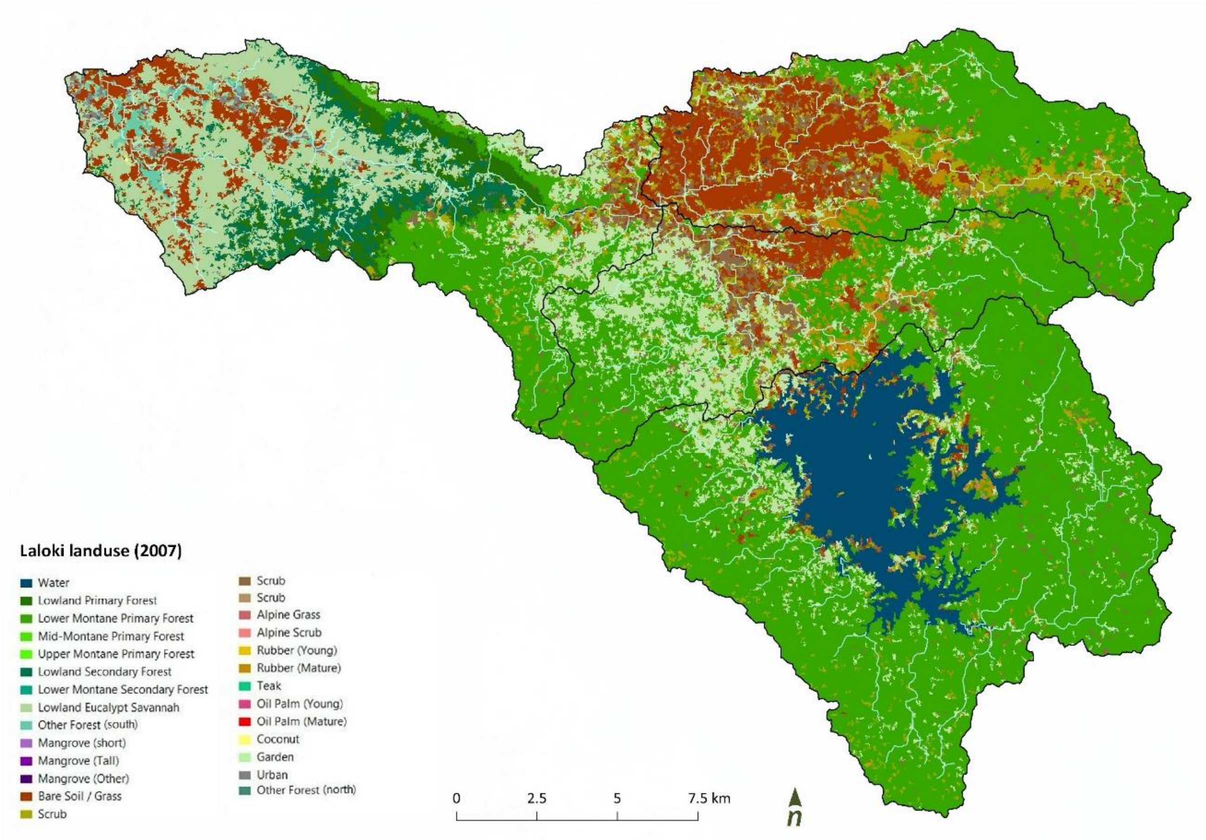


Figure 6 *Phased Array type L-band Synthetic Aperture Radar (PALSAR) analysis of land surface and inferred landuse categories for the Laloki catchment in 2007 (CEPA 2007)*

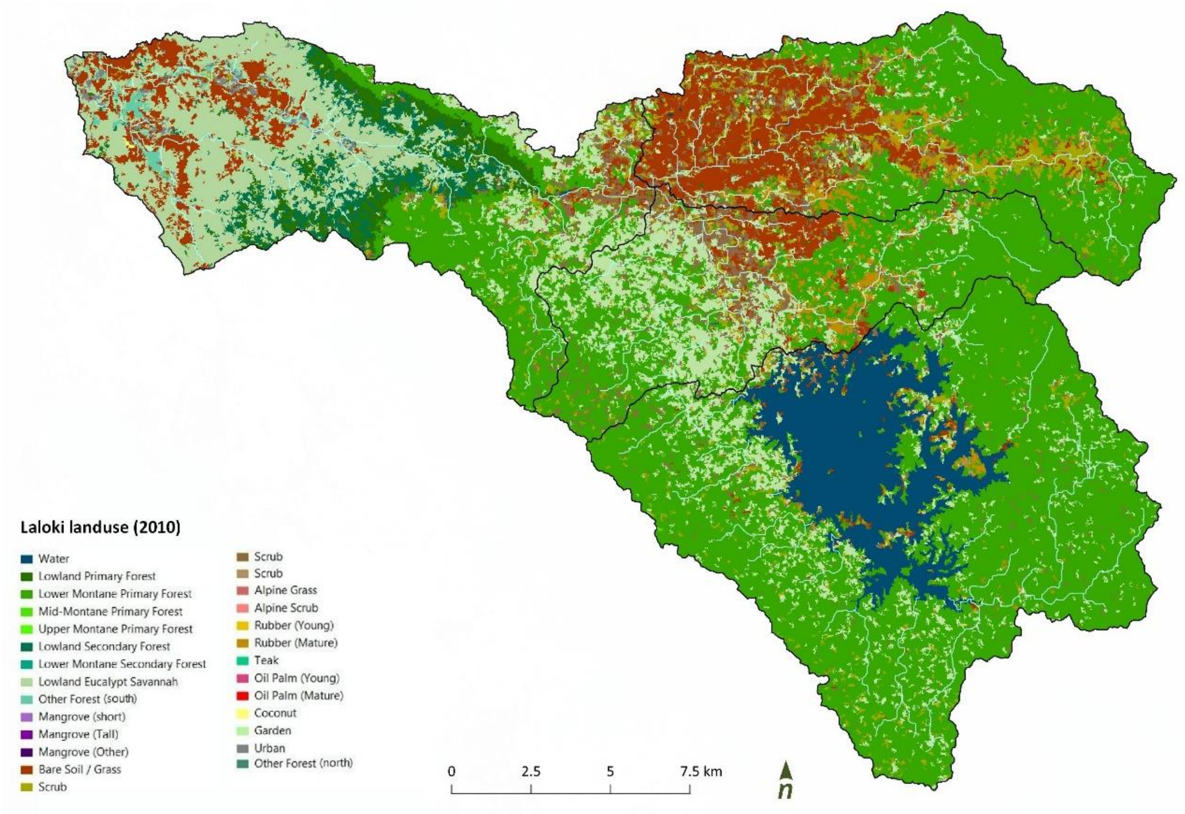


Figure 7 *Phased Array type L-band Synthetic Aperture Radar (PALSAR) analysis of land surface and inferred land use categories for the Laloki catchment in 2007 (CEPA 2010)*

2.4 SOPAC bathymetric study

A bathymetric survey of the Sirinumu Dam was undertaken by the Secretariat of the Pacific Islands Applied Geoscience Commission (SOPAC) in 2007. 123 bathymetric profiles (total length 155km) of the reservoir were processed and interpolated to yield a 10m grid DTM of the reservoir (Figure 8). The dam was divided into four broad zones and a cross-section profiles analysis examined the results of the DTM in respect to the principle branch source areas feeding the reservoir. The profiles were chosen to correlate with actual bathymetric results.

No pre-dam topography was available to compare with the 2007 survey. However, interpretation of the morphology of the bathymetry profiles indicated the widespread presence of former, well defined channels on the reservoir floor. The fact that these former channels had not been infilled indicated that sedimentation in the dam since 1967 is very low.

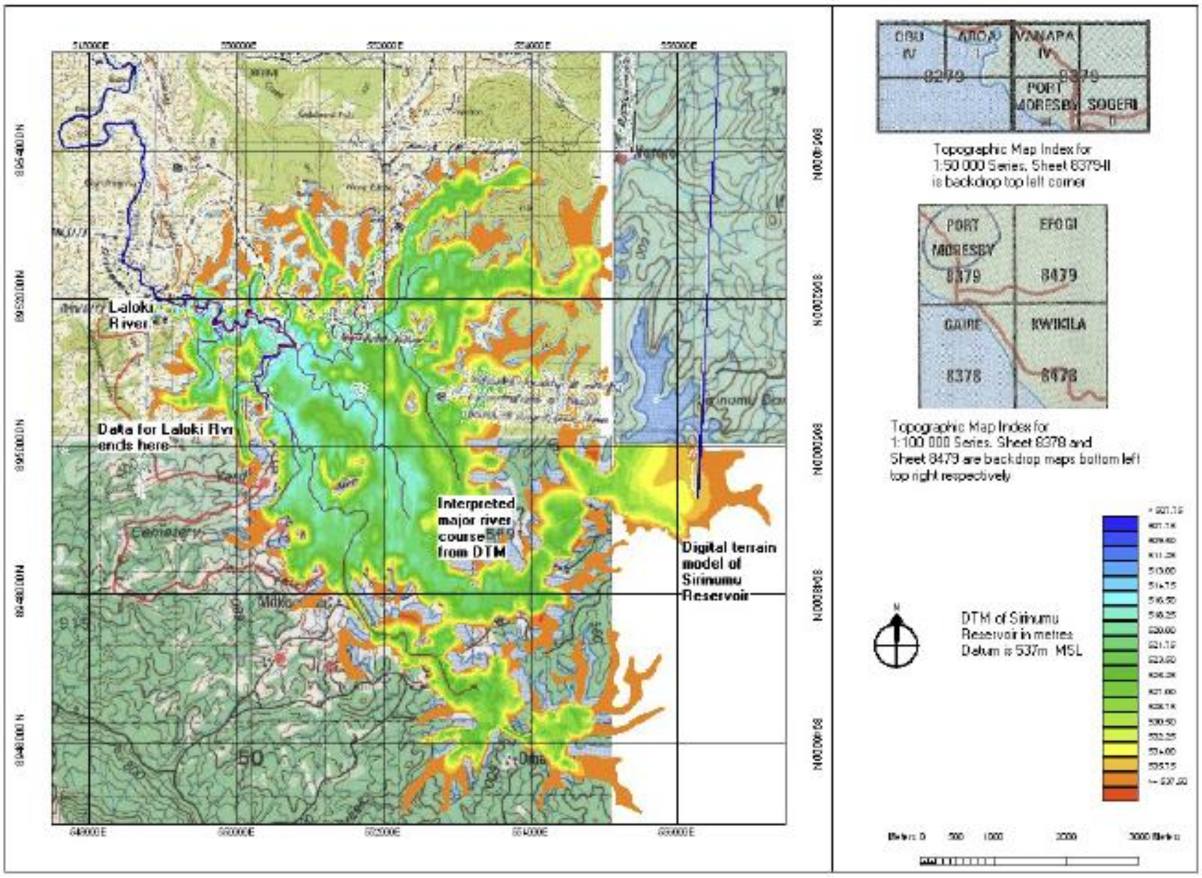


Figure 8 *The digital terrain model (DTM) produced as part of SOPAC's 2007 study*

3 Method

3.1 Bathymetric survey

The 2007 bathymetric survey and our April 2018 field observations indicated that sedimentation rates within the reservoir are low. Consequently, a full bathymetric survey was not considered necessary as there would be limited change from the 2007 survey. The revised survey extent was outlined in the our revised workplan in August 2018 (see Attachment A).

To assess any change since the 2007 survey several key sections in each of the four reservoir zones were selected for resurveying. Ten survey lines representative of the major sections of the impoundment were resurveyed (Figure 9). These cross sections can be utilised for ongoing monitoring of reservoir bathymetry.

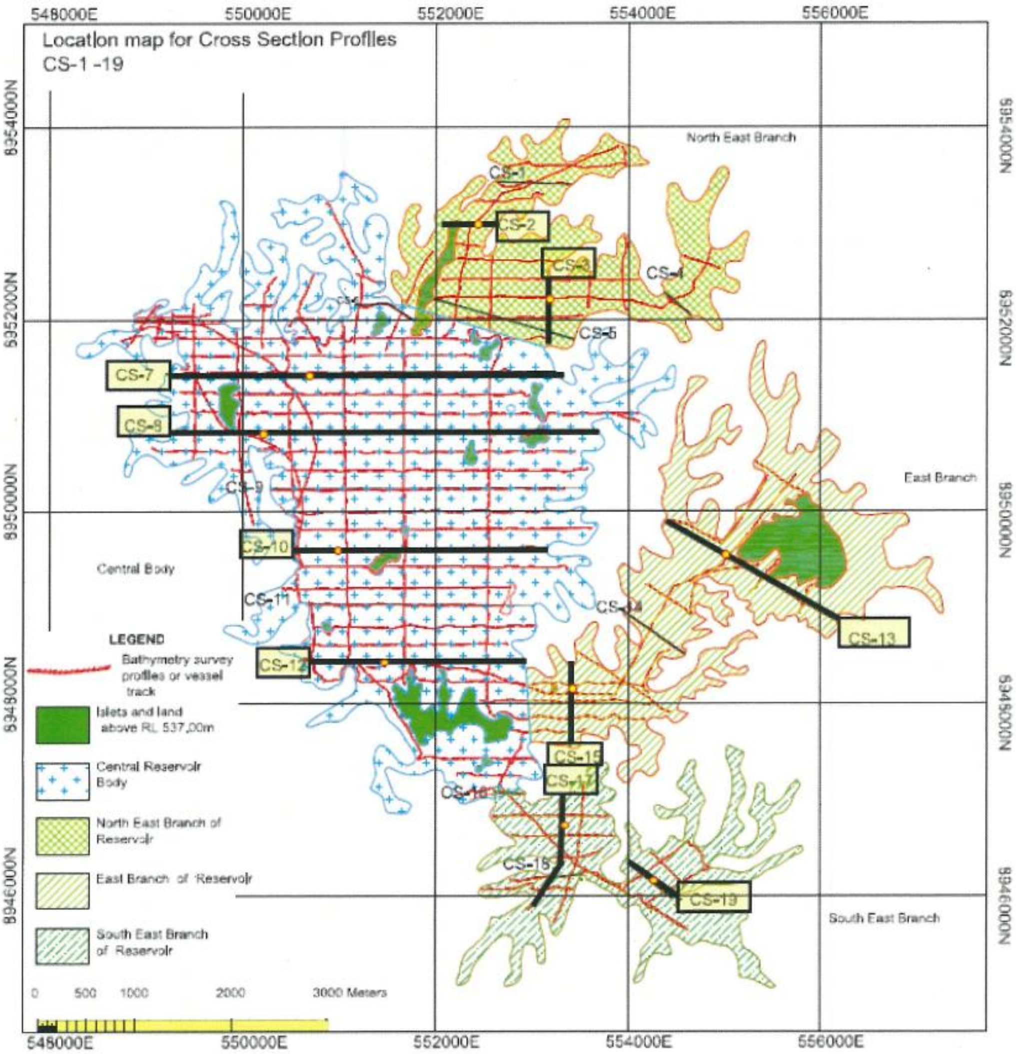


Figure 9 *The ten selected cross sections from the 2007 bathymetric study which were resurveyed as part of this assessment*

The bathymetric survey was conducted from the 5/9/2018 to the 6/9/2018 and employed a combination of equipment and software. The primary source of data collection was the Sontek M9 Acoustic Doppler profiler. This was fitted to a hydroboard and towed behind a survey boat. A Hemisphere S321 smart antennae unit was attached to the hydro-board and logged coordinates of each transect. The data collected from each survey line was visualised using the Sontek River Surveyor software.

Cross sections were taken as close as possible to the 2007 survey lines, with proximity being limited by the ground conditions experienced by the survey team. The high concentration of drowned vegetation along the reservoir floor combined with reduced reservoir levels (3.5 m lower than during the 2007 survey) made navigation along the designated points near impossible (Figure 10). Time on the water was also limited by dam access being restricted by poor weather and road conditions, limiting each section to a single beam survey.

Figure 10 *Numerous trees remain standing in the reservoir, restricting navigation*

The dam level during the time of survey was recorded at the beginning and end of each survey at 533.5m. This level did not change for the duration of the survey period (Figure 11). A total of ten bathymetry profiles representing 16.5 kilometres of data were collected.

Figure 11 *A snapshot of the reservoir water level of 533.5 m which did not change for the duration of the survey period.*

3.2 Sediment sampling

Sediment sampling of the reservoir can provide insight into the type of sediment entering the system and the degree at which it could be an issue for the quantity and quality of water available. Samples from the top, middle and bottom of the water column were taken at ten nominated locations on each transect. The samples were collected using a Hydro-Bois depth sampler. The top sample was collected one metre below the surface, the middle was determined from the depth to the bottom and the bottom sample was taken at one metre above bed. Special attention was taken to ensure that the bottom sample was not influenced by any disturbance of the bed caused by our equipment.

It was intended that a reservoir floor sediment sample was also to be collected at each of these locations. Despite several attempts with an AMS Bottom Dredge (15lb) at each location to collect sufficient sediment for testing, this method of collection was only successful in the southern reach of CS19 and CS13. This area of the reservoir was relatively clear and had very little vegetation within the lake itself. In the northern sections of the reservoir the amount of in-lake vegetation increased such that the bottom dredge was unable to access clear bed to collect a sample. The dredge intercepted fallen branches and debris which appear to line the bed throughout. Many alternate sampling points were attempted at each location with little success.

Table 1 The approximate location at which sediment sampling was attempted at along each cross section (Projection WGS84/UTMZone55S).

Monitoring point	Cross Section	Easting	Northing	Sample collected
MP02	CS02	552225.2	8952287	nil
MP03	CS03	553097.4	8952203	nil
MP07	CS07	550257.9	8951731	nil
MP08	CS08	550208.8	8950812	nil
MP10	CS10	551008.1	8949929	nil
MP12	CS12	551455.9	8948467	nil
MP13	CS13	554632.4	8949495	1
MP15	CS15	553522.4	8947896	nil
MP17	CS17	553328.4	8946451	nil
MP19	CS19	554265.3	8946153	1

Along cross sections 02,03 and 07, the dredge managed to reach the reservoir floor yet returned with minimal sediment. At these locations the bed most likely to be comprised of a solid clay and very little loose sediment available for collection.

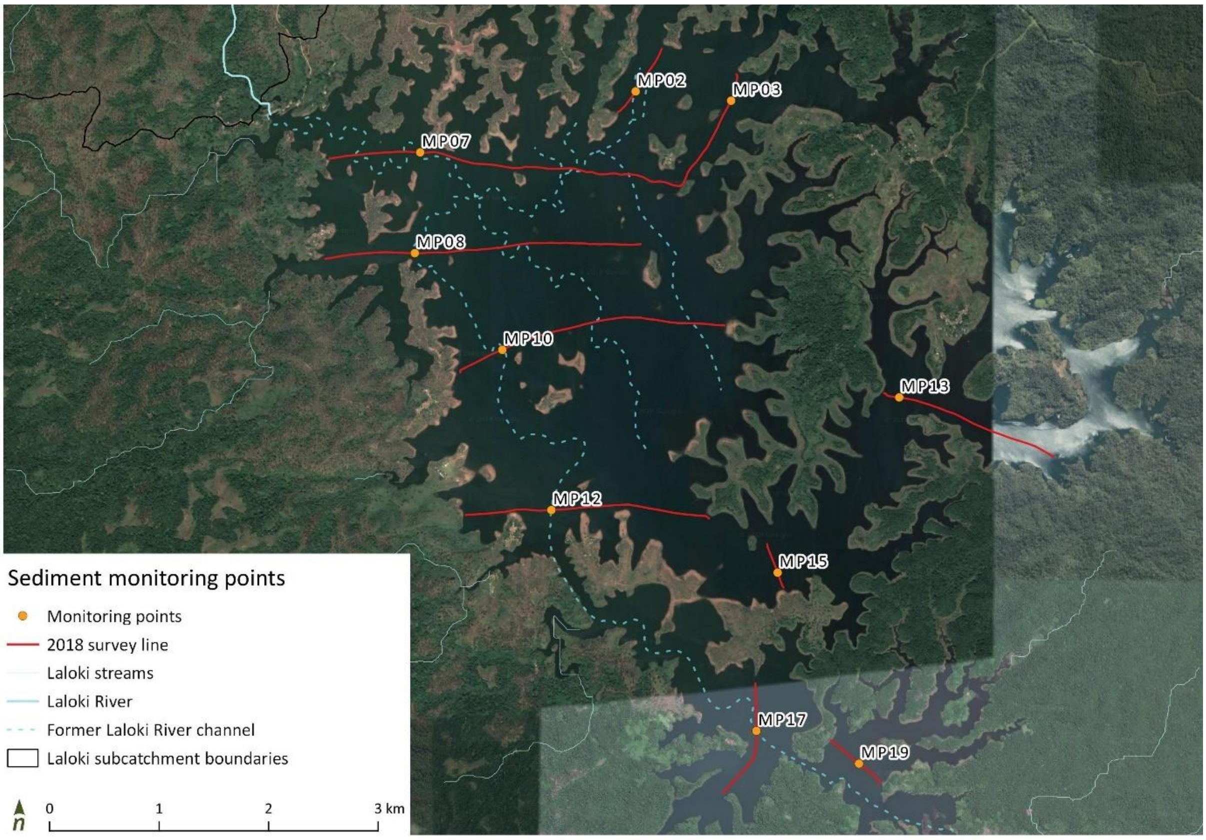


Figure 12 *The approximate location of the sediment monitoring points at the deepest section of each cross section*

3.3 Sub Bottom sampling

Ground Penetrating Radar (GPR) enables the identification of sub surface changes in substrate density which can be used in conjunction with core samples to infer the types of sediment/lithologies and their thicknesses. A 100MHZ ground penetrating radar (GPR) survey was conducted on Sirinumu Dam over a four-day period from the 21st to the 24th of September 2018 with the aim of identifying soft sediment accumulation on the reservoir floor.

The survey design aimed to replicate the bathymetric survey, using the cross-section lines to enable comparison of the datasets (Figure 12). A 100MHz GPR antenna was used in this study, the usual average penetration range for this frequency is down to 25m depth. In total 11 sections were completed on the10 proposed survey lines (cross section 19 was repeated). These are presented in the Section 4.4 below. Reflex2D & ReflexW software were used to do interpretations of the raw data collected.

The equipment was set with a penetration rate of 0.2m/ns (typical rate adopted for land based assessments) with a 100MHz antennae. This was selected to enable sediment layers below the dam floor to be assessed. However this approach limited the cutoff depth to 8.5 m. Given that the depth of the reservoir exceeds this in many areas, many profiles only captured the edges of the valley floor. However this data allowed the sediment layers below the reservoir floor to be assessed clearly. A lower depth velocity suitable for water (i.e. 0.033m/ns) would likely have penetrated deeper however is unlikely to have achieved the clarity in assessing sediment layers below the reservoir floor.

4 Results

4.1 Field assessments

On the afternoon of the 25th of April a rapid catchment assessment was undertaken visiting a number of sites along the Laloki River and on the Sogeri Plateau. On the 26th of April a boat trip around the Sirinumu Dam was undertaken. Key observations in relation to the Dam include:

- The geology of the region consists of the Astrolabe Agglomerate unit (containing large basalt rocks) and basalt units which both weather to fine sediments (i.e. clay) (see Figure 4)Coarse bed load material (i.e. sands and gravels) were not prevalent at the locations where the waterways were inspected.

- Land use across the area was a mix between forested area and areas cleared for agriculture (i.e. grazing, vegetables, fruits etc.). Often cleared areas were quite small (i.e. less than 1 hectare) but also consisted of large areas on the Sogeri Plateau which are periodically burnt. These burnt areas were often on steep slopes.

- The clay dominated soil profile is relatively cohesive and resistant to mobilisation and provides for dense vegetation growth

- Within the dam there was no evidence of major sedimentation issues. There was good water clarity, no observed deltas or sediment deposits at inflow points and limited fine sediment attached to submerged vegetation or instream timber/trees which is often observed in water bodies with high suspended sediment loads.

- A mechanism with potential to move sediment within the dam is likely to be due wind generated wave erosion in locations where there is a large fetch or on islands subject to variable inundation depths without vegetation cover. The impact of this sediment source on overall storage capacity is likely to be negligible as it is only re-distributing sediment within the dam.

- The majority of clearer areas within the dam catchment are along the western side of the dam on the footslopes of the range, however other than where gardens/pineapple growing occurs, they retain a good ground cover with sparse mature trees (typical of burnt savannah).

Figure 13 . *Evidence of active erosion within the dam most likely due to wind wave action*

4.2 Bathymetric survey

The following section compares the results from the bathymetry survey with the profiles from the 2007 survey. Given that sections of the reservoir were heavily wooded, weather was poor and that the water level was approximately four metres lower than when the original survey was conducted, the ten survey lines were restricted in their capacity to match their corresponding 2007 baselines (see Figure 14).

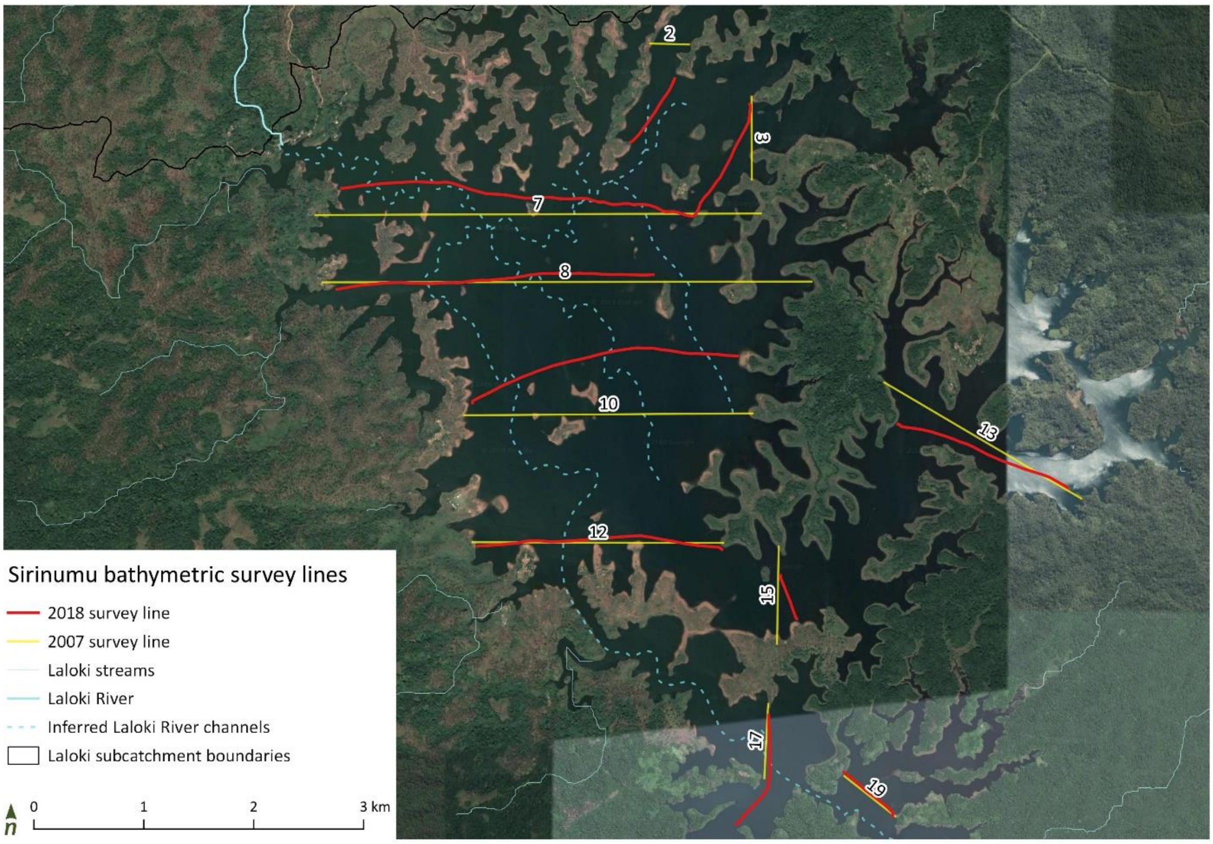


Figure 14 *Comparison of the 2007(yellow) and 2018 (red) survey lines.*

This misalignment restricts the capacity of the analysis to quantify the degree of sedimentation occurring within the reservoir. It does however enable for the recognition of patterns in the cross-sectional morphology of the drowned valley and a ridge to trough analysis which can help determine any overall changes which may have occurred over the past 11 years since the original survey.

Northeast branch

Two profiles were chosen for comparison within the northeast body of the reservoir, cross section profiles two and three (see Figure 15, Figure 16, Figure 17 and Figure 18). While the original profiles were aligned orthogonal to the original drainage network, the recent profiles verge on oblique.

Cross Section Two

- Limited comparability due to inconsistent alignment
- Ridge to trough heights comparable, within 1 m difference of each other.
- Well defined main channel in 2018 survey indicates limited sedimentation within the main channel

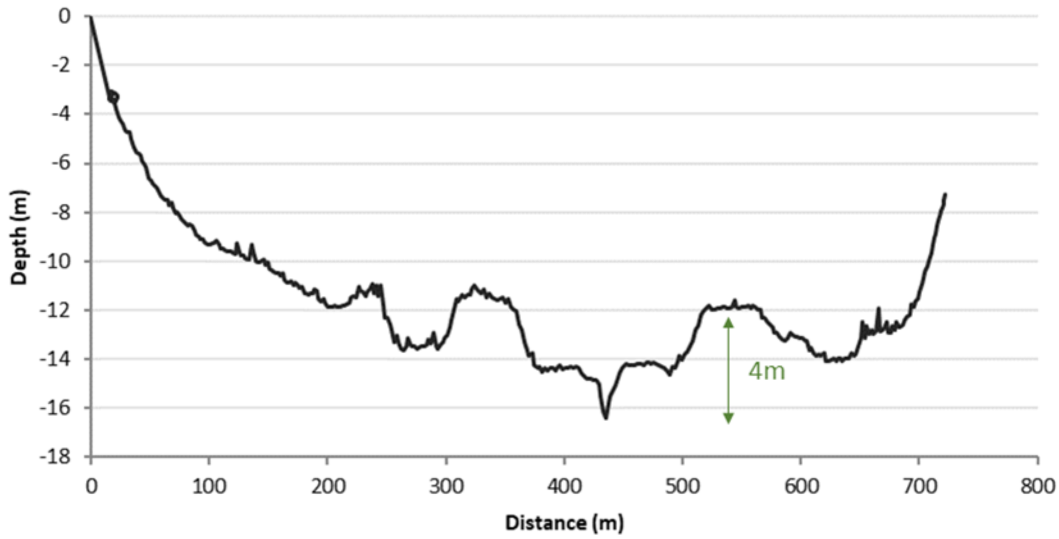


Figure 15 *Cross section two (2018) is approximately 500m downstream of the 2007 section (shown below).*

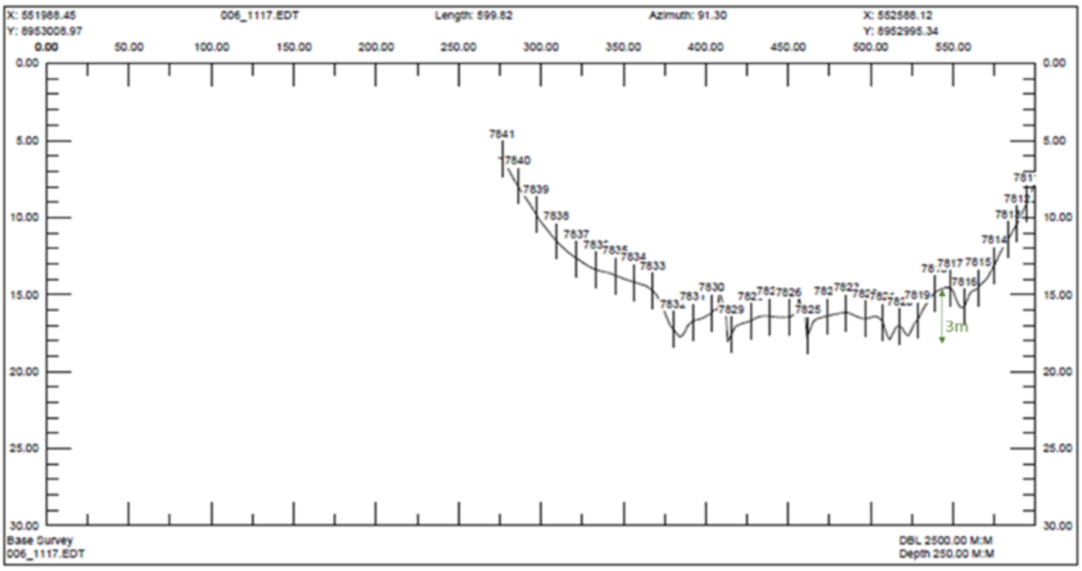


Figure 16 *Cross section two, (2007).*

__Cross Section Three__

- Not directly comparable due to inconsistent alignment. Ridge to trough measurements not indicative of sedimentation.
- Overall landform is recognisable, with three main channels consistent across both profiles. All channels are well defined across both surveys, suggesting minimal sedimentation.

