River Styles in the Bislak Catchment in Luzon, Philippines

Pamela Louise Tolentino · John Edward Perez · Esmael Guardian · Richard Boothroyd
Richard Williams · Trevor Hoey · Carlos Primo David

June 2020

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Acknowledgements

This report on the River Styles in the Bislak Catchment is made possible through the PH-UK "Catchment Susceptibility to Hydrometeorological Events: Sediment Flux and Geomorphic Change as Drivers of Flood Risk in the Philippines", (NE/S003312), a collaborative project between the University of the Philippines and the University of Glasgow co-funded by the DOST-PCIEERD of the Philippines and the NERC of the UK. The River Styles Short Course conducted in the Philippines in November 2019 was funded by the Scottish Funding Council - Global Challenges Research Fund (SCF-GCRF).

Our deepest and sincerest gratitude to **Professor Kirstie A. Fryirs**, Macquarie University, New South Wales, Australia and **Professor Gary J. Brierley**, University of Auckland, Auckland, New Zealand for imparting their knowledge and expertise during and even after the conduct of the workshops on "Introduction to Fluvial Geomorphology" and "River Styles Short Course" in the Philippines. These paved the way for the researchers and partner agencies to see the importance of understanding the concepts of geomorphology in effectively managing the rivers.

We would like to thank our project staff for their assistance in acquiring the data used in the analyses – Dr. Gennie Ramos from UP NIGS for the write-up on Geology, Mr. Ross Agot from the DENR-MGB for the Geologic Map, and Mr. Richard Orendain from PAGASA for the climate data.

We would also like to acknowledge the generosity and unwavering support of the Municipality of Vintar during the conduct of the project and the River Styles Short Course led by their Hon. Mayor Larisa Foronda. Our deepest gratitude to Mr. Robbie Benigno and Mr. Almond Leaño for their time and dedication in assisting the Catchment Project Team in all the fieldworks and activities ever since the project started (SFC-GCRF 2018, DOST-PCIEERD NERC 2018, SFC-GCRF: River Styles 2019).

Catchment Project

University of Glasgow

Brunel University London

Natural Environment Research Council

Section 1. Executive Summary

River Styles Framework and Philippines context:

The River Styles Framework integrates the social and physical aspects of a river to understand how the river behaves and how its needs must be addressed in a catchment context. It builds upon the concept of geomorphology to fill in the 'missing link' in sustainable management of rivers, especially in the Philippine setting, where river condition is assessed by the metrics of water quantity and quality. **Reading the landscape** means relating our rivers to technical river theories. This way we use our knowledge to **work with nature** and not go against it. **Knowing our catchment** by **respecting the diversity** and the different patterns of rivers at the catchment scale is another way of recognising the existence of process-based relationships in rivers. These key messages are unfamiliar concepts in the Philippines, but once instilled into our minds will enable improved planning and decision-making around the sustainability of our river systems. In this report, Stage One of the River Styles Framework is applied to a characteristic tropical river catchment in the Philippines.

Application to the Bislak Catchment:

The Bislak Catchment is located in the Ilocos Region of NW Luzon Island. Census data (2010) indicate >30,000 people live on the Bislak River floodplain, with the river having cultural significance (especially for the Vintar community) and a variety of uses (including gravel quarrying, agriculture/aquaculture, and leisure). The catchment area is 586 km^2 and elevation ranges from 0 to 1857 m. Headwaters are bounded by the Luzon Central Cordillera (LCC) Mountain Range and catchment geology is composed mostly of thick sequences of sedimentary rock units with local exposures of intrusive and volcanic igneous rocks. Three morphostructural regions (landscape units) were identified in the catchment: Steep Upland, Rugged Hills, and Lowland Plains. The catchment has Type I climate, classified as having two distinct seasons, dry from November to April and wet from May to October (mean annual rainfall = 2019 mm). The catchment experiences numerous typhoons each year, generating significant overbank flooding and the potential for damage to the Barangay communities.

River diversity in the Bislak Catchment:

Eight distinct River Styles were identified in the Bislak Catchment, indicating considerable geomorphic diversity over a relatively small catchment area. Three River Styles were identified in the confined valley setting (1-3), three in the partly confined valley setting (4-6) and two in the laterally unconfined setting (7-8). River Styles included: (1) *Confined, Steep Headwater*, *Bedrock bed;* (2) *Confined, Gorge*, *Boulder bed;* (3) *Confined*, *Occasional Floodplain Pockets*, *Boulder bed;* (4) *Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain*, *Cobble bed;* (5) *Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Cobble bed;* (6) *Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel bed;* (7) *Laterally unconfined, Continuous Channel, Braided*, *Gravel bed,* and (8) *Laterally unconfined, Continuous Channel, Deltaic*, *Sand bed.* Over the ~250 km channel length analysed, 57% of channels were located in a confined valley setting, 37% in a partly confined valley setting and 6% in a laterally unconfined setting. The most abundant River Style was *Steep Headwater* (28%), followed by *Gorge* (24%), and then *Planform-controlled, Wandering, Discontinuous Floodplain* (19%).

Downstream patterns in the Bislak Catchment:

Downstream sequences in River Styles were used to determine five downstream patterns. A characteristic downstream pattern (Pattern 1) was observed in 11 out of 17 tributaries. For this pattern, sequences from *Steep Headwaters* to *Gorges* to *Occasional Floodplain Pockets* were found in the Steep Upland landscape unit. At the base of the Rugged Hills landscape unit, as the valley setting transitioned from confined to partly-confined and the process zone shifted from source to transfer, the downstream sequence continues through *Bedrock Margin-controlled, Discontinuous Floodplain* to *Planform-controlled, Wandering, Discontinuous Floodplain*. Finally, as slope is reduced and the capacity for lateral adjustment increases in the Lowland Plains landscape unit, the downstream sequence continues through *Continuous Channel, Braided Channel* to *Continuous Channel, Deltaic*. Two subsets of Pattern 1 (Patterns 2 and 3) were identified where differences in geology and/or the presence of faulting imposed a morphological forcing. The observed differences in downstream patterns were explained by changes in boundary conditions, including: geology, stream power and the flux boundary conditions (water and sediment transport regimes).

Implications for sustainable river management in the Philippines:

Sustainable river management is not independent from geomorphic insight, but rather made more coherent from it. Stage One of the River Styles Framework has offered a physical template for identification of river character and behaviour in the Bislak Catchment, helping recognise the diversity and (potential) dynamism of the system. Continued application of the River Styles Framework will offer the opportunity to realise integrative, geomorphologically-informed river management throughout the Philippines. The succeeding stages of the framework emphasizing on river evolution and assessment of geomorphic conditions to predict its future trajectories and trends are essential in understanding river recovery towards a better river management/intervention. The River Styles Framework can be the stepping stone in addressing the gap in hydromorphological characterisation of rivers in the Philippines.

Section 2. Introduction

The River Styles Framework is a scientific tool with four stages shown in Figure 2.1 developed by Professor Kirstie Fryirs of Macquarie University and Professor Gary Brierley of the University of Auckland in 2005 to support proactive and integrative scientifically informed river management. This works on integrating the social and physical aspects of a river to understand how the river behaves and how its needs must be addressed in a catchment context. It builds upon the concept of geomorphology to fill in the 'missing link' in sustainable management of rivers, especially in the Philippine setting, where river condition is assessed by the metrics of water quantity and quality.

In general, the River Styles Framework revolves around its key philosophies:

- Respect river diversity (acknowledging the variable forms and rates of adjustment of different reaches)
- Work with change (planning for average conditions or circumstances is inappropriate)
- Work with catchment-scale linkages
- Use a geomorphic platform to integrate biophysical processes, presenting a coherent physical template for management activities

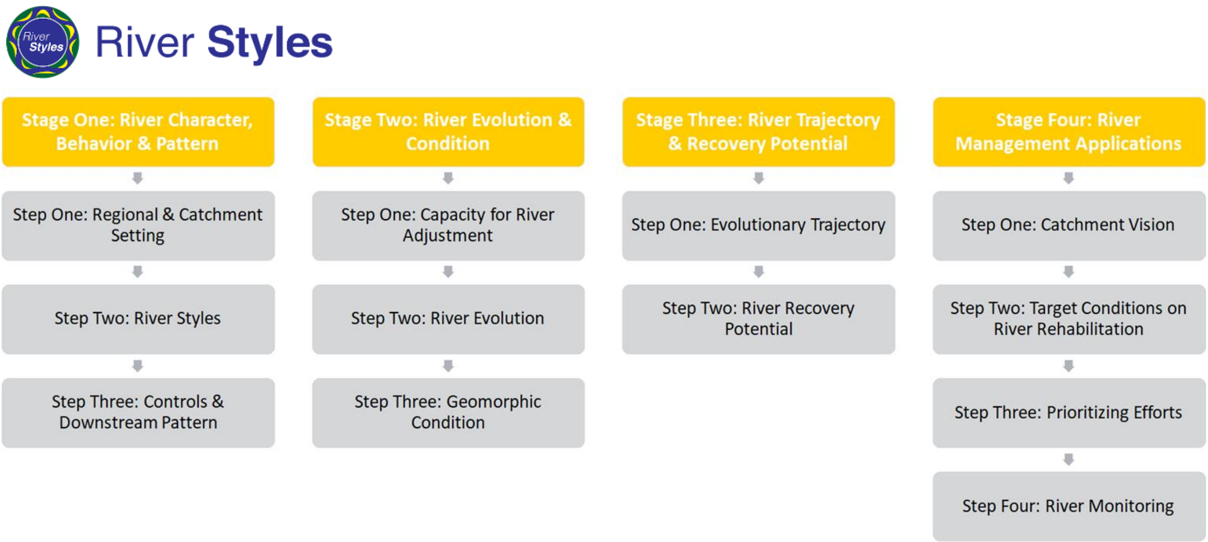


Figure 2.1 The four stages of River Styles Framework (Brierley and Fryirs, 2005).

Application of geomorphic insights at catchment scale serves as a tool to identify river diversity in relation to its underlying reach-scale forms and processes working on a reach-scale. Working on information-based assessment of our river's geomorphic condition helps us to predict its likely future trajectory and appraise its potential for recovery. These previous analyses help us to build on appropriate measures for river rehabilitation, restoration, and prevention of further harm on river health.

The River Styles Short Course (RSSC) held on November 11-15, 2019 in Vintar, Ilocos Norte, Philippines was the first time this type of course had been conducted in the country. This is one of the Impact Activities of the PH-UK research project entitled “Catchment Susceptibility to Hydrometeorological Events: Sediment Flux and Geomorphic Change as Drivers of Flood Risk in the Philippines” (Catchment Project: (NE/S003312)). This project is co-funded by the Department of Science and Technology-Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD) of the Philippines and Natural Environment Research Council (NERC) of the United Kingdom. The RSSC was attended by the project staff and project partners from different National Government Agencies (DOST-PAGASA, DENR-MGB, DPWH, DENR-RBCO, NDRRMC-Region 1, DOST-PCIEERD), Universities (De La Salle University, Mapua Institute of Technology, University of the Philippines, University of Glasgow) and staff from the Municipality of Vintar. The conduct of the workshop was funded by the Scottish Funding Council - Global Challenges Research Fund (SCF-GCRF).

Analyses for the report were completed following the RSSC. The main purpose of the report is to serve as an exercise to further develop the geomorphological skillset of the project personnel of the Catchment Project by gaining accreditation as River Stylers. This will also be the initial step to fulfill the intended publications and applications of the River Styles in the Philippines. It is also intended as an exemplar of a Stage One River Styles analysis in the Philippines, which can be used as a reference by other practitioners or researchers in the Philippines that wish to conduct this analysis on a different catchment.

Looking ahead, the goal is to pass on the employed methodology of the Stage One of the River Styles Framework to the partner agencies as a template in their respective river management plans. The project staff involved in the Catchment Project will also be assigned at least one catchment to define and interpret the River Styles.

This report is a product of the collaborative work of the Catchment Project researchers, Pamela Louise M. Tolentino, John Edward G. Perez and Esmael L. Guardian with the support from Dr. Carlos Primo C. David. The content and geomorphic analysis were reviewed and done under the supervision of Dr. Richard J. Boothroyd and Dr. Richard D. Williams of the University of Glasgow and Prof. Trevor B. Hoey of Brunel University of London.

The outline of this River Styles Report as suggested by the workbook is as follows:

SECTION 1: Executive Summary

SECTION 2: Introduction

SECTION 3: Methodology

SECTION 4: Regional and Catchment Setting Analysis

SECTION 5: Definition and Interpretation of River Styles

SECTION 6: Assessment of Controls on the Character, Behaviour and Downstream Patterns of River Styles

SECTION 7: Summary and Conclusions

Section 3. Methodology

3.1 Regional and Catchment Setting Analysis

Regional and catchment characteristics determine the boundary conditions on possible River Styles that are present in the catchment. These were derived from topographic analysis using digital elevation models (DEMs), as well as ancillary data - including climate and basin hydrology, vegetation, and land use history - that were gathered from multiple sources specifically identified later.

Landscape units are topographic features with a distinct pattern of landforms - derived in this study from topographic analysis (Spencer et al., 2004; Brierley and Fryirs, 2005; Fryirs and Brierley, 2013). Analysis was based on physiographic characteristics, landscape position, geology, relief, as well as longitudinal slope and valley width. Physiographic characteristics and landscape position were used primarily to determine and name landscape units, further identified by elevation. A map of the distribution of landscape units was produced.

Regional geology influences the catchment characteristics and availability of materials. Tectonic setting determines the sediment generation and erosion rate while lithology describes the physical characteristics of the rock units. The geologic map is provided from the Mines and Geosciences Bureau under the Department of Environment and Natural Resources (DENR-MGB). The DOST-Philippine Institute of Volcanology and Seismology (DOST-PHIVOLCS) generated the fault map. Stratigraphic column of the formations is sourced out from the Lexicon of Philippine Stratigraphy (Peña, 2008). The distribution of geology and faults in the Bislak Catchment is presented and complemented by the stratigraphic column and description of the formations underlying the catchment.

Longitudinal profiles were generated to illustrate downstream changes in elevation and slope along the stream network of the Bislak Catchment. An available nationwide digital elevation model (DEM) acquired in 2013 and generated through airborne Interferometric Synthetic Aperture Radar (IfSAR) technology, with a 5 m spatial resolution and 1 m root-mean-square error (RMSE) vertical accuracy (Grafil and Castro, 2014), was used for topographic analysis. TopoToolbox V2 (Schwanghart and Scherler, 2014) was used to extract the stream network using standard flow-routing algorithms. Elevation, slope, and contributing catchment area were computed for every 200 m segment in the generated network. The contributing catchment area is also illustrated and superimposed along the longitudinal profiles. Slope was analysed as a primary control of river character and behaviour while contributing catchment area was considered as a control on downstream changes in discharge. Relative stream power was then estimated from slope and contributing catchment area, to provide insight on the energy conditions that produce the differences in River Styles. Relative stream power is calculated as A.P.S where A = upstream area (km^2), P = mean annual precipitation (mm) and S = slope (m/m). Mean annual precipitation (2042 mm) has been calculated from the APHRODITE data set 1998 – 2015 (APHRO_MA_PREC_CLM_025deg_V1901).

The current climate condition sets the flux boundary conditions under which rivers operate (Brierley and Fryirs, 2005). It influences the energy, sediment flux and distribution of vegetation along the rivers. The impacts of climate change are important for the magnitude and frequency of high discharge events and their geomorphic effectiveness. Climate data was retrieved from the

Laoag Synoptic Station managed by the DOST-Philippine Atmospheric, Geophysical, and Astronomical Services Administration (DOST-PAGASA). 50-year (1969 to 2018) average daily and monthly rainfall and average minimum and maximum temperature were analysed.

Land cover further describes the conditions of the catchment, specifically in a contemporary setting. Land cover maps were acquired from the National Mapping Resource and Information Authority (NAMRIA) which produced the data from 2010 SPOT satellite imagery. Data acquired from these maps were supplemented by information detailed in land use and forest use plans of municipalities within the Bislak Catchment, mostly from the Municipality of Vintar.