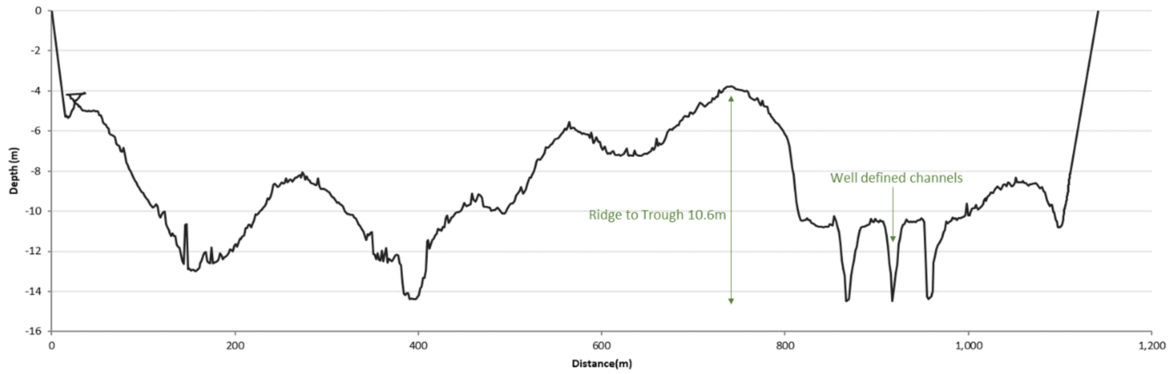


Figure 17 *Cross section three (2018) begins at approximately the same point as the 2007 section at its northern (left-hand side end) and ends approximately 600 m apart at the southern end. The well-defined channels and ridge to trough height correspond well the 2007 cross section taken further upslope*

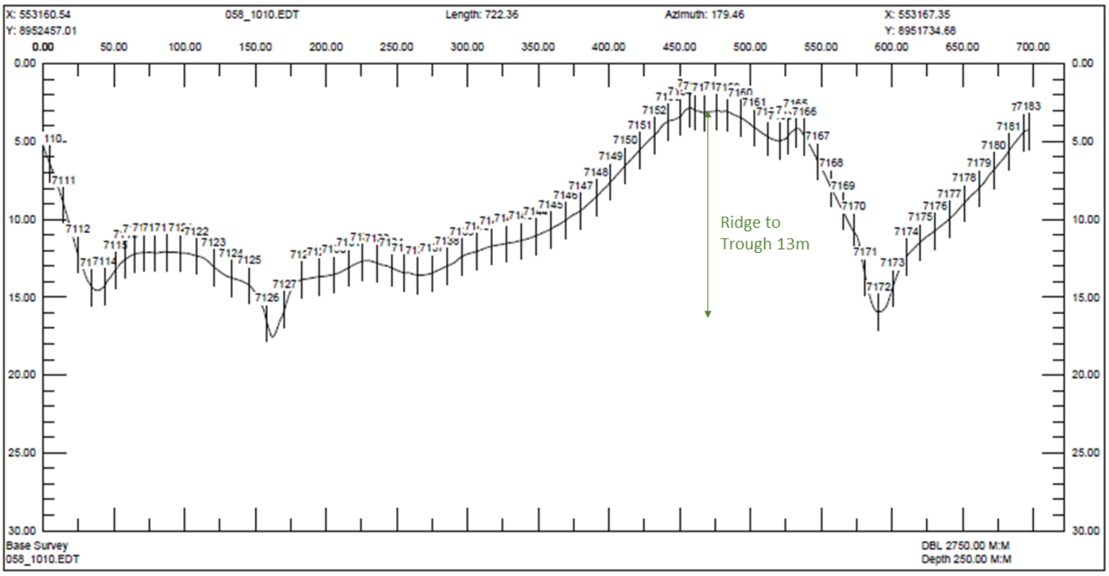


Figure 18 *Cross section three (2007)*

Central reservoir body

Four profiles were chosen across the central body of the reservoir for comparison (see Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, Figure 25 and Figure 26). Once again, inconsistent alignment restricts the degree of analysis. Nevertheless, some inferences are possible. All profiles are aligned east/west.

__Cross Section Seven__

- Overall landform is recognisable and comparable.
- 2018 profile is slightly downstream of original profile, especially at the western end.

- The 2018 profile intercepts the well-defined main Laloki River channel multiple times with little to no indication of channel infill (Figure 19)..

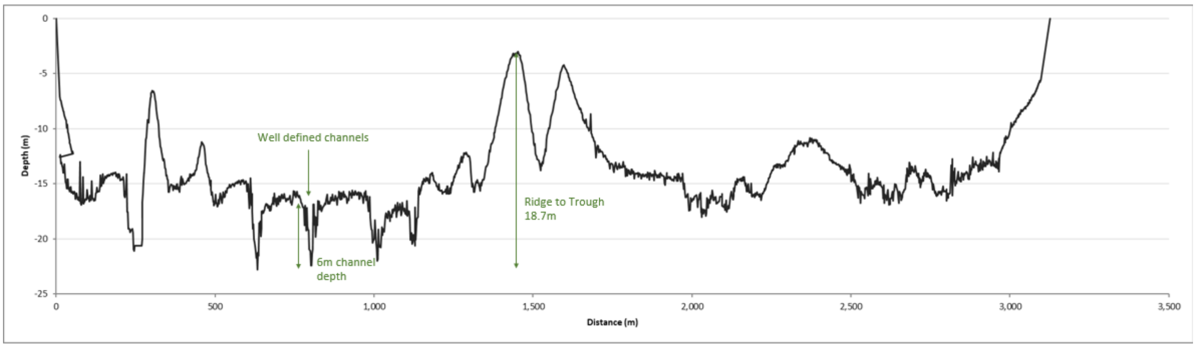


Figure 19 *Cross section seven (2018). Note how the landform corresponds well with the 2007 section below, including the channel depth and ridge to trough height.*

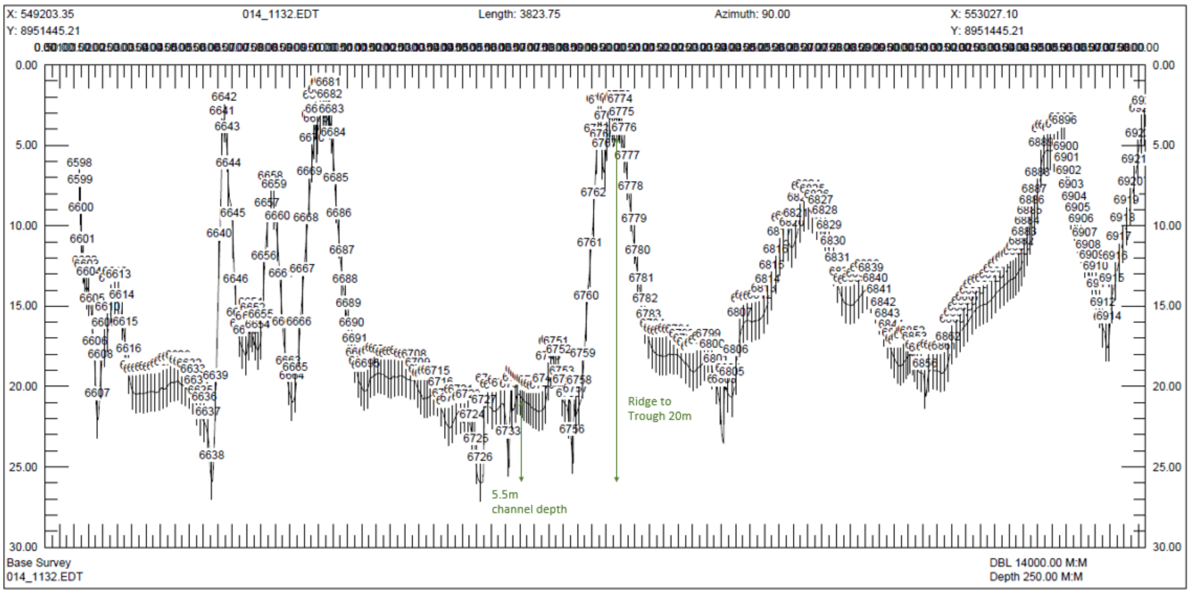


Figure 20 *Cross section seven, taken in 2007, with channel depth and ridge to trough heights.*

Cross Section Eight

- One of the more comparable profiles surveyed.
- Both have a ridge to trough measurement within a metre of each other – this small difference is likely due to the to a change in overall ridge height between the two cross sections.
- Well-defined channel features which retain similar morphology, indicating little to no sedimentation within the central body of the reservoir.

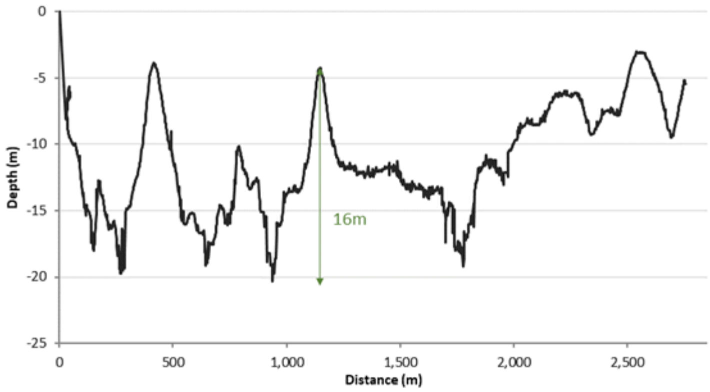


Figure 21 *Cross section eight (2018), with a ridge to trough depth which is consistent with the 2007 section below. Note the well-defined channels and their correlation with the 2007 section.*

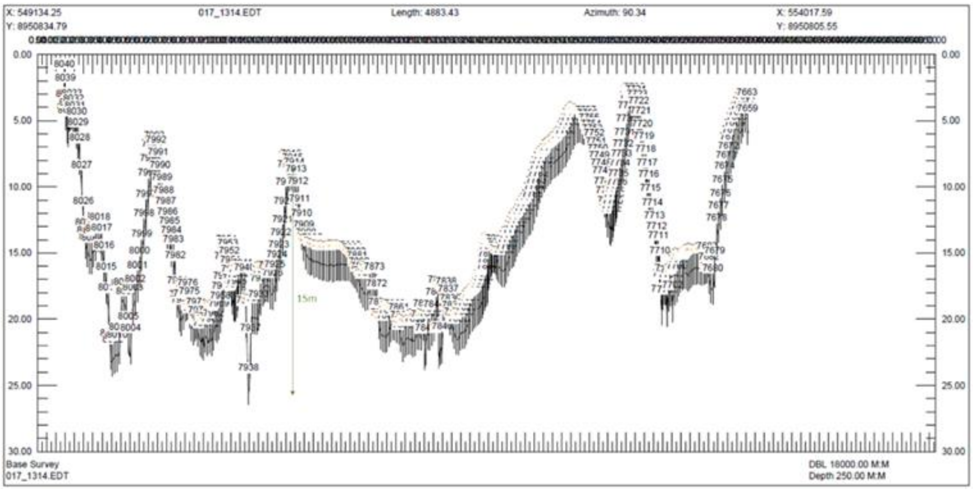


Figure 22 *Cross section eight (2007).*

Cross Section Ten

- While the 2018 profile was taken 100-500m downstream of the original profile, it remained roughly orthogonal to the original drainage network.
- Main landforms and channel features are recognisable in both profiles with both retaining a ridge to trough measurement within 1 m of each other.
- The well-defined channels in both profiles suggest minimal sedimentation within the channels of the central region.

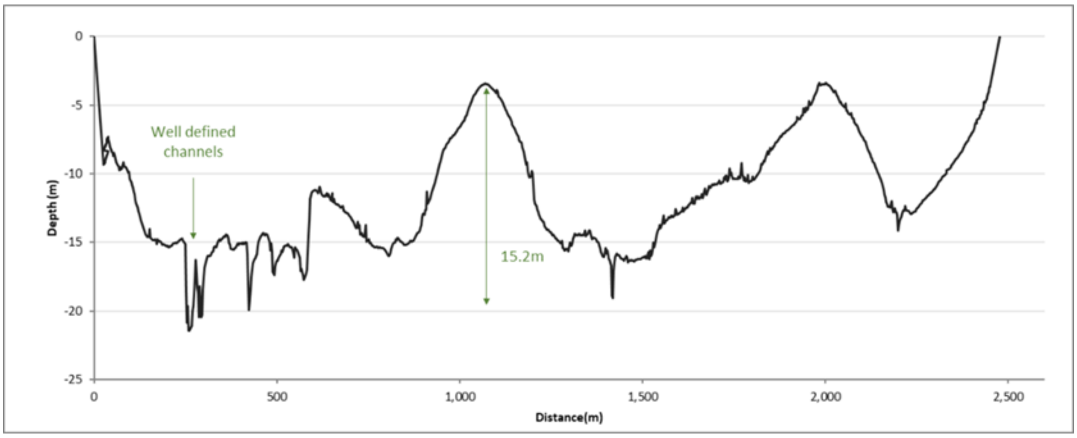


Figure 23 *The 2018 section reveals a landform which corresponds well to the 2007 section (below), with good channel definition and ridge to trough correlation.*

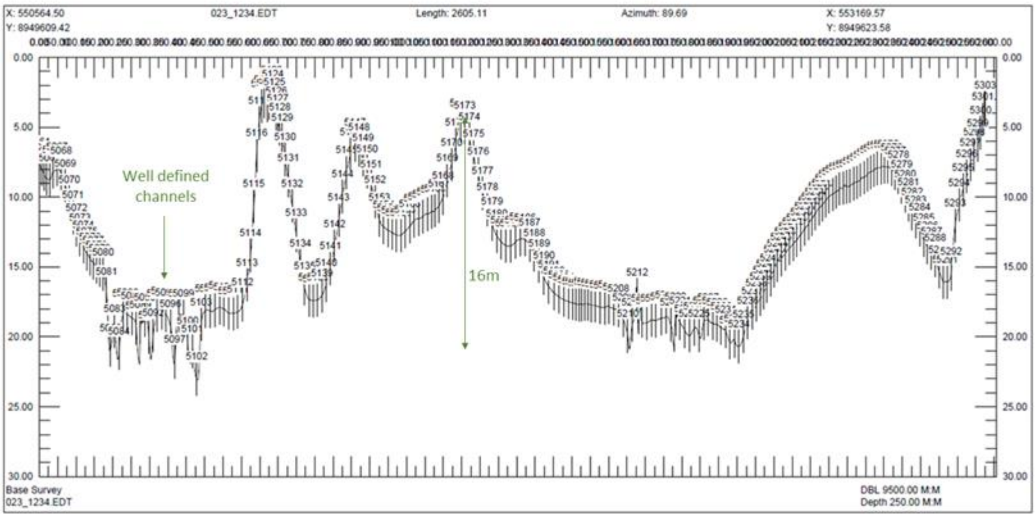


Figure 24 *Cross section ten, taken in 2007*

Cross Section 12

- Relatively comparable profiles, both approximately parallel to each other, orthogonal to original drainage network and within 50m of each other.
- The ridge to trough measurement of the main channel indicates a four-metre difference in depth. This difference is unlikely to be a result of sedimentation given the channel morphology remains similar. The channel morphology is also well defined in the 2018 survey.
- If 4 m of sediment were to accumulate within the main channel over an eleven-year period broader morphological changes across the other corresponding features would be expected. As a result, the difference is likely due to the steep variation in ridge height The changes across other landforms suggest that the reduction in ridge to trough value is a result of a change in ridge shape between the two profiles, not channel infill.

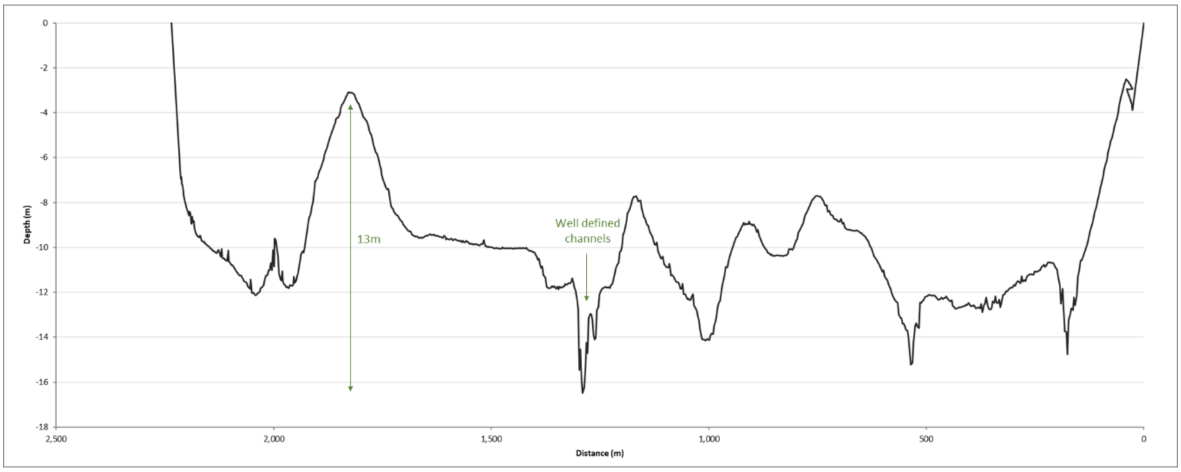


Figure 25 *The 2018 section corresponds well to the 2007 section (below), with good channel definition.*

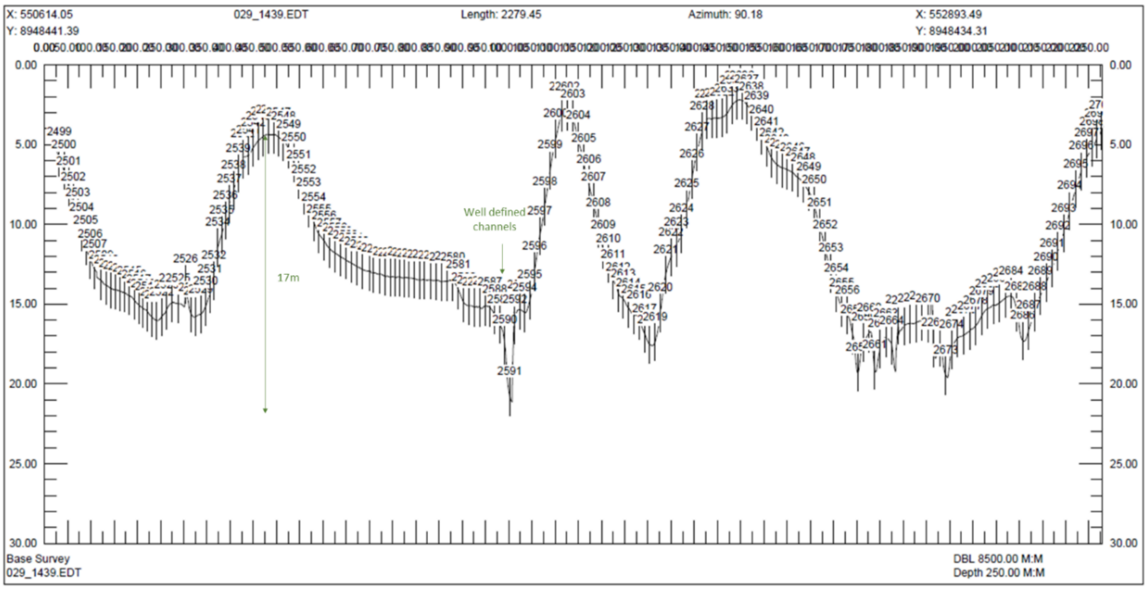


Figure 26 *The 2007 cross-section corresponds well with the 2018 section despite the large difference in ridge to trough height.*

Eastern branch

The Eastern branch represent approximately 19% of the reservoir. A relatively small proportion of the Sirinumu catchment drains into this section, which is heavily forested to the waterline in most areas. Two cross section were chosen for comparison (see Figure 27, Figure 28, Figure 29 and Figure 30).

Cross Section 13

- Profiles vary in distance from each other from zero metres at the SE (right) end to 300m at the NW (left) end.
- Both cross sections are across the widest section of the Eastern branch, with 15 main channels identified in both.
- Given the high number of stream channels and distance between profiles, the impacts of channel sinuosity restricts the direct correlation of channels and ridges to one another.
- Nevertheless, the morphology of the 2018 channels is such that minimal sedimentation is interpreted to have occurred. The channel bottoms depict clear incisions with negligible flattening or infill of their base.

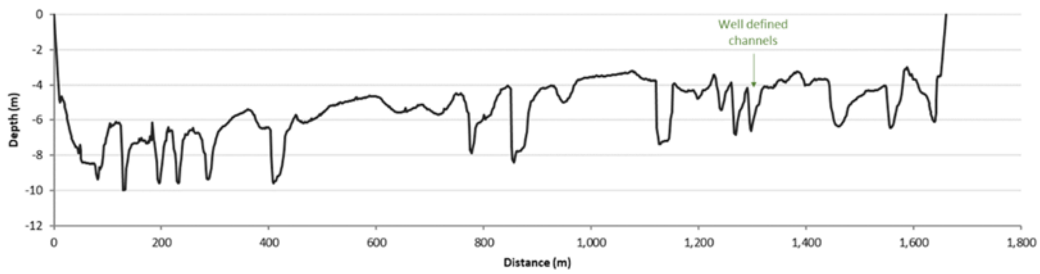


Figure 27 *The 2018 cross section indicates good channel definition. Channel shape and number correspond well with the 2007 section (below).*

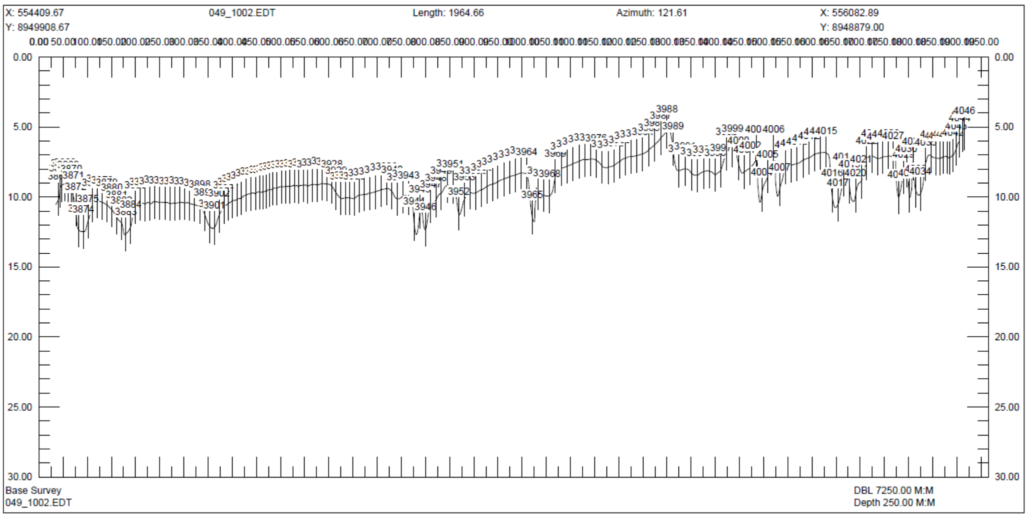


Figure 28 *Cross section ten, taken in 2007, with very similar channel shape to the 2018 section.*

Cross Section 15

- This profile was run at the approximate mouth of the eastern branch. With the left bank to the south and the right to the north (facing downstream).
- While both profiles are roughly orthogonal to the original drainage network, the 2018 profile is shorter and oblique such that its southern end is 200 m from the 2007 profile and 30 m from the northern tip..
- While the ridge to trough measurements are both 9 m, there are smaller channels in the 2007 profile which are not captured in the 2018 profile.
- Similarly, the northern channel in the 2007 profile which is interpreted by Smith (2007) to be incised in bedrock, is flattened out in the 2018 profile.
- Both these observations indicate there may have been minor sedimentation at the mouth of the Eastern Branch.

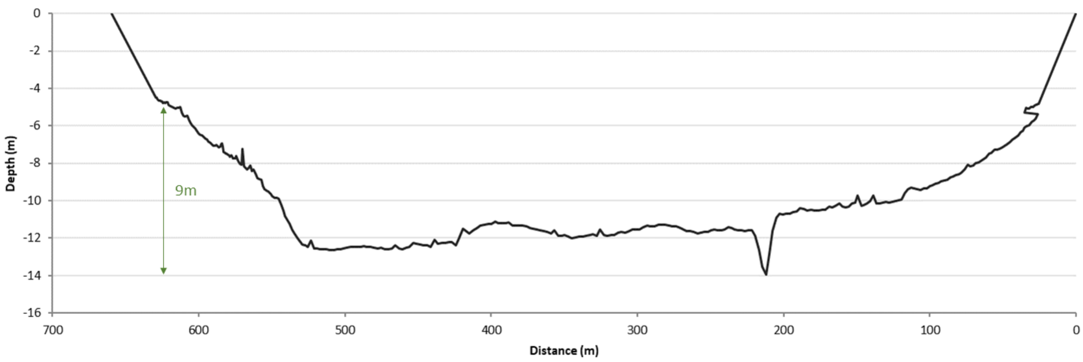


Figure 29 *The 2018 section retains a ridge to trough height identical to the 2007 section, as well as a similarly defined, incised channel. Note the lack of the channel along the left-hand side of the section, as seen in the 2007 section below.*

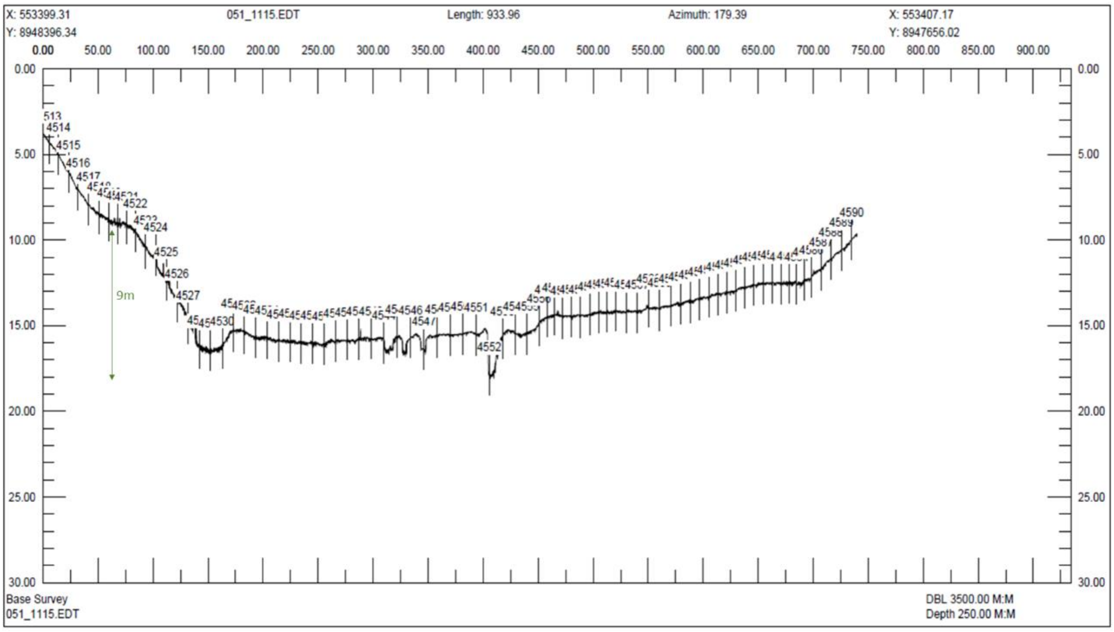


Figure 30 *Cross section 15, taken in 2007, with an extra channel defined along the left-hand side of the section.*

Southeast branch

The south east branch represents 10% of the total reservoir yet receives inflow from over half of the total Sirinumu sub catchment, much of which remains heavily forested. Two cross sections were chosen for comparison (see Figure 31, Figure 32, Figure 33, Figure 34)

Cross Section 17

- Both profiles are highly comparable given the minimal distance between each (10 -15m)
- Both profiles share very similar profiles with well-defined incised channels in each.
- Evidence for sedimentation is low.

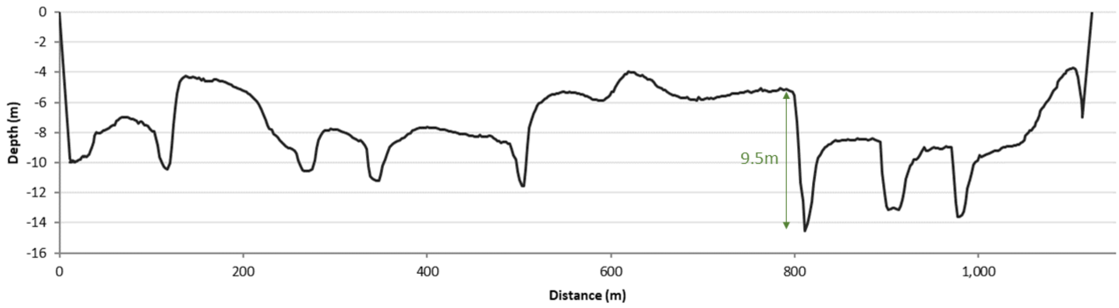


Figure 31 *The 2018 cross section delineates clear, well defined channels, with a ridge to trough value which corresponds well with the 2007 section below.*

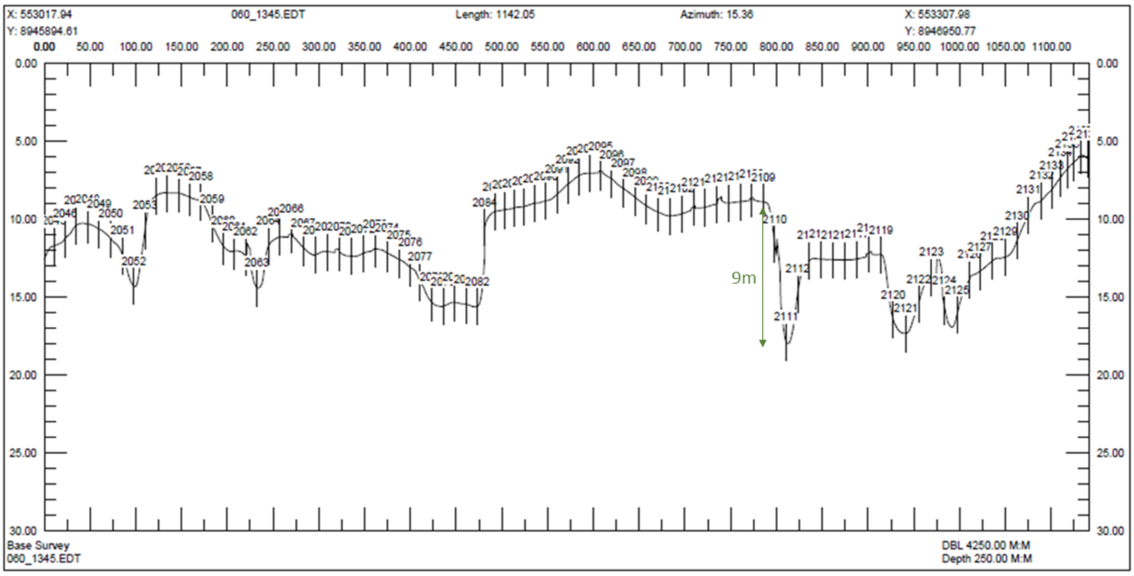


Figure 32 *Cross section 17, taken in 2007, appears very similar in channel definition to the 2018 section above.*

Cross section 19

- Both profiles are oriented orthogonal to original drainage network, are a similar length and are very close to one another (30-0m).
- Both profiles share a similar ridge to trough height yet differ in shape.
- Evidence of a meandering river exists where the Laloki River currently meets the reservoir. This pattern is likely the cause of such high variation between the two profiles.
- Despite this variation, well defined channels within the 2018 profile suggests that sedimentation is limited to perhaps the middle channel which is somewhat flattened at its base.

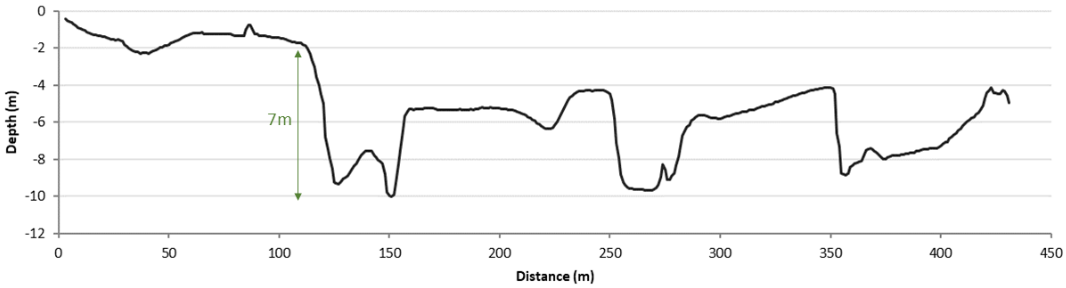


Figure 33 *The 2018 channel retains a ridge to trough measurement equal to that of the 2007 sections. The channels to the left of the section are flattened at their base, suggesting the possibility of minor sedimentation in this section of the dam.*

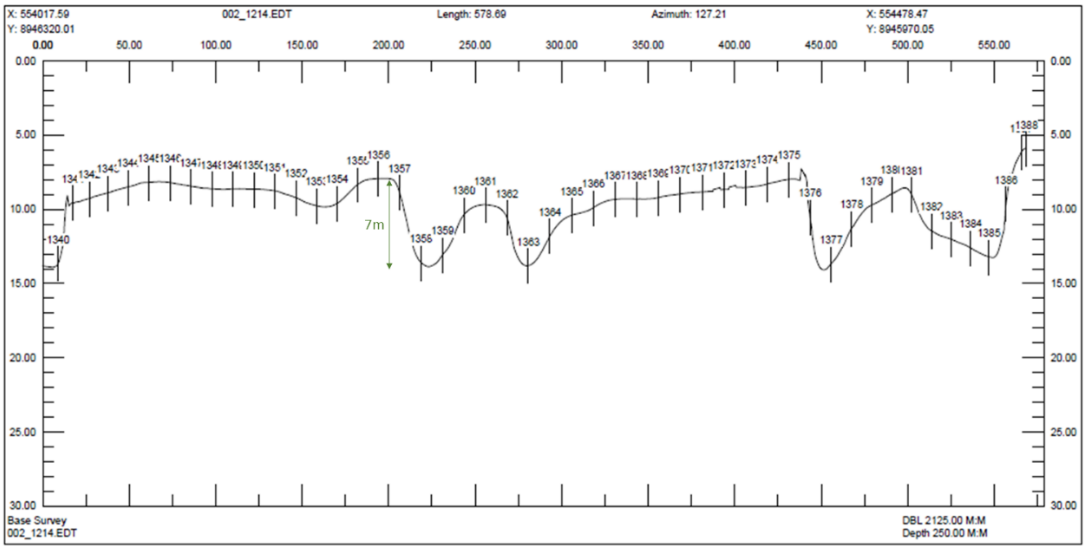


Figure 34 *Cross section 19 taken in 2007 with the same ridge to trough height with the corresponding section taken in 2018 (above).*

Conclusions

Overall it is clear that despite not all cross sections being comparable, all sections exhibit clearly defined channels. This indicates that sedimentation within the dam is minimal. The most comparable cross sections (8 and 12) within the main body of the dam confirm this, with well-defined channel morphology and strong ridge to tough correlations.

The comparison did reveal the possibility of sedimentation along the banks of reservoir. This was noted along cross section two and at the northern edge of cross section 15, where slumping of subsurface material or rilling along exposed banks may have led to channel infill. The impact of this sediment source on overall storage capacity is likely to be negligible as it is only re-distributing sediment within the dam.

4.3 Sediment sampling

Overview

The sampling program consisted of three water samples taken at the top, middle and bottom of the water column along each of the ten bathymetric survey lines (Figure 35). The sampling location was selected to be the approximate location of the deepest point on each section. A sediment sample of the reservoir floor was also collected at monitoring points 13 and 19.

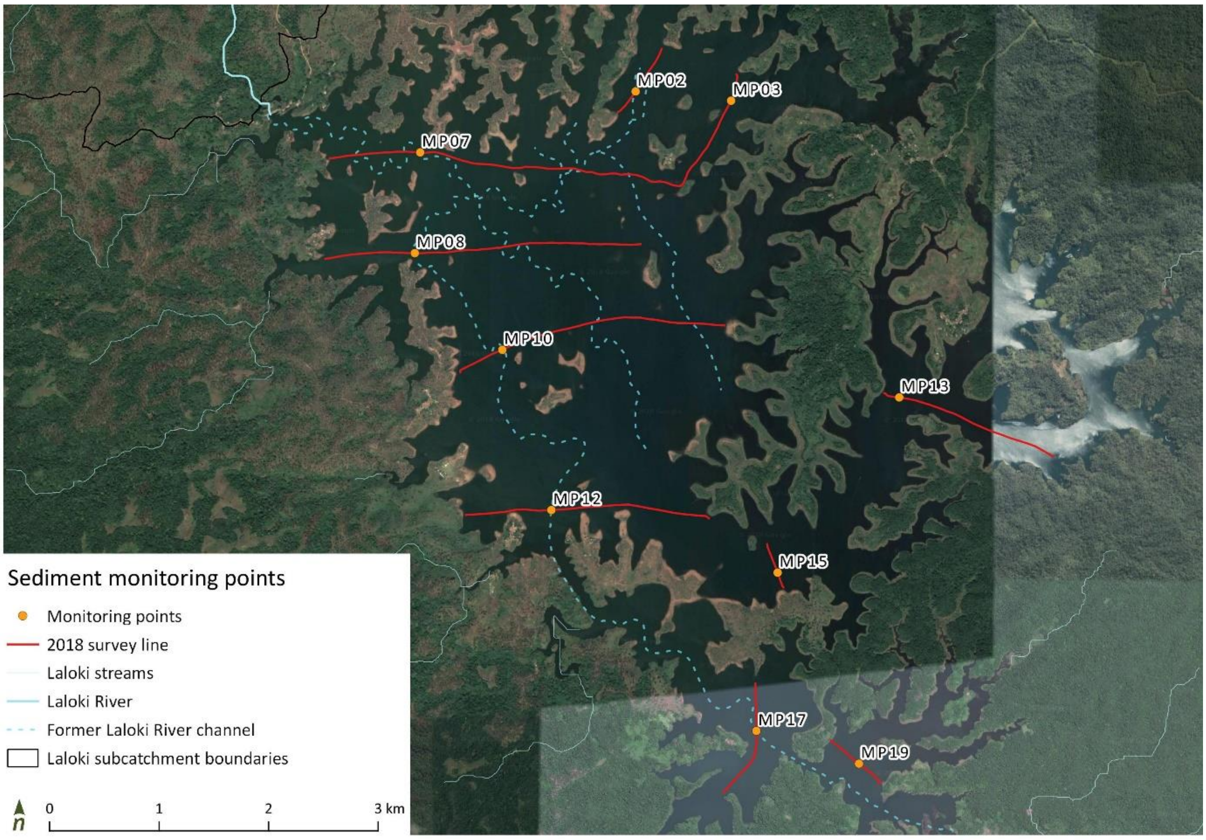


Figure 35 *Location of monitoring points at the approximate deepest point along the bathymetric survey lines*

Channel sediment samples

Only two bottom sediment samples were able to be collected as discussed in Section 3.2. The two sections were taken in the most upstream area of the dam at monitoring points 13 and 19. Any sediment depositing into the dam from the upper sub catchments is likely to drop out into these areas.

The median particle size both samples was less than 0.075mm (see Table 2, Figure 36 and Figure 37). This is to be expected given the weathering product of volcanic material comprising of clay and fine sands. Only fines are likely to be transported deposited through the dam, particularly at inflow areas such as those at MP13 and MP 19. Without knowing the original soil properties of the reservoir floor it is difficult to draw conclusions on the how inundation has changed floor sediments. However, the fact that there are some gravels in the samples may indicate that in situ material (pre-inundation) has not been buried. The bulk density of both samples is provided in Table 3. The low bulk density value for MP19 may indicate a high organic content.

Table 2 Breakdown of particle size distribution of samples MP13 and MP19

Soil Classification based on Particle size	MP13	MP19
Fines (<75 µm)	74%	68%
Sand (>75 µm)	20%	31%
Gravel (>2mm)	6%	1%
Cobbles	< 1%	< 1%

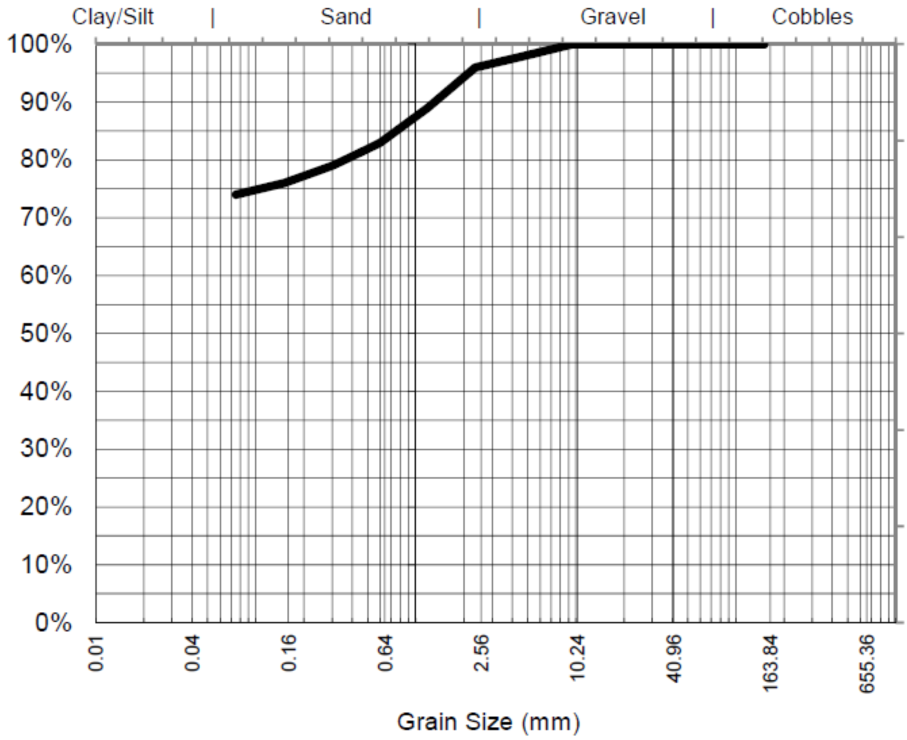


Figure 36 *Particle size distribution curve of sample MP13*

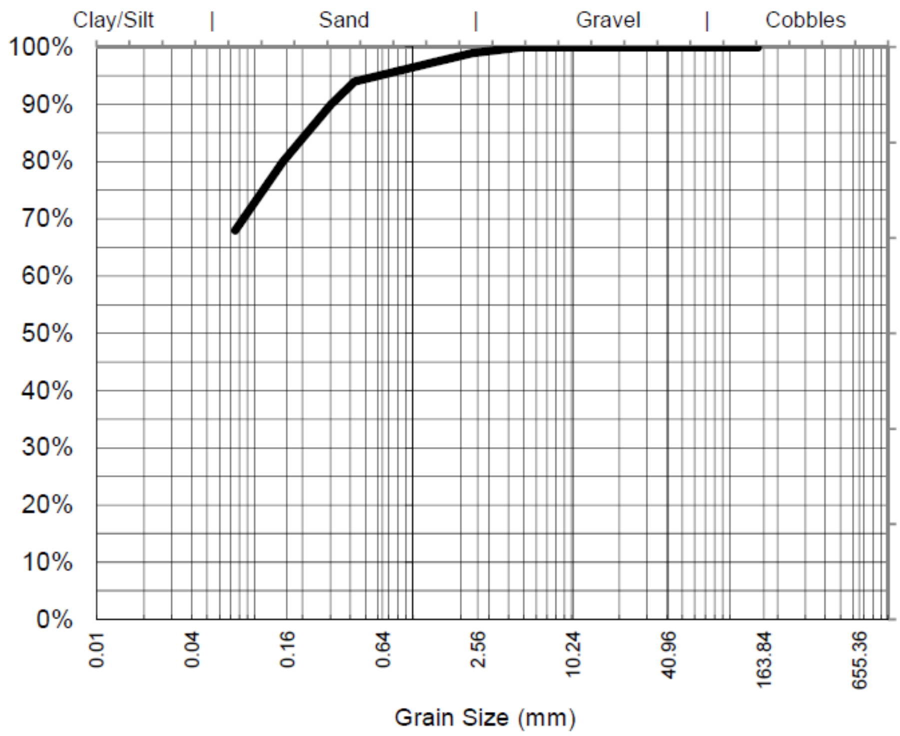


Figure 37 *Particle size distribution curve of sample MP19*

Table 3 Bulk density values for both samples MP13 and MP19

	MP13 (kg/m3)	MP19 (kgm3)
Bulk Density	2950	2210

Metal concentrations within samples MP13 and MP19 exceeded the ANZECC sediment quality guideline values for dredge material (see Table 4). These exceedances are however expected as background metal concentrations are likely higher due to the to the Astrolabe Agglomerate being known to host massive-sulphide copper-gold deposits.

Table 4 Metal and nutrient concentrations for both samples MP13 and MP19

Total Metals	MP13 (mg/kg)	MP19 (mg/kg)	Guideline value (mg/kg) (ANZECC 2000)
Arsenic	< 5	< 5	20
Cadmium	< 1	< 1	1.5
Chromium	135	266	80
Copper	28	76	65
Lead	37	20	50
Nickel	19	69	21
Zinc	64	150	200
Mercury	0.3	0.1	0.15
Nitrite and Nitrate as N (Sol.)	2.7	0.9	n/a
Total Nitrogen as N (Organic N + NH3 + TN)	2260	3000	n/a
Total Phosphorus	856	1370	n/a
Fraction Organic Carbon	0.017	0.024	n/a

Suspended sediment loads

Samples from the top, middle and bottom of the water column were taken at the approximately deepest sections of each cross section (Figure 35). The samples were analysed for turbidity/total suspended solids. In line with field observations, turbidity levels were consistently low at the surface and further down the water column at mid and bottom levels.

On three occasions an increase in turbidity was noted at the reservoir floor. Two of these were located along the main channel in the deeper section of the dam (MP07 and 08) and one at the upper end at MP13. There are multiple reasons why this could have occurred. It is likely that the ground or nearby biota were disturbed during collection of the sample however it is also possible that currents driven by temperature differences could create a similar effect.

Table 5 Total suspended sediment concentrations for all samples taken along monitoring points 2 to 19.

Monitoring point	Surface (mg/L)	Mid (mg/L)	Bottom (mg/L)
MP02	<5	<5	<5
MP03	<5	<5	<5
MP07	<5	<5	29
MP08	<5	<5	14
MP10	<5	<5	<5
MP12	<5	<5	<5
MP13	<5	<5	13
MP15	<5	<5	<5
MP17	<5	<5	<5
MP19	<5	<5	<5

4.4 Sub-bottom sampling

This section reviews the results from the GPR survey. As discussed in Section 3.3 the GPR survey was limited in the depth of penetration through the water column to a maximum of 8.5 metres.

Cross section 2

Figure 38 and Figure 39 illustrate the results gained along cross section 2. The reservoir floor is highlighted by the blue line. Figure 39 reveals what is likely to be buried bed-rock (outlined in red). The erosional surface of the reflector matches the slope of bank. The green line is an interpreted block fault.

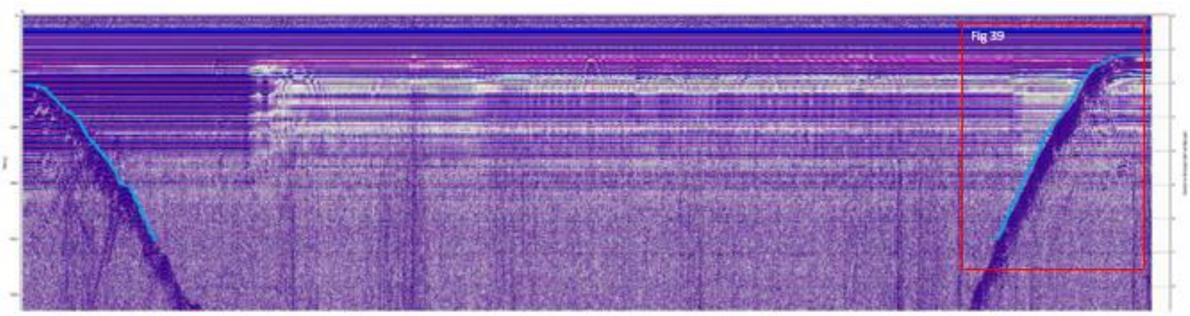


Figure 38. *Cross section 2, East to West, 341m length with expanded section outlined in red. The blue line represents the reservoir floor and the zoomed in section provides greater detail.*

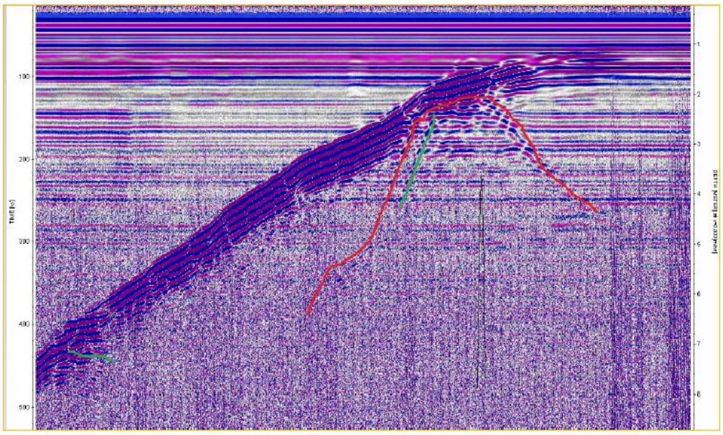


Figure 39. *The eastern bank along CS2.*

Cross Section 3

The reservoir bottom was not reached in cross section 3 (Figure 40). The reservoir floor is marked by the blue line with the yellow lines highlighting what appear to be boulders indicating minimal sedimentation in this area

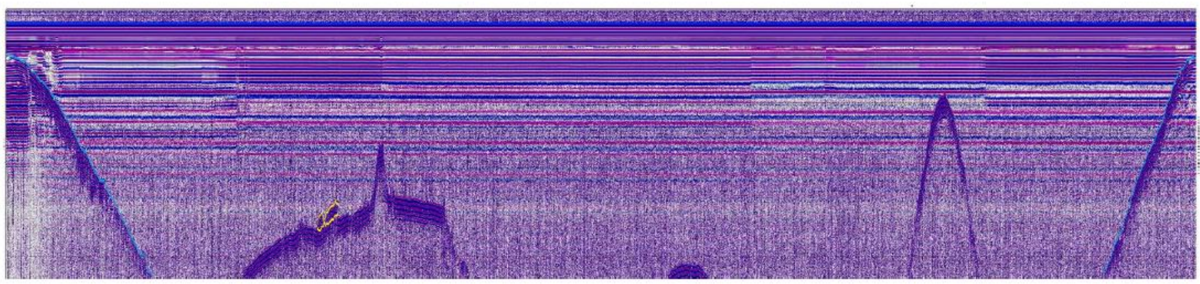


Figure 40 *A 1300m section of CS3 heading from south to north.*

Cross section 7

Cross section 7 is represented by Figure 41 and Figure 42. Imagery of the reservoir floor along this section is missing due to the limited depth of GPR at 8.5m. The hyperbola on the far-left bank is likely due to a tree stump, of which there are many throughout the reservoir. The noise in the data (blockiness) is caused by the variations in boat speed, engine noise and movements within the boat by people and equipment. Interpretation of Figure 42 suggests that the soft sediment depth is approximately 30 cm.

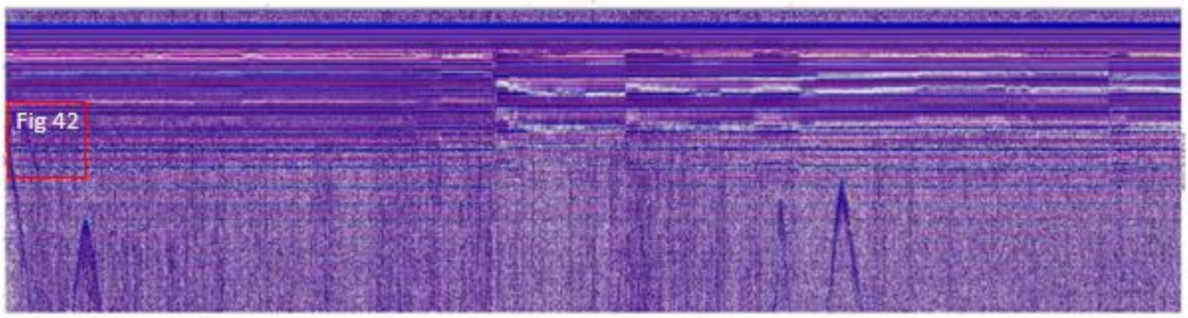


Figure 41 *A 3890m length section of CS7 from west to east with expanded section highlighted in red.*

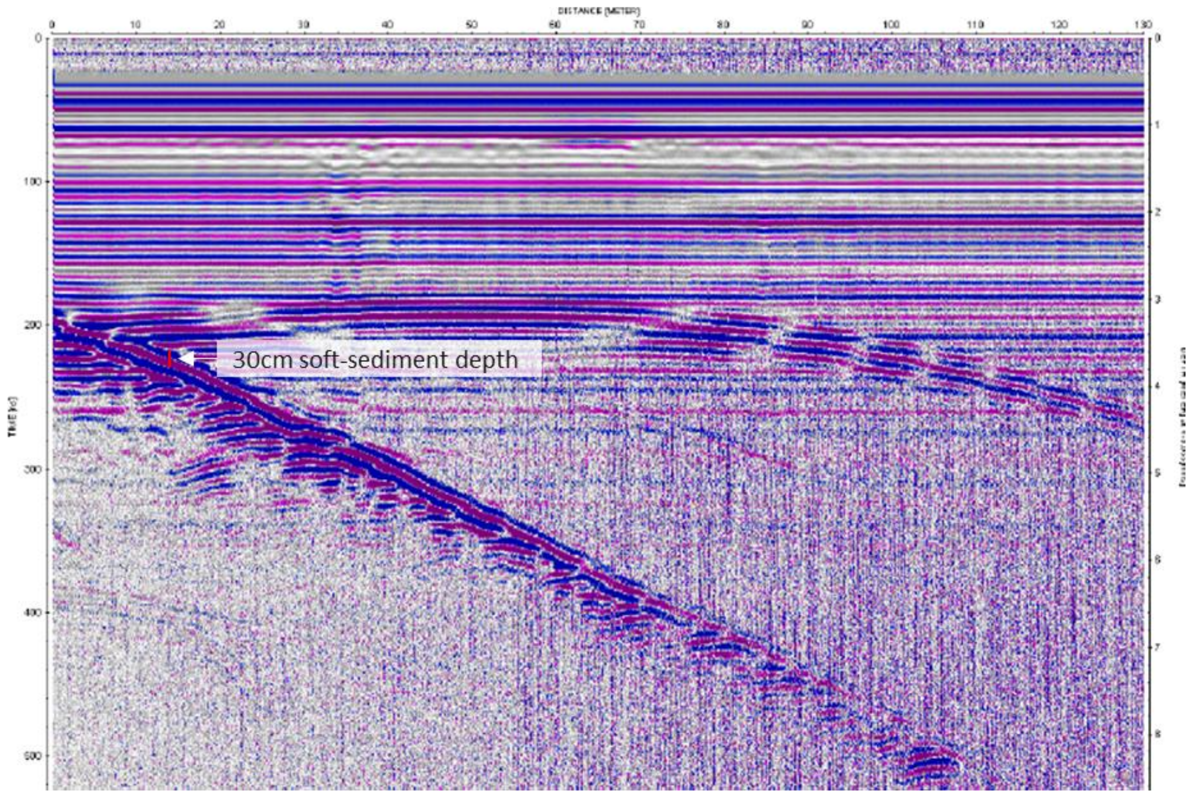


Figure 42 *The far left (western) end of the CS7 indicates a soft sediment depth of approximately 30cm.*

Cross section 8

Cross section eight is represented by Figure 43 and Figure 44. The protrusions in Figure 44 (highlighted in yellow) are likely to be boulders. The well-defined nature of the boulders suggests that sedimentation post inundation has been minimal. The orange line marks a reflector which is likely to be bedrock. This suggests a depth of saprolite in the vicinity of three metres.

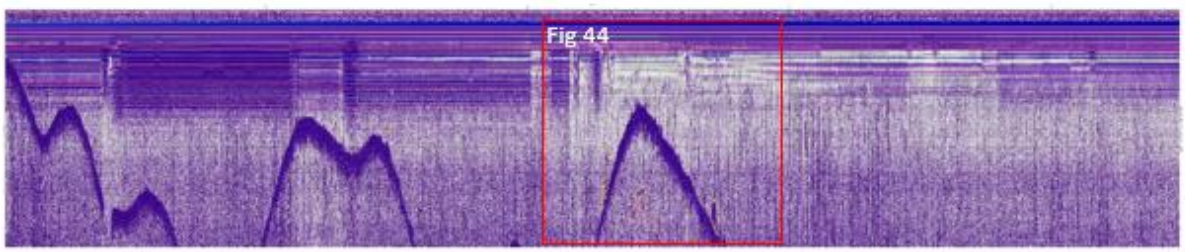


Figure 43 *A 4.45km section from east to west of CS8. The zoomed in sections below provide greater detail*

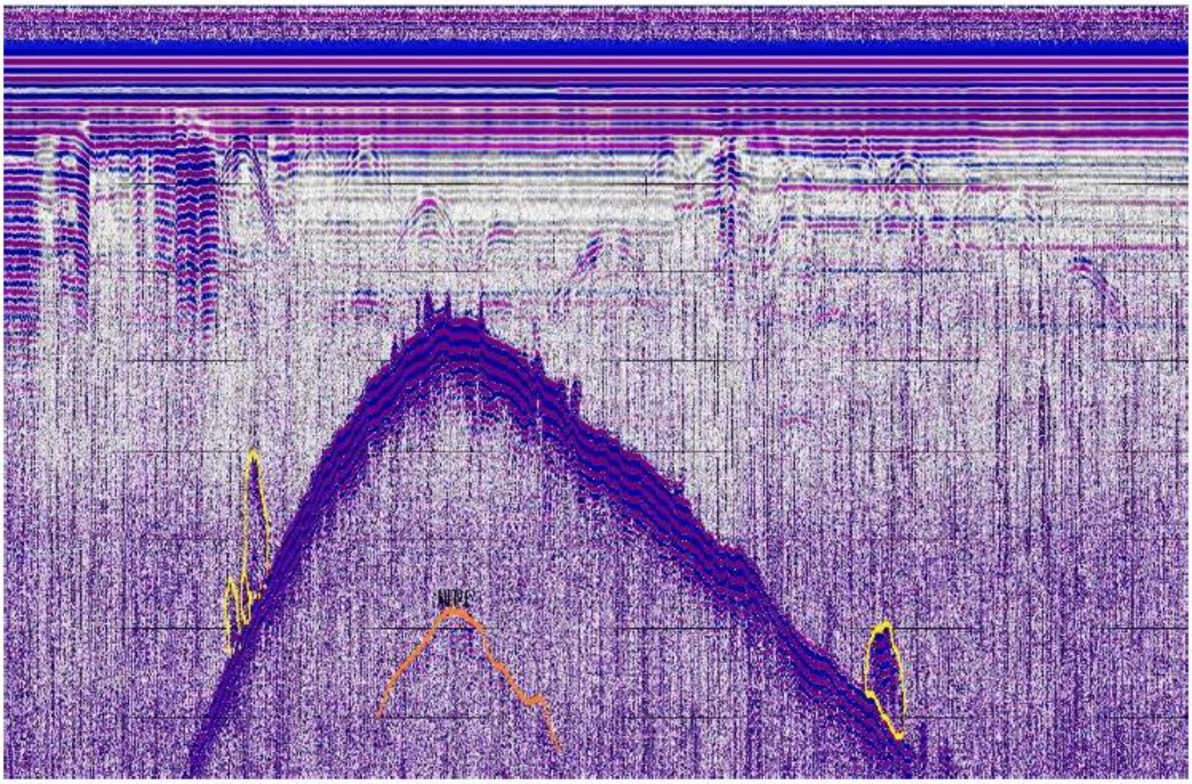


Figure 44 *A zoom in of the central section of CS8.*

Cross Section10

Cross section 10 is represented by Figure 45, Figure 46 and Figure 47. The clear definition of the boulders upon the reservoir floor (highlighted in yellow) suggests that minimal sedimentation has occurred on these higher sections since inundation.

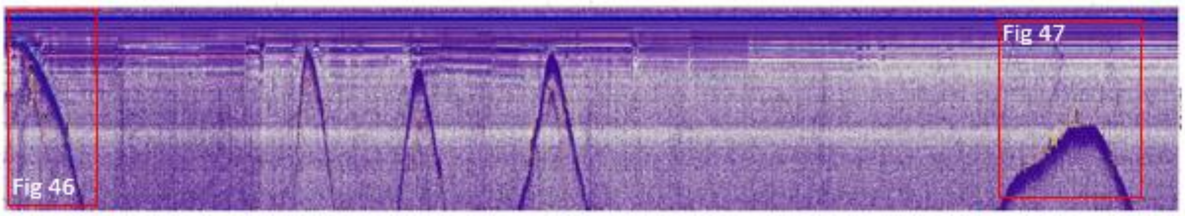


Figure 45 *CS10 with highlighted zoom sections*

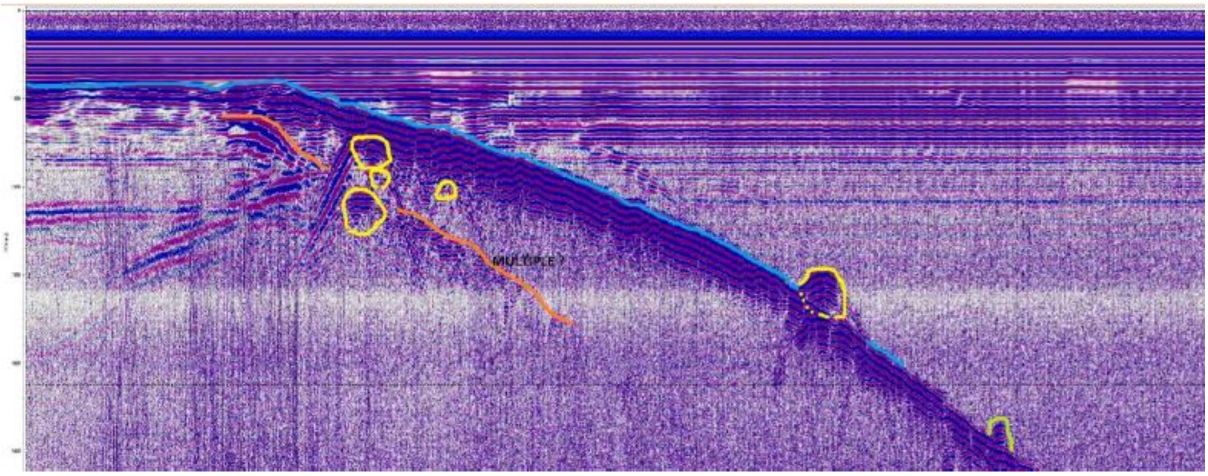


Figure 46 *Well defined boulders within agglomerate (yellow) in CS10, bedrock highlighted in orange a tree stump highlighted in green.*

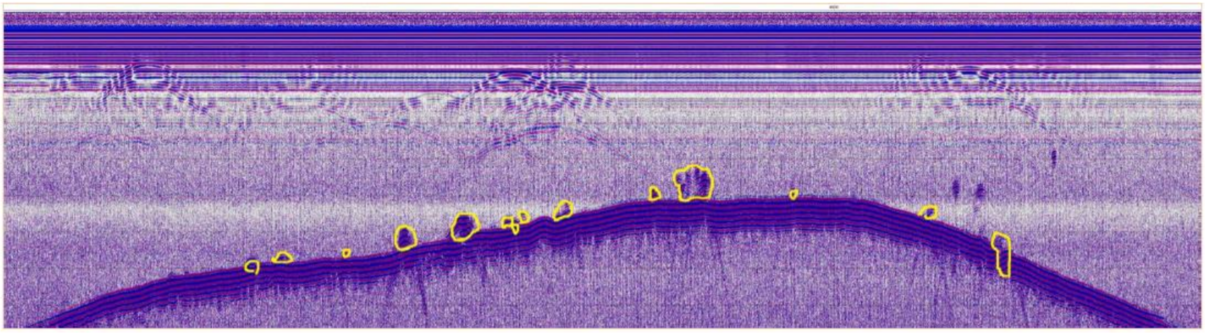


Figure 47 *Boulders highlighted in yellow along CS10.*

Cross section 12

Cross section 12 is represented by Figure 48, Figure 49, Figure 50, Figure 51,Figure 52 and Figure 53. The clear definition of the Astrolabe agglomerate below and on the surface suggests that sedimentation along the upper reservoir floor is minimal. Minimal valley fill is noted in Figure 50, with boulders (highlighted in yellow) along the channel floor. Thing suggests minimal sedimentation is occurring along this section of the reservoir.