3.2 River Styles Identification and Interpretation

River Styles present in the Bislak Catchment were identified by aerial image interpretation in Google Earth, viewed at the reach and unit scales. In addition to aerial imagery, other tools were used to supplement identification of existing River Styles and further interpretation of river behaviour.

Identification was completed following the procedural tree prescribed by the River Styles Framework shown in Figure 3.1 (Brierley et al., 2002; Brierley and Fryirs, 2005). The River Styles are then named following the naming convention of Fryirs and Brierley (2018) shown in Figure 3.2. Reaches with the same valley setting, lateral confinement, river planform, and bed material size even with different prominent geomorphic units were clumped into one River Style. From 18 initially identified River Styles, the number of analysed River Styles was clumped down to eight River Styles - three in the confined valley, three in the partly-confined valley and two in the laterally unconfined valley setting.

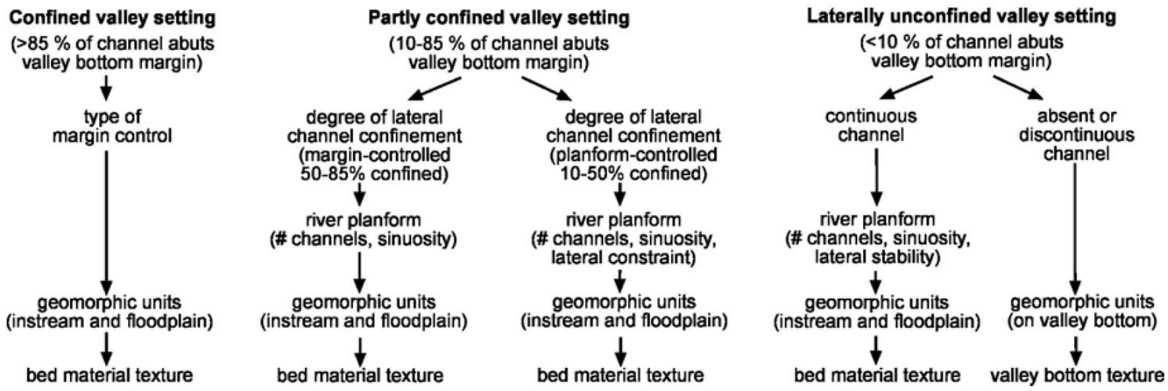


Figure 3.1 River Styles procedural tree for river identification.

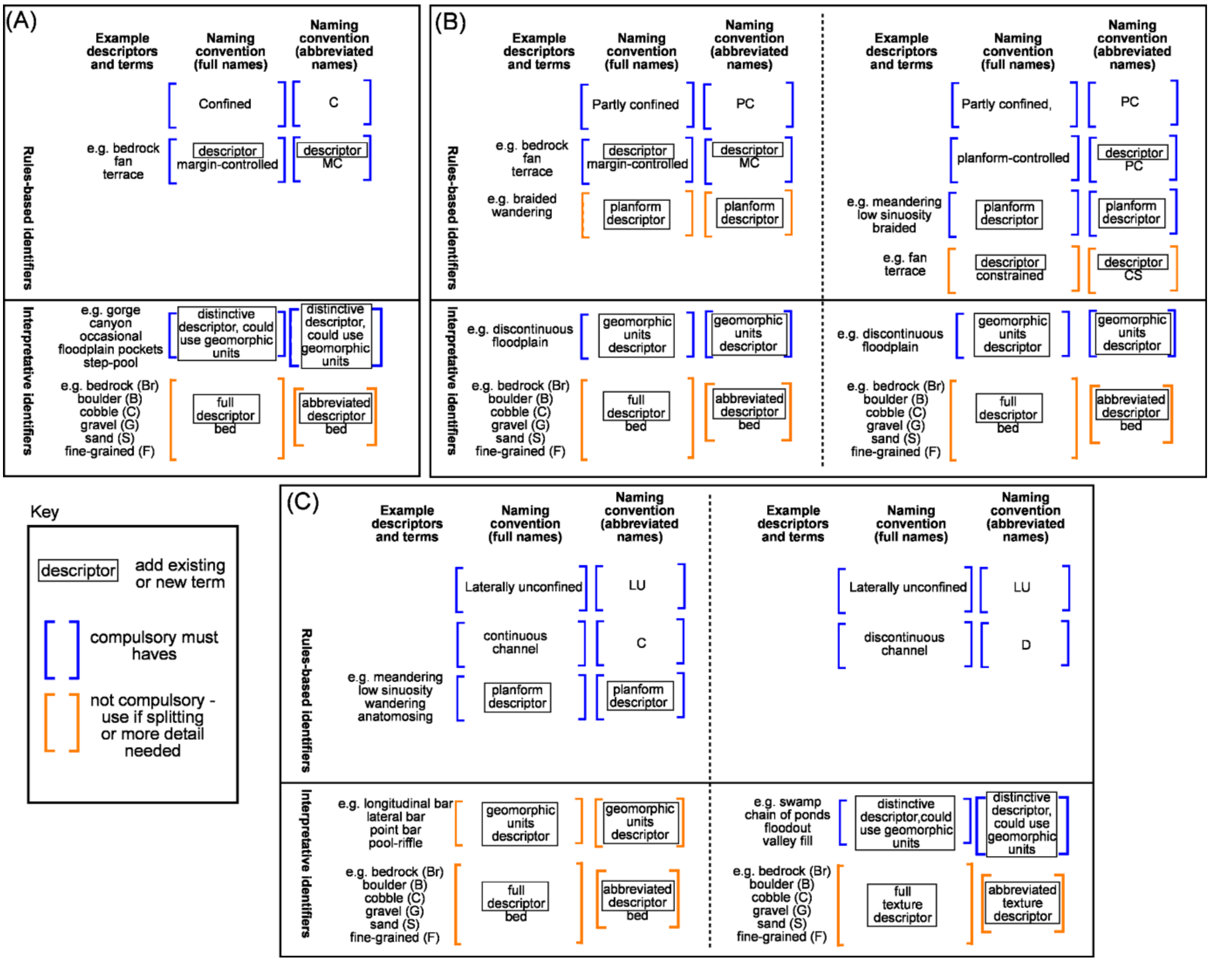


Figure 3.2 River Styles naming convention. Abbreviations are enclosed in parentheses (Fryirs and Brierley, 2018).

Further supporting the analysis made on each proforma was the *in situ* observation of the geomorphic units identified and examined during field exposure of the River Styles Short Course and supplementary fieldworks of the Catchment Project which includes sediment sampling from different bar locations and identifying bed and bank material in bathymetry surveys. Reaches in the confined valley settings are inaccessible, limiting the analysis to aerial images.

3.3 Controls

Imposed and flux boundary conditions identified from the regional and catchment setting are used to appraise and identify different downstream patterns and behaviour. Downstream patterns of River Styles were assessed for all major tributaries that drain the Bislak Catchment. For each distinct pattern, controls that determine the character and behaviour of each River Style were analysed using a representative river. Plots of longitudinal profiles superimposed with contributing catchment area and relative stream power were interpreted and presented with corresponding diagrams that defined boundaries of River Styles, landscape units, valley setting, lithology, contemporary process zones, and sediment transport regime along these profiles

4.1 General Overview

The Bislak Catchment is located in the northwestern part of Luzon Island, Philippines as shown in Figure 4.1. A large portion of the catchment lies within the Municipality of Vintar while portions of the upstream are in a number of municipalities – Dumalneg and Bangui in the north and Carasi in the south – while the downstream end is within the Municipality of Bacarra. The headwaters are bounded by the Luzon Central Cordillera (LCC) Mountain Range in the east. The river primarily flows through the Municipalities of Vintar and Bacarra (Ilocos Norte) although parts of the catchment are in a further five municipalities. The Bislak River discharges into the West Philippine Sea. The total catchment area is 587 km^2.

Figure 4.1 Location map of the Bislak Catchment. Labeled municipalities in dark grey belong in Region I while adjacent regions, Region II and Cordillera Administrative Region (CAR) are also labelled. Darker shade of grey shows the location of Bislak Catchment where most of its area is in the Municipality of Vintar while the downstream end is located in the Municipality of Bacarra.

4.2 Landscape Units

Three morphostructural regions were identified for the Bislak catchment – Steep Upland, Rugged Hills, and Lowland Plains landscape units – and are summarised in Table 4.1. Figure 4.2 shows the distribution of the landscape units within the catchment. Figure 4.3 shows the elevation map of the catchment. Steep Uplands are located in the headwaters of the catchment, ranging from elevations of 300 m to a peak of 1857 m and with slopes reaching up to 71°. This landscape unit occupies approximately 60% of the catchment, covering 349 km^2. Valleys in the Steep Upland landscape unit are mostly v-shaped and incised. These valleys are typically less than 25 m in width. This landscape unit is densely vegetated, comprised of closed and open forests.

Rugged Hills are situated at the foothills of the Steep Upland landscape unit, characterised by partly-confined valleys. Valley width ranges between 25 to 1300 m while elevation ranges between 35 - 300 m, with slopes reaching up to 68°. The Rugged Hills landscape unit occupies approximately 36% of the catchment. Vegetation cover in this landscape unit is less dense compared to the Steep Upland landscape unit, comprised of open forests, plantations, and shrubs, as well as grasses.

Lastly, Lowland Plains are found in the alluvial portions of the catchment, starting from the emergence of wide, continuous floodplains on both banks from elevations of 35 m, down to the outlet of the Bislak River where it is situated in laterally unconfined valleys. Valley width in this landscape unit is greater than 400 m. It is mostly gently sloping and covers approximately 5% of the catchment area. Natural vegetation cover is relatively sparse, with most of the landscape being built-up or used for crop farming.

Table 4.1 Characteristic description of landscape units in the Bislak Catchment.

	Steep Upland	Rugged Hills	Lowland Plains
Physiographic character or landscape morphology	Steep slopes with narrow, incised valleys.	Moderately elevated areas with steep slopes and partly-confined valleys.	Relatively flat plains with wide partly-confined to laterally unconfined valleys.
Landscape position	Headwaters of the catchment.	Between the foothills of the Steep Upland and the alluvial plains.	At the foot of rugged and hilly landscapes.
Geology	Sandstone, shales, reef limestone; marine clastics, pyroclastics; quartz diorite; undifferentiated metavolcanics	Sandstone,shales,reef limestone; Sandstone, shales, conglomerate	Recent deposits
Area	349 km^2 (59.1%)	212 km^2 (35.9%)	29 km^2 (5.0%)
Elevation	300 – 1857 m Mean: 705 m SD: 307 m	35 – 300 m Mean: 170 m SD: 75 m	0 – 35 m Mean: 20 m SD: 8 m
Relief	1557 m	265 m	35 m
Mean Slope	0.53 m/m	0.33 m/m	0.04 m/m
Valley width	> 25 m	25 – 1300 m	Laterally unconfined

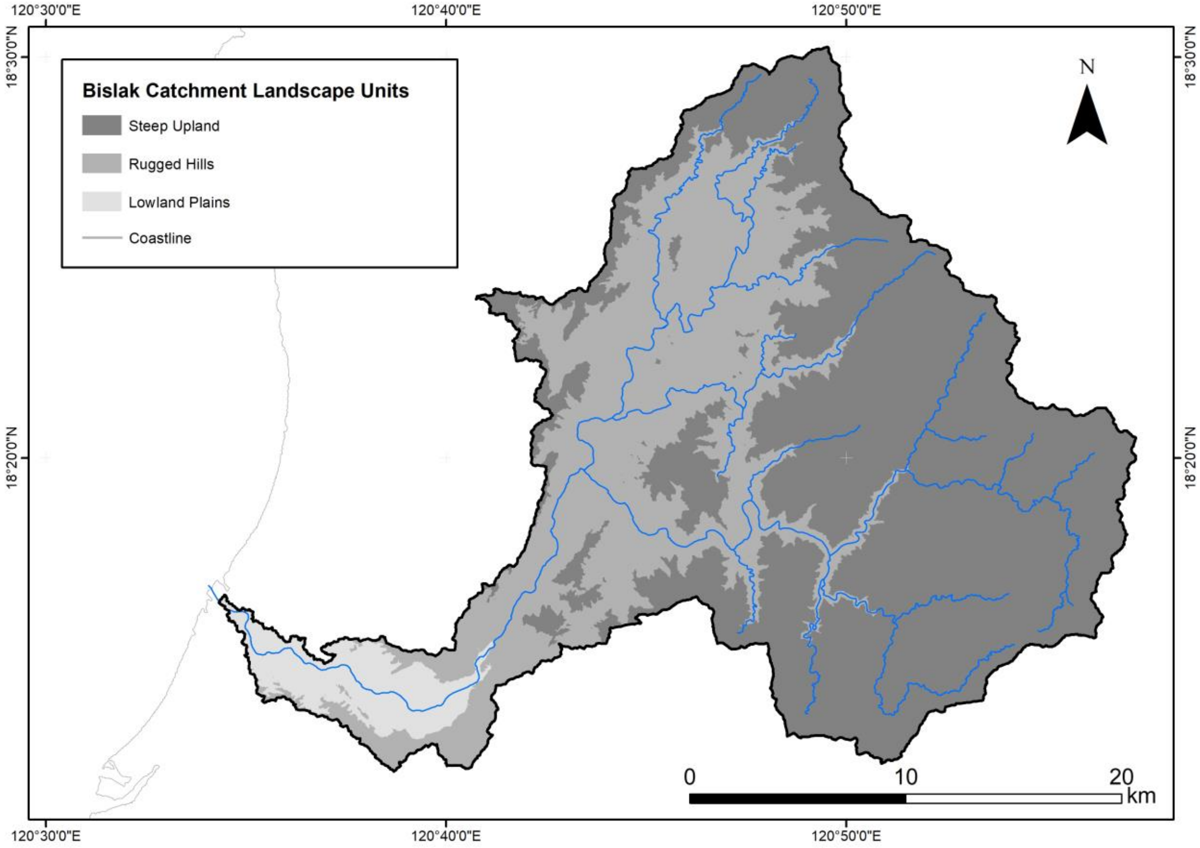


Figure 4.2 Distribution of landscape units in the Bislak Catchment

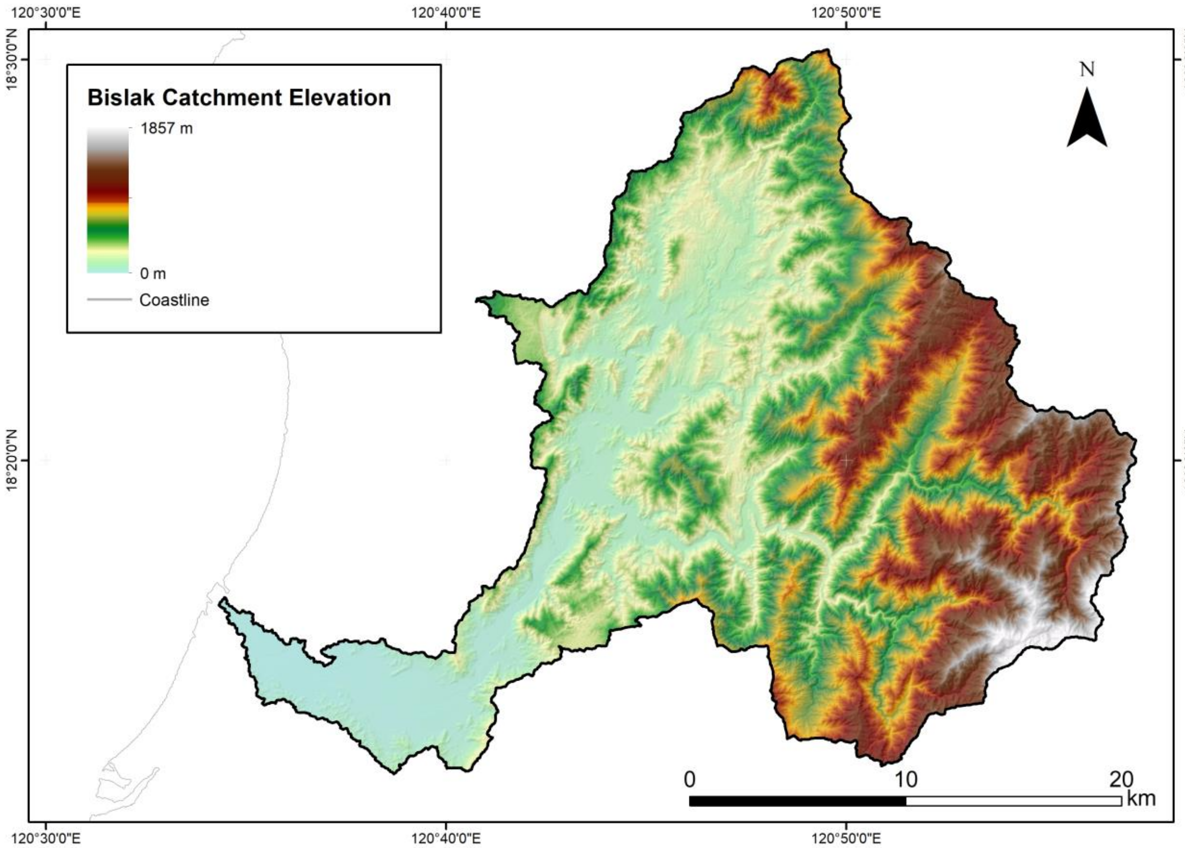


Figure 4.3 Elevation map of the Bislak Catchment.