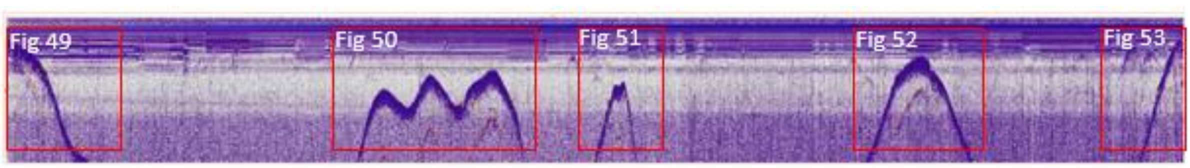


Figure 48 *CS12 from east to west. 2210m in length. Highlighted sections expanded below.*

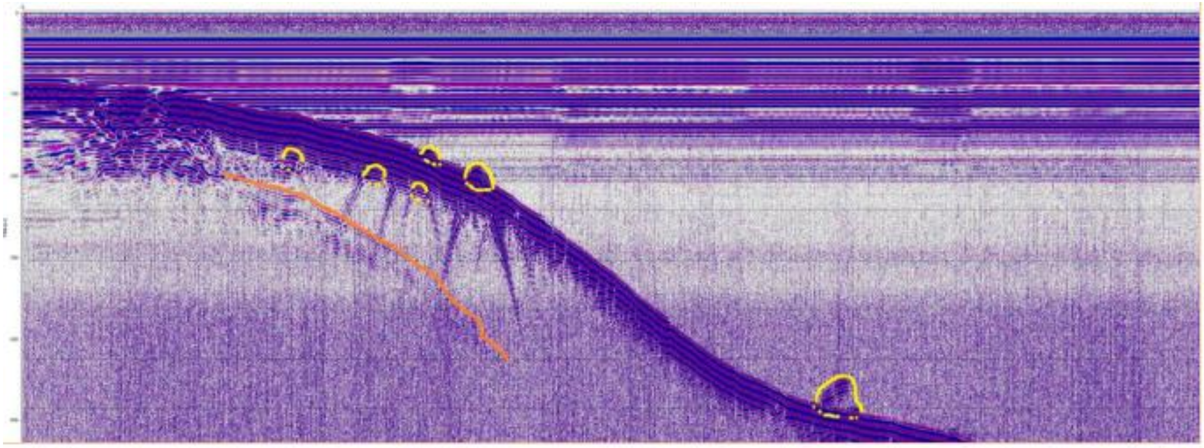


Figure 49 *Orange line delineates subsurface reflector, probably base of saprolite. Yellow marks the outlines of agglomerate boulders on CS12*

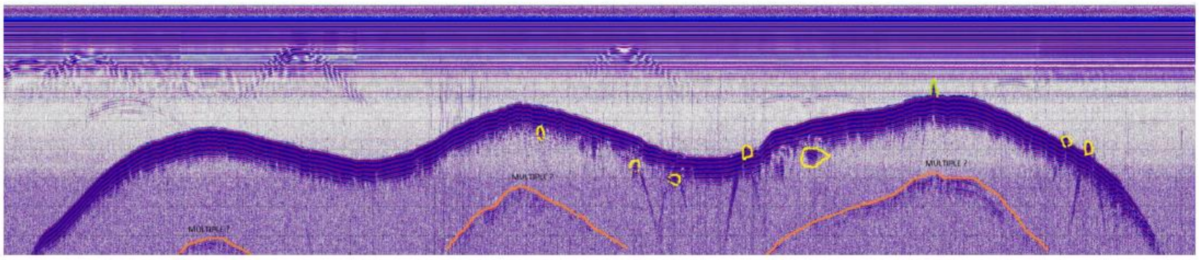


Figure 50 *Orange line delineates subsurface reflector, probably base of saprolite. Green marks a tree stump and yellow marks the outlines of agglomerate boulders on CS12*

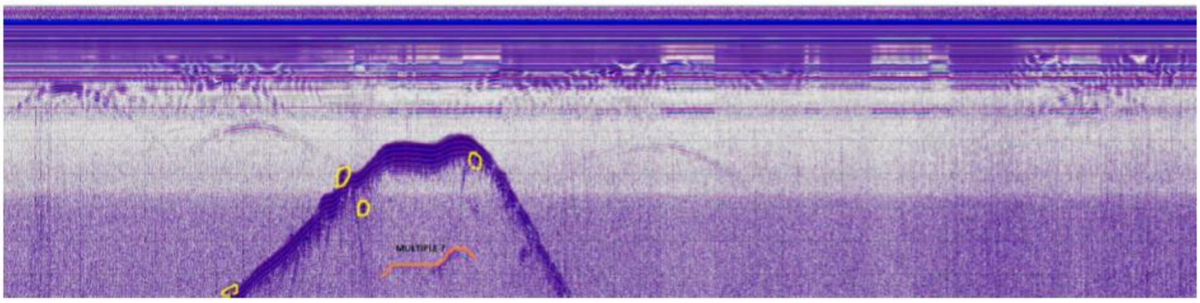


Figure 51 *Orange line delineates subsurface reflector, probably base of saprolite. Yellow marks the outlines of agglomerate boulders on CS12*

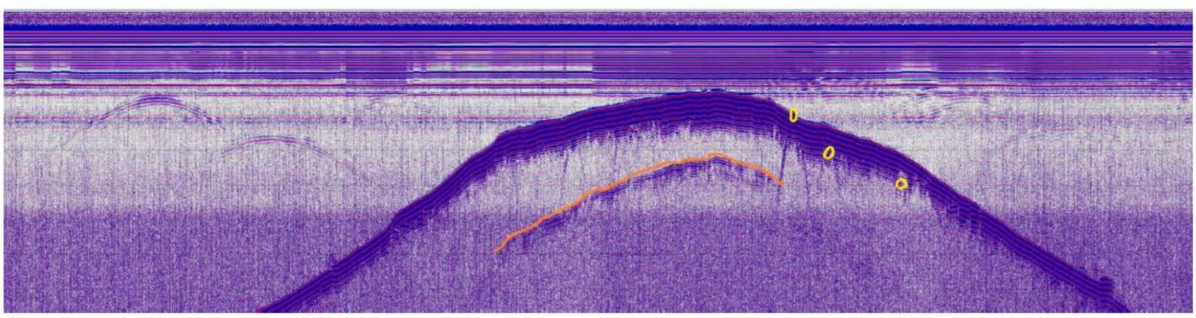


Figure 52 *Orange line delineates subsurface reflector, probably base of saprolite. Yellow marks the outlines of agglomerate boulders on CS12*

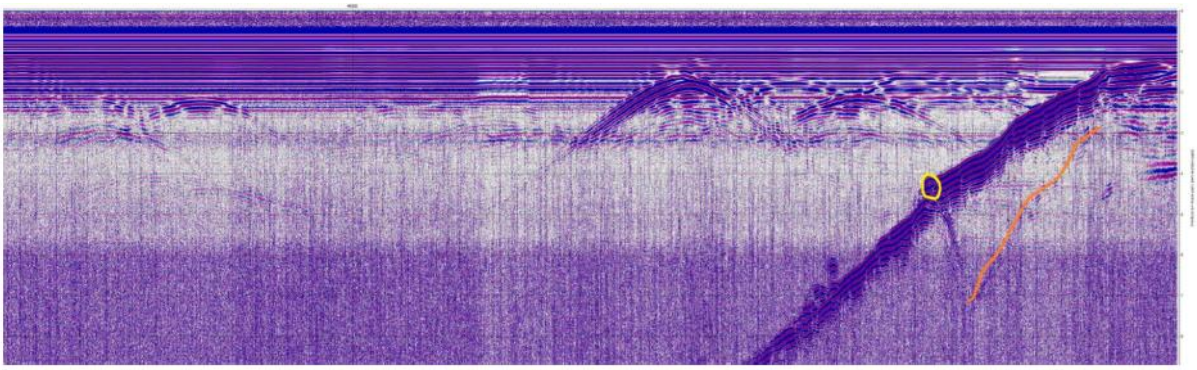


Figure 53 *Orange line delineates subsurface reflector, probably base of saprolite. Yellow marks the outlines of agglomerate boulders on CS12*

Cross section 13

Cross section 13 is represented by Figure 54, Figure 55, Figure 56 and Figure 57. Weed obstruction and poor weather introduced noise to the dataset. Nevertheless, the shallow depth enabled the reservoir floor to be profiled. The sub-surface profile does not reveal differentiation between sediments on the table-tops or in the channels. If the channels were experiencing pronounced post inundation siltation, a considerable difference between table top and channel floor profiles would be expected. Channel features are well defined, suggesting minimal sedimentation is taking place.

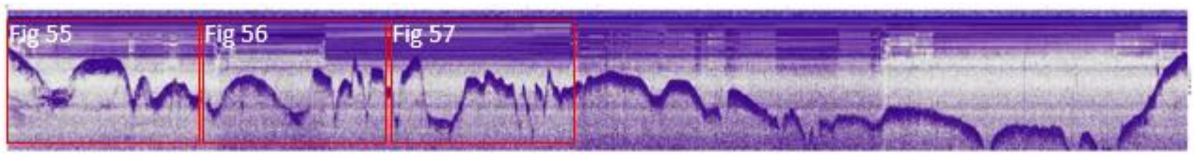


Figure 54 *2210m long section along CS13. Figures 55 -57 provide higher detail.*

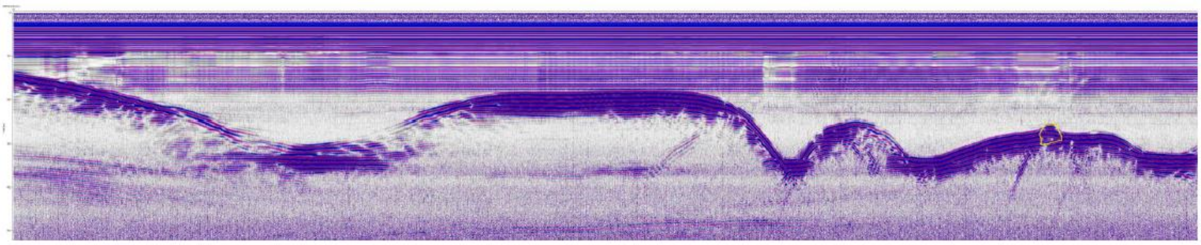


Figure 55 *Slightly flattened channel bottoms. Boulder outlined in yellow on CS13*

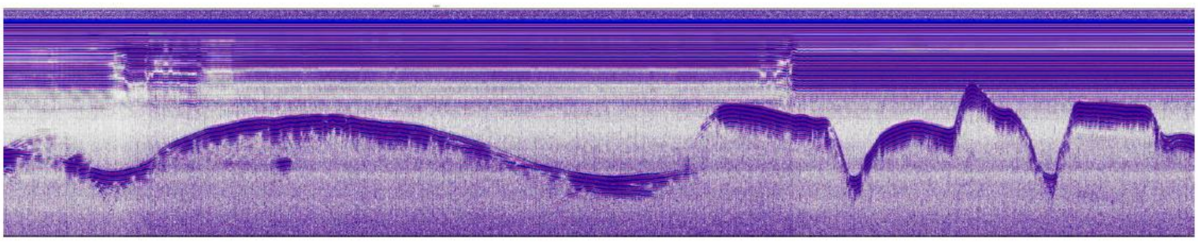


Figure 56 *The reduced penetration of the radar restricts the ability to estimate the true thickness of sedimentation in the channels on CS13*

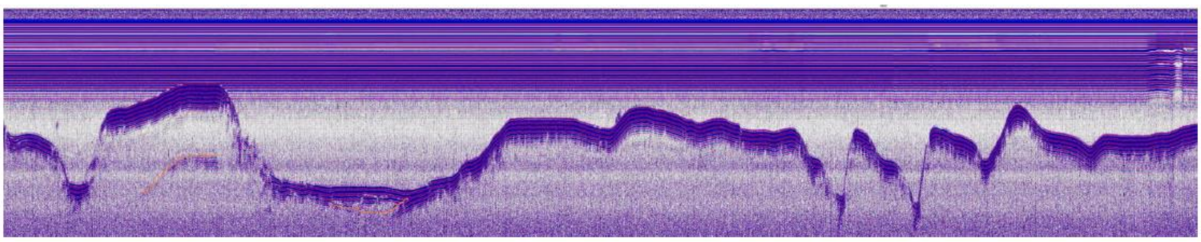


Figure 57 *Orange outlines the top of bedrock. Note the well-defined channels on CS13 with minimal flattening at their base.*

Cross Section 15

Cross section 15 is represented by Figure 58,Figure 59, Figure 60 and Figure 61. Boulders marked in yellow in Figure 60 and Figure 61 suggest that the layer above the orange line is likely to be saprolite (weathered rock). The definition of the boulders also suggests that sedimentation post inundation has been minimal.

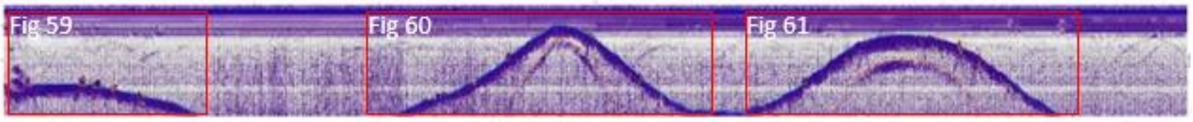


Figure 58 *CS15 from south to north. 1230m long. Figures 59 -61 provide higher detail*

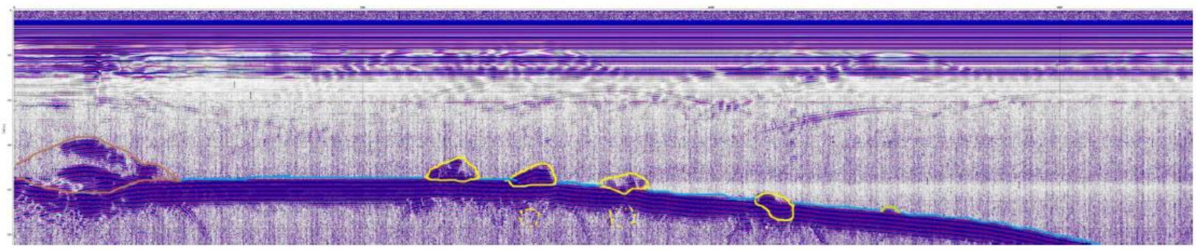


Figure 59 *Tree stumps highlighted in green and agglomerate boulders in yellow*

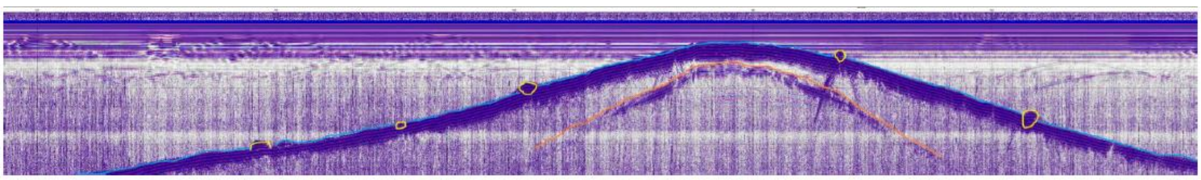


Figure 60 *Orange reflector possibly base of saprolite or sedimentation. Boulders marked in yellow*

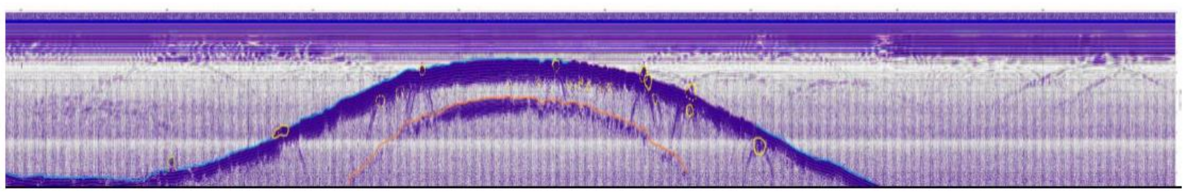


Figure 61 *Orange reflector possibly base of saprolite or sedimentation*

Cross section 17

Cross section 17 is represented by Figure 62, Figure 63 and Figure 64. The depth of post inundation sedimentation is not clear across the three images. The parabolic reflector in the centre right of Figure 62 is likely to be a tree. The delineation of a tree stump in Figure 63 suggests that that sedimentation on the elevated slopes of this cross section is minimal.

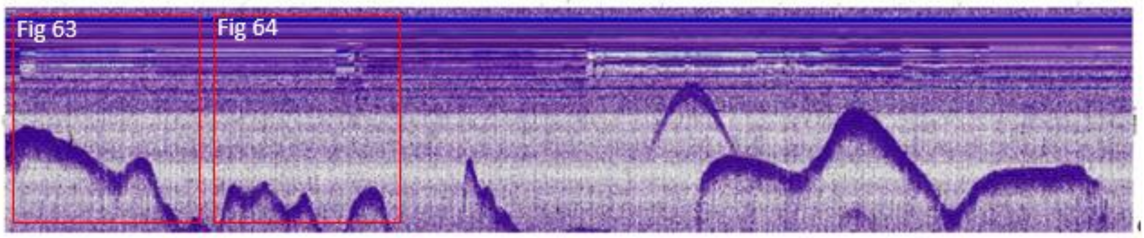


Figure 62 *Depth to channel floor beyond penetration depth on CS17. Depth of weathered rock approximately 3m. Depth of soft sediment post inundation is not clear. Figures 63 -64 provide higher detail*

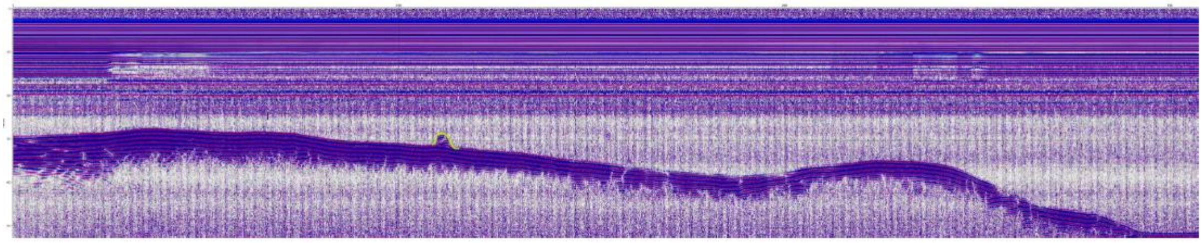


Figure 63 *The shallow reservoir floor on CS17 features multiple tree stumps, marked in green. The delineation of these finer features suggests that sedimentation on these higher slopes in minimal.*

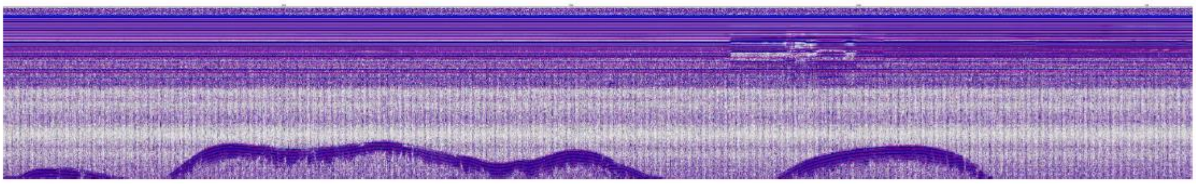


Figure 64 *The main channels in CS 17 fall below the 8.5m limit.*

Cross Section 19

Cross section 19 is represented by Figure 65, Figure 66 and Figure 67. The radar signal is lost in the channel features which restricts interpreting the magnitude post inundation sedimentation. However, the upper channel banks appear well defined. Each end of the cross section displays a relatively thicker zone of saprolite or possibly soft sediment.

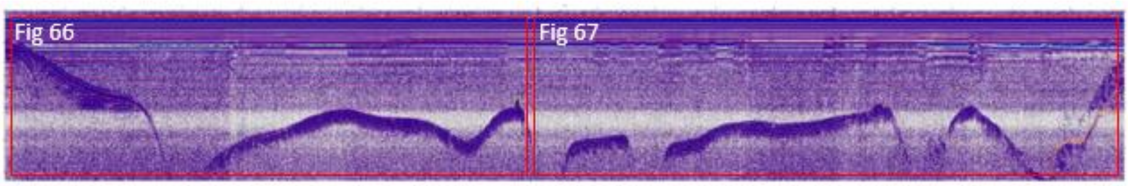


Figure 65 *CS 19, a north-west to south-east section 553 m long. Figures 66 -67 provide higher detail*

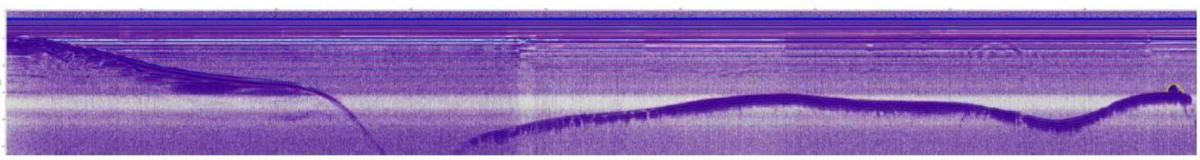


Figure 66 *Possibly a thickening of soft sediment or the saprolite horizon on the upper left-hand terrace in CS19. Main channel below 8.5m limit.*

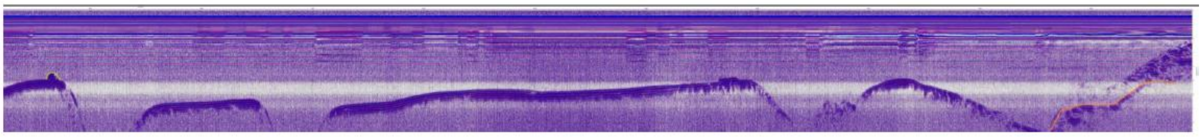


Figure 67 *The far right of the section suggests that the bank terrace has experienced sedimentation, possibly through slumping.*

Conclusions

Interpretation of the GPR dataset is limited. The poor penetration and lack of calibration does not allow for a high degree of confidence in distinguishing sedimentary layers from saprolitic ones. The presence of boulders within the subsurface and surface strata however does suggest that the main reflector highlighted in orange marks the saprolite/fresh rock boundary. Observations made during the construction of Sirinumu Dam noted that the saprolite depth can vary in the tens of metres.

If this is the case, in conjunction with the well-defined channel -beds in the shallower sections, it is likely that sedimentation within the dam is low.

However, without drill-core data or another means to ground truth the reflectors, GPR alone cannot absolutely differentiate between:

- Modern sediment load (post valley drowning)
- Quaternary soft sediments
- Regolith/Saprolite

5 Summary and next steps

5.1 Summary

Field observations in April 2018 indicated that within the dam there was no evidence of major sedimentation issues. There was good water clarity, no observed deltas or sediment deposits at inflow points and limited fine sediment attached to submerged vegetation or instream timber/trees which is often observed in water bodies with high suspended sediment loads.

The SOPAC 2007 bathymetric study of the reservoir supports these field observations. It found that the former channels had not been infilled, indicating that sedimentation in the dam since 1967 is very low. These findings meant that a comprehensive resurvey was not warranted.

The bathymetric survey, sediment sampling and sub-bottom profiling undertaken as part of this study have confirmed that there appears to have been minimal sedimentation within Sirinumu Dam since construction. The evidence to support this conclusion include:

- The bathymetric survey comparisons did not identify significant channel fill or change in channel reservoir floor morphology. This indicates that rates of sedimentation are very low.
- The only noted change was possible slumping of reservoir margins, which does not impact overall reservoir capacity as it is a redistribution of floor sediment.
- The GPR survey revealed well defined reservoir floor features across most sections of the dam. This suggests that rates of sedimentation are very low.
- Suspended sediment samples suggest that turbidity levels are at a minimum within the reservoir.
- The two successful sediment samples contained gravels. This indicates that the sample contains in situ sediments prior to dam construction. This suggests that rates of sedimentation are very low.
- The lack of soft sediment available for sampling by the dredge suggests that post inundation sedimentation is minimal across the other sections of the dam.

From these observations, it is clear that the reservoir is currently experiencing low levels of sedimentation, however this may increase in the future if there is extensive land clearing.

5.2 Next Steps

The next steps for the project are outlined in our revised work plan (see Attachment A). In summary these steps include:

- Geomorphic assessment of waterways to assess sediment storage and transport processes (nearing completion)
- Hydraulic assessment of waterways to determine sediment transport capacity (nearing completion)
- Catchment modelling to determine catchment erosion rates (nearing completion)
- Estimate the impacts of different future changes to land use, climate and management strategies on sedimentation within Sirinumu Dam and the downstream Laloki River
- Analysis of ecological impacts of sedimentation
- Analysis of socio-economic impacts of sedimentation
- Development of recommendations to mitigate sedimentation impacts

6 References

Sedimentation survey of Sirinumu reservoir Eastern Highlands, Papua New Guinea, 2007, SOPAC technical report 411, Smith, R.

Simpson SL, Batley GB and Chariton AA (2013). Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines. CSIRO Land and Water Science Report 08/07. CSIRO Land and Water.

UNESCO, 2001. Partners in coastal development – The Motu Koitabu people of Papua New Guinea. Proceedings of and follow-up to the 'Inaugural Summit on Motu Koitabu Development, National Capital District, Papua New Guinea', Baruni village, 31 August – 1 September 1999. Coastal region and small island papers 10, UNESCO, Paris, 78 pp.

Attachment A
Revised work plan

Memo

Subject	Summary of inception mission and work plan
Distribution	Joycelyn Nagai-Muriki (UNDP), Gretel Orake (UNDP), Emily Fajardo (UNDP), James Sabi (CEPA)
Date	July 2018
Project	Sedimentation study of Sirinumu and Laloki River

Introduction

Alluvium Consulting has been engaged by the UNDP and the Conservation and Environment Protection Authority (CEPA) to undertake an assessment of sedimentation processes to provide an empirical baseline understanding of the existing sources and extent of sedimentation within the Sirinumu Dam and the Laloki River. The work will help inform the development of the Sirinumu Dam Integrated Land Use Plan.

This memo provides an overview of an inception mission undertaken between the 23rd and 27th of April 2018 by Rohan Lucas and Misko Ivezich (both of Alluvium Consulting)..A revised work plan is also proposed following a review of the data supplied by CEPA and PNG Power in June and July 2018

Overview of meetings and workshop

Meetings and discussion were held on the 24th and 25th of April between Alluvium and staff from the UNDP, CEPA, PNG Power, Eco Custodian Advocates, Kokoda Initiative and a local government representative from Sogeri (Alfred Kennedy). The key learnings from these discussions included:

- CEPA primarily want to understand and protect the ecosystem services provided by the Sirinumu Dam and Varirata Protected Area.
- Sedimentation of Sirinumu Dam does not currently seem to be impacting on PNG Power's operations. Major issues for PNG Power is siltation of their head ponds further downstream on the Laloki River.
- Catchment derived sediments in the Laloki River catchment are most likely being generated in Sogeri Plateau region due to land use practices.
- Eco Custodian Advocates are currently undertaking a land use study. The sedimentation study and land use study are intrinsically linked, and dialogue will need to be maintained between the project teams.
- The dam wall currently leaks (SMEC, 2018) up to 70ML/d. The dam may also leak through geologic structures or where the clay cover on the agglomerate has been lost in the base of the dam.

Field observation

On the afternoon of the 25th of April a rapid catchment assessment was undertaken visiting a number of sites along the Laloki River and on the Sogeri Plateau. On the 26th of April a boat trip around the Sirinumu Dam was undertaken. Key observations include:

- Laloki River downstream of the Sogeri Plateau is a steep gorge system with high sediment transport capacity and very limited potential for sediment deposition.
- Upstream of the gorge (upstream of waterfalls) the waterways are both confined and partly confined with isolated zones of discontinuous floodplain deposits where sediments are stored (and eroded)

- Downstream of the gorge the river transitions from partly confined by hillslopes and bedrock to predominantly unconfined with mostly alluvial channel boundaries that can be eroded and floodplains where deposition will occur

- The geology of the region consists of the Astrolabe Agglomerate unit (containing large basalt rocks) and basalt units which both weather to fine sediments (i.e. clay) (see Figure 1). Coarse bed load material (i.e. sands and gravels) were not prevalent at the locations where the waterways were inspected.

- Land use across the area was a mix between forested area and areas cleared for agriculture (i.e. grazing, vegetables, fruits etc.). Often cleared areas were quite small (i.e. less than 1 hectare) but also consisted of large areas on the Sogeri Plateau which are periodically burnt. These burnt areas were often on steep slopes.

- The clay dominated soil profile is relatively cohesive and resistant to mobilisation and provides for dense vegetation growth

- Within the dam there was no evidence of major sedimentation issues. There was good water clarity, no observed deltas or sediment deposits at inflow points and limited fine sediment attached to submerged vegetation or instream timber/trees which is often observed in water bodies with high suspended sediment loads.

- A mechanism with potential to move sediment within the dam is likely to be due wind generated wave erosion in locations where there is a large fetch or on islands subject to variable inundation depths without vegetation cover. The impact of this sediment source on overall storage capacity is likely to be negligible as it is only re-distributing sediment within the dam.

- The majority of clearer areas within the dam catchment are along the western side of the dam on the footslopes of the range, however other than where gardens/pineapple growing occurs, they retain a good ground cover with sparse mature trees (typical of burnt savannah).

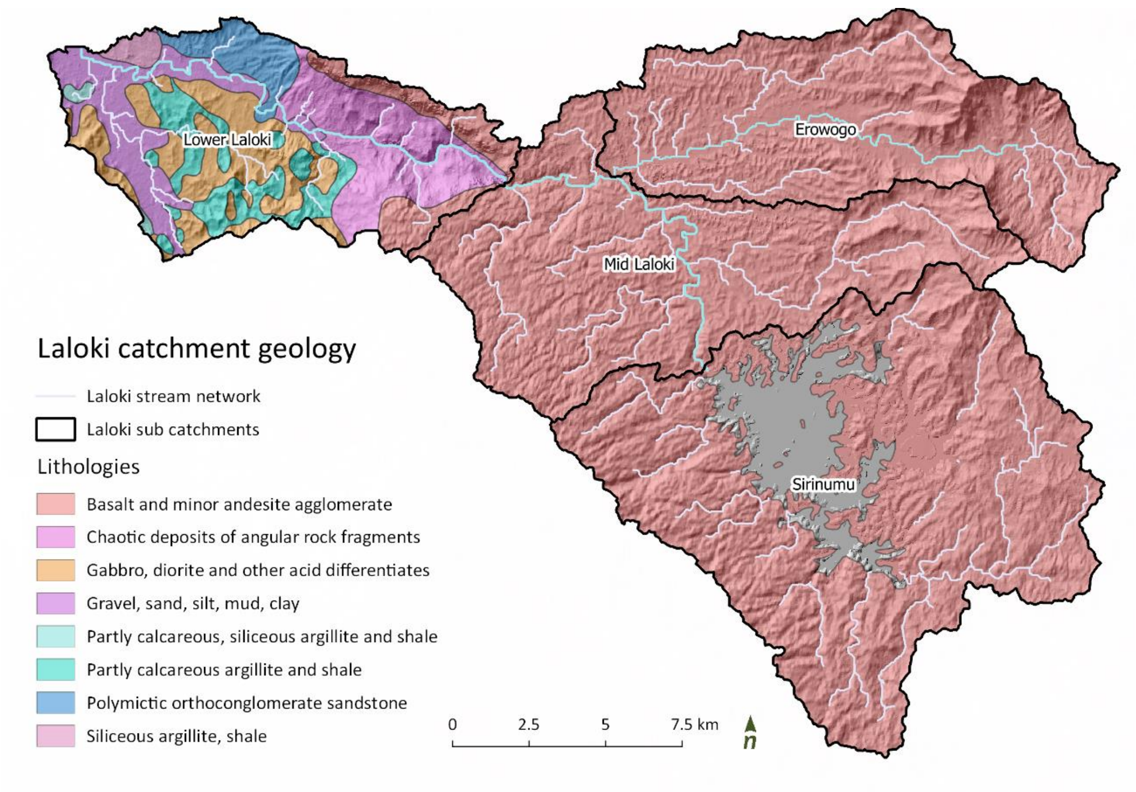


Figure 1. *Geology within the Laloki River catchment*

Data availability

A large component of our meetings and discussions focussed on what data will be available to inform the study. Determining what data is available will be critical to finalising our proposed work plan. In June 2018 and July 2018 both CEPA and PNG Power provided data to inform the study. The below table provides an overview of required data sources and their purpose for the sedimentation study. The third column provides an indication on what data has been supplied and its implications on the proposed work plan.

Situation understanding

Port Moresby water supply and hydro power generation relies on flows in the Laloki River. These are the unregulated flows from the Sogeri Plateau (Varo Creek and other smaller tributaries) and releases from Sirinumu Dam. In general, water supply to the Eda Ranu treatment plant comes from Rouna 2 power station, relatively high in the catchment. In the event adequate flows are not present in the upper catchment, water is drawn from the Laloki River at Bomana pump station. The quality of water at this pump station is likely to be far poorer than at Rouna 2 due to increasing land use pressure in the catchment (human and agricultural effluent, sediment, solid waste, etc). With increasing land use activity in the catchment for agriculture and impacts such as burning of savannah, water quantity and quality in the catchment are likely to change.

Sediment is a key driver for this study. Sedimentation appears to be affecting the head ponds for PNG Power and the structures in the Laloki River channel. The high energy conditions of the river allow for relatively easy flushing of finer sediment through the system. Suspended sediment will also impact on cost of water treatment for Eda Ranu. In the lower reaches of the Laloki River, sediment will impact direct human consumption and amenity.

In 2007 a bathymetric survey of the Sirinumu Dam was undertaken by the Secretariat of the Pacific Islands Applied Geoscience Commission (SAPOC). 123 bathymetric profiles (155km) of the reservoir were processed and interpolated to yield a 10m grid DTM of the reservoir. The dam was divided into four broad zones (Figure below) and a cross-section profiles analysis examined the results of the DTM in respect to the principle branch source areas feeding the reservoir. The profiles were chosen to correlate with actual bathymetric results.

No pre-dam topography was available to compare with the 2007 survey. However interpretation of the morphology of the bathymetry profiles indicated the widespread presence of former channels on the reservoir floor. The fact that these former channels had not been infilled indicated that sedimentation in the dam since 1967 is very low.

No major sedimentation issues were observed during the preliminary field inspections undertaken in April 2018. This finding correlates strongly with the 2007 study and indicates rates of sedimentation within Sirinumu Dam are currently low. However rates of sedimentation may increase in the future if there is significant land use change within the catchment.