4.3 Geology

The Municipality of Vintar is mostly underlain by thick sequences of sedimentary rock units with local exposures of intrusive and volcanic igneous rocks. The upstream section of the Bislak River is characterised by a steep terrain that is underlain by conglomerates, breccias, sandstones, and intrusive rocks of the Bangui and Bojeador Formations. Downstream, sedimentary rocks belonging to the younger Pasuquin Limestone and Laoag Formation are exposed. Figure 4.4 shows the stratigraphic column of the Ilocos Basin from Peña (2008). Northeast-trending lineaments are also apparent along ridges in the upland areas and are reflective of tectonic structures, mainly the Vigan-Aggao Fault, which underlies the region. These tectonic structures also possibly influence the variation in fluvial characteristics of the Bislak River as shown in Figure 4.5.

4.3.1 Bangui Formation

The Late Eocene – Late Oligocene (28.4 - 37.2 Ma) Bangui Formation consists mainly of volcanic sand-stones interbedded with varying amounts of conglomerates and mudstones, with local exposures of olistostrome units (Pinet, 1990; Pinet and Stephan, 1990). Pinet and Stephan (1990) described the olistostrome unit along the Vintar River section to contain serpentinite, radiolarian chert, graywacke, basalt, and gabbroic clasts.

4.3.2 Bojeador Formation

The Early Miocene (~20.43 Ma) Bojeador Formation consists of conglomerate, graywacke, shale, limestone, and associated volcanic flows and pyroclastic deposits (MGB, 2010). The conglomerate is composed of poorly sorted pebbles and cobbles of angular to subrounded andesite, basalt, and limestone set in a sandy and slightly calcareous matrix. Sandstone and shale units are well-bedded, cream to buff, and slightly recrystallised. The probable late Early Miocene age is inferred from the age of diorites intruding the rock sequences. The Bojeador Formation is widely exposed in the municipalities of Vintar in Ilocos Norte and Vigan in Ilocos Sur.

4.3.3 Pasaleng Quartz Diorite

The intrusive unit is named after exposures in Pasaleng, Pagudpud. The diorite is leucocratic, coarse-grained, and composed of quartz, feldspar, and chloritized amphibole. A late Early Miocene to early Middle Miocene age (~15.97 Ma) was assigned based on its correlation with the Itogon Quartz Diorite Complex in the Central Cordillera (MGB, 2010).

4.3.4 Pasuquin Limestone

The Late Miocene (5.33 - 7.25 Ma) Pasuquin Limestone unconformably overlies the Bojeador Formation east-northeast of Vigan. It is well-bedded, light cream to light buff, porous, and sandy in some places. The basal portion is described by a conglomerate unit with carbonate matrix and sometimes with clasts of serpentinite (Pinet, 1990). The upper facies consists of calcirudites, calcarenites, and fossiliferous limestones.

4.3.5 Laoag Formation

The Laoag Formation consists of sandstone with interbeds of siltstone and claystone with occasional reef limestone and limestone breccia. Abundant shells and molluscs, as well as wood and leaf fossils found in the conglomerates reveal a Late Early Pliocene to Pleistocene age (0.78 - 3.60 Ma) (Pinet, 1990).

4.3.6 Quaternary deposits

Quaternary fossil coral reefs are extensive along the coasts of Ilocos Norte and Ilocos Sur. Emergent marine terraces are generally made up of fossil coral reef platforms and are well preserved in Pasuquin, Currimao, and Badoc (e.g., Maeda et al., 2004; Ramos et al., 2017; Maxwell et al., 2018).

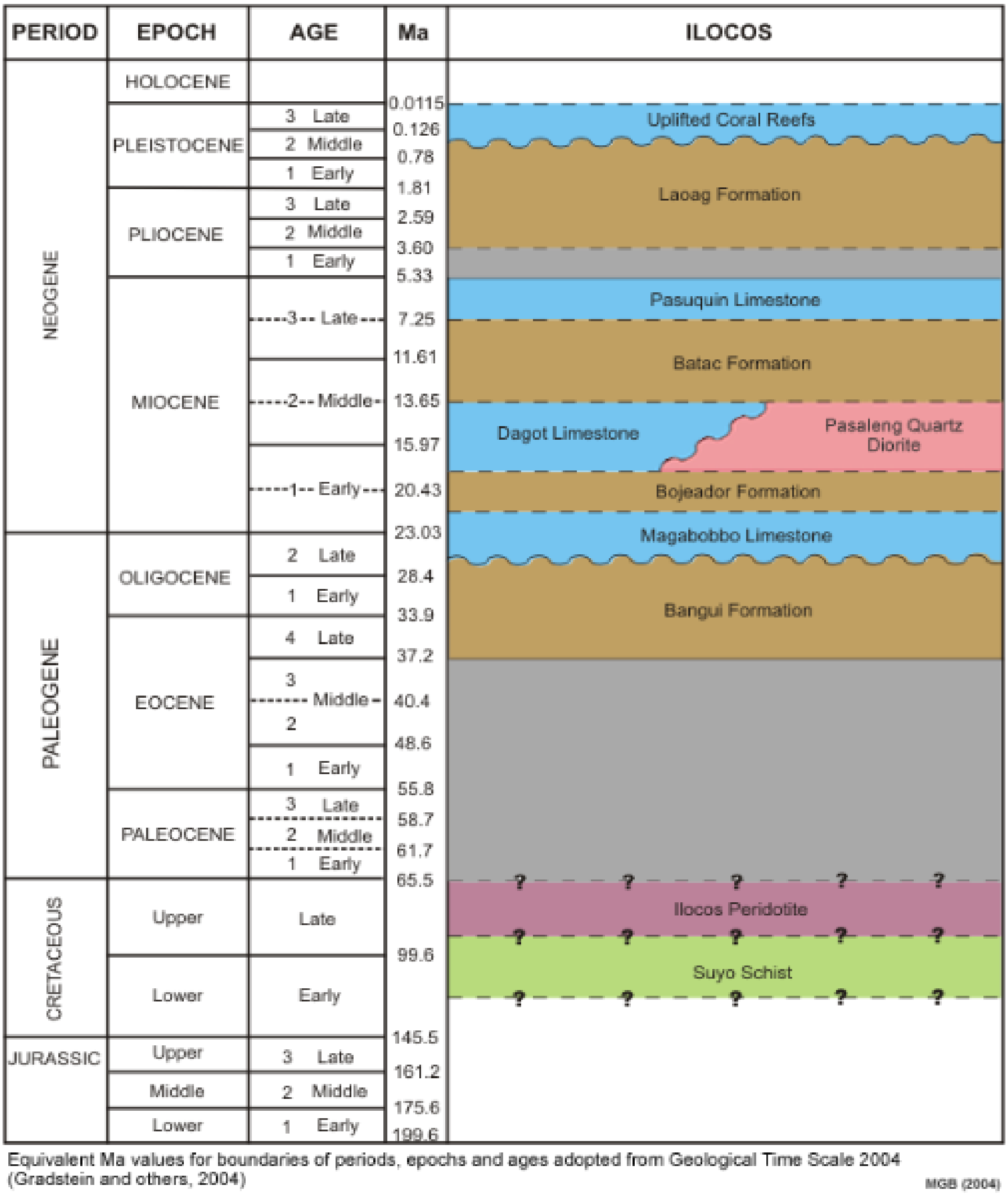


Figure 4.4 Generalised stratigraphic columns of the Ilocos Regional Basin (Peña, 2008).

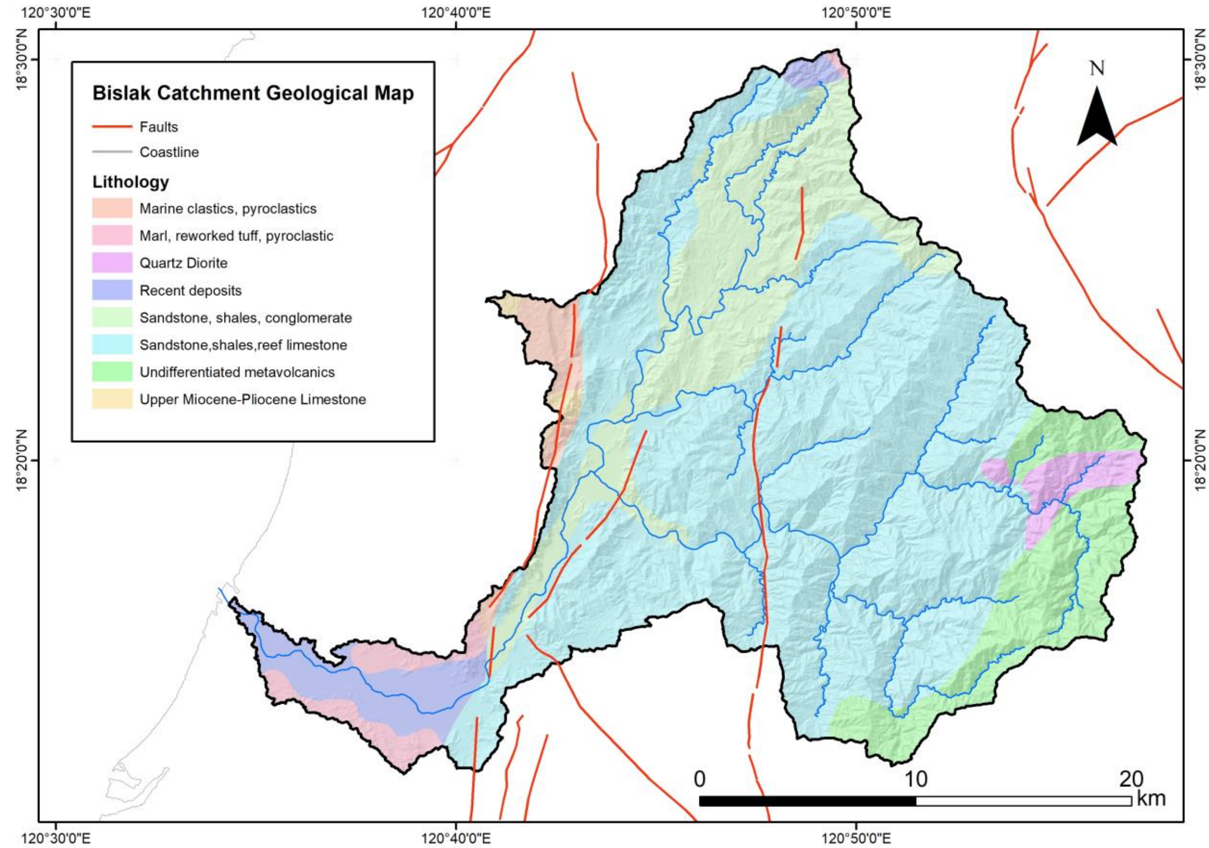


Figure 4.5 Geological map of the Bislak Catchment (MGB) showing faults and lineaments (PHIVOLCS).

4.4 River Longitudinal Profiles in the Bislak Catchment

In total, 17 tributaries were identified and named after their respective barangay locations. Figure 4.6 shows the distribution of these streams across the catchment. The total length of the tributaries and the downstream portion, Bislak River, is 252 km. Table 4.2 shows the lengths of the assessed streams and their percentage versus total stream length in the Bislak Catchment. Bislak is the longest river which is 74 km long while Dagupan Gitna is the shortest tributary with only 2.68 km length.

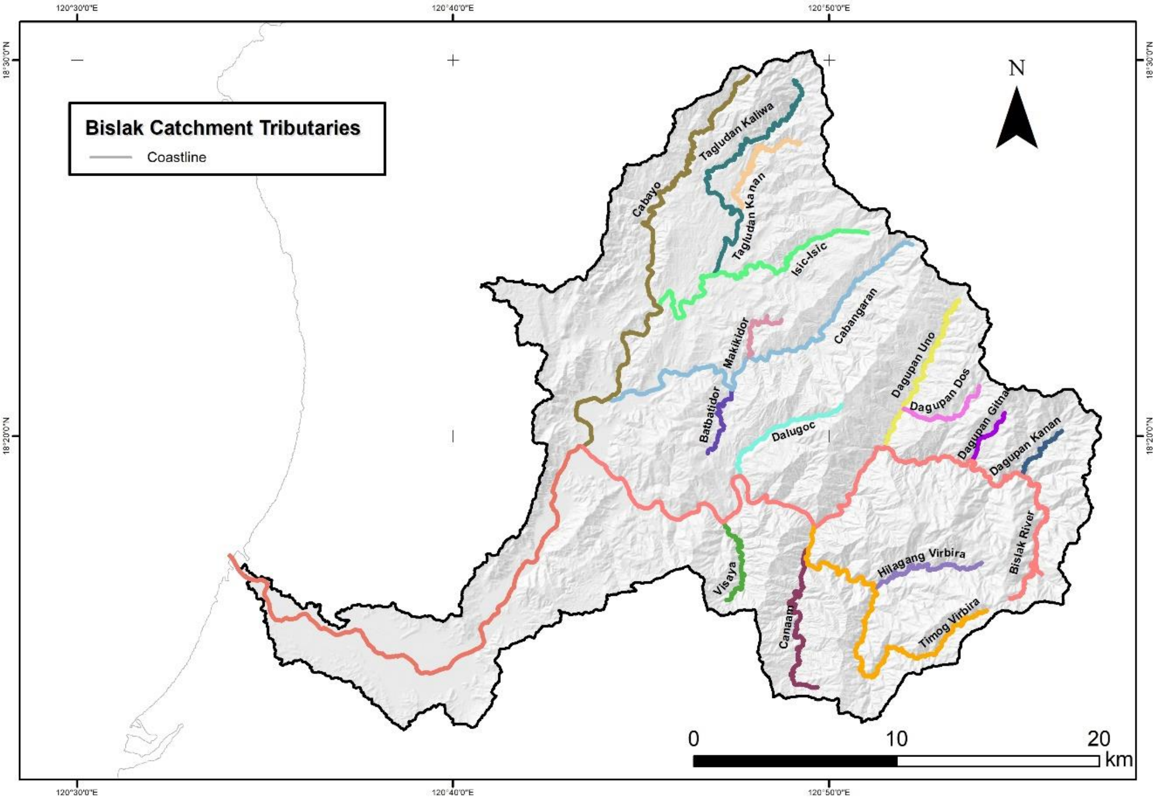


Figure 4.6 Distribution of tributaries in the Bislak Catchment.

Table 4.2 Length of streams and their relative percentage vs total length.