Table 1

Required data	***Purpose***	***Data supplied***	***Implications on study***
Hydrological data including rainfall and stream flow data within the Sirinumu Dam and Laloki River	*To inform the understanding of rainfall runoff relationships within the catchment including seasonal, annual and longer term variations*	*None*	*Will need to rely on available data from Port Moresby*
Land use data within the Laloki River (i.e. the mapping Department of Agricultural & Livestock had in the 80s or 90s)	*To inform the understanding of sediment generation within the catchment*	*A land cover layer was supplied by CEPA* *There is also a current land use study being undertaken which will feed into this investigation*	*Will assist in calculating hillslope erosion rates*
Geology and soils data with the Laloki River catchment	*To inform the understanding of sediment generation within the catchment*	*A Geology layer was supplied*	*Will assist in understanding the sediment generation processes*
Terrain data (i.e. the 5 m Digital Elevation Model (DEM)) derived from Radar survey)	*To delineate catchments, determine river morphology to assess sediment transport capacity and catchment slope analysis to inform sediment generation*	*A 5 m DEM was supplied by CEPA*	*The terrain data will be used to determine hillslope erosion rates and geomorphic classifications*
River bathymetry surveys	*To determine cross-sectional area to assess sediment transport capacity and any sediment accumulation impacts*	*None*	*Detailed hydraulic modelling of the river will not be possible* *Higher level hydraulic modelling can be undertaken utilising the 5 m DEM*
Satellite and aerial imagery including historical imagery (i.e. JICA satellite imagery)	*To determine current land-use, riparian and catchment vegetation condition and geomorphic units i.e. bars, deltas, islands etc*	*None*	*Will rely on Google Earth imagery*
Information relating to the Dam and other hydropower sites (i.e. old surveys, inflow/outflow information, bathymetry, historical sediment	*To understand the scale and impacts of sedimentation on hydropower generation and water supply*	*Only a report supplied by PNG Power - Sedimentation survey of Sirinumu reservoir Eastern Highlands, Papua New Guinea,*	*A detailed bathymetric survey of the dam, concluded no sedimentation issues. Revised survey plan required – see proposed work plan below.*

removal works, leakage assessments (i.e. SMEC report) etc.)	*2007, SOPAC technical report 411, Smith, R.*

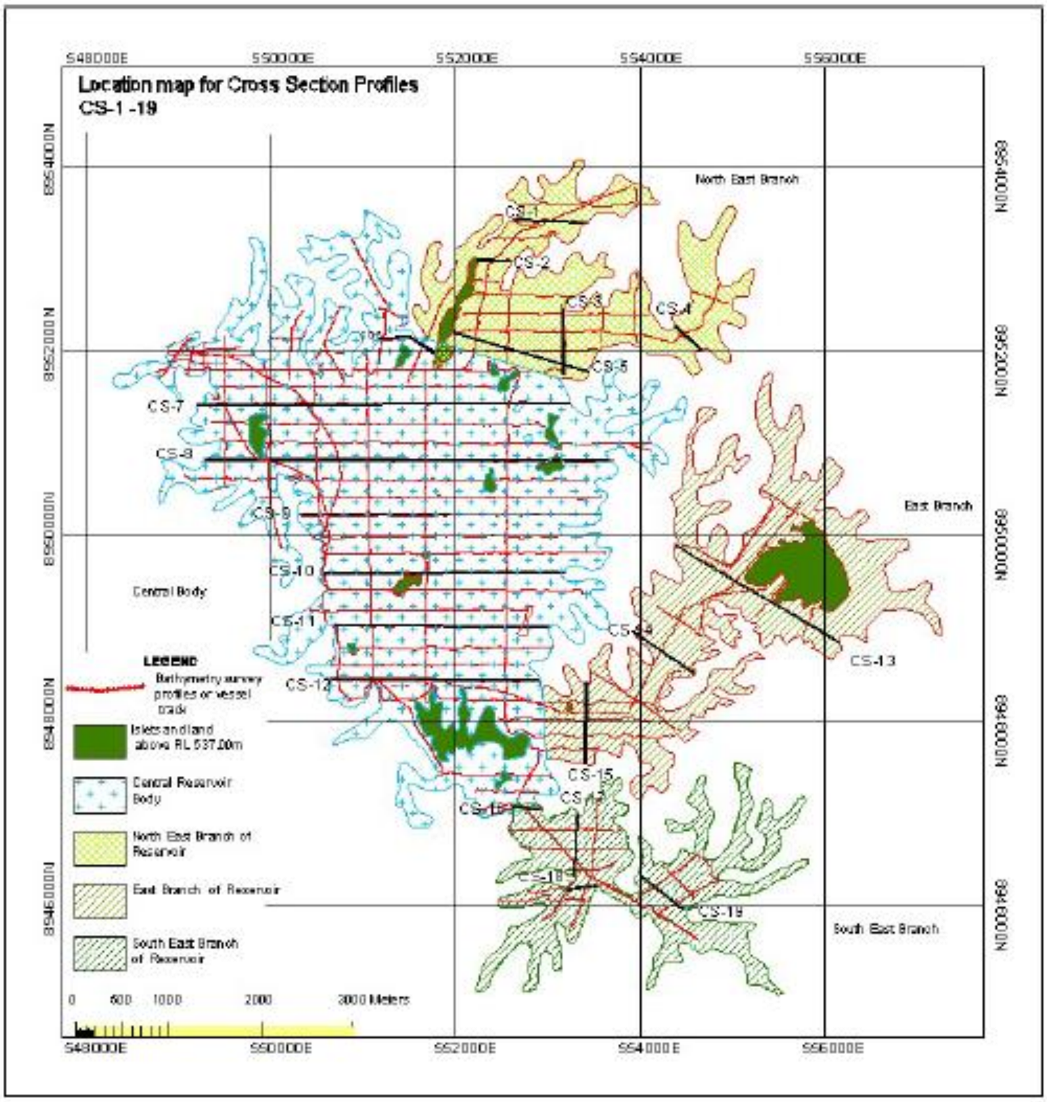


Figure 2. *The Sirinumu Dam was divided into four sectors with cross-section profiles in each sector*

Can the study provide benefits for multiple stakeholders?

Based on conversations during the inception mission it would seem that gaining a better understanding of the biophysical functions of the Laloki River catchment are highly important to a number of stakeholders. Primarily it is a situation where the reliability of hydropower and domestic water supply for Port Moresby and surrounds needs to be better understood and managed. For water, this includes both quantity and quality.

Examples of benefits to various stakeholders could include:

- **PNG Power –** risk management for the business by understanding water balance in the system (regulated vs unregulated flows), reduced requirement to remove sediment from head ponds and interrupt power and water supply
- **Eda Ranu –** better understanding of quantity and reduced cost of treatment for quality and the further implications of people being able to drink the tap water without the threat of illness (and the consequential benefit of less plastic bottle waste)
- **Varirata NP** – increased protected areas in the ecotone, which in turn reduces water quality impacts from catchment use

- **People of Sirinumu dam catchment –** custodians of water quality for the national capital city
- **People of Sogeri plateau** – linked with the land use study, potential for better land use productivity by understanding land use practices that don't lead to erosion

Delivery issues/constraints/opportunities
The original Terms of Reference (TOR) was not specific about the study area. The TOR referred to sedimentation and siltation in Sirinumu Dam and Laloki River. Within our proposal we had assumed this was the Laloki River upstream of the Sirinumu Dam. However, based on discussions with CEPA the study area was intended to extend downstream to the confluence of the Goldie River and Laloki River (or at least as far as Bomana pump station) (Figure 3).

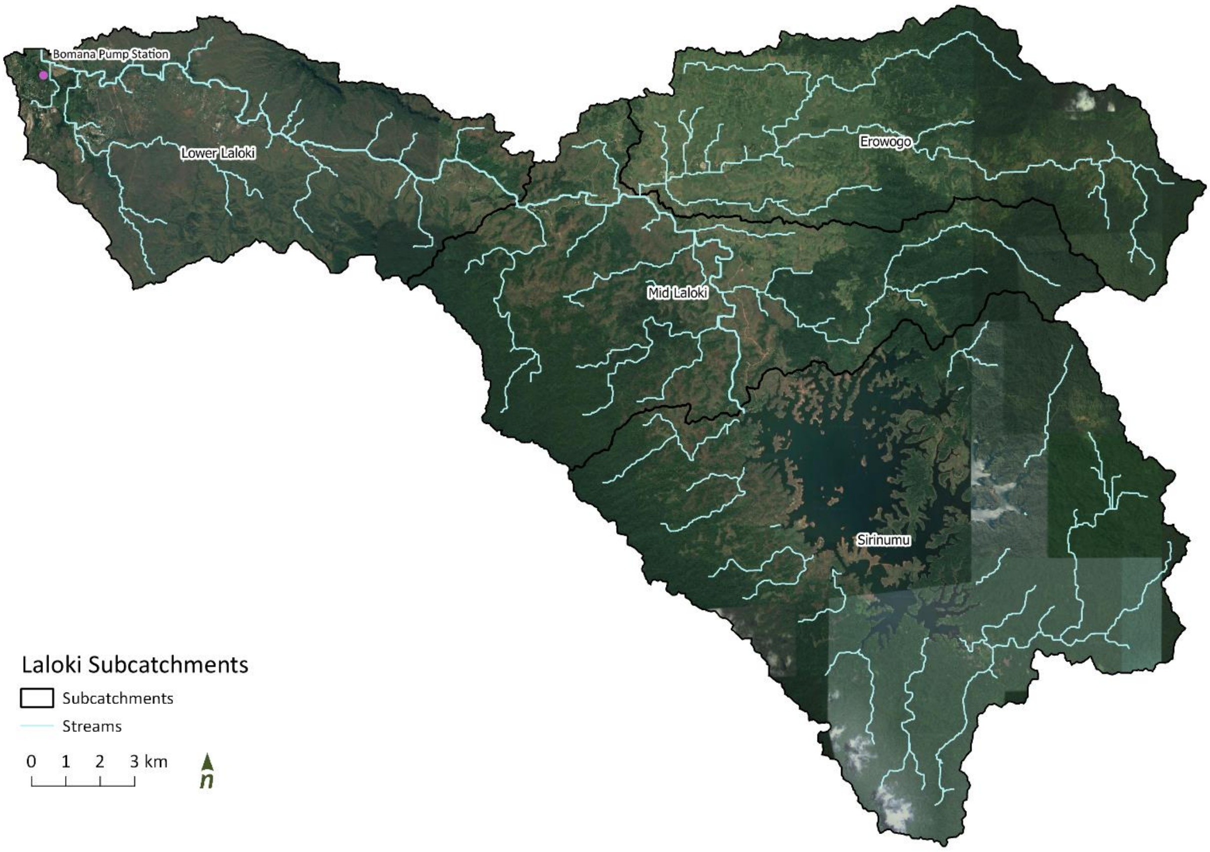


Figure 3. *Intended study area of the Laloki River catchment*

Most of the sediment within the Laloki River system appears to be derived from outside the Sirinumu Dam catchment. Given that a full bathymetric survey of the dam was undertaken in 2007 it is recommended that this is not repeated. There is an opportunity to reduce the proposed level of assessment within the Sirinumu Dam and instead undertake more detailed assessments of the broader Laloki River catchment.

We have developed a revised work plan based on the available data and findings from the 2007 sedimentation survey. The revised workplan is presented below.

Revised works plan

Task 2 – Bathymetric survey and sediment sampling
Given a detailed bathymetric survey was undertaken 2007 and its correlation with the 2018 field inspection thatsedimentation rates are low we are not proposing a full bathymetric survey be repeated. Rather it is recommended that a number of key sections in each of the four reservoir zones be resurveyed. These locations can be utilised for ongoing monitoring of bathymetry. The proposed monitoring sections for survey

are presented in Figure 4. The bathymetry team will use a Remote Control ‘Q Boat’ (Survey Boat) which can be fitted with a range of Echo Sounder and Acoustic Doppler instrumentation, with integrated Differential or RTK survey base station units, providing accurate depth information and location survey data. Two dimensional topographical plots will be produced at each monitoring section to allow comparison to the 2007 sections.

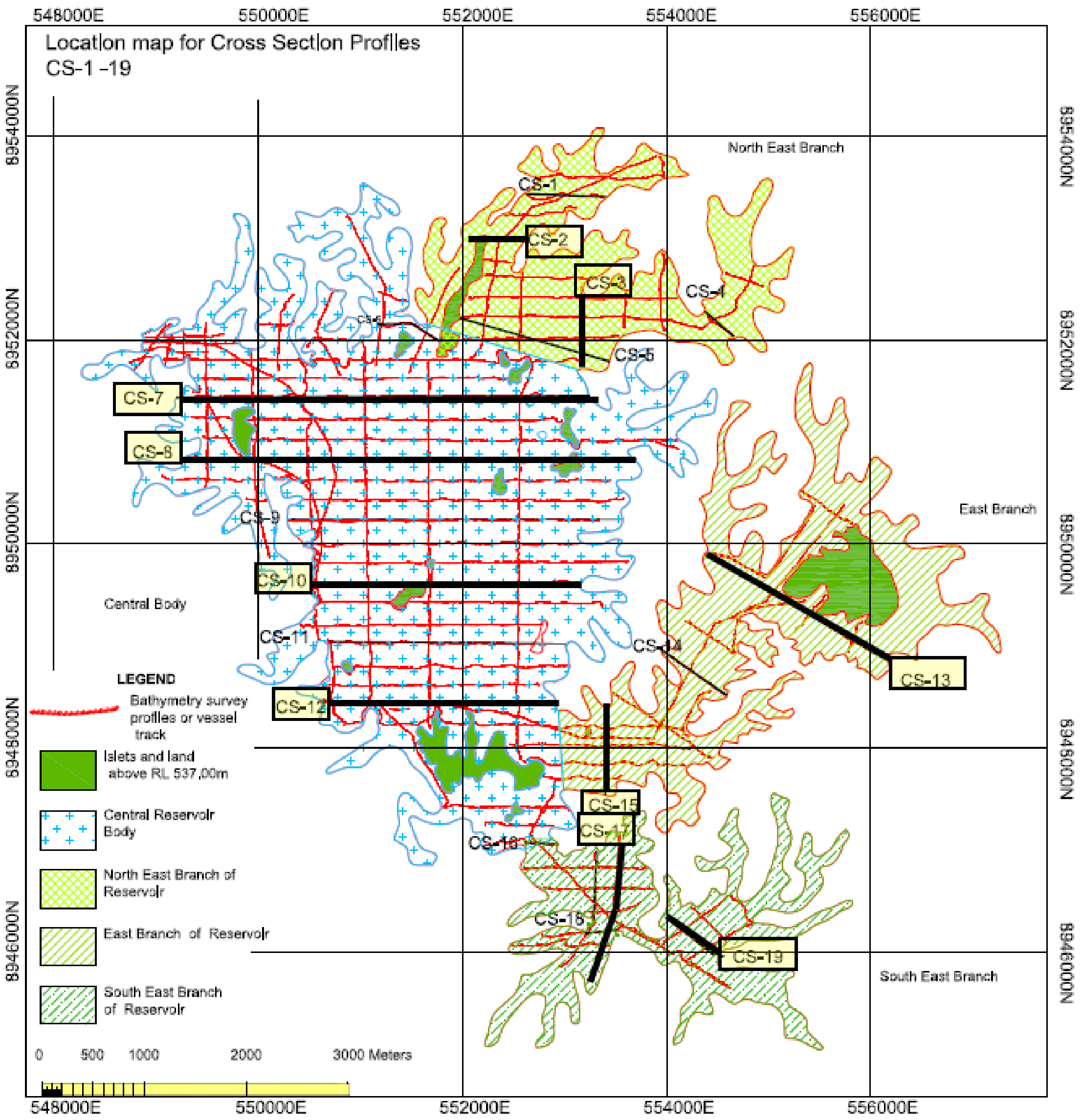


Figure 4. *The ten monitoring sections shown in bold within Sirinumu Dam*

Sub bottom profiling using a Ground Penetrating Radar unit will be conducted simultaneously with the bathymetric survey data at each monitoring section. Sub bottom profiling systems are employed to identify and characterise layers of sediment and rock. We will determine the sediment layer thickness at each monitoring section. Two dimensional topographical plots will be used to present the sediment layer thickness at each monitoring section.

Sediment samples will be undertaken for the Sirinumu Dam. The purpose of the sampling is to physically and chemically characterise the sediments which will provide indicative data to support the sedimentation rate analysis, physical and biological processes, anthropogenic influences and possible ecological impacts. The proposed parameters to be measured include:

- Grain Size Distribution, sieve analysis

- Fall Velocity (dispersed system)
- Bulk Density
- Organic Fraction
- Total Nitrogen
- Total Phosphorus
- Heavy metals (limited number of samples)
- Persistent Organic Pollutants (limited number of samples)

Output: Bathymetry files at the monitoring sections and sediment sampling results (to be included in the Sediment Study Report)

Task 3. River and reservoir sedimentation analysis

Task 3.1 Topography and geomorphology

We will undertake a desktop assessment of fluvial geomorphology across all major streams in the Laloki River upstream of the Goldie River confluence. The assessment will utilise the 5 m DEM, aerial imagery and geology data to undertake a geomorphic classification of streams. This will include:

- Degree of lateral confinement which can provide an indication of the capacity for lateral channel erosion
- Areas of floodplains where sediment is stored within the fluvial system
- Riparian condition including a desktop assessment of vegetation extent
- Any active channel erosion areas which are likely to be sources of sediment to the river system
- Areas of high slope and potentially gully erosion

The desktop assessment will help inform a targeted field program to assess sediment transport processes.

Output:
- Information on geology and geomorphology of the catchment (to be included in the Sediment Study Report)
- Sediment sources and pathways identified (to be included in the Sediment Study Report)

Task 3.2 Hydrology

No hydrologic information (i.e. stream flow and rainfall) has been supplied. As a result, we propose a higher level hydrologic assessment which will involve:

- Delineate sub-catchments within the Laloki River and surrounding the dam
- Develop a rainfall-runoff model (i.e. a RORB model) using available information and default parameters to calculate flood hydrographs from rainfall and other channel inputs
- Compare RORB model results to PNG Rational Method calculations

The purpose of the assessment is to understand the relative magnitude of peak events within the catchment. This can help in determining the sediment transport capacity of reaches within the catchment. Without existing streamflow data within the catchment it is not feasible to develop a daily rainfall runoff model as the uncalibrated results may be misleading.

Output: Information on the catchment hydrology (to be included in the Sedimentation Study Report)

Task 3.3 Catchment and river sediment yields

We will undertake sediment yield and transport modelling at two levels of detail: the catchment and the river network.

For the catchment, we will calculate natural rates of erosion by a GIS based application of the Revised Universal Soil Loss Equation (RUSLE). This will utilise the 5 m DEM to calculate slope and slope-length and land use data based on the land use study of the Sogeri Plateau currently being undertaken by Eco Custodian Advocates. The RUSLE calculates the soil loss per unit area from rainfall induced sheet and rill erosion across the catchment taking into account topographic factors, rainfall erosivity, soil erodibility, vegetation cover and any management practices. We will determine the soil loss per unit area in each sub-catchment based on the existing land use. We will also calculate soil loss in each-catchment for a pre-disturbed scenario (i.e. naturally forested). This will help determine the increase in sedimentation rates in each sub-catchment.

For the river network, we will use information from the topographic, geomorphic and hydrologic assessments to describe natural channel hydraulics and estimate the sediment transport capacity of the system. We will develop a one-dimensional HEC-RAS model of the major streams using the 5 m DEM. Note that the 5 m DEM will provide a relatively crude cross-section of the channels however there is no better topographic or bathymetric information available.

Alluvium proposes to apply the sediment routing capabilities of the latest version of HEC-RAS to this task. Results from the hydraulic model will be used to determine stream power throughout the system for a variety of inflows. Stream power is the rate of energy dissipation on the bed and banks of a river or stream, and is correlated with sediment transport. These results will be used to estimate and identify relative sediment transport capacity between reaches. The results can be combined with geomorphic assessments undertaken in Task 3.1 to predict areas of erosion and deposition within the river system.

Note that to manage costs Alluvium does not propose to undertake any new soil survey and will be reliant on existing information.

Output:

- Hypsographic curves of the catchment (to be included in the Sedimentation Study Report)
- Sub catchment maps
- Hillslope erosion estimates for each sub-catchment for existing conditions and pre-disturbed condition
- Sediment transport capacity of each reach (to be included in the Sedimentation Study Report)

Task 3.4 Reservoir sedimentation rate

We will compare the bathymetric survey collected in Task 2 to the representative sections collected in 2007. We will determine if there has been any change in the reservoir floor level between 2007 and 2018 in each of the four reservoir zones identified in the 2007 study. This will help to determine any sedimentation since 2007. We understand there is no survey data of the reservoir floor prior to 2007 and no detailed pre-dam topography. We will use the sub bottom profile layer thickness data collected at each representative section to determine the accumulated sediment over time - assuming all observed sediment was not present prior to the dam construction.

Output:

- Estimation of accumulated sediments in Sirinumu Dam since 2007 and pre dam at representative sections (to be included in the Sedimentation Study Report)

- Sedimentation rates in Sirinumu Dam for existing conditions (to be included in the Sedimentation Study Report)

Task 3.5 Field investigations

Field investigations will be undertaken to ground truth findings from the desktop study. The field team will undertake assessments of river reaches and the broader catchment to determine:

- Stream reaches likely to produce excess sediment
- Stream reaches and floodplains likely to experience sedimentation
- Areas of the catchment where the slope and/or land use is likely to result in high rates of hillslope sediment generation

Water samples will be taken at a number of sites across the catchment to determine suspended sediment loads. It is proposed that CEPA staff will accompany the team for the first sampling period (i.e. in the dry season of late 2018) and repeat the sampling after a rainfall event in December 2018.

Task 3.6 Estimation of 5 and 10 year sedimentation

5 and 10 year sedimentation of the river and dam is dependent on future climate, changes in land use and any sedimentation mitigation works undertaken. To estimate sedimentation in 5 and 10 years we will:

- Work with UNDP and CEPA to identify scenarios including a mixture of future rainfall, changes in land use and sedimentation mitigation works. In addition a "no change" scenario will be adopted to provide a baseline case for comparison
- Analyse the future scenarios using the developed RUSLE GIS model and HECRAS model to understand changes in catchment sedimentation generation and river sediment generation and transport; and as well as their implications for reservoir sedimentation and water supply

Output: Modelling of sedimentation rates in Sirinumu Dam under different scenarios and seasons for five and 10 years from now (to be included in the Sedimentation Study Report)

Task 4. Analysis of ecological and social impacts of sedimentation

Task 4.1 Analysis of Ecological Impacts of Sedimentation

Current ecological impacts of sedimentation will be assessed through the sampling of flora and fauna in the respective lotic and lentic ecosystems. This work will cover the parameters outlined in Table 2. For each parameter the current condition will be assessed along with an assessment of the effect of sedimentation on the parameter.

Table 2. Ecological parameters to be assessed

Parameter	Description
Sirinumu Limnological study	Monitoring of reservoir physicochemistry (Temperature & DO profiling, Turbidity, Total suspended solids (TSS), pH, dissolved & particulate metals of metals* such as Cu, Cd, Pb, Zn), Dissolved organic matter (DOM)
Aquatic macrophyte diversity in the reservoir and along Laloki River	Transect surveys to identify macrophyte species and abundance
Macroinvertebrate diversity	Prawns and other aquatic macroinvertebrates
Fish species diversity and biomass	Using electrofishing and possible gill netting techniques
Plankton assessment in Sirinumu	Plankton biomass and diversity correlates to productivity

Physiochemistry of Laloki River	Measure DO, Temperature, pH, TSS, Turbidity, DOM, and dissolved and particulate metals* such as Cu, Cd, Pb, Zn

** Inclusion of metals is because the Laloki drains a highly mineralised region of the central ranges*

Task 4.2 Analysis of Socio-Economic Impacts of Sedimentation

The social impacts of sedimentation will be assessed through stakeholder interviews and review of existing literature for impacts within the area and in PNG more widely. Stakeholder interviews will ensure coverage of people in the PA located in the upper catchment, landowners around the catchment, riparian communities downstream and users of water and electricity from the dam.

There are a number of long-running local sensitivities related to the Sirinumu Dam, as evidenced by the September 2017 closing of the dam by local landowners. To help navigate these issues we have identified a sociologist for our team that understands the local issues and speaks the local language, Motu.

Impacts of sedimentation on the socio-economics in the region are likely to include:

- Threats to water supply and power production capability
- Dam management providing priority over water supply to power production
- Reduced food supply
- Decreased access to subsistence and native hunting practices
- Potential threats to traditional and cultural practises

Output:

- Socio-economic impacts of sedimentation (to be included in the Sedimentation Study Report)
- Biological and physical impacts of sedimentation (to be included in the Sedimentation Study Report)

Task 5. Development of recommendations to mitigate sedimentation impacts

Recommendations to mitigate the sediment impacts will be developed based on the sedimentation analysis results and detailed site reconnaissance of the current environmental conditions, land use practices and urban development setting throughout the entire catchment. We will develop the recommendations in consultation with local landowners, UNDP and CEPA.

We expect that improved management of the catchment will be a key recommendation for improving sedimentation of the river and dam. Likely recommendations will include detailed outlines for development of:

- Land use management plan practices
- Natural resource management plans
- Accumulated sediment remediation plans
- Sediment monitoring programmes
- Environmental monitoring programmes
- Social management plans
- Reservoir water supply management plan

Output:

- Reservoir sedimentation management options and management system sedimentation (to be included in the Sedimentation Study Report)
- Proposed sediment monitoring design and system sedimentation (to be included in the Sedimentation Study Report)

Task 6. Preparation and presentation of results and recommendations

We will summarise and synthesise the findings from the sediment study into a draft report. The report will include the following:

1. Executive summary (1 to 2 pages)
2. Hydrological, geological and geomorphological context
3. Laloki catchment sediment yields (including hypsographic curves of the catchment and sediment sources and pathways)
4. Laloki River sediment yields and transport (including estimated accumulated sediments in Laloki River)
5. Sirinumu Dam sedimentation rate
6. Sedimentation of Sirinumu Dam and Laloki River catchment in five and 10 years under different scenarios
7. Socio-economic and ecological impacts of sedimentation
8. Dam sedimentation management options and management system
9. Sediment monitoring design and system

Appendix: Draft MoU for sedimentation management and monitoring

The report will be written suitable for the project audience and users of the outputs (UNDP, CEPA and other key stakeholders). We aim as much as possible to use conceptual graphics to communicate complex information. We will present the draft report to relevant UNDP and CEPA staff at a meeting in Port Moresby. After submission of the draft report and presentation, we have allowed for two weeks to receive comments from UNDP and CEPA. Based on these comments we will develop and submit a final Sedimentation Study Report.

Output:

- Draft and final Sedimentation Study Report

References

Sedimentation survey of Sirinumu reservoir Eastern Highlands, Papua New Guinea, 2007, SOPAC technical report 411, Smith, R.

Attachment B
Socio-economic assessment

Sedimentation Assessment of the Sirinumu Dam, Laloki River and Eilogo Creek catchments

A supplementary paper on the socio economic and environmental impacts on the Koiari people.






Artie Jacobson Protected Area Management

on behalf of Alluvium

April – May 2019

Executive Summary

This report is a result of consultation with the Koiari people of the Sogeri plateau and other interested parties on the following issues within the 'greater catchment' area of Sirinumu impoundment, Laloki river and Eilogo Creek:

- Water quality and associated impacts on community livelihoods.
- Water and power supply issues that affect communities.
- Land use practices, both current and proposed, and
- Future opportunities for community based economic development and conservation.

The fundamental principle applied to the consultation process was for all discussions to preference local landowners, clan leaders, communities and Ward councillors. Over the term of the consultation process eight organised meetings and discussions were held with representatives of the 33 Koiari clans that occupy the area. Other interested parties i.e. Ward councillors, members of the Sirinumu Development Company Limited were also either briefed or consulted.

There is a general view that water quality throughout the greater catchment has significantly deteriorated since the dam was constructed but become dire over more recent years. Many people also expressed disappointment with the level of water and power supply services claiming their frustrations are further compounded knowing that Edu Ranau and PNG Power are 'resourced' from Koairi water and they receive little (if any) benefit.

Communities are reluctant to use water sourced from 'stagnant' reserves, often affected by effluent flows and containing sediments at varying levels depending on season. A routine practice across communities is to collect water 'in pots' and let it stand prior to using it for cooking and drinking.

Communities claim that water quality related health issues are common. Irresponsible domestic practices i.e. using the creeks and rivers to dump wastes, and poor public services and facilities i.e. lack of waste management services, non-existent or unreliable sewerage facilities, contribute heavily to poor water quality. There was a general level of acceptance that community 'behaviour' is a contributor to poor water quality and a desire to change was often advocated.

While hunting and gathering is commonly practiced subsistence farming is the main means of providing communities with food. Some suggested that community gardens are becoming less productive (even under 10 year rotations) and that it's often necessary to prepare new ground through clearing and burning the forest. Savanah grasslands are also considered poorer in nutrients than forest soils which further encourages communities to clear forest. Diminished native fish stocks and access to other aquatic resources which is affecting community nutrition security and cultural practices, is of concern.

Village economies throughout the greater catchment were once complimented through local (mainly Port Moresby) tourist activities however over recent decades this has significantly slowed and is now limited to trekking the Kokoda track (which commences at Owers corner) and some activities on Lake Sirinumu. This decline is partly due to loss of tourism related services i.e. tour operators and facilities, poor road conditions beyond Sogeri and limited marketing and promotion capability.

Lack of maintenance of the main roads i.e. Sogeri to Sirinumu and Depo junction to Owers Corner is also regarded as a contributor to sedimentation during heavy rain events.

Social and cultural well-being in general terms is of key concern among all communities. A reliable supply of quality water, power to households and improved regional sanitation services were regarded as major constraints to advancing other socio-economic initiatives. It was claimed that improving these services would have an immediate effect on community health, the quality of water in rivers and creeks and consequently the natural environment. These services were also considered integral to advancing a tourism industry.

The Koiari people remain aggrieved with the loss of access to customary lands, particularly places of traditional and historical significance, and the subsequent affect this has had on their culture. Communities struggled with differentiating between 'environment' and the physical 'cultural landscape' referring to impacts on environment as an impact on culture. This is evidenced through concerns with the loss of the traditional food sources i.e. aquatic plant, 'tumutumu' and other native aquatic species. There is substantial interest in people reconnecting with the natural/cultural landscape to serve environmental/conservation outcomes and to reinvigorate community integrity and improve health and well-being.

The Sogeri Plateau offers significant tourism potential through its unique landscape, diverse environmental setting and the cultural values of the area. A number of products are on offer however patronage is random and insufficient as a reliable income for business. A barramundi restocking program for Sirinumu is considered of primary importance to compliment the range of tourism products (adventure fishing) but to also provide improved protein for communities. Proximity to PNG's capital city, an international airport and other tourism support services are also additional 'tourism' assets for the region.

Concern was expressed on the lack of environmental stewardship within communities and across all clans. The concept of a Koiari Community Ranger program as a way of improving social, cultural and environment outcomes within the greater catchment was flagged. This is of particular interest to the Sirinumu community who suggested Rangers would work closely with local tourist operators and landowners and undertake compliance monitoring and awareness once the barramundi program is introduced.

It is common knowledge and evident that there is a diverse range of produce grown and harvested within the area. While this is primarily for the local market there is a strong appetite within communities to increase yields to service an extended market.

While communities (and individuals within) were limited in capacity to change current land use practices there was considerable discussion on improving local economies through a focus on communities specialising in produce and/or certain services. It was agreed that this 'regional approach' would not only 'grow the market, consolidate and/or develop specialist skill and knowledge but would potentially draw 'buyers' to the region mitigating the logistical constraints of transporting produce. It was agreed across communities that there is potential within the area to accommodate the concept - with an appropriate level of support. This would also contribute to regional tourism.

A series of community development initiatives will make an immediate difference to livelihoods and community well-being however it is generally agreed to ensure these initiatives are sustained and to achieve an acceptable standard of living a foundation community empowerment program is required.

The reports advocates for strategic implementation of the recommendations to not only improve the socio-economic status of the catchment communities but importantly position the Koiari people of the plateau long term through the empowerment/leadership program. If this can be achieved there is a high likelihood that social, economic, cultural and environmental values will be better observed across the greater catchment and as a consequence significant advances made toward sustainable development within the region.

1. Context

The consulting company Alluvium have been commissioned to undertake a technical study on sedimentation processes within the catchment areas of the Sirinumu dam, Laloki River and Eilogo creek (the greater catchment) including a small socio-economic component to help understand some of the issues that the customary landowners, the Koiari people, have been historically confronted with, and challenged by, on a day to day basis.

This component of the work does not attempt to solve the more complex issues associated with the project but may assist with providing an improved understanding through capturing concerns as expressed by representatives of the Koiari people who responded to a series of questions relating to the study.

According to recent advice there are 33 Koiari clans within the catchments who are primarily subsistence farmers however they do utilise the lands for hunting and traditional gathering purposes and for other customary practices.

'Settlers' also live in some areas of the catchment as result of historical land management practices i.e. rubber plantations and grazing, and through marriage.

The greater catchment is divided into four Regions to assist with resolving regional issues from clan level to matters of an interest to the national government. It is not known if this is a formal governance arrangement or voluntary.

According to some local clan leaders and Ward councillors the regional boundaries generally align with boundaries of the catchment areas that are the subject of this work (see Attachment B). A clan leader is elected as Regional Chair to represent the respective clans of each region.

The regions are:

- Region 1 (Rauno) - four clans
- Region 2 (Sirinumu) - 14 clans
- Region 3 (Iditu/Hogeri) - six clans
- Region 4 (Sogeri Central) - nine clans

(Clan names and their assignment to each Region are described in Attachment A1 - Stakeholders.)

Papua New Guinea (PNG) Governance arrangements are also applied within the regions and consist of:

- National representation at two levels:
  - Central Province Government - Governor Robert Agarobe, and
  - Kairuku-Hiri District - Mr Peter Isoaimo MP

- Local Level Government (LLG):
  - Mr Ogi David President of Koiari Rural LLG, and
  - Ten Wards are represented by Ward Councillors

While five decades have passed since the Sirinumu dam was constructed and the area flooded (1963) the Koiari people continue to hold long standing grievances with the loss of access to customary lands and associated cultural practices. Some have advised that this had a significant impact on ancient Koiari culture such as; traditional resource use (access to food, medicine, materials and tools), trade between villages, traditional clan ceremony, story-telling and *tatu* (song) and associated feasting, and customary marriage.

Some clans claim they are now clustered in places remote from their specific homeland and living within 'a heavily modified' landscape. As a result, lifestyle and customary adjustments have been made which to some are not conducive to Koiari cultural and social needs. This 'grievance' is evidenced by the 2017 closing of the dam by local landowners, more recent threats to do similar and continuing disharmony and unrest within the local area. Recent (2019) statements within social media also attest to this. This particular issue did arouse significant emotion during most meetings.

Customary land ownership including the significance of patriarchal inheritance remains of paramount importance to the Koiari people. As a consequence, there exists a cultural expectation that all dealings relating to land use be held first and foremost with the relevant landowners, their nominated representative (including Ward councillors), associated clan elders and more generally the people within village communities.