River Name	Length (km)	% vs Total Length
Bislak	74.75	29.64
Cabayo	29.29	11.61
Cabangaran	22.31	8.85
Timog Virbira	21.08	8.36
Tagludan Kaliwa	18.2	7.22
Isic-Isic	17.18	6.81
Canaam	11.05	4.38
Dagupan Uno	10.71	4.25
Tagludan Kanan	7.76	3.08
Hilagang Virbira	7.57	3.00
Dalugoc	5.81	2.30
Visaya	5.46	2.16
Dagupan Dos	5.42	2.15
Dagupan Kanan	4.61	1.83
Batbatidor	4.43	1.76
Makikidor	3.87	1.53
Dagupan Gitna	2.68	1.06
Total	**252.17**	**100.00**

Figure 4.7 presents the elevation and contributing catchment area of each tributary. Figures 4.8 to 4.24 show the individual longitudinal profiles of each river where elevation, slope and catchment area is plotted against distance.

In general, most of the tributaries have steep slopes draining the Steep Upland and Rugged Hills. The slope decreases as they exit the Steep Headwaters and Gorge. The Tagludan Kanan and Kaliwa are notable long tributaries but have gentler slopes even while located in the upstream area of the catchment. A 'step' in the catchment area plot of each tributary indicates a confluence point. The knick-points in elevation profiles of Canaam, Dagupan Dos and Dagupan Kanan are found upstream of the confluences where abrupt change in slope is observed. The abrupt rise in slope along the Batbatidor Tributary is at the location of a waterfall along its confined valley setting. At the downstream part, slope starts having zero values approximately 8 km away from the outlet.

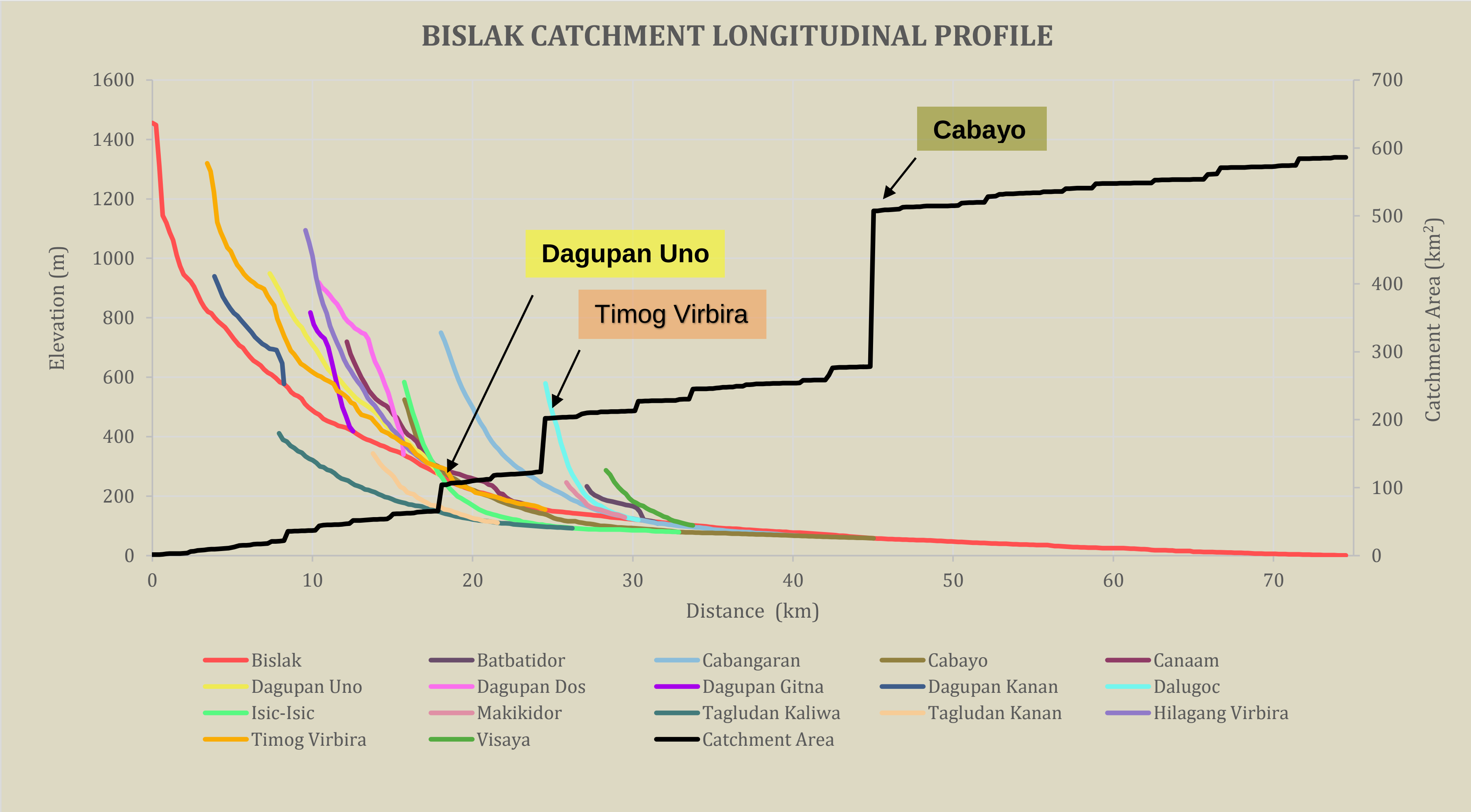


Figure 4.7 Longitudinal profiles of the 17 assessed tributaries in the Bislak Catchment.

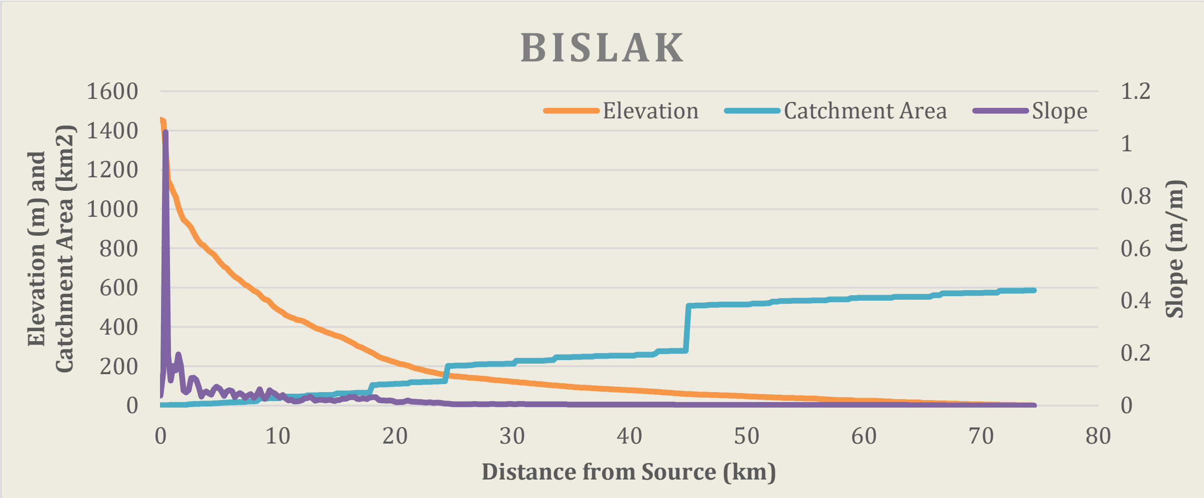


Figure 4.8 Longitudinal Profile of Bislak.

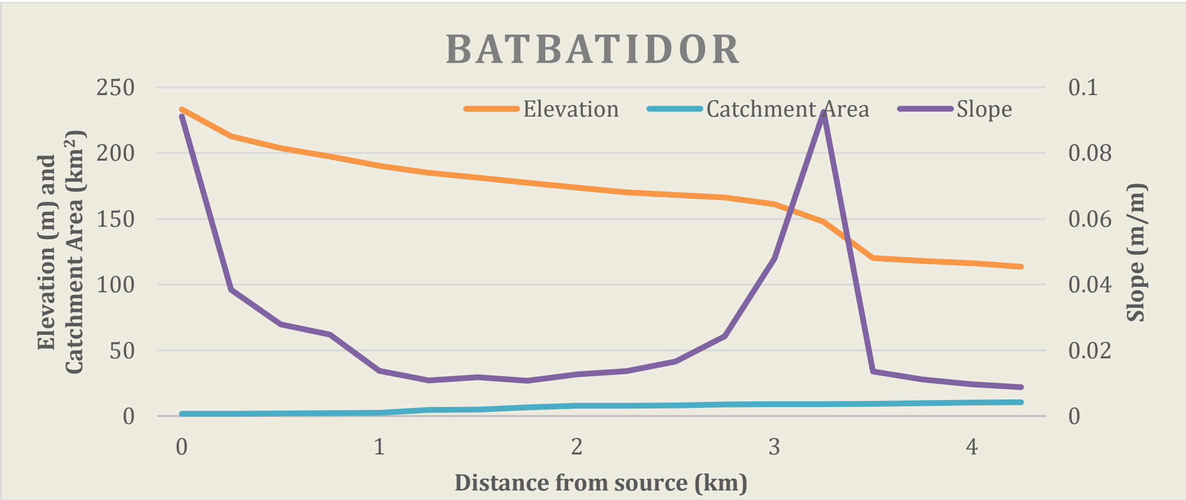


Figure 4.9 Longitudinal Profile of Batbatidor.

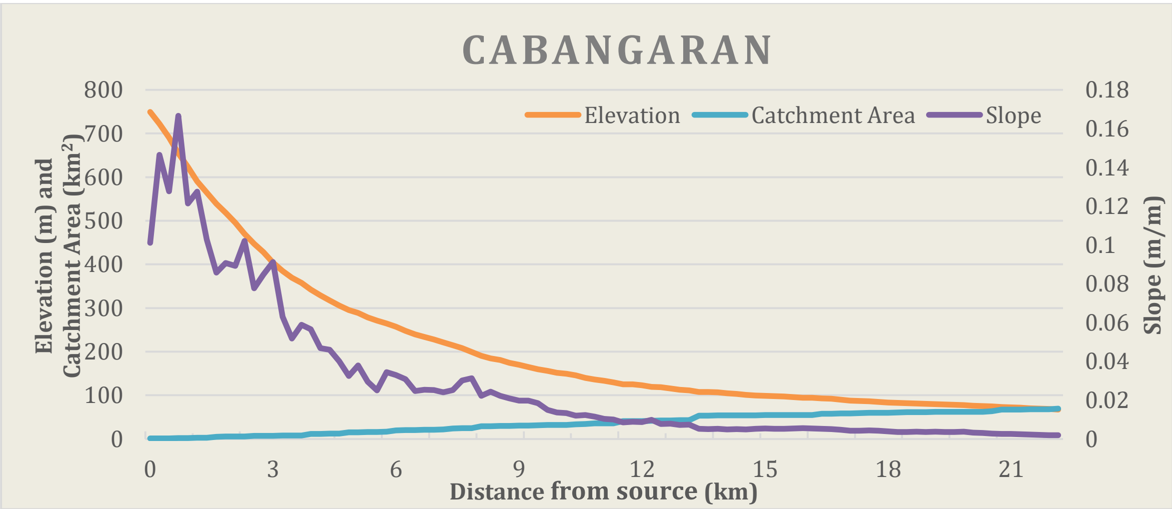


Figure 4.10 Longitudinal Profile of Cabangaran.

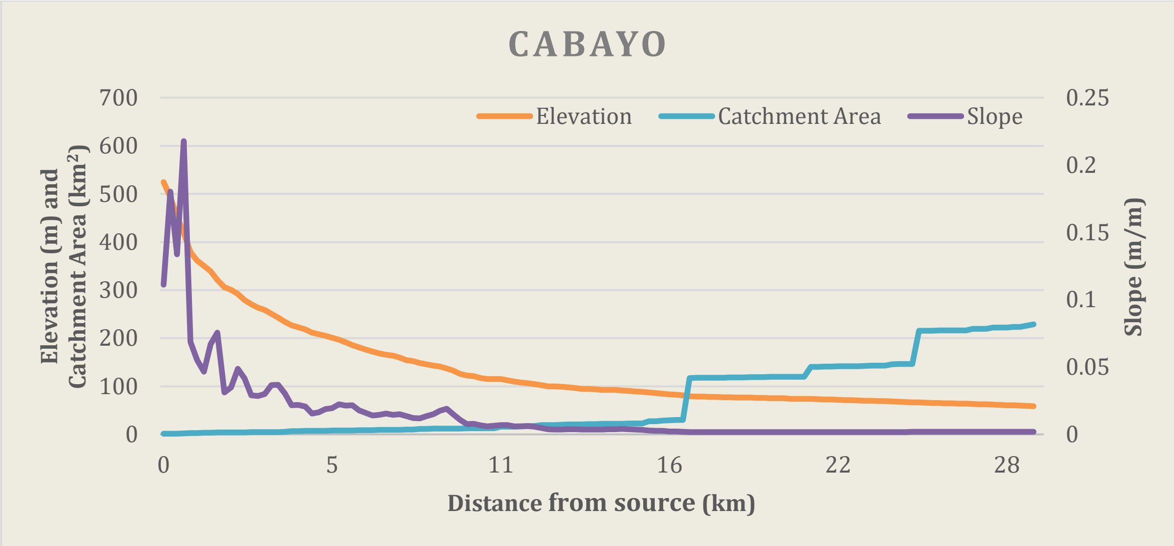


Figure 4.11 Longitudinal Profile of Cabayo.

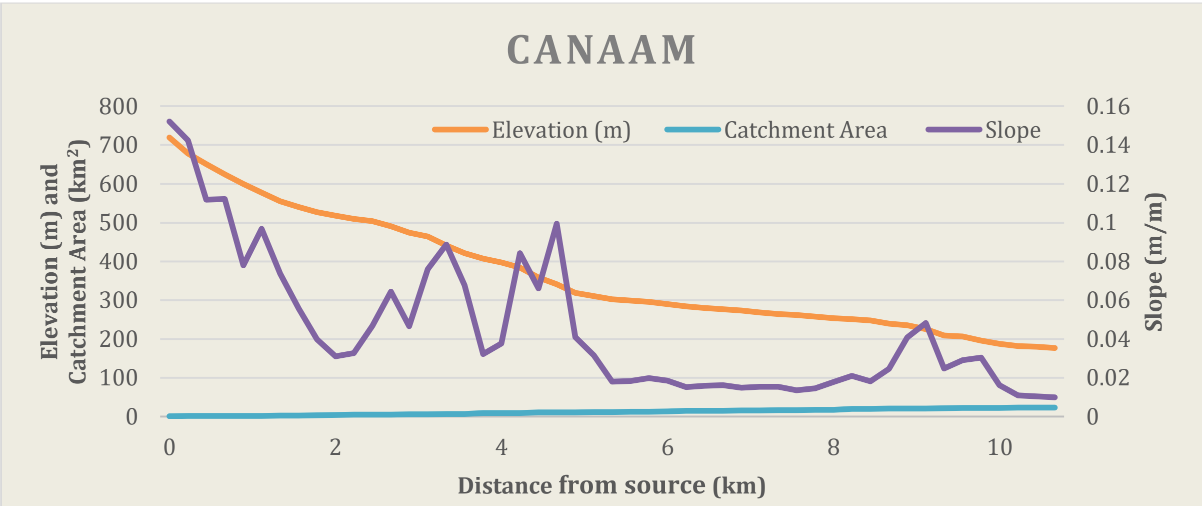


Figure 4.12 Longitudinal Profile of Canaam.