It is considered important to Koiari people that all members of the community are engaged in conversation to ensure messages and intentions are consistently understood across all of the community.

For additional context it is worthy to note that the Koiari people also own and occupy lands in the rugged Owen Stanley Ranges to the north east of the greater catchment (including the Kokoda Track corridor) and within other areas of the Central Province and National Capital District.

1.1 The Report

This report is a response to a request by Alluvium to consult with and seek information from Koiari people of the greater catchment area and other interested parties on the following issues relating to catchment management:

- Water quality:
    - How does the quality of the water in the dam, Laloki River and Eilogo Creek impacted on the communities' livelihoods?
    - Has there been noticeable changes in water quality in recent decades?
- Utilities:
    - Are there water supply/power supply issues that impact their communities?
- Land use practices:
    - What is the current status of land use practices?
    - Are there any plans for any future changes to land use practices?

- Future use and development options:
    - What are the future opportunities and community aspirations for:
        - economic development and/or
        - conservation?

Subsequently, the report provides:

- an overview of the approach taken and methods used to gain insight into the concerns people of the catchment (community and government representatives) have in regard to the issues described above.

- some discussion on the finding of the consultative process.

- an outline of the issues and a series of recommendations for future use options such as economic development (including tourism) and conservation.

- details of a number of community and meetings and other impromptu discussions.

- information on the level of participation of the Koiari clans and other interested parties.

2 Methodology and Approach

The fundamental principle applied to the consultation process was for all discussions to preference local landowners, clan leaders, communities and Ward councillors. This was supplemented where practically possible on an opportunistic basis with discussions with other elected officials, representatives from government and others with an interest in the study and its potential outcomes.

More specifically the approach taken was to:

- conduct brief discussions with Alluvium representatives regarding the context of the exercise.

- limit the scope of the exercise to the catchment of the Sirinumu Dam, Laloki River and Eilogo creek - referred to as 'the greater catchment' and (as stated above) place the emphasis of consultation on landowners, clan leaders, local communities and local level government representatives relative to the greater catchment.

- undertake semi-structured meetings and discussion with:
    - clans, those who claim landownership and community members who reside within the greater catchment, and
    - Provincial and Local Level Government representatives including Ward councillors, and clan related Associations.

- conduct opportunistic discussions (and draw on previous discussions) with others who have an interest in community development within the greater catchment, at present and potentially in the future, including:
    - representatives from PNG's Tourism Promotion Authority TPA) and the Kokoda Track Authority (KTA)
    - local area tour operators (PNG and Australian)
    - potential donors (Kokoda Track Foundation (KTF) representatives).
    - corporate representatives.

- undertake an informal assessment of land use practices through field based observations and when discussing land use issues during community meetings in villages and at other locations within the catchment.

- draw on previous experience as the Australian Governments Advisor to the KTA and participation in meetings and workshops with Koiari people and other relevant stakeholders.

- give due consideration to:
    - Koiari people having an historical link with Australia as a consequence of the 'Kokoda campaign' of WWII and remain 'custodians' of existing (and under-utilised) heritage sites within the greater catchment, and
    - the Koiari culture as the founding and prevailing culture of the greater catchment.

- remain mindful of logistical constraints and risks associated with consulting within remote parts of the Koirai landscape, such as:
    - seasonal weather patterns which often brings heavy afternoon rains or harsh afternoon temperatures (requiring shelter).
    - poor road conditions that take time to navigate and potential delays.
    - limited communication capability between and within communities.
    - limited or no public transport and where this is available the inhibitive cost of fares.
    - the time required for people to walk to meeting places.
    - the capacity of some clan elders to travel beyond the village and the need to go to them.
    - respecting the Sabbath.

In summary eight organised meetings/discussions were held with representatives of 32 Koiari clans and other interested parties involving approximately 260 individuals over the term of the consultation process (see Attachment A1 and A2 - Stakeholders, and Attachments D1 to D8 - Key Responses and Suggestions). A briefing was also given to members of the Sirinumu Development Company Limited (SIDCO).

Importantly, during each meeting attendees were advised that no commitments could be given in regards to the outcomes of the exercise. While this was understood and accepted it was however stressed that the exercise was indeed sincere and being conducted in good faith to gain an improved understanding of the views of the various community's in relation to the specific issues.

Further, to ensure all participants were clear on the purpose of the meetings and the meaning of the issues/questions a 'Tok pisin one pager' was developed and provided for their reference prior to and during each meetings (see Attachments C and H - Issues/Questions, and Meeting purpose papers translated to Tok pisin).

Additionally, throughout each meeting the two-way conversation was translated from English to Tok pisin and visa-versa for clarity in messaging and reporting. Approval was also sought from community members to collect images (including of their children) and to use these in the report.

Unfortunately, not everyone who was identified as a potential contributor i.e. PNG Power and Edu Ranua were unavailable over the period of the exercise.

The application of this approach established a useful means of sharing information and subsequently formed the basis for the report including the series of 'bottom-up' recommendations that follow.

Feedback has been received that due to the level of participation the responses and suggestions is reflective of landowner and community views and highly likely to be representative across the greater catchment. Numerous comments were also offered commending the 'bottom-up approach' which according to some was not commonly applied.

Please note the report is provided in draft form for further discussion with and refinement by Alluvium in order to consolidate the recommendations and to further inform other relevant work.

3 Water quality in the dam, Laloki River and Eilogo Creek

3.1 Current Perceptions

All communities within the greater catchment have access to water through either Sirinumu dam, the Eilogo creek, Laloki river, the many small tributaries and numerous springs and small 'dams'. Within some villages there are a few houses that collect roof water to store in tanks but these supplies are generally not made available for community use.

All participants agreed that throughout the year these various sources fail in some way which compels villages to select particular sources for particular uses depending on the quality of the water each source provides at a particular time. Communities stated that more often than not they had no choice than to use water from non-preferred sources of poor quality due to other sources either not being available or deemed to be even more inferior at the time.

Strong claims were also made that the Laloki River (traditional name - Iaro) is being contaminated by effluent flows into the river from the Sogeri Police Station, the Sogeri Hospital, a number of the local schools, the hydroponic farm (chemicals) and the Koitaki Country club.

It is also claimed that locals who live on the river/creek banks use the river 'as a toilet' and dispose of their household rubbish (including diapers) directly into these systems. This practice is most obvious on the banks of the Eilogo at the Sogeri markets where a large dump site is located. Consequently, when the river and creeks are used for domestic applications people's health is more often adversely affected.

Village communities on the Laloki are reluctant to use water from the Laloki for drinking and cooking when water that has sat 'stagnant' for some time in the lake is released from the dam. There were claims that people are 'traditionally suspicious' of still water as running water is more a part of their cultural landscape - not an 'impoundment'.

During dry times the Laloki also becomes turbid and often algae is observed in pools of still water.

It was mentioned that many springs within the area that were traditionally used were contaminated in the early days by Koitaki cattle, eventually turning into useless, permanently damaged bogs and no longer available as a source of clean and reliable water for locals thus further diminishing the availability of clean water.

A very productive spring is located at the entrance to the Koitaki Country Club (and used by the Country Club) however this is not formally available for local community use and is somewhat remote from local villages.

The 13 village communities in the immediate vicinity of Sirinumu lake claim to have been more significant impacted by the construction of the dam and the flooding of their lands. They continue to access natural water sources that are locally available (on higher ground) but also utilise lake waters. However, they do have to contend with turbid water on a daily basis. This is overcome by collecting water in large pots and letting the water stand until the soil particles settle and clean water can be claimed. They are also now heavily reliant on Tilapia as a means of protein having lost access to native species that were hunted and collected from the upper reaches of the Laloki (prior to 1963).

Nainumu village, located near the dam wall use a reliable 'all year' spring on the foreshore of the lake. Women have to walk to the spring via a steep slope to collect clean water for domestic use, mainly drinking and cooking. The spring submerges when the water level of the lake is high, cutting of supply to the clean water and while there is power to the village and potential to install a pump to supply clean water from the spring into a community storage tank there is limited community capacity to do so.

The community of Botoguni on the banks of the Eilogo creek rely on two small stream that feed into the Eilogo i.e. Botoihu and Deiribido above the village, however both regularly diminish in supply capacity or turn turbid. Two houses in the village do store water in tanks however for others within the community reliable clean water is

A small community dam was constructed at an elevated point on the Botoihu creek in 1977 with four pipelines installed to deliver water to particular households. Others manually collect their water from the dam or have an arrangement with a householder. This is the major source for the village however is not reliable all year - only available for one to two months per year – between the wet and dry seasons (May/June). Further to this, during low water flows the dam becomes overgrown with 'algae'. It was suggested that a gravity fed (minimum maintenance) community storage tank, protected by a sediment trap, could be included within the reticulation system to improve quality and supply.

Sogeri Market 'store holders' use Eilogo water to wash their produce before sales. This practice is suspected of being the cause of 'pak pak wara' or upset stomach amongst regular market customers and locals.

Use of Eilogo creek for domestic purposes is avoided. Reasons given were:

- contaminants enter the creek from the Hydroponics farm (chemicals) and Koitaki Country Club (sewerage effluent),
- last year Sogeri National High school's sewerage system failed and the effluent was directed into the Eilogo – for a period of approx. 12 months and it is believed other establishments dispose of raw effluent into the Eilogo,
- the water is consistently turbid and often smells,
- if someone does swim or bath in it they also smell – and their skin becomes irritated,
- large amounts of rubbish disposed of and/or washed into the creek.

While village children are discouraged from swimming in the Eilogo this is difficult for the communities to manage. Subsequently children are often effected by skin irritations (including boils) and gastro related sickness.

Kailaki village, approximately 12 km from Sogeri on the banks of the upper reaches of Eilogo creek only use the creek for laundry and bathing, but not all of the year. During the wet season water is often too muddy and often the water flows are too dangerous – particularly for children. Conversely, when water levels are low there are significant 'algal' blooms which also make the water unattractive for use.

Their preferred water source for drinking and cooking is through a recently installed and privately sponsored reticulation system that draws water from an elevated dam approximately 2 km into the foothills to the north. Each house hold has a tap that is used for all domestic applications. This does become muddy in the wet season when the dam floods due to excess and turbid runoff. While the water is held in a storage tank prior to 'entering' the village it often needs to be tapped into large cooking pots so the soil particles can settle. Clean water is then taken from the pots for cooking and drinking. It is claimed that clean water supplies remain insufficient to meet community needs on a day to day basis. The local school is not connected to the village reticulation system.

Clean and reliable water is collected from Vesilogo creek on south side of the populated ridge near Girinumu village – but this requires a 'two-hour' return walk to the creek bed. This is the preferred source but access is more difficult particularly when carrying 20ltr water containers. An alternative but less popular source is now used from within the Goldie River catchment.

In order to have readily available water for drinking and cooking small quantities of water are stored in the larger cooking pots to allow turbid water to 'stand' until the sediments settles. This is a common practice across all of the villages visited.

3.2 Historical changes

There is a general view that water quality and reliable water supply throughout the catchments has significantly diminished since the dam was constructed but become dire over more recent years.

There was some acceptance that communities had contributed to this through inappropriate waste management practices including dumping household and commercial rubbish (Sogeri market creek side dump) and through household effluent discharges into creeks and rivers. Governments were also criticised for failing to provide adequate waste management services i.e. regular rubbish runs, and for failing to maintain the governments sewerage facilities at Sogeri.

Some suggest that the change to water quality and the Koiari way of life (hunting, gathering, etc) was instant and dramatic from the time the dam was completed and the lands flooded in 1963 and that the impacts (as described in 3.1) have prevailed since then. These changes have particularly impacted villagers that were displaced through the flooding of the dam and for those who continue to live along the Laloki river.

Strong and somewhat emotional claims were made that the Laloki River is no longer considered and used as the valued resource it once was and that over more recent time it has become a 'dumping ground' for people that live on its banks. Large quantities of rubbish are now more obvious in all the creek and river systems and as mentioned above people continue to use the creeks and the river to dispose of their rubbish.

The Bereadabu people claim that before the dam traditional food was 'harvested' from the Laloki river but now the 'constantly strong flows' (for power generation) has destroyed natural river habitat such as slow moving waters and 'still' lagoons. This has manifest in the loss of traditional aquatic foods such as, Eel, Gurumu (small native fish – also impacted by Tilapia), native catfish (varying in size becoming larger downstream), other native fish such as Korobo and Soveka and a freshwater shellfish and a small freshwater crab. An aquatic plant, 'tumutumu' was once a heavily utilised traditional food however this has also disappeared.

On occasions when river flows stop or significantly slow heavy blooms of 'algae' appear and again impact on water quality and associated habitat.

Some suggested that community gardens are becoming less productive and that it's often necessary to prepare new ground through clearing and burning the forest. If this coincides with a heavy rain event soil (and ash) is often washed into the creek systems. Savanah grasslands are considered poorer in nutrients than forest soils which further encourages communities to clear forest – even so, there are claims that ten year rotations still produce less yields.

Native fish stocks and other aquatic life have also diminished within the Eilogo over recent years - but interestingly some claimed that some species (particularly the introduced Tilapia) are on the recovery in the upper reaches of the Eilogo creek.

High use commercial recreational activity (picnics and swimming) is limited to 'Crystal Rapids', a locally owned and managed day use area below the dam wall which is most popularly visited at weekends by people from the local area and PoM. The water does become turbid during heavy rains.

3.3 Social/Cultural impacts

Social and cultural well-being is a key concern among all community's.

Significant concern is held by many that without convenient access to a clean and reliable water supply, other socio-economic initiatives could not be sufficiently advanced. This ranged from improving day to day living standards i.e. to be able to wash and cook with clean water, to the loss of access to traditional aquatic food sources i.e. aquatic grass and native fish, and to improve community livelihoods through tourism i.e. tourists aren't attracted to areas where there are no basic services i.e. clean water and sanitation.

Many people expressed disappointment with the level of both water and power supply services within the greater catchment stating that this was further compounded knowing that Edu Ranau and PNG Power are 'resourced' from Koairi water and that Koiari people are not benefitting i.e. being provided with the basic services that they contribute to others i.e. Water and Power

There is a power supply to a number of villages however not everyone can afford it. It is also unreliable and when it fails it can take a week for it to be reinstated which means that large quantities of stored foods can spoil. It was discussed that there are no 'back up' systems in place.

SIDCO who receive payments from PNG Power do provide support funds to communities however not everyone benefits – mainly those clans up at the dam. Communities seem to be unaware of any agreement in place that describes the arrangements between the water and power companies and the 'resource owners'.

Some claimed that the 'KoiarI way' (culture) was lost when the area was flooded, citing the displacement of people to alien high grounds and losing 'ownership' of and access to; productive gardens, sacred sites, burial grounds, trade routes, hunting grounds, traditional foods and medicines, clan ceremony (stories being lost as a consequence) and to 'country' generally. There remain however some cultural 'tabu' sites and other places of cultural significance that are cared for by the people.

It is also of concern that traditional agricultural techniques such as growing and harvesting kaukau which was once a primary food source within the catchment (including and annual harvest festival) is being lost due to this information not being passed down by elders. It was stated that this could be overcome if local youth were motivated to learn traditional agricultural skills through being 'employed' to work on community based commercial kaukau farms.

The communities from Botoguni and Kailaki on the banks of Eilogo creek and the Bereardubu people on the banks of the Laloki river, all claim that poor water quality is contributing to ill health. People are continually suffering with upset stomachs – particularly children, and that skin irritations (dry and itchy skin, sometimes describes as 'grilly skin') and infections are also common. Some suggested that this often coincides with when the gardens are cleared close to the bank of the creek while others suggested that chemicals are leaching into the water from abandoned rubber plantations and sawmills.

It was pointed out that following the closure of the aid post at Magamaga that there are no longer health services within the greater catchment apart for the health centre at Sogeri which can cause illnesses to linger unabated for days.

Hunting of native and introduced species (pigs, deer) and gathering of traditional food, medicines and building materials is still practiced within the greater catchment as a part of Koiari tradition and cultural but also as a means to contribute to the local economy that is primarily sustained through subsistence farming.

There were a number of claims (primarily at the Sirinumu dam meeting but also at the Bereardubu meeting) that the dam has impacted on traditional hunting and gathering practices that were Laloki river based which has subsequently impacted on culture as traditional skills associated with these activities cannot be passed down i.e. the connection between the people and the natural/cultural landscape has been 'lost'.

There is a general view that improved power and water supply to households would also have an immediate effect on sanitation standards which would not only contribute to improved community health but also (if connected to functional effluent treatments systems i.e. septic or community sewerage systems) improve the quality of water in the rivers and creeks – which would in turn have environmental and cultural spin-offs.

There is also strong support for a Koiari Cultural Centre at Depo as the 'gateway to Koiari country' for both the Sogeri/Sirinumu region and the Owen Stanley Ranges (the Kokoda track). This is considered a necessary yet practical initiative to assist people to reconnect with the natural/cultural landscape which would not only serve environmental/conservation outcomes but have a strong influence on community integrity, self-worth as individual Koiaris and clans and importantly community health and well-being.

It was suggested that the Cultural Centre would also stimulate the Depo community economy through the provision of saleable items other services such as cultural performances. Note: the Koiari Cultural Group (Certified by National Cultural Commission ct. No 0795) is based at Depo.

A number of the more elderly participants expressed some cynicism toward the exercise stating that while they had been involved in many of these in the past nothing meaningful had ever eventuated. It became evident that while there seemed a degree of gratitude that more effort was being put into 'making a difference' that the people wanted more than another 'welfare' program. There is considerable interest in establishing an environment that not only built community and clan 'development capacity' but empowered them more long term.

Some also commented that the community needed to also change 'its attitude' from one of 'expecting handouts' to wanting to take control of its own destiny. This followed some random requests for chainsaws and tractors to be donated to the community.

3.4 Environmental impacts

During discussions the communities seemed to struggle with differentiating between 'environment' and the physical 'cultural landscape' often stating that any impact on environment was an impact on culture. The examples offered related to their diminished capacity to harvest the aquatic plant, 'tumutumu' a traditional food source and fish for native species within both the Eilogo creek and the Laloki river as a result of suspected environmental impacts on these systems.

An increase in traffic and lack of regular and proper maintenance on the roads from Depo to Owers Corner and from Sogeri to Sirinumu, particularly during heavy rain events turns sections of the roads into 'bogs'. These conditions produce large volumes of mobile soil which is in turn washes into both the Vesilogo creek (tributary to the Laloki) and the Laloki river significantly compounding water quality and natural processes that support the function of aquatic ecosystems.

Other minor roads are also in need of significant repair work to prevent soils from being mobilised and subsequently impacting on waterways and associated habitat

Uncontrolled burning of grasslands followed by heavy rains has caused ash and soil to be washed into river systems and has subsequently accelerated erosion in some areas. 'Hot' grass fires are also causing the forests to retreat as the large forest tress and understory that are not fire tolerant are killed off.

There was some discussion on the lack of environmental stewardship within communities. Some, who at times work as porters and guides on the Kokoda Track, referred to the Kokoda Track Authority Ranger program and while they were not overly complimentary they saw this approach i.e. a Koiari Community Ranger cohort, as a way of improving social, cultural and environment outcomes across the catchment. They also advocated for a Koiari Community Ranger program to become a role model for younger children, to mentor community youth and to play a significant role in assisting with Tourism management (interpretive, educational and compliance services) as tourism is developed.

It was offered that community leaders charged with cultural responsibilities are given technical and other practical knowledge and skills to deliver community based projects.

A Ranger program is of particular interest to the Sirinumu community who suggested Rangers would work closely with local tourist operators and landowners to ensure permit compliance and local 'special area management' requirements were conformed with – once introduced.

3.5 Economic impacts

The local 'community or village' economies are mainly reliant on the sale of surplus produce at local open air markets i.e. Sogeri, or small family run roadside markets (kiosks) that sell buai, soft drinks and snacks such as 'two minute noodles' and 'twisties' and sheltered markets such as at Depo and the Sirinumu Dam that sell both snacks, drinks, fresh produce and some hot foods.

While there is an emerging interest in Sirinumu Dam as a tourist destination i.e. the establishment of the Sirinumu Dam Ecotourism Development Cooperative Society Limited, its own Facebook page, some local 'word of mouth' promotion (tapping into PoM based expats) and the conduct of the Sirinumu Dam Ecotourism Feasibility Study in 2016, and while there is some random tourist activity taking place i.e. Nainumu picnic area, day trips to the Dam, the area remains relatively untapped. Local are very aware that there is potential to 'tap into the passing trade' of the 3500 Kokoda Track Trekkers per annum and are also well aware of the large number of WWII military heritage sites within the Sogeri region.

The Kailaki community referred to 'the 50's when the upper reaches of the Eilogo was a 'major tourism destination' car loads 'white man' would drive from PoM and locals from the surrounding area to swim and picnic on the banks of the Eilogo and the Musgrave river. During those times the road from Sogeri to Kailaki (12 kms) and beyond was managed and maintained by and for the rubber plantation owners.

The condition of the road from Sogeri to the village is 'bigpla concern stret' (considered a major impediment) to social and economic welfare of the communities in the upper reaches of the Eilogo and described by the local Kailaki community as a higher priority to improving community well-being that any other issue. To now travel either way for whatever reason i.e. school, market, medical aid, maternal health services, there are only two viable options for the community – either walk for four hours or if it can be afforded go by vehicle (4WD only) which is one and a half hr drive (or more).

Barramundi are known to inhabit Sirinumu lake however are now rarely caught. It is reasonably assumed by the locals that the population has declined considerably since the dam was last 'stocked'. Barramundi will not breed within an impoundment.

Over recent years the clans within the lake area have indicated a strong interest in re-establishing and consolidating a Barramundi restocking program for the lake. The rationale for this is to improve access to a reliable source of protein for communities, potentially attract adventure fishing (including international visitors), to provide local employment and business opportunity for locals and importantly to provide and attractive learning theme for Magamaga students. To this end the Magamaga School Board has offered school facilities and land (situated on the banks of the lake) and teacher and student support to establish a fingerling receiving and management facility at the school.

The Barramundi project once established will need compliance monitoring which could be supported through the Koiari Community Ranger program.

All communities expressed a frustration with having limited capacity to transport produce to markets. They claimed that while they have the land and the knowledge and skill to increase their yield they were reluctant to do this without guaranteed access to the local markets including PoM. Specific impediments were road conditions (particularly Kailaki to Sogeri) and affordable transport.

There was also considerable discussion on the prospect of communities adopting a regional approach to improve local economies i.e. not everyone doing a little of the same thing, and to potentially draw the market to the region. The general concept is that communities would continue to produce a variety of fruit and vegetables for local consumption but become specialised in providing 'exclusive' products and services. In doing so not only would specialist skill and knowledge be consolidated and/or developed but this approach would also likely be attractive to tourists.

All meetings agreed that this is an initiative could be workshopped involving Ward councillors, clan leaders, other leaders from within the community (men and woman) and specialist experts to determine the feasibility of the idea.

The following table (Table 1) gives an outline of the ranges of products and services the different communities could offer under a regional approach to economic growth:

Table 1 - Products and Services within the greater catchment

Community/clans	Specialised theme	Product	Service	Comment
Sirinumu clans	Barramundi	Improved source of Protein for local communities	Adventure fishing	Feasibility study required. Note this initiative was flagged during a public meeting at Sogeri in 2016 with significant local support Some preliminary liaison undertaken with Kokoda Track Foundation, RRC Nth Aus, Aus Fishing fraternity, Magamaga School Board
		Marketable products i.e. fish fillets	Learning opportunity for students	
		Other bi-products from fish processing including organic fertiliser	Possible training centre	
	Ecotourism		Day tours and picnics	Includes cultural sites

		Environmental and cultural landscape	Camping	Riverside and island
Kailaki	Produce	Full range of marketable produce i.e. chilli, cabbage, pineapple		
	Eco and Cultural tourism		Cultural sites, Scenic landscape, camping and day use	Riverside
Girinumu/Vesilogo	Organic Ginger	Raw Ginger and variety of ginger products	Tourism	Pioneered Ginger as a cash crop before other communities. Claimed they grow the best ginger and would like to become the Ginger capital for the greater Sogeri region
Karakadabu (Depo Junction)	Koiari culture	Koiari culture centre and market	Range of culturally attractive events including singsing and story telling	Depo Junction is the gateway to the Kokoda Track and the greater Sogeri Plateau Annually approx. 3500 trekkers pass by.
	Floriculture	Heliconia - cut flowers	Tourism	Semi established
Botoguni	Yam and Taro	Yam for local and commercial market	Tourism – annual Yam harvest festival	
Bereadabu	Produce - primarily for PoM Hotels/Int visitors	Brochilli, cauliflower, onion, tomato, water melon, carrots, leak, bock choy, snake beans	Also tourism – 'pick a basket'	
	Kokoda Track and Sogeri Tourism	Screen printing T-shirts and banners		With proper marketing this business could be expanded to make sales to Kokoda Trekkers (3500 per annum)
Note 1: strong views were expressed that any commercial enterprises be community driven for the benefit for the community. *Note 2: claims made that Koiari people must work together and become more inclusive and cooperative (some jealousy toward those that use initiative and make money).* *Note 3: advised that DPI have held discussions with communities on how yields can be improved but they come and go and nothing changes.* *Note 4: advised that the local soils were suitable for growing Yam and a 3-5 year rotational program was practiced by some.* *Note 5: claimed that with additional knowledge/assistance from experts, yield could be increased to commercial levels.*				

Local services and land use practices

4.1 Services

The township of Sogeri is situated on the Sogeri Plateau at about 500m above sea level. It is the most populated village within the catchment area and connected to Port Moresby (PoM) by a sealed road. The town is only a few kilometres from Depo Junction, the formal start of the Kokoda Track. A public transport system (PMV's) operates between Sogeri and PoM on a daily basis and there is a number of helicopter land zones nearby.

Sogeri has a population of approximately 1000 people, a rural hospital, a police station, a number of family roadside markets and a community fruit and vegetable market place on the bank of Eilogo creek. A large percentage of people live in small communities interspersed throughout the catchment where access to basic services and public infrastructure is lacking.

The catchment boasts six Elementary schools i.e. Depo Junction, Rouna, Vesilogo, Magamaga, Itiki and Doe; five Primary schools i.e. Magamaga, Sogeri, Bisiatabu Seven Day Adventist Mission, Itiki and Doe; two Secondary schools i.e. Iarowari and Sogeri National High.

Locals proudly claim that the former (and first) Prime Minister of PNG Sir Michael Somare attended Sogeri National high as a student.

Three hotels i.e. Sogeri Lodge, Kokoda Trail Hotel and Koitaki Country Club are located in close proximity to Sogeri catering for local clientele, Australian expats from PoM and Australian Trekkers (primarily Sogeri Lodge). Koitaki Country Club has a golf course and also offers horse riding.

Car wash services are also offered along the Laloki river. This usually involved the vehicles (sometimes PMV's) being driven into the river to easily access the water required for the wash.

Seventh-Day Adventist (SDA) missionaries established the Bisiatabu mission station, near Sogeri, in 1908. The mission still exists and continues to function as a local SDA church.

4.2 Land use

Sogeri plateau is home to the large property known as 'Koitaki'. Previously managed as an extensive cattle station the only stock that remain on the property are a few locally owned horses. Stockyards and other infrastructure on the property are either in a state of disrepair or not being used for purpose. Extensive grasslands (previously open woodlands cleared for grazing) are a prominent feature of the landscape known as Koitakinumu.

There is also a hydroponic farm (Sogeri company) on the outskirts of Sogeri (toward the lake) that supplies a variety of vegetables to supermarkets and restaurants in PoM and to hotels in the local area.

Sogeri Spice, a foreign owned but locally based agricultural company, has a pineapple plantation that supplies pineapples to markets in PoM and also manufactures a number of pineapple products i.e. jams etc. The area of the plantation is unknown.

The locality also has a number of rubber plantations. These range in production rates and acreage from the extensive plantation of Bisianumu Rubber Plantation between McDonald's Corner and Bisiatabu, to the Koitaki plantation south of Koitaki Station to the smaller plantation of Heilogo near Crystal Rapids day use area (swimming and picnicking) on the Laloki river. Remnant plantations can also be observed in the upper reaches of the Eilogo catchment.

Floriculture for cut flowers (Haliconia) is an emerging industry within the area. The Sogeri Floriculture Womans Group (SFWG) has 23 financial member and seven community gardens. There is no 'restriction' to the size of a garden as the land is owned by those that farm it. This is also dependant on the species of flower under cultivation. The industry is supported by Sogeri Tropical Plants, a small two-person business who grow their own flowers and foliage but who also purchase from the SFWG. At this point in time there are no standing order with business dependant on fluctuating demands.

Other small acreage family farms i.e. pineapple, watermelon and ginger gardens, are scattered throughout the catchment.

The lake, Laloki River, Eilogo creek and lands within the catchments are utilised for a range of purposes but primarily to support the livelihood of the many small villages that are interspersed across the landscape - some of which are relatively recent having been established in the mid 1960's to replace those villages submerged during the flooding of the lands that now form the bed of the lake.

While the whole of the catchment is regarded by the Koiari people as customary lands and a part of their cultural fabric, specific cultural sites also exist within the general area that are regularly visited for cultural purposes – and sometimes for extended periods. Their locations and specific use remain the 'business' of the Koiari people and this is respected.

Subsistence farming of fruit and vegetables such as banana, cassava, taro, pineapple, paw paw, kaukau and pumpkin is a common practice for all communities. Traditional hunting, fishing and gathering continues to take place on country beyond the villages. Hunting activities are also often assisted through deliberate burning of grasslands. Local plants are also harvested for food, traditional medicines and specific cultural purposes.

Water for drinking, cooking and washing (laundry and bathing) is sourced from local creeks, rivers and springs. Depending on the time of year different sources will be used with daily preference given to collecting water from those streams with natural flows rather than the Laloki. Nainumu village utilises a perennial spring on the high water level of the lakes foreshore west of the village. Water supplies have been known to 'dry up' during extreme dry seasons.

Rainwater is also harvested however this is not widespread due to the cost of infrastructure i.e. roofing iron, tanks, plumbing, delivery and maintenance requirements.

Passive recreational activities (independent and commercially supported) take place on the lake and in the surrounding area and while a sincere attempt was made in 2016 to encourage tourism and recreation through a feasibility study, the true potential of the area has yet to be realised. (This may be partly due to the limited capacity of locals to follow through on sound concepts or to promote and consistently deliver such enterprises).

The few tourist programs that operate within the catchment as demand presents include:

- day use areas i.e. Crystal rapids and other river/creek side locations.
- overnight (multiple days) and day trekking.
- birdwatching as a component of trekking and undertaken independently.
- cultural site visits.
- village and remote picnicking which may include sing sings and story telling.
- camping (remote campsites and village stays including the Bausaka fish farm.

The lake also supports a number of commercial aquaculture enterprises who 'grow' and target the introduced fish species, Tilapia (a native of Africa and Middle east). A Tilapia hatchery is managed on Bausaka island on the southern end of the lake. Fresh water prawns are also harvested commercially.

Within the general area of Sogeri many WWII military heritage sites exist and while there are few physical remnants the locations of these sites and their historical use is well documented.

While conservation management is not formally practiced it could be reasonably suggested that local cultural practices i.e. regularly burning of grasslands and open forests, hunting of feral pigs and deer, to some degree assist with sustaining local biodiversity.

4.3 Future (proposed) land use practices

According to some the Koitaki (Cattle) Station was recently purchased by Pacific Balance Fund (Melanesian Trustees Limited) and its speculated that the new owners are planning to diversify into tourism, agriculture and a resumption of grazing. *The accuracy of this information is not known.*

A number of communities also advocated for a 'regional approach' to providing specific products and services (see Economics). It is not anticipated that this will change existing land use practices unless the demands for marketable produce exceed expectations and further cultivation is required.

During all of the discussions while there were concerns in relation to low productivity soils there was no mention of the use of fertilizers, pesticides or herbicides. To the contrary there was significant interest in crop rotation, leaving plots fallow, companion planting and on improving community knowledge in relation to composting and organic farming.

5 Opportunities

The Sogeri Plateau possesses a range of unique attributes. These include, among others things:

- the close proximity to PoM, PNG's capital city with a population of 375,000 people, an international airport and accommodation houses of varying standards.
- a culturally and physically unique and attractive landscape including ancient and rugged terrain, remote, pristine creek and river systems, cultural sites and art 'galleries' i.e. 'giant's footprint', Ifa Kuruku ('writings on the stone wall') rock shelter, stories and song belonging to the Koiari people
- a diverse environmental setting that offers a range of recreational and tourism opportunities from passive eco-tourism i.e. trekking, camping, observing wildlife to more adventurous activities i.e. adventure fishing, paddling (standup paddle boards and kayaks), sailing.
- a number of attractions including:
    - Varirata National Park
    - Depo Junction - an historical monument and the formal start of the famous Kokoda Track
    - the township of Sogeri which supports many Australian military heritage sites from WWII
    - Lake Sirinumu
    - many natural perennial rivers and streams
    - the unique biodiversity with a variety of forest types and habitats of equally unique species i.e. Bird of paradise, PNG Cassowary, Bush Wallaby, Bandicoots etc. within natural settings
    - specific picnic areas, campgrounds and guest haus's within the general area but also lakeside, and
    - Koiari culture
- productive agricultural lands with potential to reinstate grazing and responsibly expand community crop production.

Of significant importance to any socio-economic initiative is the enduring reputation the Koiari people have as welcoming and hospitable people. This is clearly observed through:

- the role of the Koiari people in delivering the annual Kokoda Trekking season through guiding, porter services and accommodating 3500 trekkers annually across the Track (or approximately 138 trekking klms), and
- the determination of the Koiari people within the catchment to embrace new initiatives and deliver improved services for their people and others.

These attributes (among others) provide the people of the area with many opportunities for improving their social and economic status through a range of low key and environmentally friendly business initiatives.

If developed wisely and responsibly a unique opportunity is offered to present and protect the environmental integrity of the landscape.

Adopting sustainable and culturally appropriate land management practices to ensure all activities benefit the people and protect the range of unique values could become the cardinal principle for the Sogeri plateau.

5.1 Issues and recommendations

The following table describes a series of recommendations derived from discussions with Koiari Clan members and community representatives.

Each recommendation has been 'time-lined' according to the level of concern expressed during the consultative exercise and an unqualified yet confident view of the risk to socio-economic development across the greater catchment if these recommendations are not acted upon accordingly.

Table 2 – Issues and Recommendations

Issue	Recommendation/s	Consequences of timely action	Suggested timeline		
			As soon as can be arranged	Within 6 months or sooner	Within 12 months or sooner
Community access to reliable and clean water	Undertake a Gap analysis exercise to determine the current performance levels of village water supply services/systems, report on the status of each village with recommendations on actions required and implement a prioritised remedial program. Note: It has been claimed that PNG Power and Edu Ranu have been involved in discussions to provide clean reliable water (2x tanks and electric pumps per community) but conditional on an agreed 50:50 arrangement with Koiari LLG. A submission has gone to Kumul Consolidated Holding but status unknown apart from LLG has no capacity to contribute.	Improved health and general well-being of communities	X		
	Edu Ranua and PNG Power engaged as a part of further regional planning process.	Increase in efficiencies through improved collaboration	X		
Access to reliable Power	PNG Power engaged as a part of further regional planning process.	Improved domestic services to communities Significant reduction to the amount of food spoilt	X		
Empowering communities through creating an 'enabling environment (beyond	Arrange for a selection of clan/community leaders to visit the Martu community in WA - an internationally acclaimed community empowerment program to advance social, cultural and environmental standards	To further demonstrate to those recently consulted that community empowerment is of primary importance Community driven activities to improve knowledge, work cooperatively across clans and	X		

conventional skill based capacity development)	Consider a more formal 'twinning arrangement between the Koiari and Martu peoples	Commits to a long term community empowerment strategy Note: Martu Elders have advised their interest in this program as it will have reciprocal benefits and will extend a formal invitation to visit on request.		X	
Tourism	<u>Ecotourism</u> Undertake a review of the Sirinumu Dam Ecotourism study report with the intent of: i) supporting the development of a number of Ecotourism products as pilots, and ii) assisting with the drafting of an implementation plan	Recognises the area as having significant value as a tourism destination for PNG – including expanding the Military Heritage market Provides business and employment opportunity for local community members and landowners.		X	
	<u>Military (and other) Heritage Tourism</u> Conduct a study on the scope of Historical sites within the four greater catchment (from 17 Mile and east) to determine the potential to establish the area as a tourism destination. Noteworthy places include: - First mining site in region - PNG first PM the Hon Michael Somare was a student at Sogeri High - First State of Origin held in area - WWII Military Heritage sites within the township of Sogeri and surrounds (including 'Fleet Street') - the Kuppa Kuppa Track (American WWII)				X
	<u>Cultural tourism</u> Undertake an assessment of Cultural sites available for tourism and develop site management and protection plans (in collaboration with landowners)	Compliments activities that take place at the Koiari Cultural centre (if established) Assist with reinvigorating Koiari culture and stimulates cultural well-being Provides business and employment opportunity		X	

Regional approach to economic growth	Organise and deliver a scoping workshop to further consider the merits of the proposal and (if accepted) initiate the development of a considered community driven implementation plan. To involve Ward councillors, clan leaders, other leaders from within the community (men and woman) and specialist experts i.e. PNG DPI	Potential to: - improve efficiencies in use of land and community expertise. - reconnect youth with traditional land use practices and customs - develop community skill and knowledge - establish a foundation for further development of the region as a food hub - further attract tourism	X		
	Offer workshops/courses on: - change management. - small business management - promotion and marketing	Provides communities with adequate skill and knowledge to adjust to change and conduct small sustainable businesses	X		
Improve crop yield for domestic and commercial production **Fruit, vegetable and floriculture**	Arrange a series of field demonstrations/workshops to assist communities to garden yields - organic farming techniques - composting - rotations companion planting	Provides communities with adequate skill and knowledge to increase yield Contribute to improved community wellbeing and local economies Sound conservation measure		X	
Waste management	Assist Depo community youth to establish a pilot rubbish collection and recycling program potentially partnering with local businesses	Sound conservation measure Improved water quality, a positive effect on other environmental standards and a more appealing landscape A local idea/initiative is supported which will encourage others	X		
	Assist with conducting an annual Koiari clean-up day for the greater catchment	Removes rubbish from the local area and creates an improved awareness of the community benefits of waste management		X	

Reinvigorate and/or reconnect with Koiari culture and country (land and waterways)	Undertake a feasibility study on the establishment of a Koiari Cultural Centre/Ranger station at the junction at Depo.	Visitors to the region (including those who are about to trek the Kokoda Track) are welcomed by the Koiari people at the centre (their country) and introduced to Koiari culture and the historical relationship the people have with their lands, through: - scheduled performances - interpretive and educational displays, and - story telling Instil a reinvigorated sense of place and belonging to the Koiari people and assist with reinvigorating Koiari culture and stimulating cultural well-being			
	Provide support to the Depo based Koiari Cultural Group (Certified by National Cultural Commission ct. No 0795) to conduct Koiari cultural awareness workshops for Koiari youth within the greater catchment.				
	Assist the Koiari Cultural Group to design a welcome to Koiari Country greeting				
Fisheries / Aquaculture	Review Reef and Rainforest Cooperative Research Centre (RRRC) draft 2016/17 proposal to introduce a Barramundi restocking program and associated Barramundi farm in Sirinumu lake. A community driven and managed project with all profits distributed for greater community benefit The following organisations have expressed an interest in supporting the project: - RRRC – project planning and provision of expert advice - Sirinumu dam Ecotourism Development Cooperative Society Limited – Ranger Services and funds management - Kokoda Track Foundation – assist managing project establishment - Victoria Recreation Fishing fraternity – fund raising and promotion of adventure fishing - Magamaga School Board – provision of school resources to manage a fingerling reception facility See Education below	Appropriate utilisation of an available resource Draws on local skills and experience of the fish farmers' cooperative. Establish partnership between local people to improve livelihoods. Further attract tourism through recreational/adventure fishing ventures	X		

Education	Assist Mugamuga School to establish a Barramundi fingerling reception facility as a receiving facility for Barra restocking program	Provides students with an interesting and stimulating learning theme across the curricular. Students contributing to local economy	X		
Conservation Management	Establish a Koiari Volunteer Community Ranger program for the greater catchment. (Rangers roles and responsibilities to be delegated by Clan and community leaders).	Establishes a semi-professional entity to: - promote environmentally friendly activities across the catchment - undertake compliance monitoring to support Barramundi farming and 'permitted' tourism activity - undertake community mentoring and role modelling within the community.			X

6. Conclusion

A common concern expressed at all meetings was the need for reliable and affordable power for all communities and convenient access to a clean and reliable water supply.

While the Kailaki community would like improvements to their water and power supplies the most pressing issue for them is a reliable all-weather road to improve access to services including markets and to encourage day visitors (tourism).

It was often stated that without improvements to these basic services other socio-economic initiatives (including tourism) could not be sufficiently advanced.

The key areas of impact were described as:

- low socio-economic status of the people that prevents or inhibits the establishment of small businesses.
- communities (or able bodied members) needing to commit their time to subsistence farming.
- lack of transport services/poor road conditions beyond Sogeri into the upper reaches of the plateau i.e. difficult to transport goods to and from market places, visitors discouraged.
- lack of basic facilities to support tourism (day visits and camping).
- limited knowledge:
    - business management.
    - marketing.
    - organic agricultural practices.
- limited or no power supply (for electric pumps) and a reticulation system to irrigate crops.
- community water infrastructure i.e. tanks, pumps and reticulation systems to store previously sourced water.

While the 'colonial' past was often raised in a non-complimentary way there were many indications that communities held a strong desire to 'move forward' and work cooperatively across the greater catchment for the betterment of the Koiari people. A number of people also made it clear that while they were happy to constructively participate in this exercise they held a degree of scepticism – their past experience suggests nothing is likely to eventuate.

Aside from the scepticism there is no doubt that the Koiari people have a sincere desire to improve they social, economic and cultural wellbeing. This must be considered a welcome precursor to the implementation of any change management process whether it be incremental and somewhat random (the conventional approach) or whether it be more strategic and staged.

As described within table 2 there are a number of initiatives that if implemented will make an immediate difference to the livelihoods and well-being of communities however for the Koiari people of the greater catchment it could be reasonably argued that the key to their long term development and subsequently an acceptable standard of living is community empowerment.

It is therefore suggested that while due consideration be given to the implementation of a series of actions (as described within the recommendations) that the key to positioning the Koiaris more long term is to concurrently deliver a leadership program that will empower and enable the Koiaris to take carriage of their own affairs. If this can be achieved there is a high likelihood that social, economic, cultural and environmental values will be better observed across the greater catchment and as a consequence significant advances made toward sustainable development.

……………………………………………………………………

Attachment A1

Stakeholders

Note 1. Either Interviewed/Consulted - formally and impromptu April/May 2019 or prior (p) or identified for future engagement

Note 2. See Attachment B for Regional Boundaries as they relate to the Catchments

Note 3. According to some Koiari people a person has a cultural right to represent more than one clan at their Grandparent l (Bubu) level. This was openly demonstrated at meetings, however the table has captured independent clan representation

Note 4. Further 'ground truthing' required to confirm accuracy of i) spelling of a clan name, and ii) locality against region acknowledging the likelihood of overlapping boundaries.

Clans (30) and cultural representation			
Clan Name	**Representative and Status** Landowners (L/O), Clan Chairman (CC), Community Elder (CE), Community Member (CM)	**Participation** Y – Yes April/May 2019 p – previously in matters of relevance	**Recommended for future engagement** Y – Yes I – to determine level of interest and influence only
	Region 1 – Rouna		
Babea Toina – Chairman		Briefing only (13 May)	Y
Narime	Mr Inara Moio (L/O, CC)	Y,p	Y
Other Clan representatives		Y	Y
Omani	Mr Kala Meia (L/O, CC)	Briefing only (13 May)	Y
Other Clan representatives		Y	Y
Ianari	Mr Kotio Womara (L/O, CC)	Briefing only (13 May)	Y
Other Clan representatives		Y	Y
Nadeka	Mr Aron Varite (L/O, CC)	Briefing only (13 May)	Y
Other Clan representatives		Y	Y
	Region 2 – Sirinumu		
Jonah Oga Bobogi – (Chairman) **Wanowari clan**			Y

Magibiri	Mr Korotti Airo (L/O, CC) Mr Max Kidu (CE)	Y Y	Y
Other Clan representatives		Y	Y
Tuia	Mr Airo Ano (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Bemuri	Mr Wala Nuana (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Orari	Mr Deia Wuibora (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Wanowari	Mr Momoa Nuana	Y	Y
Other Clan representatives		Y	Y
Togo Korohi	Mr Manea Sarua (L/O, CC)		Y
Other Clan representatives		Y	Y
Korohi Bareri	Mr Korohi Vagi (L/O, CC)		Y
Other Clan representatives		Y	Y
Nidori	Mr Mageta Osiva (L/O, CC)		Y
Other Clan representatives		Y	Y
Amoa Monotori	Mr Yomeri Sarua (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Maneri Korohi	Mr Inaro Biai (LO, CC)		Y
Other Clan representatives		Y	Y
Omori Korohi	Mr Sarua Maeana (L/O, CC)		Y
Other Clan representatives		Y	Y
Veburi	Mr Futi Nari (L/O, CC)		Y
Other Clan representatives		Y	Y
Dagoda	Mr Biai Inaro (L/O, CC)		Y
Other Clan representatives		Y	Y
Region 3 – Iditu/Hogeri			

Tyson Boboro – Chairman **Clan - ?**			Y
Baruari	Mr Manara Mana (L/O, CC)	Y	Y
Other Clan representatives		Y	
Korovari	Mr Ray Vaga (L/O, CC)		Y
Other Clan representatives		Y	
Meuri	Mr Eddie Nanuka (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Hogeri (the name 'Sogeri' came from 'Hogeri')	Ms Nido Girina (Womans rep)	Y	Y
Other Clan representatives		Y	Y
Haveri	Mr Kaia Nanuka (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Moroka	Ms Mune Dumo (Womans rep)	Y	Y
Other Clan representatives		Y	Y
Vano Rori	Mr Babaga Yaduna (L/O, CC)	Y	Y
Other Clan representatives		Y	Y
Region 4 – Sogeri Central			
Arua Soge – Chairman **Clan - Dauri**			Y
Dauri	i) Mr Inara Mariori (Clan Elder) ii) Mr Walo Benson (L/O, CC)	Y	Y
Other Clan representatives (**at Depo**)		Y	Y
Aoberi	Mr Alfred K Edene (L/O, CC)		Y
Other Clan representatives		Y	Y
Eikiri	Ms Barbra Iori (L/O, CE) (**at Depo**)	Y, p	
Other Clan representatives (**at Depo**)		Y	Y
Manari	Mr Berio Sogie (L/O, CC)		Y
Other Clan representatives		Y	Y

Ioriwari	Mr Gebi Namari (L/O, CC)		Y
Other Clan representatives		Y	Y
Mokava	Mr Tiube Biai (L/O, CC)	Briefing only (13 May)	Y
Other Clan representatives		Y	Y
Vakari	Mr Billy David (L/O, CC)		Y
Other Clan representatives (**at Depo** – Lisa, Rose and Barbra Yori)		Y	Y
Taburi	Mr Sabea Uwea (L/O, CC)		Y
Other Clan representatives (**at Depo** and at Bereadabu)		Y	Y
Vaiakori	Mr Ivai Iarei (L/O, CC)		Y
Other Clan representatives		Briefing only (13 May)	Y
Koiari Culture			
Koiari Cultural Group (Certified by National Cultural Commission ct. No 0795)	Mr Yabba Toina	Y (at Depo)	Y
Other Group representatives			Y

Attachment A2

Stakeholders (Other)

Local Associations			
Name	**Organisation and Role**	**Participation** Y – Yes April/May 2019 y – yes April May 2019 (Community members only not Including Clan chair) p – previously in matters of relevance	**Recommended for future engagement** Y – Yes I – to determine level of interest and influence only
Mr Inara Moio	Chairman - Sirinumu Dam Ecotourism Development Co-operative Society Limited	Y p	Y
Mr Steven John	Chairman - Sirinumu Landowner Development Company (SIDCO)		Y

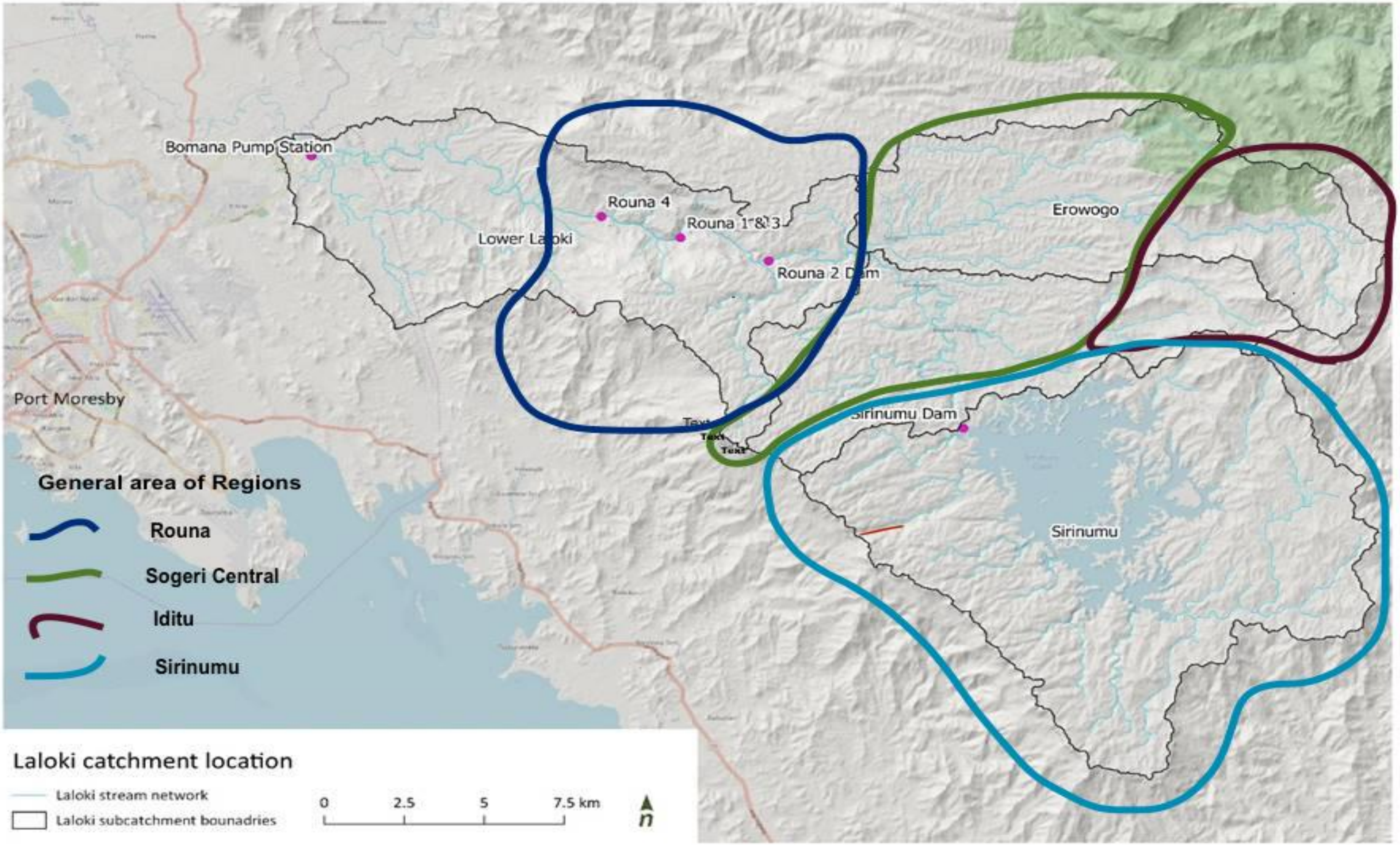
PNG Government			
Central Provincial Government			
Mr Edward Kila	Deputy Assistant Administrator Social Services	Y, p	Y
District Kairuku-Hiri			
Mr Peter Isoaimo MP	Open Member (Shadow Minister for Environment Conservation, Climate Change, Culture Art and Tourism)	p (Fisheries and Tourism only)	I
Koiairi Local Level Government			
Mr Ogi David	President of Koiari LLG	Meeting arranged – but not attended	Y
LLG Ward Councillors Region 1 - Rouna			
Mr Billy Ivai	Ward Councillor (Ward 5) – Karababu (Depo)	Y	Y
Mr Oga Erehe	Ward Councillor (Ward 9) - Doe		Y
LLG Ward Councillors Region 2 - Sirinumu			
Mr Avana Korohi	Ward Councillor (Ward 11) – Nafoka	Y	Y
Mr Geno Vince	Ward Councillor (Ward 12) – Derihe	Y	Y
Mr Kareki Karemu	Ward Councillor (Ward 13) – Varutanumu	Y	Y
LLG Ward Councillors Region 3 – Iditu/Hogeri			
Mr Baia Toina	Ward Councillor (Ward 10) – Ogotana		Y
Mr Kerogo Kaeapo	Ward Councillor (Ward 8) – Kailaki (Koitaki area)		Y
LLG Ward Councillors Region 4 – Sogeri Central			
Mr Tauke Muna	Ward Councillor (Ward 20) – Sogeri		Y
Mr Kidu Toina	Ward Councillor (Ward 7) – Befa	Y	Y
Ms Helen Weana	Ward Councillor (Ward 6) - Vesilogo to Owers	Y	Y
Conservation Environmental Protection Authority			
Mr. James Sabi	Manager - Biodiversity program	p	Y
Tourism Promotion Authority (TPA)			
Mr Nathan Lati	Product Development Officer	p	Y
National Museum and Art Gallery (NMAG)			

Dr Andrew Motou	Director – NMAG		Y
Mr. Greg Bablis	Principle Curator, Modern History Branch – NMAG	Y, p	Y
Commercial Entities			
PNG Power			
Mr Titus Tsigese			Y
Ms Martha Ginau			Y
Ms Carolyn Blacklock			Y
Eda Ranu (Water supply)			
			Y
Fisheries/aquaculture			
Mr Jonah Oga Bobogi	Business owner – Super Tilapia Fisheries	p	Y
Mr Francis Maruka	Business owner – Super Tilapia Fisheries	Y,p	Y
Mr Moduba Tom	Business owner – Super Tilapia Fisheries		Y
Tourism (overnight stays and day use areas) N – National F – Foreign			
Bouda Inara (LO), (N)	Business Owner - Crystal Rapids picnic/swimming pools	Y	Y
Douglas Asi (N)	Product Owner – Picnic area and Car 'waswas' (Depo)		Y
Momoa Nuana (N)	Product Owner – Picnic area and bird watching (lakeside)	Y	Y
Billy Max (N)	Product Owner – Picnic area and guest haus		Y
Baradea Yomeri (N)	Product Owner – Picnic area, campsite and birdwatching		Y
Laui Yomeri (Casey Laui) (N)	Product Owner – Picnic area/camp site owner	Y	Y
Namari family (N)	Product Owner – Picnic area (stop over on way to cultural site)	Y	Y
Sisi Namari (N)	Product Owner - Picnic/camp site owner (lakeside)	p	Y

William and Inara Moio (N)	Business Owner - Nature Tours	Y, p	Y
Inara Sarua and Francis Maruka (N)	Product Owner – Cultural site	p	Y
Mr David Howell (F)	Business Owner - Kokoda Historical	Y, p (Tourism aspect only)	I
Mr Mick O'Malley (F)	Business Owner - Australian Kokoda Tours	p (Tourism aspect only)	I
Ms Sue Fitcher (F)	Business Owner - Getaway Trekking	p (Tourism aspect only)	I
Capacity development - Training and Educational (and advocates)			
Mr Tom Korohi	Chairman – Magamaga Primary School Board	Y, p	Y
Ms Lisa Yori	Community Development Officer and Court Mediation Officer	Y, p	Y
Dr Genevieve Nelson	Kokoda Track Foundation (KTF)	Y, p	Y
Dr Matthew G Leavesley	University of PNG; Senior Lecturer in Archaeology Capacity development Archaeological Site Protection and Management	Y, p	I
Mr Tim Schneider	Martu Community Leadership program - Pilbara WA 20+ years Protected Area Management and Indigenous Community Empowerment/Capacity Development programs (incl Rangers)	Y,p	Y
Ms Sheridan Morris	Managing Director, Reef and Rainforest Research Centre, North Queensland Fisheries expert (Barramundi restocking initiative) Indigenous Community Empowerment Capacity Development	P (Fisheries and Ranger training)	I
Mr David Rutherford and INLOC Rangers	INLOC Ranger training PNG Indigenous Community Empowerment Coordinated a Field trip for CEPA staff 2017 (sponsored by UNDP) Poah Island and Mabuduan	P (Ranger training)	I
Mr James Enage	Exec officer NCD KTA ex CEO (and counterpart)	Y,p (Community development – tourism)	I

	Advocate for Sirinumu Ecotourism development and instrumental in securing funding for the Ecotourism Feasibility Study.		

Attachment B – Regional Boundaries as they relate to the catchments



Attachment C – Issues/Questions translated to Tok Pisin

Issue	Question	Tok Pisin translation
Water Quality	WQ1 Has the quality of the water in the dam, Laloki River and Eilogo Creek impacted on community livelihoods? (i.e. reduction in drinking water quality, fish stocks, recreation?)	WQ1tp Nau wantaim dam, wara insait long Laloki na Eilogo na dam yet i gutpla na klin oh? Yupela stil igat gutpla wara blong dring? Wara stil igat planti pis? Yupela stil igat ol gutpla hap long arere long wara long pilai na hamamas?
	WQ2 Has there been noticeable changes in water quality in recent decades (i.e. more turbidity, reduction in drinking water quality, reduction of fish stocks, recreational impact)	WQ2tp Insait long ol yar ol i bin wokim dam i kam inap nau, yupela ken luksave long senis long klinpla bilong wara tu? Wara em i klin or deti? Wara em i stil gutpea long dring tu? Igat ol planti pis stap yet insait long wara? Yupela stil igat ol gutpla hap long arere long wara long pilai na hamamas?
Utilities	U1 Are there water supply/power supply issues that impact their communities?	U1tp Inap yupela stori moa long sampela ol hevi long sait bilong klinpla bilong wara we yupela ol lain long ples i lukim? Yupela igat sampela hevi tu long sait bilong kisim pawa o nogat?
Land Use practice	LUP1 What are the current land use practices ? Examples: hunting, gathering (from within natural systems) burning, clearing, drainage works, stock/animal management, gardens/horticultural, revegetation, fertilizers etc.	LUP1tp Hau yupela save usim graun long nau taim? Kain olsem long hunting long painim abus, painim ol kaikai long bus nambaut; kukim na katim bus na wokim baret bilong wokim gaden o rot; wokim gaden na planim ol kaikai or flawa na diwai; lukautim ol animol, pik, kakaruk, sipsip or bulmakau bilong abus bilong kaikai; planim ken ol diwai na bus bihain long gaden i pinis; na tu long sait bilong usim fertilizers (or kemikol wara bilong ol waitman) long wokim giraun bai karim kaikai ken. Plis stori moa long sampela ol dispela samting na sapos igat ol narapela wei tu we yupela save usim giraun bilong yupela.

	LUP2 Are there any plans for future changes to land use practices in the future ? Examples: hunting, gathering (from within natural systems) burning, clearing, drainage works, stock/animal management, gardens/horticultural, revegetation, fertilizers etc.)	**LUP2tp** Yupela igat plan or tingting long senisim hau yupela bai usim graun long bihain taim? Or igat sampela wei or pasin bilong usim giraun nau we yupela laik senisim? Kain olsem long hunting long painim abus, painim ol kaikai long bus nambaut; kukim na katim bus na wokim baret bilong wokim gaden o rot; wokim gaden na planim ol kaikai or flawa na diwai; lukautim ol animol, pik, kakaruk, sipsip or bulmakau bilong abus bilong kaikai; planim ken ol diwai na bus bihain long gaden i pinis; na tu long sait bilong usim fertilizers (or kemikol wara bilong ol waitman) long wokim giraun bai karim kaikai ken. Plis stori moa long sampela ol dispela samting na sapos igat ol narapela wei tu we yupela save usim giraun bilong yupela. Na yupela igat sampela tingting long senisim hau yupela save usim giraun nau o nogat?
Future Use Options	FUO1 What are the potential future opportunities for economic development?	Wonem ol sampla tingting, wei o rot we yupela ol lain long ples ken bihainim lo makim mani long kamapim gutpla sindaun bilong yupela yet?
	FUO2 What are the potential future opportunities for conservation management?	Wonem ol sampela tingting, wei o rot we yupela ol lain long ples ken bihainim lo lukautim ol bus, giraun, wara na abus bilong yupela long nau na bilong ol lain bilong yupela long bihain taim tu?

Attachment D1 - Key Responses and Suggestions

Meeting Date: 2 May (0915 - 1130)

Group: Preliminary meeting with Sirinumu Ward Councillors Mr Avana Korohi (W11),Mr Geno Vince (W12), Mr Kereki Kerema (W13) and Magamaga School Board Chairman, Mr Tom Korihi.

Four people.

Location: Holiday Inn (catered)

Issue	Question	Response/suggestions
Water quality	WQ 1 – Impact on community	<u>General comments</u> There is a wide spread perception that the water in Laloki is not what it used to be prior to the dam. Communities are reluctant to use water from the Laloki for drinking – particularly water released from the dam that has sat 'stagnant" for some time. During dry times it can become turbid and often algae is detected. Locals do bath in it and fish stocks seem OK Requested a treated water supply system (as is provided to many PoM residents) and/or tanks to catch rainwater. Strong comments relating to the water being caught on their land and that they have to struggle to get reliable clean water for day to day living. Preference is to use springs and other tributaries but these are often remote and seasonal. Reliable, clean water is also required: ○ For sanitation at homes, schools and hospitals ○ Prior to advance any economic initiatives such as tourism or hospitality

		PNG Power and Edu Ranu have been involved in discussions to provide clean reliable water (2x tanks and electric pumps per community) but conditional on an agreed 50:50 arrangement with Koiari LLG. A submission has gone to Kumul Consolidated Holding but status unknown apart from LLG has no capacity to contribute.
	WQ2 – Changes to quality over recent time	See above
Utilities	U1 – Water and Power services	See above re water Power supplies are inconsistent across the area – including where supply line exist, failures are common and power restoration can take up to a week
Land use practices	LUP1 – Current practices	<u>School Board Chairman</u> Limited discussion on this apart from the significant loss of traditional practices when the lands were flooded When the dam was flooded communities were scattered and located on alien lands: a) loss of trading systems and routes b) lost opportunity to gather in traditional groups to feast, share stories c) lost access to sacred site and other places of significant customary value d) lost access to traditional resources
	LUP2 - Proposed changes	As local populations increase (including settlers) there is increasing demand to clear ground for more gardens or expand existing. This is of concern as it will continue to impact the environment with potential to further reduce traditional hunting and gathering areas.
Future use options	FYO1 - Economic	<u>Avana Korohi</u> Community welfare is the priority - Water - Health services – no longer and aid post at Magamaga - Small (sustainable) business beyond roadside markets <u>School Board Chairman</u> Establish a Barramundi restocking program at the dam and utilise community resources at Magamaga School as a receiving and processing facility

		Barramundi project once established will need compliance monitoring <u>General comments</u> Advocated for: - the development of a range of eco-tourism activities as described within the 2017 Sirinumu Feasibility study - a permit system (referred to Kokoda Track permits) - a Sogeri/Sirinumu Ranger Program to administer the permit system and more generally undertake environmental awareness, compliance and Tourism standards checks
	FYO2 – Conservation/Culture	<u>Nil</u>

Attachment D2 - Key Responses and Suggestions

Meeting Date: 3 May (1400 - 1645)

Group: Preliminary meeting with Mr Billy Ivai, Ward 5 Councillor and Mr James Enage, Exec Officer NCD Koiari Clan leader from Efogi and advocate of Sirinumu Ecotourim Feasibility Study.

Two people

Location: Holiday Inn (catered)

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	Billy Ivai There is a wide spread perception that the water in Laloki is not what it used to be prior to the dam. Communities are reluctant to use water from the Laloki for drinking – particularly water released from the dam that has sat 'stagnant" for some time in the lake. People are 'suspicious' of still water – running water is a part of their cultural landscape not an 'impoundment'.
	WQ2 – Changes to quality over recent time	Billy Ivai As above
Utilities	U1 – Water and Power services	Billy Ivai There is no access to clean water. This must be rectified before communities can move forward.
Land use practices	LUP1 – Current practices	Billy Ivai Referred to community meeting next week as a source of information

	LUP2 – Proposed changes	As above
Future use options	FUO1 – Economic	<u>James Enage</u> Advocated for a more concerted effort be put into a more 'far reaching community empowerment/capacity building' program and suggested the idea* of a 'twinning arrangement between the Koiari and Martu (Australian Aboriginal community) peoples be further * As counterparts within Kokoda Track Authority James Enage and I made contact with the Martu people to propose an 'information sharing' arrangement to assist both communities to build their social, economic and conservation management capacity. Referred to the Sirinumu Tourism Feasibliity study <u>Billy Ivai</u> There is no access to clean water. This must be rectified before communities can move forward in other areas of development i.e. tourism, hospitality, other small business
	FUO2 – Conservation/Culture	<u>Nil</u>

Attachment D3 - Key Responses and Suggestions

Meeting Date: 6 May (1030 – 1330, *1430 - 1500

Group: Girinumu**/**Vesilogo Community. Vakeri, Manari and Eikiri clan members. Community Leaders; Ms Barbara Yori (Senior Member of the Clan, elected as Womans representative) and Mr Wilson Weana Nobea (Community Leader)**.**

Ward 6 Councillor Ms Helen Weana*

17 to 20 people

Location: Girinumu village (near 'Lamb Shelter' Church)

Note: Girinumu/Vesilogo Community village is on the ridge of the northern boundary of the Eilogo catchment. Traditional name of area is U'vorvana.

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	General Comment Community sources water within the catchment and beyond i.e. Goldie River Clean and reliable water can be collected from Vesilogo creek on south side of ridge – but a two hr walk from ridge to the creek bed and rtn. This is the preferred source but access is more difficult. (20ltr containers) A feasibility study has been done (2016/17 Central Prov Gov, Division of Health) on installing a pipeline to pump water from Vesilogo creek to the ridge however nothing has been realised. There is a small dam on the north face of the ridge (outside the catchment) but this is used wet season only – but often contaminated by garden runoff (soil), pigs and soil relocation from Owers Corner dirt road - which (according to the people) causes sickness. One house has a water tank that collects water from its roof.
	WQ2 – Changes to quality over recent time	General Comment No change over time. Consistently unreliable, access difficult and time consuming.