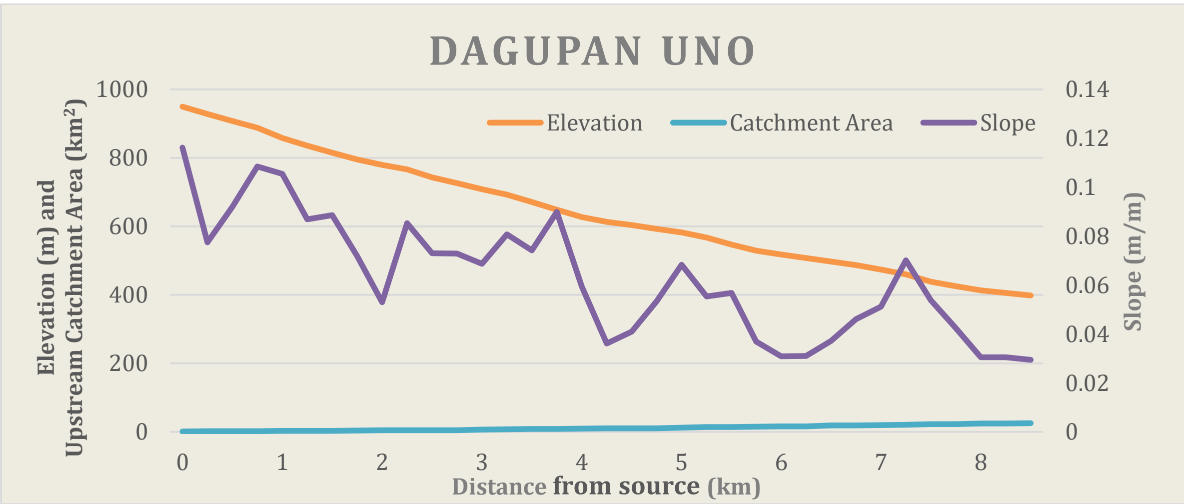


Figure 4.13 Longitudinal Profile of Dagupan Uno.

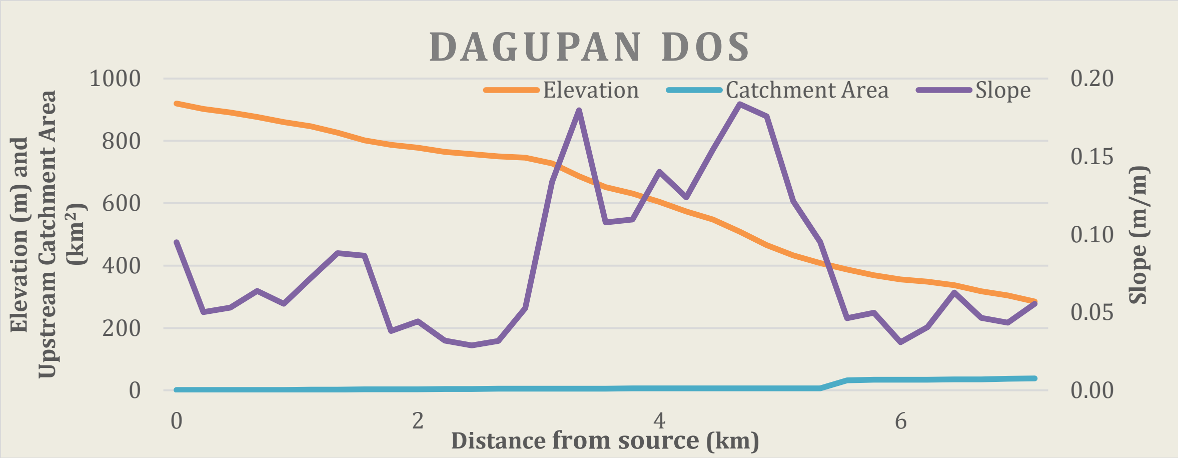


Figure 4.14 Longitudinal Profile of Dagupan Dos.

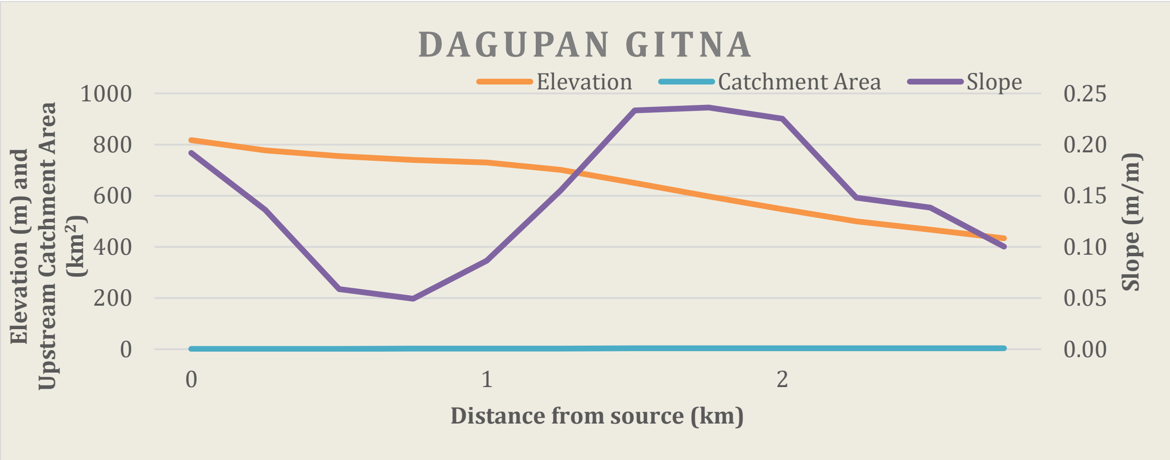


Figure 4.15 Longitudinal Profile of Dagupan Gitna.

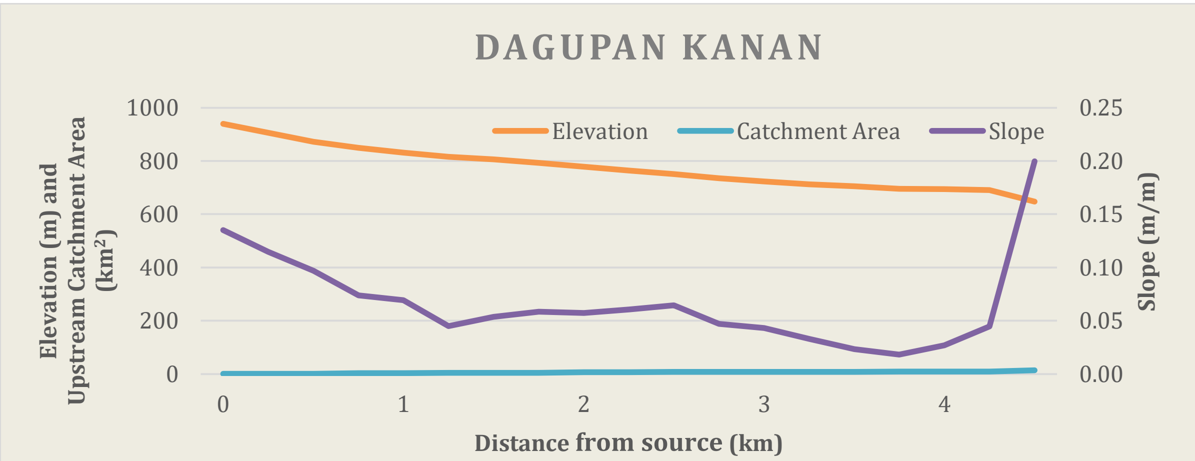


Figure 4.16 Longitudinal Profile of Dagupan Kanan.

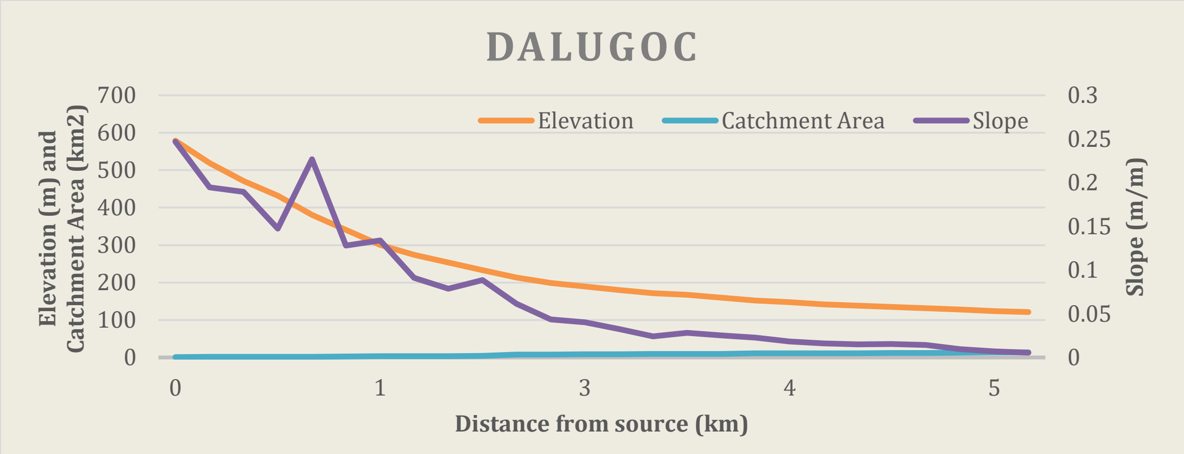


Figure 4.17 Longitudinal Profile of Dalugoc.

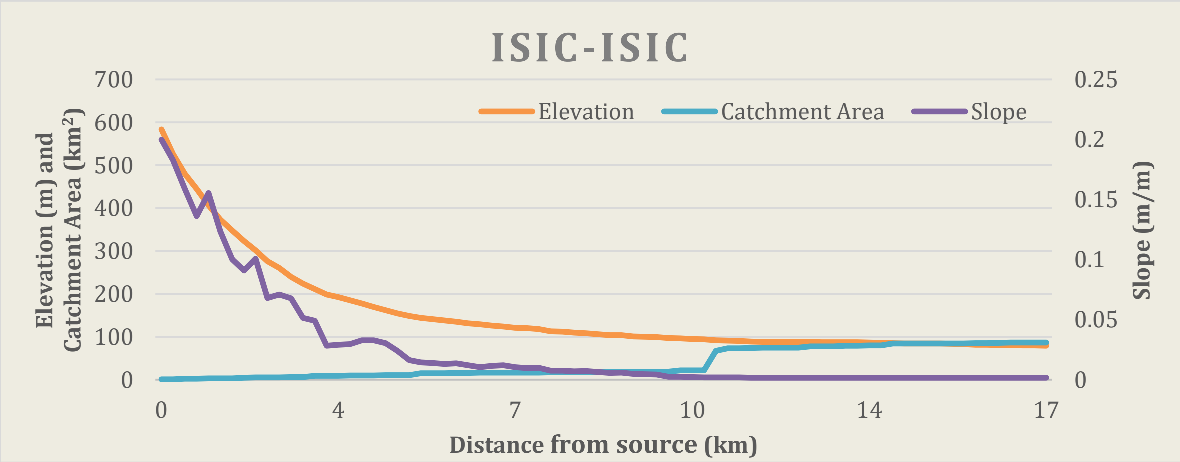


Figure 4.18 Longitudinal Profile of Isic-Isic.

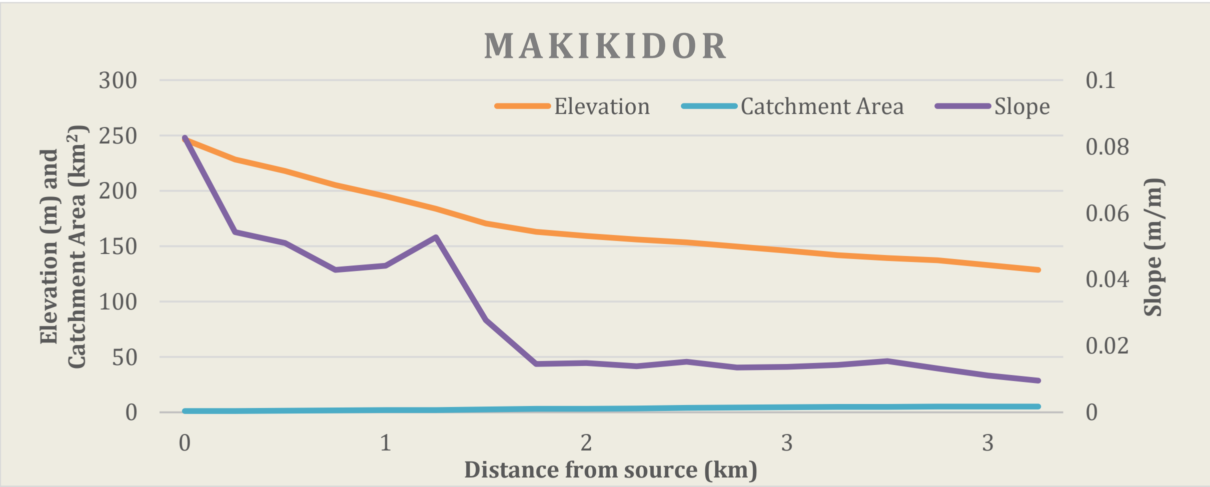


Figure 4.19 Longitudinal Profile of Makikidor.

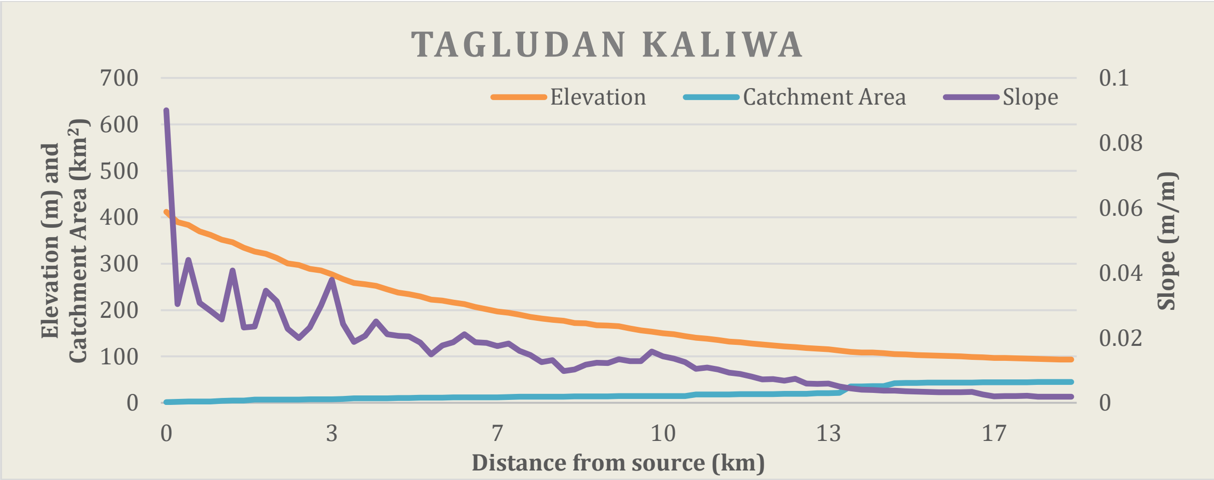


Figure 4.20 Longitudinal Profile of Tagludan Kaliwa.

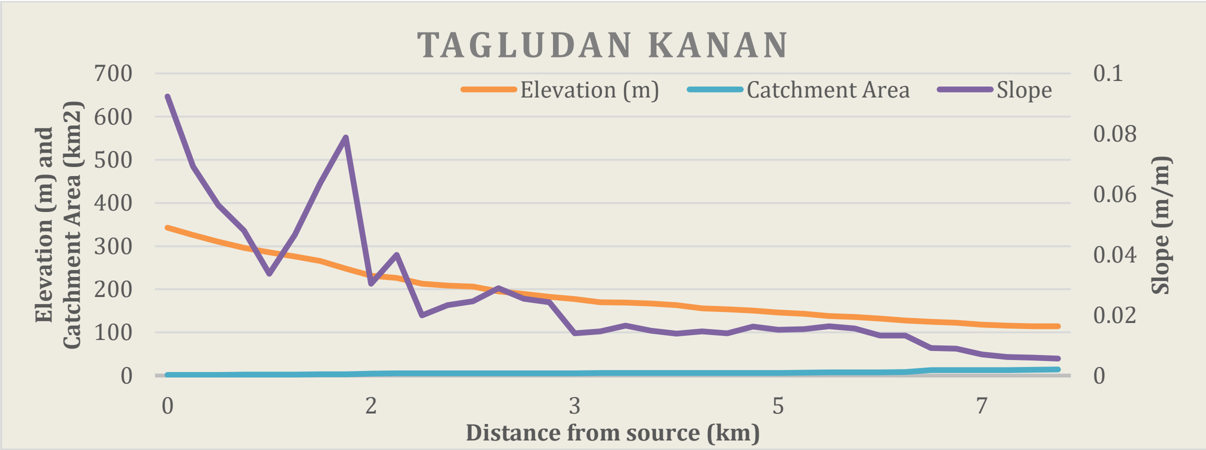


Figure 4.21 Longitudinal Profile of Tagludan Kanan.

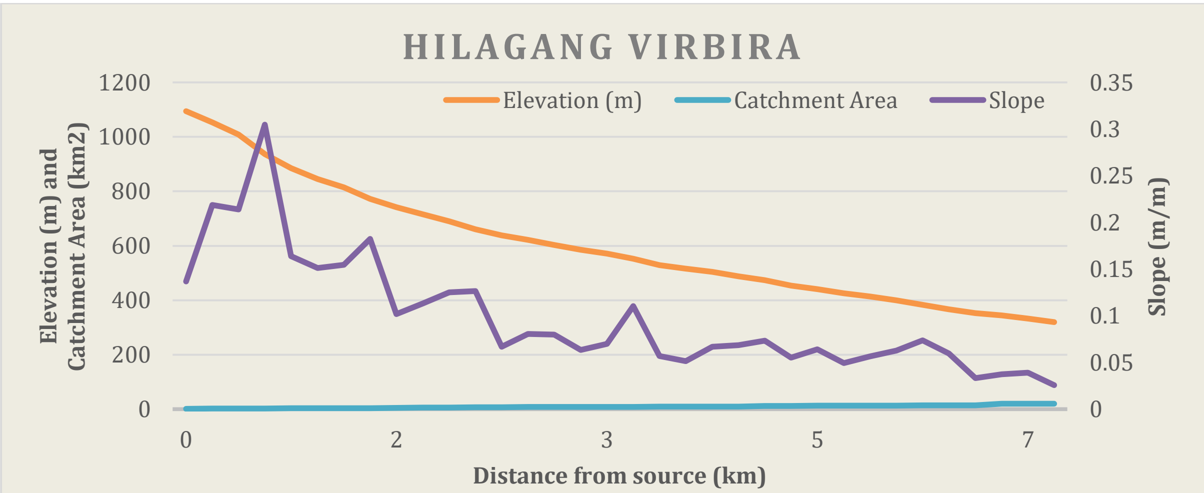


Figure 4.22 Longitudinal Profile of Hilagang Virbira.

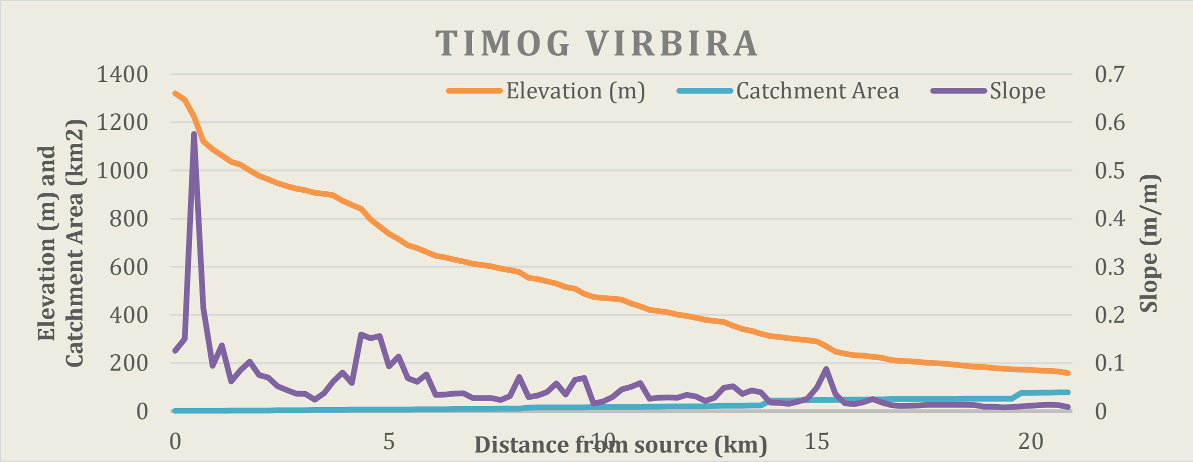


Figure 4.23 Longitudinal Profile of Timog Virbira.

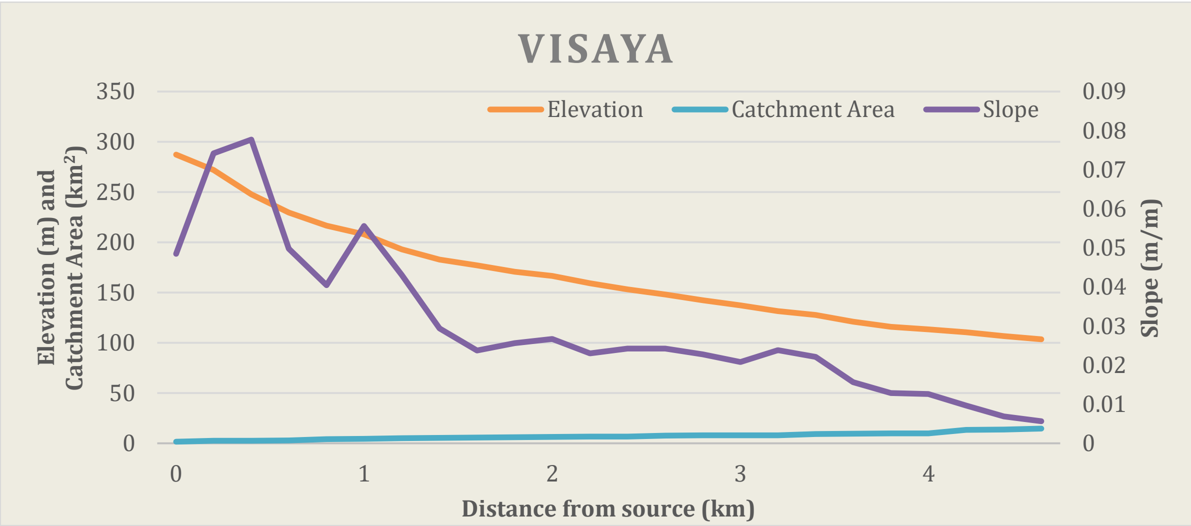


Figure 4.24 Longitudinal Profile of Visaya.

4.5 Climate

The Bislak Catchment has a Type I Climate under the Modified Coronas Climate Classification (Coronas, 1920) with distinct dry season from November-April and wet season during the rest of the year (Figure 4.25). Climate data from 1969 to 2018 (50 years) was supplied by the national meteorological agency, the Department of Science and Technology - Philippine Atmospheric, Geophysical, and Astronomical Services Administration (DOST-PAGASA). The nearest weather station is the Laoag Synoptic station located at Laoag International Airport (18.182811°N, 120.533898°E), located 10 km from the Bislak River outlet.

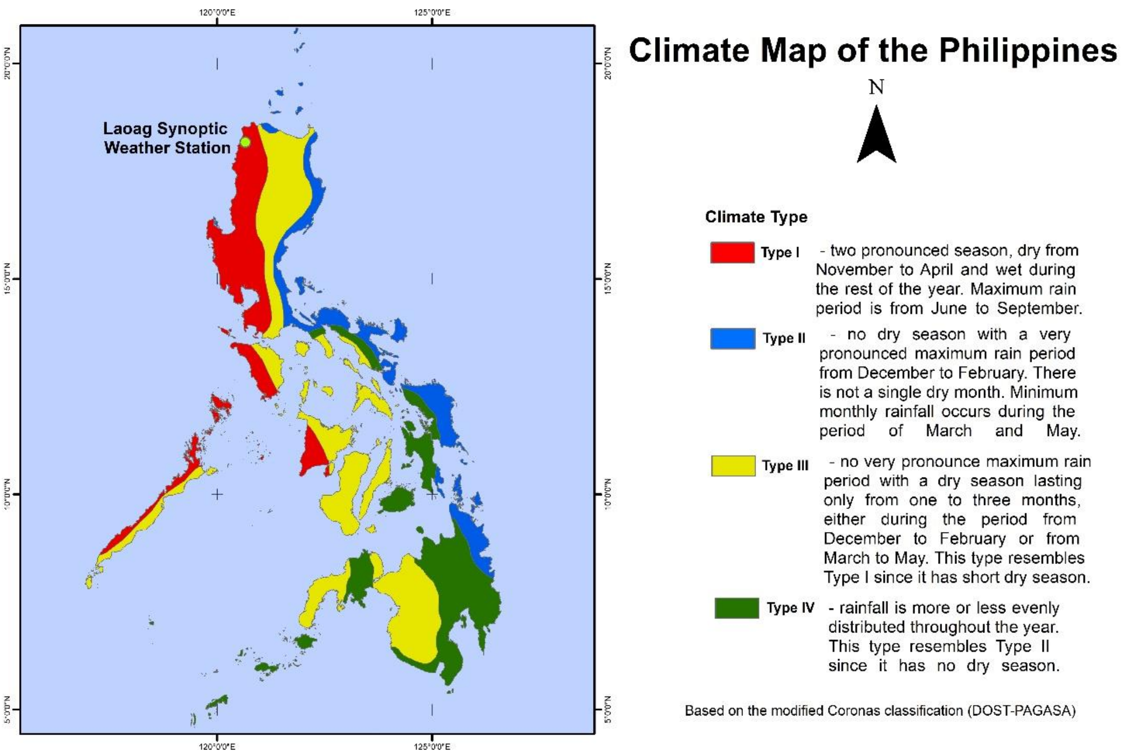


Figure 4.25 Climate map of the Philippines (Coronas, 1920).

4.5.1 Climatological Normal

There are two large-scale systems that affect the variability of rainfall in the Bislak Catchment. These are the Southwest Monsoon (Habagat) that typically advance from May to October bringing rains in many parts of the country and the Northeast Monsoon (Amihan) that lasts from October to March. Localised weather patterns also contribute to the climate of the catchment.

Rainfall and temperature data are from the DOST-PAGASA. Mean annual rainfall (1969-2018) estimated from the station is 2019 mm with mean monthly maximum of 546 mm in August and low mean record of 2 mm in February. An increase in average monthly rainfall is observed in the region. Tolentino et al. (2016) also predicted an increase in amount of

The observed mean monthly maximum and minimum temperature are highest in March to June while the coldest months are typically December to February. The lowest mean monthly recorded is 19.4°C degrees Celsius in January and highest is 33.8°C in April. The

50-year mean daily and monthly rainfall and mean monthly maximum and minimum temperature records are presented in Figure 4.26.

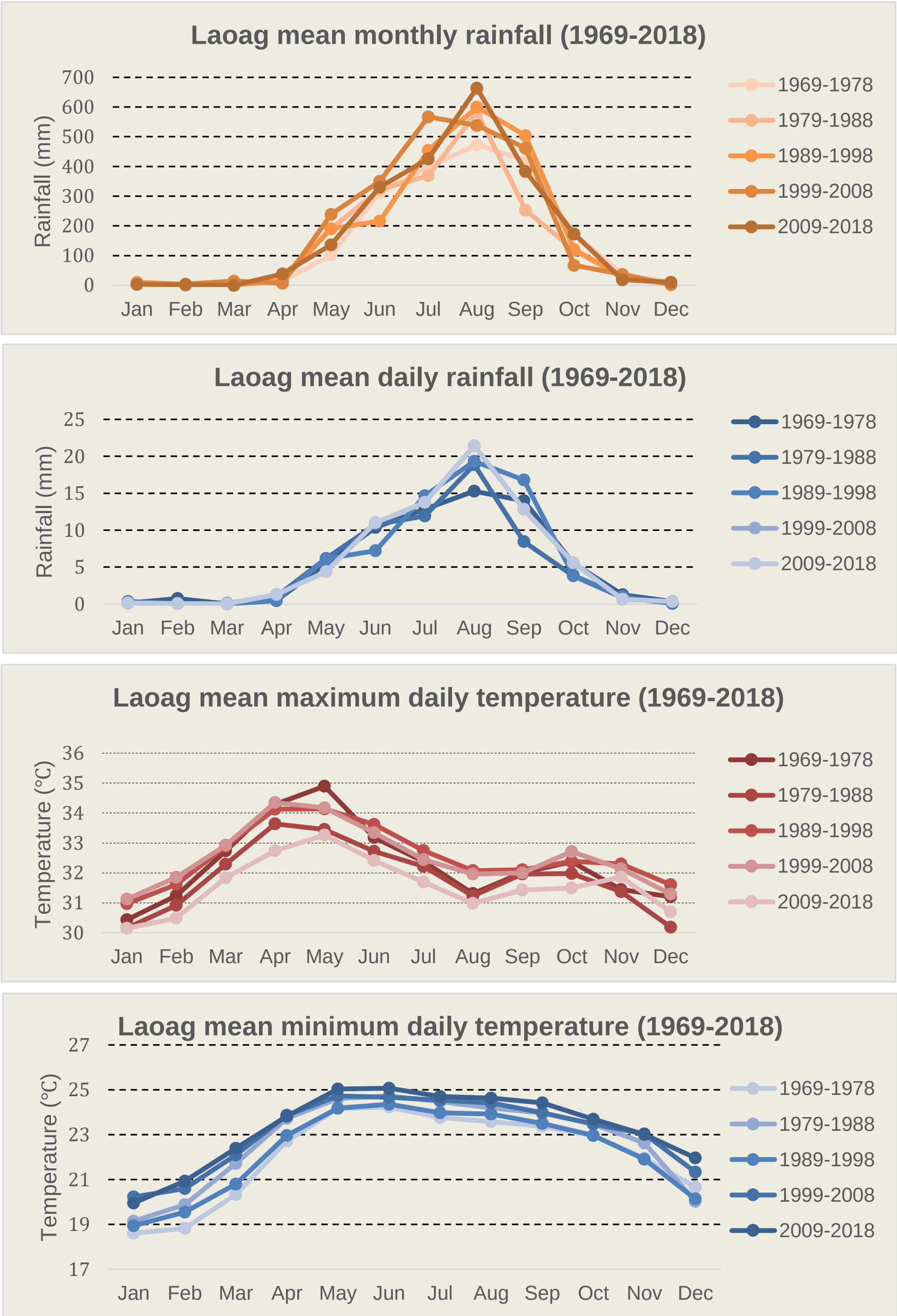


Figure 4.26 Summary of the climate data from 1969-2018 recorded at the Laoag Synoptic Station of PAGASA (18.182811°N, 120.533898°E).

4.5.2 Tropical Cyclones

Typhoon tracks extracted from the International Best Track Archive for Climate Stewardship (IBTracs) from the National Oceanic and Atmospheric Administration, National Climatic Data Center (NOAA NCDC) revealed that in the period of 1980-2019, there were 83 tropical cyclones (TCs) that crossed within the 100-km radius of Bislak Catchment. Most of these TCs occurred from May to November. Only one was recorded to occur in April and December, in 2015 and 2004, respectively. On record, October has the highest number of TCs recorded where 22 TCs were registered.

The highest daily rainfall recorded was 483.9 mm on July 15, 2008 when Typhoon Helen (Kalmaegi) struck the north of Luzon. In August 2019, Typhoon Ineng (Bailu) displaced a total of 23,925 families or 99,734 persons to Regions I, II, III and CAR. It affected at least 2400 families in the Bacarra and Vintar Municipalities (DSWD Typhoon Ineng Terminal Report, 2019). It was reported by the Ilocos Norte Province Governor Matthew Joseph Marcos Manotoc that the typhoon left Ilocos Norte with Php 1.16 Billion cost of damages in agricultural infrastructure, buildings and other facilities.