Utilities	U1 – Water and Power services	General comment Power is available – not 100% reliable. Blackouts (usually during heavy rain) cause damage to appliance such as rice cookers, washing machines, refrigerator's etc and food often spoilt. Suggested solar panels to supplement power supplies and as backup during blackouts. Water supply - see above
Land use practices	LUP1 – Current practices	General comments Of significant concern - 18 klm dirt/clay based road from Depo to Owers Corner that lack maintenance and heavily erodes during the wet season. Drainage system is disturbed during annual maintenance mobilising soils that are subsequently washed into adjoining creek/river systems. Subsistence farming plot rotation – however have concerns with diminishing returns and population increases which may create a need for more land clearing. Ginger is grown as a source of income to families. Hunting (pigs and deer) and gathering (traditional foods, medicines and customary ceremonies)
	LUP2 – Proposed changes	None – although do want the road 'stabilised' to mitigate ongoing soil relocation through accelerated erosion.
Future use options	FUO1 – Economic	General comment In order for communities to advance 'economically" there is a need for reliable power and clean reliable sources of water – this was considered a critical issue – also for community health and hygiene Suggested field demonstrations/workshops in improving garden yield through organic farming techniques (rotations, composting) Would like to increase yield for Ginger and Heliconias'. Vesilogo communities initiated Ginger as a cash crop before other communities. Claimed they grow the best ginger and would like to become the Ginger capital for the greater Sogeri region. Agreed that there was merit in the greater Sogeri community establishing a 'specialist approach to improving local economies ie , not everyone doing a little of the same thing and that this is an initiative that could be workshopped involving Ward councillors, clan leaders and other leaders from within the community (men and woman). They also see potential to 'tap into the passing trade' of the 3500 Kokoda Track Trekkers per annum i.e. craft market

		Would like training in - 'small business management' - marketing <u>Wilson Weana Nobia</u> Expressed concern that once again another 'community meeting' was being held to discuss the same issues of which in the past nothing has eventuated.
	FUO2 – Conservation/Culture	<u>General comments</u> Concerns; - Ongoing soil runoff from Owers Corner Road and associated drainage - Risk of having to clear more land for gardens and cash crops (Ginger) - if yield can't be improved on lands already cleared

Attachment D4 - Key Responses and Suggestions

Meeting Date: May 7 (0910 - 1145)

Group: Depo Community, (Clan members from: Omani, Ianari, Narime, Nadeka, Dauri, Mokava, Eikiri, Vakari and Taburi)

58 adults in attendance at close of meeting,

Ward 5 Councillor Mr Billy Ivai), Ms Lisa Yori, Community Development Officer.

Location: Karakadubu (Depo) Market

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	<u>Mr Billy Ivai</u> Laloki River (Iaro) is being contaminated by effluent that is being discharged into the river by: Police Station, Hospital, number of schools, hydroponic farm and country club. River water is used for all domestic applications and people's health is affected Two heavily used major roads also washing into the creeks and river systems when it rains causing the river to become turbid. Freshly cleared land for gardens can also erode during heavy rains. Lack of town waste management system causes rubbish to end up in the Laloki (includes diapers). Locals on the river also use the river as a toilet. Water quality is a constraint on establishing Tourism services Locals prefer springs, water tanks and wells – not creeks and the river, but these are either remote or limited in number Fishing not affected Is a spring at Sogeri market place (not used due to rubbish contamination) and Sogeri High School (not accessible to community)
	WQ2 – Changes to quality over recent time	See above

Utilities	U1 – Water and Power services	<u>Mr Billy Ivai</u> Has a view that water and power services have deteriorated over recent time – and he intends to raise this as a key issue with Edu Ranau and PNG Power first opportunity. <u>Bore Womara Daburi Clan Elder</u> Heavily criticised Edu Ranau and PNG Power claiming that the companies are 'resourced from Koairi water and that Koiari people ate not benefitting i.e. beingh provided with basic services that they contribute to i.e. Water and Power <u>General comment (same as Vesilogo)</u> Power is available – not 100% reliable. Blackouts (usually during heavy rain) cause damage to appliance such as rice cookers, washing machines, refrigerator's etc and food often spoilt. Suggested solar panels to supplement power supplies and as backup during blackouts. Advised loss of street lighting was a community safety issue. Water supply – two sources of Spring water. - on the banks of the Laloki below Kokoda Trail Motel but some distance from the settlement, and - at the Sogeri markets – but contaminated with rubbish see also above
Land use practices	LUP1 – Current practices	<u>General comments</u> Subsistence farming common on the fringes of the township Open grasslands and woodland burnt regularly but 'not used'
	LUP2 – Proposed changes	<u>General comments</u> No changes proposed but lots of interest in improving the yield of current practices to input into the commercial market. Claims made the locals are good at growing things including poultry and pigs
Future use options	FUO1 – Economic	<u>Kalka, a Koiari Elder and elected representative of the Depo women's group</u> Expressed concern for the loss of culture and the ability to tell Koiari stories.

		Advocated for the establishment of a Koiari cultural centre and craft market at the junction. <u>Margaret Ufa Sogeri Tropical Plants and Bloom (Local Business)</u> Suggested **floriculture** be promoted more heavily and and changes to land use give priority to sustainable minimal impact activities. This received strong support from the community. Strong views expressed that any commercial enterprises be community driven for the benefit for the community. General view that the community needed to change 'its attitude' from one of chasing welfare to wanting to become empowered to take control of its own destiny. (This followed some random requests for chainsaws and tractors to be donated to the community.)
	FUO2 – Conservation/Culture	General concern expressed regarding to the impacts of burning i.e. regular burning of grasslands to improve access and when clearing land for gardens <u>Yomari Yaris SDA Church leader</u> Reinforced the above point

Attachment D5 - Key Responses and Suggestions

Meeting Date: May 8 (1040 - 1230)

Group: Various villages from around the dam - representatives from the Clans; Magabiri, Tuia, Bemuri, Orari, Wanowari, Amoa Monotori, Maneri Korohi, Korohi Bareri, Veburi, Togo Korohi, Nidori, Omori Korohi, Dagoda and Taburi.

82 adults in attendance at close of meeting.

Clan Leaders at meeting: Deia Wuibora (Orari), Yomeri Sarua (Amoa Monotori), Aroma Ano (Tuia), Korotti Airo (Magibiri), Momoa Nuana (Wanowari) and Max Kidu (Magabiri).

Ward councillor Geno Vince (W12).

Location: Sirinumu Dam wall

Note: Post meeting visited; the 'giants foot' (geological feature of cultural significance south of dam wall), fresh water spring at Sogeri markets and fresh water the spring on banks of the Laloki river (adjacent Kokoda Trail Hotel on opposite bank).

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	<u>General opening comments</u> Reliable and clean water and convenient access to water sources is of major concern to all clans. All agree services are poor in catchment Some emotion based on Dam water 'belonging' to Koiari people as it 'sits on Koiari land' Koiari water is being used to provide the Capital with treated water and power and others are profiting - yet continue to struggle. <u>Max Kidu (clan elder Magabiri)</u> Advised there are 3 Wards, 13 villages and 14 clans around the dam and all suffer with lack of clean and reliable water. <u>Casey Lahui Nainumu</u>

		Village is on the foreshore of Dam yet only reliable water supply is a spring on the foreshore remote from the village. Women have to walk to the spring to collect clean water. The spring submerges when lake water level is high cutting of supply to the clean water. There is power to the village and potential to install a pump to supply clean water from the spring. Some comment that the 'Koiari way' (culture) was lost when the area was flooded, people displaced and located on high ground. Sacred site, burial grounds, gardens, trade routes and clan ceremony taken away from the people. Want to 'resurrect' Koiari culture.
	WQ2 – Changes to quality over recent time	Water quality i.e. seasonal fluctuations re supply and quality consistently poor over decades
Utilities	U1 – Water and Power services	Water – see above Power: Not supplied to all villages and where supply is provided is unreliable. Power line spans the dam near the wall and often the line breaks and falls into the water. Prefer it follow the alignment of the road
Land use practices	LUP1 – Current practices	<u>General discussion</u> Sirinumu Lake and river fishing (Tilapia – Commercial and subsistence) Hunting – Pig, Cassowary, Cuscus, Wallaby, Deer Gathering – traditional food and medicine, building materials For other 'cultural' purposes – *detail not offered nor sought* Subsistence farming and gardening – however lots of comment on soils being nutrient deficient and far inferior to the soils under the lake on 'old country. Savanah grass land soils not sustainable – get one good crop then need to prepare new ground – approx. a 10 year rotation (lay fallow) required. Some tourism – camping, picnics (Nainumu village) and guided walks

	LUP2 – Proposed changes	General comments All acknowledged that there is much land underutilised – example given was the island on the lake with potential for camping and picnicking and that a 'water taxi service was available to support these activities. Significant support expressed for sustainable tourism. See also below
Future use options	FUO1 – Economic	General comments Communities have a strong interest in developing local tourism products and some attempts have been made to do this including the drafting of an 'ecotourism feasibility study', the development of a face book page and some local promotion (tapping into PoM based expats). All agree that to offer services to tourists communities need to be able to provide consistently reliable clean water and sanitation services. Continued support for the introduction of a barramundi restocking program for the Lake and for a receiving facility for fingerlings to be constructed at the Magamaga school. Also discussion on benefits of improved protein for communities and commercial uses i.e. processed fish products (food and organic fertiliser and 'adventure fishing' for foreign tourists. *Note this initiative was flagged during a public meeting at Sogeri in 2016 with significant local support and offers of external support made known at the time.* Some discussion on the benefits of developing focal points of specialist development within the greater area i.e. Sirinumu lake Barramundi and ecotourism, Vesilogo ginger, Depo cultural centre and floriculture etc
	FUO2 – Conservation/Culture	Inara Moio (Chair of Sirinumu Ecotourism Society and Geno Vince (Ward Councillor) Advocated for a Sogeri/Sirinumu Ranger program be introduced to provide interpretive, educational and compliance services as tourism grows. Rangers would specifically work with local tourist operator to ensure permit compliance and local 'special area management' requirements were conformed with. Rangers would be locals and also be mentors for youth. Was strong support for a Koiari Cultural centre at Depo as the 'gateway to Koiari country" for both the Sogeri/Sirinumu and Owen Stanley Ranges (where the Kokoda track is)

Attachment D6 - Key Responses and Suggestions

Meeting Date: May 9 (1020 - 1315)

Group: Dauri Clan attended. Community leaders; Mr Inara Mariori (Clan Elder), Mr Obue Meia, (Dauri Community leader) Mr John Kone Daube (Central Sogeri region rep), Ms Nido Inara (Clan Elders daughter (also woman's rep and holds cultural knowledge))

Ms Barbra Yori also attended.

32 adults in attendance.

Location: Botoguni village

Included post meeting inspection of small dam constructed in 1977 on a small creek known as Botoihu

Note: chief system not applied within Sogeri Koiari clans since the arrival of SDA however still observed.

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	<u>Ms Nido Inara</u> Water quality a critical issue for the village people. During the dry season there is a dramatic decline in supply and during the wet all sources become 'muddy'. Eilogo (that the village is on the bank of) is not used for domestic purposes. There are two small stream that feed the Eilogo that the people rely on i.e. Botoihu and the Deiribido however both diminish in supply capacity or turn to mud in heavy rain. Reliable clean water is only available about one to two months per year – between the wet and dry (May/June) When water is turbid it is let 'stand' in pots until the sediments settle. It can then be used for drinking and cooking. <u>John Kone Daube</u> Advised the meeting that he had five points he wanted to raise: 1. water supply was unreliable and quality was inconsistent. The main supply dam on the Botoihu had four (4) supply pipes that lead to different households and that supply didn't match demand. There was a need for a storage tank similar to the tank at the Sogeri store (9000 ltrs)

		2. Eilogo Creek was too dirty to use for domestic purposes including fishing – children are advised not to use or swim in it. Contaminants enter the creek from the Hydroponics farm (chemicals), Koitaki Country Club (sewerage) 3. Last year Sogeri National High school sewerage system failed and the effluent was directed into the Eilogo – for a operiod of approx. 12 months 4. Water from the Eilogo often smells and if someone does swim or bath in it also smell – and their skin is irritated. 5. Large amounts of rubbish is put into the creek by locals or washed into the creek from street litter. <u>General discussion amongst community</u> On what behavioural changes the greater community could do about it – some discussion on the depo initiative that involve youth conducting a commercially sponsored (local businesses) clean up exercise and possibly an annual Koiari clean-up day <u>Barbra Yori</u> Advised that the people at Sogeri Market use the Eilogo water to wash their product before sales – which has been known to cause 'pak pak wara'. Also that the (now contaminated) spring at the market was once clean and used on a daily basis.
	WQ2 – Changes to quality over recent time	No – has been consistently unreliable for most of each year
Utilities	U1 – Water and Power services	Water: Expressed need for improved supply capacity i.e. capture clean water when available and store it for when natural supplies diminish in quality and quantity. see above also Power: <u>John Kone Daube</u> Power is available in the area and a line does enter the village however of the 19 houses within the village only five have power. Suggested the line be extended to service the remaining houses.

Land use practices	LUP1 – Current practices	Subsistence farming of Banana, cassava, Sweet Yam and Yam, Pineapple etc Two small 'fish farms that provide fish (Super Tilapia) to the local community and to the Sogeri market
	LUP2 – Proposed changes	Would like to increase their yield of Pineapple and Yam to service the commercial market. Claimed that the Dauri people grow the best Yam and Pineapple, Yam is a part of their customary ways and they would reintroduce a Yam harvest festival to feed the greater community but also as a tourist attraction. Would also like to expand the fish farming ponds.
Future use options	FUO1 – Economic	See proposed changes to land use General agreement that sustainable economic growth was dependant on the availability of clean, reliable water and reliable power. Some discussion on the benefits of solar as a backup when power fails but agreed that if there economy grew solar could be achieved independent of donor support. Would like to focus their commercial effort on Yam and Pineapple – and as a part of reengaging with culture and learning about cultural practices (some younger people commented on not knowing how to grow yams and of a need for Koiari Cultural Awareness Workshops
	FUO2 – Conservation/Culture	Some open discussion on the benefits of a Sogeri/Sirinumu Ranger program to create improve awareness of caring for country and reinvigorating Koiari culture – with all agreeing in the merits of this

Attachment D7 - Key Responses and Suggestions

Meeting Date: 10 May (1315 – 1530)

Group: Clans in attendance – Baruari, Hogeri, Haveri, Moroka, Meuri, Vano Rori and Korovari.

Clan Leaders and senior community reps at meeting – Mr Manara Mana (Baruari), Ms Nido Girina (Hogeri), Mr Kaia Nanuka (Haveri), Ms Mune Dumo (Moroka), Mr Eddie Nanuka (Meuri), Mr Babaga Yaduna (Vano Rori)

47 adults in attendance at close of meeting.

Location: Kailaki village (upper reaches of Eilogo Creek)

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	<u>Mune Doumo</u> Eilogo creek is only used for washing i.e. laundry and bathing. But not all year. During the wet season water is too dangerous for children often muddy. When water levels are low there are serious 'algal' blooms which also make the water unattractive. Preferred water source for drinking and cooking is through a recently installed and privately sponsored reticulation system form an elevated dam approx. 2 klm into the foothills to the north. Each house hold has a tap that is used for all domestic applications. This does become muddy in the wet season as the dam is flooded with excess runoff. Water comes from the dam to a storage tank then is tapped into large cooking pots so the soil can settle. Clean water is then taken from the pots. <u>General comments</u> Claims made that clean reliable water was the key issue for the community <u>Mark Kone</u> Raised a number of points: i. challenged the claim re water as key issues and said that on any day he can find clean drinking water. ii. Raised power supply as a more pressing issue for the community. iii. raised the poor condition of the road from Sogeri to the village and claimed this was the major impediment to social and economic welfare – 'bigpla concern stret'. - All people (school children, pregnant mothers, elderly, those unwell etc) had at least a 4 hr walk from the village to Sogeri and

		by vehicle (4WD only) this was a one and a half hr drive (or more) over the 12 klm distance. - To get produce to the market more commonly there are only two options – either carry it or hire a 4wd (not feasible) as no PMV's travel to Kailaki - Similar issue if people go to market to buy essentials like oil, flour and rice. iv. referred to '50's when the area was a major tourism destination for 'the whiteman'. When the road was managed and maintained by and for the rubber plantations people would drive from Pom and the surrounding area to swim and picnic in the Musgrave river. Road conditions and water quality over recent time have put a stop to that. v. Expressed concern that Eda Raunu and PNG Power use and make profit from Koiari water to supply others with power and water and Koiari people are not benefitting
	WQ2 – Changes to quality over recent time	<u>Mune Doumo</u> <u>Over recent time</u> people have suffered skin irritations after bathing (referred to as 'grilly skin'). This seems to coincide with when gardens are cleared close to the bank of the creek. Fish stock (Tilapia) and other aquatic life diminished some years back but is now slowly recovering – some seemed to think chemicals were leaching out of the ground of abandoned plantations (rubber) and that previous logging had an effect. <u>Bonnie Kauka</u> Reinforced the comments made by Mune – but added: - that the school on the other side of the river (300 mtrs away) has no water supply. - Tilapia is the primary source of protein for the village Rubbish is now more often found in the creek – from people upstream and also from Kailaki village.
Utilities	U1 – Water and Power services	Water – see above Power – There is no power supply to the village
Land use practices	LUP1 – Current practices	All activities are local community based i.e. subsistence farming.
	LUP2 – Proposed changes	<u>General discussion</u>

		There may be an expansion of the 'terraced gardens' by the Highlanders Would like the road repaired/upgraded as an all-seasons access road.
Future use options	FUO1 – Economic	<u>Mark Kone</u> Strongly advocated for road upgrade and emphasised that without reliable access economic development in any form would be significantly constrained. Stressed the potential of the valley's fertile soils to 'grow anything' (chilli, ginger, banana, pineapple, cabbage) and that within the village they have knowledge and skill to grow things better than others - referred to the success of the 'highlanders' further up the valley who produce yield suited to the markets (but they also have 4WD transport). Advised that there is no point in increasing yields when there is no supply road.
	FUO2 – Conservation/Culture	<u>General discussion</u> There are cultural 'tabu' sites and other places of cultural significance that are cared for by the people. Also many stories. This could become a component of tourism as an initiative to better embrace the culture and better manage the country for conservation purposes. Continually boggy road and associated runoff is impacting on surrounding water systems. Uncontrolled burning of grasslands followed by heavy rains can cause ash and soils to be washed into river systems and accelerated erosion. 'Hot' grass fires are also causing the forests to retreat as the large forest tress and understory (not fore tolerant) are killed off. Favour a Community ranger program to not only preserve culture and the environment but to also assist with education and community driven community development projects.

Attachment D8 - Key Responses and Suggestions

Meeting Date: 13 May (0920 - 1125)

Group: Clans in attendance – Wanowari, Aoberi, Bemuri, Nidori, Magibiri and Taburi

Clan Leaders and senior community reps at meeting – Kidu Toina (Chief of Wanowari clan, Ward Councillor Ward 7 (Befa), Mr Babo Aramu (committee member of Ward 7), Mr Gembori Marava (Community Elder)

15 adults in attendance at end of meeting.

Location: Bereadabu village (Community occupies land between Sogeri markets and Sirinumu)

Issue	Question	Response/suggestions
Water quality	WQ1 – Impact on communities	<u>Ms Baba Babo</u> Water quality in the Laloki River is poor (coloured 'yellow') most of the year. Before using the water for drinking and cooking the water from the river needs to sit in a pot to allow to the soils to settle to the bottom of the pot. There are two tanks in the village but these are not for community use. There is a spring about a klm from the village which is used at times. Water is collected in 5 ltr containers. <u>Kidu Toina</u> Many springs within the area were contaminated and eventually permanently damaged by Koitaki cattle.
	WQ2 – Changes to quality over recent time	<u>Mr Babo Amara</u> The water quality has been poor for as long as the dam has existed. Villagers often suffer with upset stomachs – particularly children. Skin irritation is also common (dry and itchy skin). There is a noticeable difference between the three water sources – the Laloki being the less preferred including an unattractive odour. Since the dam aquatic life has diminished with some food species lost i.e. eel, freshwater prawn and a water grass (tumutumu) that has been harvested as a traditional food.

		The 'constant flow' prevents breeding during the dry season. On occasions when flows do stop there are heavy blooms of 'algae'. Before the dam there was plant of food 'harvested' from the river. The changes have not only impacted on the capacity to fish and gather 'tumutumu' for livelihood has also had an impact on culture. *(On being questioned the community doesn't believe this has anything to do with population increase – which is according to them has been minimal.)* The community receives no support from Edu Ranau or landowners that receive a benefit.
Utilities	U1 – Water and Power services	Water – see above <u>General comments</u> Power – There is a power supply to the village however not everyone can afford it. It is also unreliable and when it fails it can take a week for it to be reinstated. There is no back up system to prevent food from being spoiled. The community is disappointed with the lack of support from Edu Ranau and PNG Power – they are unaware if there is an agreement in place that describes support to communities within the catchment. SIDCO (Sirinumu Development Company) who receive payments from PNG Power do provide support funds to communities however not everyone benefits – mainly those clans up at the dam.
Land use practices	LUP1 – Current practices	<u>General comments</u> All activities are local community based i.e. subsistence farming and hunting with some gathering of traditional foods. <u>Mr Babo Aramu</u> Hunting: Pig, Cassowary, Deer (as per other communities) Fishing: Gurumu (small native fish – impacted by Tilapia), native catfish (varies in size becoming larger downstream), other native fish are Korobo and Soveka. Also freshwater shell (common) and a small freshwater crab. <u>Ms Baba Babo</u> Garden varieties: Taro, Yam, Banana, Pineapple. Yam is traditional Koiari food There is also a small T-Shirt printing business in the village – however not active on a continuous basis. Owned by Mr Recks Ea'ah.

	LUP2 – Proposed changes	General discussion Some aspiration to increase yield of Yam to serve the local market but cost of getting to market prohibitive. Support a more 'regional approach to market supply through different villages specialising in different products and services. They suggested that Koiari people must work together and become more inclusive and cooperative (some jealousy toward those that use initiative and make money. Kidu Toina Yam was heavily produced by Koiari people in the past but not marketed properly – currently sold of the back of a truck. Would like to see this reintroduced but with proper marketing. DPI have been discussing how yields can be improved but they come and go and nothing changes. Potential for more variety suited to PoM market such as: Brochili, cabbage, carrot, onion (which grows well), tomato, water melon, leak, snake beans, boch choy and cauliflower. Edu Ranau and Koiari LLG also developed a plan to improve water quality (tank installation – 2 per village) in 2016 but nothing has eventuated.
Future use options	FUO1 – Economic	Babo Aramu Advised that the local soils were suitable for growing Yam and they practiced a 3-5 year rotational program in existing gardens. With additional assistance from experts yield could be increased to commercial levels. Within the village there was a small t-shirt and banner printing business. With an increase in tourism this business could also grow – and potentially be expanded to make sales to Kokoda Trekkers (3500 per annum)
	FUO2 – Conservation/Culture	General discussion The dam has impacted on traditional hunting and gathering practices that were Laloki river based. This has also impacted on culture as traditional skills cannot be passed down. The connection between the people and the natural/cultural landscape has been lost. Any initiative that assists people to reconnect with the natural/cultural landscape would likely have an influence on community health and well-being which would also develop local capacity to improve 'traditional' economies.

Attachment E – Clan Representation at each Community meeting

Region	Clan	Meeting place and date					
		Girinumu 6 May	Karakadubu (Depo) 7 May	Sirinumu 8 May	Botoguni 9 May	Kailaki 10 May	Bereadabu 13 May
Rauna	Narime		x				
	Omani		x				
	Ianari		x				
	Nadeka		x				
Sirinumu	Magabiri			x			x
	Tuia			x			
	Bemuri			x			x
	Orari			x			
	Wanowari			x			x
	Togo Korohi			x			
	Korohi Bareri			x			
	Nidori			x			x
	Amoa Monotori			x			
	Maneri Korohi			x			
	Omori Korohi			x			
	Veburi			x			
	Dagoda			x			
Sogeri Central	Dauri		x		x		
	Aoberi						x
	Eikiri	x	x				
	Manari	x					

	Ioriwari			x			
	Mokava		x				
	Vakari	x	x				
	Taburi		x	x			x
	Vaiakori	Representative of clan briefed only					
Iditu/Hogeri	Baruari					x	
	Korovari					x	
	Meuri					x	
	Hogeri					x	
	Haveri					x	
	Moroka					x	
	Vano Rori					x	

Attachment F - Other impromptu discussions

Name of person/group	Issue	Comment/Aspiration
Frank Godua – Scenic Lookout over Rauna Falls	Tourism	Limited parking/safety Increasing tourist visitors to boost local economy and empower locals
Ms Sammi (Susan) Toina Nadeka clan Military Historical site Sogeri Located on original Dauri village	Military Heritage Tourism	Papuan Courier Printing Press (WWII) Fleet street site Relocated to PoM as Post Courier Possible site of interest to PNG heritage and tourist potential
Mr Iaba Toina Omani clan Koiari Cultural Group	Cultural awareness and practice	To reintroduce culture (dance, song and story) to young people. To introduce Koiari culture to all tourists who visit/pass through Depo
Bouda Inara and Recks Ea'ah Crystal Rapids picnic and swimming Laloki river	Tourism and Conservation	Turbid water – impacting on visitor experience Locals bath here Would like to expand to accommodate camping Also T-Shirt printing 'Studio' at Bereadubu village
Dr. Matthew G Leavesley University of PNG; Senior Lecturer in Archaeology	Education (PNG context) Capacity development Archaeological Site Protection and Management	Interested in providing input into archaeological site management and Ranger training (PNG context)
Ms Margaret Ufa (margaretufa@gmail.com)	Sogeri Floriculture	Would like to be involved in future discussion of Floriculture as an local economic initiative.
Clan Chairs and community members Kala Meia (Omani), Inara Moio (Narime), Koitio Womara (Ianari), arron Warite (Nadeka, Eikiri) and Vaiakori rep Ward 5 Councillor – Mr Billy Ivai	Rouna (17 mile) Region 1 Meeting - briefing only	Gave an outline of the project and then community meetings to date and encouraged those that haven't been involved to seek feedback from participants. Briefing was well received

Attachment G - Points to introduce the meeting and questions (first person and final version)

Pass out the two page tok pisin paper 10-15 mins before the meeting.

Encourage those that are able to, to brief others not versed in tok pisin

Encourage some discussion amongst people before the meeting.

Call meeting open

Opening Prayer from member of community (if relevant)

Introduce self

Pay respect to:

> Clan leaders, Elders and all Koiari people that have come before us (the old people)
>
> All Koiari people and their beliefs and culture who are with us today
>
> Acknowledge that the young and those that have yet to come are entitled to healthy and happy lives
>
> and to achieve this we must

Wok bung wantaim

Purpose of visit:

I've been asked to come to your village to talk with the Koirai communities of the Sirinumu Dam, Laloki River and Eilogo creek catchment areas to seek from you information on the following issues:

- Water quality:
- Water Supply and Power supply concerns
- How the land is being used
- How we can work together to improve livelihoods (economic and social) and conservation

I cannot give any commitments or guarantees *(this must be clearly understood – ask if people understand this)*

But I do come (on behalf of the people that sent me here) with good intentions and want you to know that I am sincere in wanting to 'wok bung wantaim'.

I have been working in PNG with Koiari people (mountain Koiari and Sogeri Koiari since 2014 – mainly on the mountain but have spent time on the Sogeri plateau.

I regard Koiari people as friends and feel very comfortable when in the company of Koiari people.

I want you to feel the same way toward me.

We will achieve more by working together – as did the old people and as you continue to do so in your communities.

Our conversation must be friendly and positive and have a big focus on the future (we can't undo the past)

Please feel free to be open and honest. I am happy to hear your frustrations and concerns and any information you feel will assist us (together) to put up a good argument for making change.

<u>Questions</u>

I would like your help to answer the following:

- How does the quality of the water in the dam, Laloki River and Eilogo Creek impact on the communities' livelihoods? (i.e. reduction in drinking water quality, fish stocks, recreation?)
- Has there been noticeable changes in water quality in recent decades (i.e. more turbidity, reduction in drinking water quality, fish stocks, recreation)

- Are there water supply/power supply issues that impact their communities

- What are the current land use practices (i.e. hunting, gathering (from within natural systems) burning, clearing, drainage works, stock/animal management, gardens/horticultural, revegetation, fertilizers etc.)

- Are there any plans for any future changes to land use practices

- What are the community aspirations for:
    - economic development
    - conservation.

I will be talking (have talked) with other Koiari clans, leaders and landowners and also Ward councillors and possible PNG Government representatives

After I talk to everyone I'll put your messages into a report and give that to the people that have asked me to talk to you.

In real terms I am your messenger. From this moment on I am also working for you.

What happens after I submit the report will be up to others but as I mentioned if we can put together a good story then maybe we can influence some changes.

Tenkyu tru

Pass to Inara for a brief interpretation and then focus on the 'questions'

End meeting with closing prayer from community member (if relevant)

Attachment H- Ol Point Blo Statim Miting na sampla askim

Displa em i Artie na sampela ol biglain i askim em long kam na toktok wantaim na kisim sampla tingting bilong yupla ol lain long ol Koiari komuniti long ol hap olsem Sirinumu Dam, Laloki River na Eilogo Creek catchment eria (Fopela Regions ie. Sirinumu, Sogeri Central, Rouna na Iditu/Hogeri). Em bai givim sampla askim long kisim infomasen or tingting long ol kain ol samting olsem or hevi long sait blong:

- Water quality

helt or klin bilong ol wara bilong yupela

- Water Supply or Power Supply concerns

lukluk bilong yupela long hau yupela save kisim wara bilong kuk or dring na tu hau yupela save kisim pawa

- How the land is being used

hau yupela na ol narapela wok long usim graun bilong yupela stap

- How we can work together to improve livelihoods (economic and social) and conservation

hau mipela ken wok bung wantaim long kamapim gutpela sinduan bilong olgeta man na meri insait long ples; na tu long sait bilong ol pipol long painim liklik wan toea tu toea; na seim taim tu long hau bai yumi ol lain bilong nau taim ken makim dispela olgeta samting na lukautim bus, graun, wara na ol abus bai stap longpela taim tu we ol lain bilong yumi long bihain taim ken hamamas long ol dispela samting tu

Artie laik makim klia olsem em i nonap long wokim komitment or makim promis nating long wanpla samting bikos dispela wok nau em makim em i wok painim aut tasol.

Tasol, long seim taim em i askim na laikim olsem yupela olgeta mas givim stretpla na gutpela infomasen, tingting or bekim long ol askim blong em long halivim em long kamapim gutpla na strongpela tingting na toktok bilong kamapim gutpela senis insait long ol komuniti or lain blong yumi long ples.

Artie i kam wantaim gutpela bel na em i laik wok bung wantaim yupela long kamapim gutpela senis tasol dispela bai i nonap kamap sapos yupela ino givim gutpela tingting blong yupla tu. Yumi nonap long senisim wonem samting bin kamap long taim bifo tasol yumi mas tingim ol tumbuna bilong yumi long bihain taim na stretim rot bilong ol nau yet.

Artie i bin wok insait long PNG na wantaim ol lain long Koiari long 2014 yet – bikpla hap taim em i wok insait long Kokoda tasol em i bin wok tu long Sogeri plateau na em i gat planti poroman long hia tu.

Ol Askim

Artie i laikim bai yupla ol komuniti givim bekim bilong yupela long ol dispela ol askim:

- How does the quality of the water in the dam, Laloki River and Eilogo Creek impact on the communities livelihoods? (i.e. reduction in drinking water quality, fish stocks, recreation?)

Nau wantaim dam, wara insait long Laloki na Eilogo na dam yet i gutpla na klin oh? Yupela stil igat gutpla wara blong dring? Wara stil igat planti pis? Yupela stil igat ol gutpla hap long arere long wara long pilai na hamamas?

- Has there been noticeable changes in water quality in recent decades (i.e. more turbidity, reduction in drinking water quality, fish stocks, recreation)

Insait long ol yar ol i bin wokim dam i kam inap nau, yupela ken luksave long senis long klin bilong wara tu? Wara em i klin or deti? Wara em i stil gutpea bilong dring tu? Igat ol planti pis stap yet insait long wara? Yupela stil igat ol gutpla hap long arere long wara long pilai na hamamas?

- Are there water quality/power supply issues that impact their communities?

Inap yupela stori moa long sampela ol hevi long sait bilong klin bilong wara we yupela ol lain long ples i lukim? Yupela igat sampela hevi tu long sait bilong kisim pawa o nogat?

- What are the current land use practices (i.e. hunting, gathering (from within natural systems) burning, clearing, drainage works, stock/animal management, gardens/horticultural, revegetation, fertilizers etc.)

Hau yupela save usim graun long nau taim? Kain olsem long hunting long painim abus, painim ol kaikai long bus nambaut; kukim na katim bus na wokim baret bilong wokim gaden o rot; wokim gaden na planim ol kaikai or flawa na diwai; lukautim ol animol, pik, kakaruk, sipsip or bulmakau bilong abus bilong kaikai; planim ken ol diwai na bus bihain long gaden i pinis; na tu long sait bilong usim fertilizers (or kemikol wara bilong ol waitman) long wokim giraun bai karim kaikai ken. Plis stori moa long sampela ol dispela samting na sapos igat ol narapela wei tu we yupela save usim giraun bilong yupela.

- Are there any plans for any future changes to land use practices?

Yupela igat plan or tingting long senisim hau yupela bai usim graun long bihain taim? Or igat sampela pasin bilong usim giraun nau we yupela laik senisim?

- What are the community aspirations for:

Wonem ol tingting or bilip bilong komuniti or ol lain long ples

    - Economic development or

    Long sait bilong wokim moni or painim moni long bihain taim?

    - Conservation or

    Long hau bai yupela i lukautim bus, giraun, wara na abus long nau na bihain taim tu?