The Municipality of Vintar was declared under state of calamity on the 24th August 2019 because of flooding from Typhoon Ineng. This was confirmed by the Hon. Mayor Larissa Foronda after hundreds of livestock drowned and 33 barangays were submerged in floodwaters during the typhoon (Lazaro, 2019). Figure 4.27 shows two photos of the Bislak River at Tamdagan Bridge, under low flow stage on the left and under high flow stage on the right.

Typhoon Ineng (2019) occurred only one year after Typhoon Ompong (Mangkhut) put the Ilocos Norte Province in a state of calamity due to flood damages in September 2018. The typhoon affected five regions in the country. The Provincial Disaster Risk Reduction and Management Office of Ilocos Norte estimated the total damage in agricultural land of 48,299 hectares to about Php 1.4 Billion (Citizen's Disaster Response Center, 2018).

Figure 4.27 Photos showing Tamdagan Bridge in the Bislak Catchment showing low flow stage in March 2019 and high flow stage in August 2019 during Typhoon Ineng (Bailu). Photo courtesy of Catchment Project local hire, Mr. Joem Fernandez.

4.6 Hydrology

There are currently no hydrologic datasets available from government mandated agencies for the Bislak Catchment. However, Paringit and Pascua (2017) generated discharge estimates at the Bacarra Bridge (Figure 4.28) in the Bislak River for different return periods using scenario-based rainfall-runoff modeling. These models were based on Rainfall Intensity Duration Frequency (RIDF) values from the PAGASA Station that were converted into synthetic storm events. The RIDF values were derived from the Laoag City RIDF Station situated proximal to the outlet of the Bislak catchment and extreme values were computed based on a 59-year record. Peak discharge for different return periods are presented in Table 4.3. Using climate change scenarios, a study of Tolentino et al., (2016) projected an increase in both magnitude and variability in river flows in across the country.

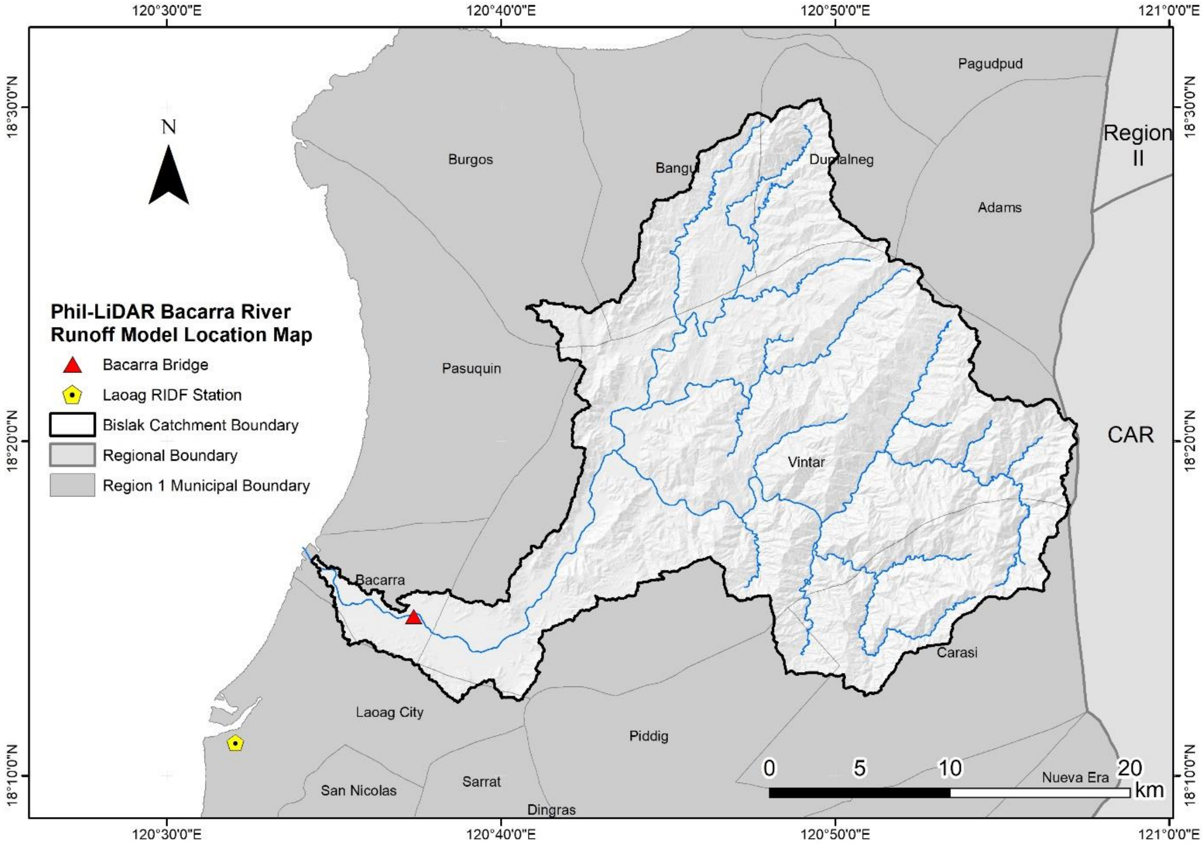


Figure 4.28 Location of the Bacarra Bridge where discharge estimates were computed and Laoag Synoptic Station where RIDF values were retrieved.

Table 4.3 Modelled peak discharge at the Bacarra Bridge in the Bislak catchment based on synthetic storm events of different recurrence intervals (from Paringit and Pascua, 2017).

RIDF Period	Total	Peak rainfall	Peak discharge	Time to peak
5-Year	331.7	31.4	1309.8	11 hrs
10-Year	397.1	37.2	1729.3	10 hrs 50 mins
25-Year	479.8	44.5	2294.6	10 hrs 50 mins
50-Year	541.1	50	2730.5	10 hrs

100-Year	602	55.3	3178	10 hrs 40 mins

4.7 Land Cover and Land Use

4.7.1 Catchment-scale

Land Cover is classified into annual crops, built-up areas, grassland, inland water, open forest, open/barren areas, shrublands, and wooded grassland in the 2010 NAMRIA dataset shown in Figure 4.29. Wooded grasslands and grasslands occupy approximately 30% (171.95 km^2) and 26% (153.09 km^2) of the total land area respectively. Grasslands are dominant from the Steep Upland to Rugged Hills, while wooded grasslands only becomes dominant at the base of the Rugged Hills. Open forests occupy 23% of the catchment area (137.74 km^2) and tend to be positioned at the eastern edge of the catchment in steep headwaters. Shrublands occupy approximately 10% (59.81 km^2) of the catchment area and tend to be positioned on valley bottoms. About 7% (43.67 km^2) of the catchment area is occupied by agricultural activities (including annual croplands) positioned along gentler hillslopes and relatively flatter floodplain areas adjacent to the inland water. Barren areas cover 2% (12.38 km^2) of the catchment area. Only a small fraction (0.5%) of the catchment is classified as built-up, with scattered urban settlements throughout the rugged hill landscape and municipality centers at the Lowland Plains. Table 4.4 summarises the land cover of the Bislak Catchment.

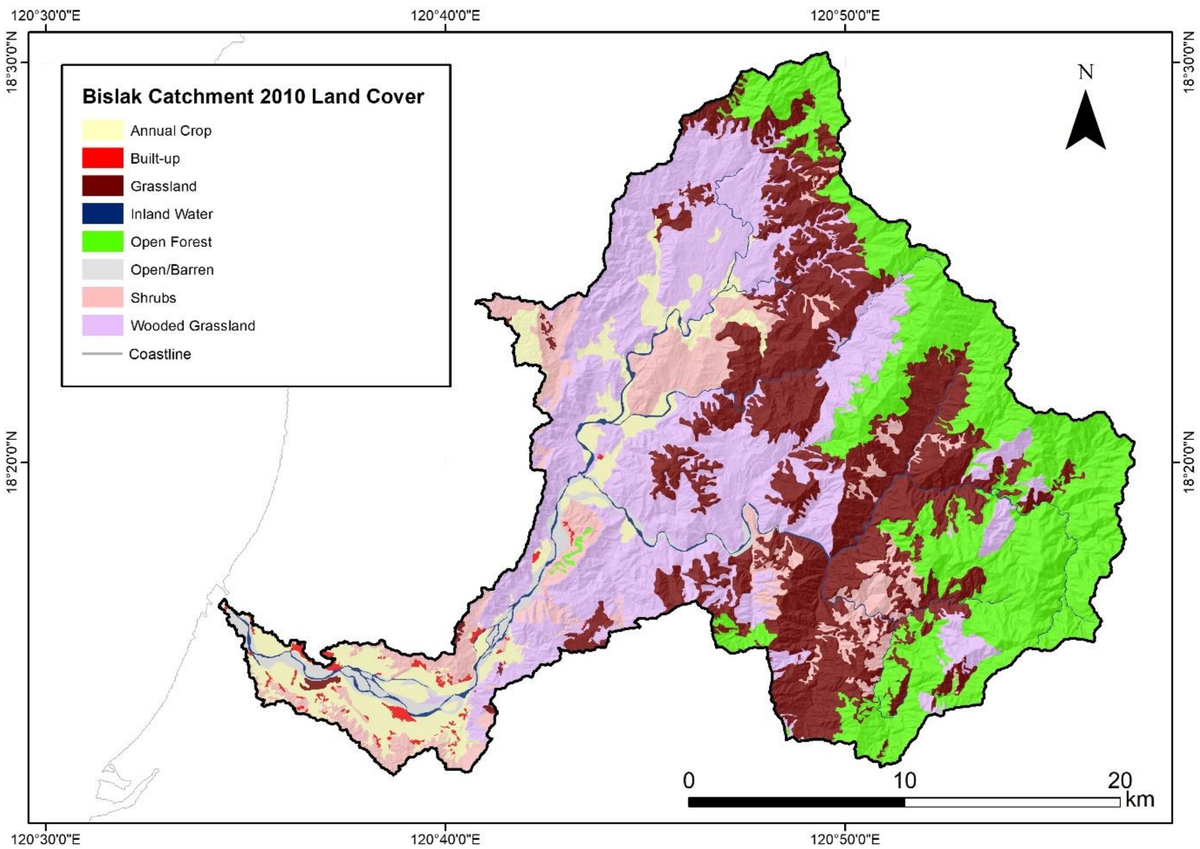


Figure 4.29 Land cover map of the Bislak catchment (2010 NAMRIA dataset).

Table 4.4 Bislak Catchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area
Annual Crop	43.67	7.40
Built-Up	3.38	0.57
Grassland	153.09	25.93
Inland Water	8.49	1.44
Open Forest	137.74	23.33
Open/Barren	12.38	2.10
Shrubs	59.81	10.13
Wooded Grassland	171.95	29.12
TOTAL	**590.50**	**100.00**

4.7.2 Subcatchment-scale

The Bislak Catchment is further divided into seven subcatchments based on the identified subwatersheds from the Vintar Forest Land Use Plan 2020-2029 (Figure 4.30). The Dalugoc-Pangasaan and Kurawi subcatchments drain along Bislak River while Cabayo, Tagludan, Makikidor-Batbatidor, and San Lucas subcatchments drain towards Cabayo River. The two rivers reach their confluence eventually draining to the Bislak subcatchment at the downstream section of the catchment.

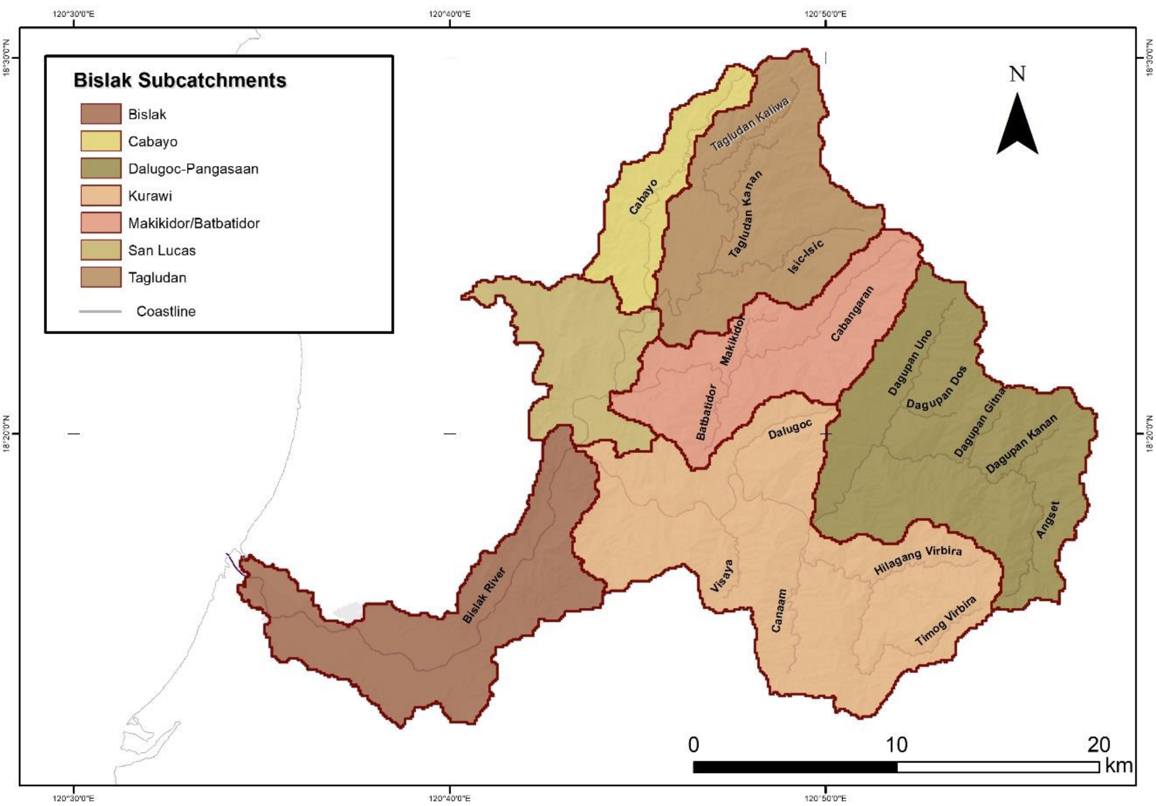


Figure 4.30 Distribution of subcatchments in the Bislak Catchment.

The Bislak subcatchment covers almost 90% of the total built-up areas since the Municipalities of both Vintar and Bacarra are located within its Lowland Plains. Approximately 82% of the total open/barren areas are present in this subcatchment. Furthermore, more than 50% of the total croplands cover up the continuous floodplains and about 30% of shrublands are present along the edge of this subcatchment. Grasslands and open forests are rare in this area.

The Cabayo subcatchment is dominated by wooded grasslands which covers almost 70% of the total subcatchment area but takes up only 12% of the total wooded grasslands. Small regions of grasslands, open forests, croplands, and shrublands are also present within this subcatchment.

Open forests and grasslands dominate the entire Dalugoc-Pangasaan subcatchment located at the Steep Upland of the southeastern region. Approximately 52% of the total open forests and almost 26% of the total grasslands are present here. There are concentrated areas of wooded grasslands and occasional shrublands are also present. No built-up areas and croplands are observed.

Kurawi, which has the largest total subcatchment area is dominated by grasslands, wooded grasslands, and open forests. In relation to this, the largest portions of total grasslands (34%) and total wooded grasslands (30%) are observed within this catchment. Wide open forests are concentrated at the easternmost region. Shrublands and small croplands are also present in this subcatchment.

Grasslands and wooded grasslands covers up almost 70% of the Makikidor/Babatidor subcatchment, followed by open forests that takes up 17% and is located at the Steep Uplands. The remaining subcatchment area is divided into smaller portions of croplands and shrublands.

In the San Lucas subcatchment, wooded grasslands are also dominant and covers 48% of the total subcatchment area. This is followed by shrublands and croplands that take up 26% and 21% respectively. Furthermore, 20% of the total croplands is present within this subcatchment.

Like its neighboring subcatchment, Tagludan follows the land cover trends of the Makikidor/Batbatidor subcatchment. Grasslands and wooded grasslands take up almost 66%, followed by open forests which takes up 18% of the land area. Shrublands and croplands only become prominent at the downstream end of the subcatchment, and small built-up areas are also observed. Table 4.5 to 4.11 summarises the land cover units per subcatchment area.

Table 4.5 Bislak Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Annual Crop	23.19	28.72	53.10
Built-Up	3.03	3.75	89.76
Grassland	2.87	3.55	1.87
Inland Water	2.59	3.21	30.53
Open Forest	0.55	0.68	0.40
Open/Barren	10.16	12.58	82.07
Shrubs	19.08	23.63	31.90
Wooded Grassland	19.28	23.87	11.21
TOTAL	80.75	100.00	

Table 4.6 Cabayo Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Annual Crop	2.54	8.45	5.81
Grassland	3.81	12.69	2.49
Open Forest	2.79	9.30	2.03
Shrubs	0.01	0.03	0.01
Wooded Grassland	20.87	69.54	12.14
TOTAL	30.02	100.00	

Table 4.7 Dalugoc-Pangasaan Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Grassland	39.30	32.02	25.67
Inland Water	1.21	0.99	14.30
Open Forest	72.15	58.80	52.38
Shrubs	4.19	3.41	7.00
Wooded Grassland	5.86	4.78	3.41
TOTAL	122.71	100.00	

Table 4.8 Kurawi Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Annual Crop	1.09	0.70	2.49
Grassland	52.18	33.52	34.09
Inland Water	1.78	1.14	20.91
Open Forest	33.13	21.28	24.06
Open/Barren	2.06	1.32	16.64
Shrubs	13.13	8.44	21.96
Wooded Grassland	52.30	33.60	30.42
TOTAL	155.68	100.00	

Table 4.9 Makikidor-Batbatidor Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Annual Crop	2.30	3.33	5.26
Grassland	24.44	35.46	15.97
Inland Water	0.91	1.32	10.71
Open Forest	11.88	17.23	8.62
Open/Barren	0.08	0.11	0.62
Shrubs	5.18	7.51	8.66
Wooded Grassland	24.16	35.04	14.05
TOTAL	68.94	100.00	

Table 4.10 San Lucas Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Annual Crop	8.75	21.21	20.03
Built-Up	0.05	0.11	1.36
Grassland	0.95	2.30	0.62
Inland Water	1.08	2.62	12.72
Open/Barren	0.01	0.02	0.07
Shrubs	10.73	26.01	17.94
Wooded Grassland	19.69	47.73	11.45
TOTAL	41.26	100.00	

Table 4.11 Tagludan Subcatchment 2010 Land Cover from NAMRIA.

Land Cover	Area (km^2)	%vs Total Land Area	%vs Total Land Cover Area
Annual Crop	4.69	5.39	10.75
Built-Up	0.04	0.05	1.23
Grassland	29.27	33.61	19.12
Inland Water	0.91	1.05	10.73
Open Forest	16.07	18.46	11.67
Shrubs	6.91	7.94	11.55
Wooded Grassland	29.17	33.51	16.96
TOTAL	87.06	100.00	

Forest and freshwater areas of the Municipality of Vintar are rich with indigenous species. Fauna are commonly used as food and flora are used as wood resources, fuel and medicine. Some species like the Philippine deer *(Rusa Marianna)* and the Luzon warty pig *(Sus philippensis)* are threatened with extinction and can only be found at isolated forests. Some of the freshwater species of Vintar includes tilapia *(Oreochromis)*, karpa *(Cyprinus carpa)*, bukto (various species of gobiid fish), kiwet and tutut *(Leiopotherapon plumbeus)*, crustaceans like kippi *(Hemigraspus sanguineus)*, and udang *(Macrobrachium rosenbergii)*, and edible freshwater shellfish species like tukmem *(Curbicula fluminea)*, suso/sugpel *(Melanoides tuberculata/Tarebia granifera)*, birabid *(Lymnaea cumingiana)*, and bisukol *(Pomacea canaliculata)*. Some water-plants include ballaiba *(Vallisneria nana)*, balangeg *(Ipomoea aquatica)*, and aba *(Colocasia esculenta)*. Insect species like Kualalanti (firefly), Billo-billo (dragonfly), Atlas moth and Kundidit (cicada) are also locally declining through the years (Vintar Municipal Planning and Development Office [Vintar MPDC], 2019).

Trees including ipil *(Albizia latisiquala)*, taroktok (red cotton tree) *(Bombax ceiba)*, agem (tailor tree) *(Decaspermum fruticosum)*, fire tree *(Delonix regia)*, apitong *(Dipterocarpus grandifloras)*, mabolo (Diospyrus philippinensis), balete *(Ficus benjamina)*, bagbag (coral tree) *(Erythrina fusca)*, manga *(Mangifera indica)*, narra *(Pterocarpus indicus)*, acacia *(Samanea saman)*, and mahogany *(Swietenia macrophylla)* inhabit the forest lands. Various species of flowers like ground orchids *(Spathoglottis plicata, Spathoglottis kimbaliana, Spathoglottis vanoverberghii)*, wild sunflower *(Tithonia diversifolia)*, Bambang *(Plumbago zeylanica)*, and santan *(Ixora macrophylla)* are present (Vintar MPDC, 2019).

4.9 River Use

4.9.1 Quarrying

Part of the industrial sector, quarrying and mining contributes to 1.7% of the gross regional domestic product of the Ilocos Region which includes four provinces – one of which covers the whole Bislak Catchment. Quarrying and mining had the highest average growth among industries between the period 2011 – 2015 (National Economic and Development Authority – Regional Office 1, 2017).

Within the Bislak Catchment, commercial mining is limited to non-metallic materials, particularly sand and gravel, as well as silica, which are acquired within the Bislak River (Mines and Geosciences Bureau – Regional Office No. 1, 2017). These are located in most of the downstream barangays along the river – within the barangays of San Simon, Santa Rita, Santa Filomena, and Buyon in the municipality of Bacarra; and within the barangays of San Ramon, Parparoroc, Visaya, Dipilat, and Tamdagan in the Municipality of Vintar. Dredging work has also been done by the Department of Public Works and Highways (DPWH) in the barangays near the mouth of the river, particularly San Agustin and Cabaruan in Bacarra, as part of flood mitigation measures which aim to decrease bed level, as well as to use dredged materials as backfill for river embankments. The locations of these barangays with respect to the Bislak Catchment are illustrated in Figure 4.31.

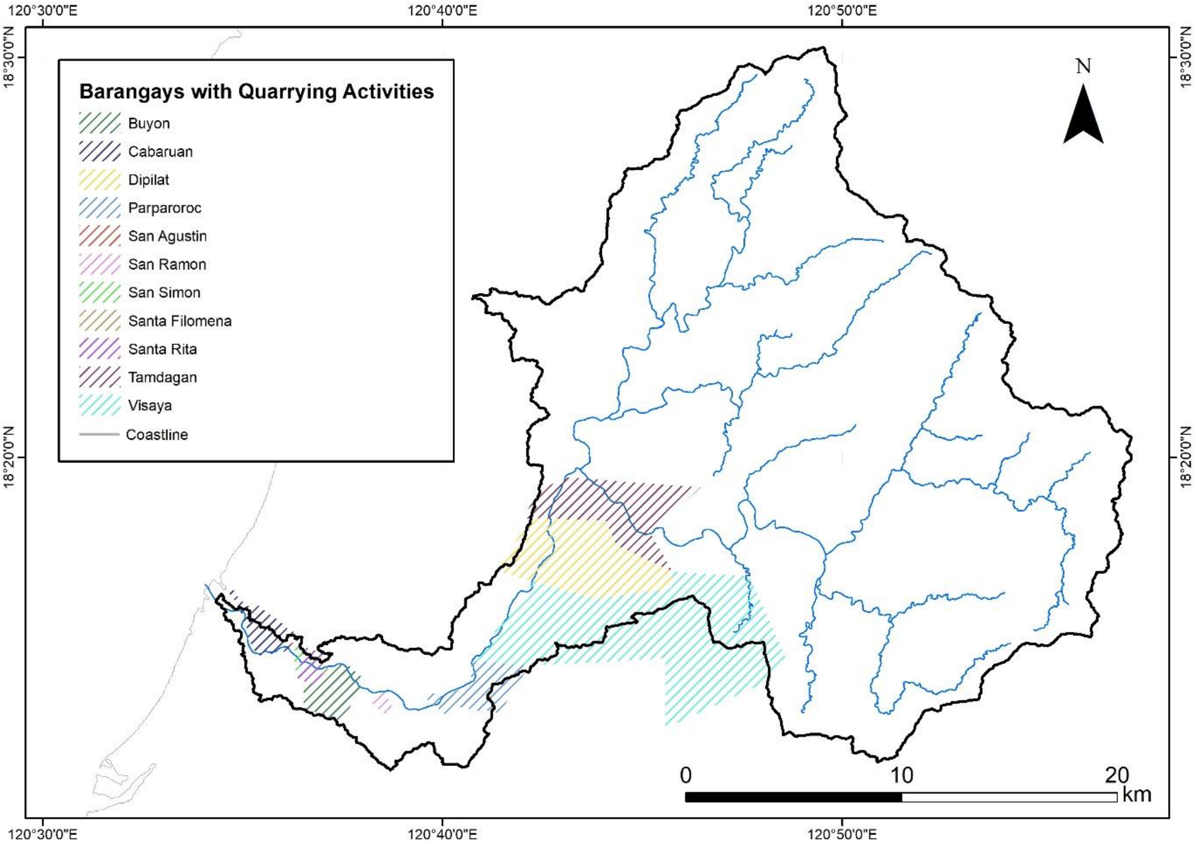


Figure 4.31 Location of barangays with reported quarrying sites within the Bislak Catchment.

4.9.2 Agriculture and Aquaculture

Agriculture and fisheries provide a small contribution to economic activities, reflecting their vulnerability to natural hazards. Successive typhoons and El Niño events have decreased agricultural production between 2011 – 2015, while the fishing industry has declined due to the overflowing of fish pens during typhoons events and the non-stocking of fish farms due to limited water supply (NEDA – RO1, 2017).

4.9.2.1 Agriculture

Between 1980 and 2012, there was a decrease in farm area within the Ilocos Norte Province while the number of farm parcels in the province increased. This may be attributed to continuous agricultural land conversion due to urban expansion. Total agriculture area for Ilocos Norte, decreased from 49 thousand hectares to 27 thousand hectares – a 45% decrease in total area. Temporary crops – primarily rice, with a small percentage of corn, tobacco, and string beans – cover approximately 89% or 24 thousand hectares of the total parcels in the province, while permanent crops, mostly fruit trees, cover only 3.7% or one thousand hectares. (Philippines Statistics Authority, 2012).

The Bislak River is primarily used for irrigation to sustain agriculture within the Province of Ilocos Norte. In the Municipality of Vintar, those located at the built-up area situated in its south, as well as its peripheries, are irrigated by the National Irrigation Authority's Lateral A canal; while farmlands at the northern portion running alongside the Bislak River are irrigated by communal irrigation systems. It is important to note that farmlands along this area commonly face the hazards of the floodwaters and can be rendered unproductive due to the gravelly deposits brought by flash floods. In contrast to this, arable accretion sites along the river are also seen by the municipality as potential land for agriculture, agroforestry, and even urban purposes if provided with wall protection (Vintar MPDC, 2009).

While the Bislak River runs mostly within Vintar, irrigation from the river also supplies the needs of other adjacent municipalities clustered within the food production zone of the Ilocos Norte Province including Sarrat, Piddig, Bacarra, Pasuquin and the City of Laoag (Vintar MPDC, 2009).

4.9.2.2 Fisheries and Aquaculture

Fisheries production within the catchment is limited to inland rivers due to the absence of swamps and marshes which are more conducive for commercial scale fishponds. Fishing is usually an alternative livelihood for residents – typically farmers – and not a full-time occupation. As such, fisheries are limited to a "backyard scale" of production (Vintar MPDC, 2009).

Aquatic resources in the Bislak River include fish species such as tilapia (*Oreochromis*), karpa (*Cyprinus carpa*), and bukto (various species of gobiid fish), kiwet and tutut (*Leiopotherapon plumbeus*); crustaceans such as kippi (*Hemigrapsus sanguineus*) and udang (*Macrobrachium rosenbergii*); edible freshwater shellfish species locally known as tukmem (*Curbicula fluminea*), suso /sugpel (*Melanoides tuberculata/Tarebia granifera*), birabid (*Lymnaea cumingiana*) and bisukol (*Pomacea canaliculata*); and aquatic plants such as ballaiba (*Vallisneria nana*), balangeg (*Ipomoea aquatica*) and aba (*Colocasia esculenta*). Several of these species are in decline locally.

4.9.3 Other uses

A primary use of the river aside from agriculture and mining is to be a source of potable water, in addition to other domestic uses. There are abundant springs for potable water supply in the Bislak Catchment. The most rural barangays maintain and manage their own potable water supplies, while barangays being served by a Level II water system (Margaay, Salsalamagui, Cabisuculan, Malampa, Dipilat, and Isic-Isic) have watercoming from dug wells and improved springs.

The river is also currently being used for tourism purposes. The Municipality of Vintar aims to develop tourism amenities anchored on water and eco-based recreational and leisure activities. There is an increasing number of resorts being constructed within the municipality which includes swimming pools and scenic vistas (Vintar MPDC, 2009).

4.10 Bislak River and the Vintar Community

For the year-round benefits derived from Bislak River, the community in Vintar practice a ceremonial ritual to celebrate the river and give thanks to the Almighty God. The Vintar River Ritual, usually done before the end of the year, also serves as a community gathering to pray for continuous bounty of adequate water for the needs of the Vintarinians (people from Vintar).

On the 27th of December 2019, the ritual was held at Umok ni Siwawer in Vintar Dam. Honorable Mayor Larisa Foronda graced the ceremony and provided the rationale for the River Ritual. A series of prayers were offered such as Prayer for Repentance and Confession, Prayer for Protection from Calamities and Municipal Progress and Development, Prayer for Commitment and Dedication of Vintar Leader, and Community and Prayer for Abundance of Blessings and Bountiful Harvest. Leaders of different religious sectors also prayed over the Municipal Officials of Vintar (Figure 4.32) for wisdom in making sound decisions for the benefit of all while always taking into consideration the health of the Bislak River. Students and teachers from different schools in Vintar also offered songs and dances like the *'Panagyaman,'* an Ilocano term for thanksgiving, (Figure 4.33) to call for the preservation and conservation of the healthy Bislak River.

Towards the end of the program, the officials and guests were invited to offer candles placed on coconut shells to the river and to release fingerlings of *Tilapia* for more production of fish (Figure 4.34). The very first Fluvial Parade was led by the Mayor and other officials along the Vintar Dam to symbolize unity of the community towards a sustainable Bislak River. The program closed with a prayer, singing of "Heal the World", and a symbolic blessing with the fire hose showering the participants with water from the river.

Rivers are also central to Ilocanos' leisure. They are fond of spending afternoons and holidays on the river, with some locals even setting up build nipa huts along the Bislak River in late January, especially near pool areas. Temporary tents and grilling areas on the bars are also usual sights in the area. In fact in 2019, the Municipality of Vintar built a zipline and bike line, and acquired kayaks for use at the Vintar Dam to attract tourists.

Community fishing is also common in the Bislak River. A common practice is where fishers form a straight line across the river from bank to bank while holding a fishnet and then walking for kilometers towards the flow of the river. Other fishing activities are collectively called "*Panagrama ken Panagburak*"—*Panagrama* means "to build a reef" while *Panagburak* means "to harvest fish from the reef". Building the *rama* (reef) involves gathering of big rocks and piling them to create a *kunukun* (pile of stones) on a *ban-aw* (shallow area of the river with steady flow of water). Uncooked pig entrails or a can of sardines with holes are then placed to attract fishes into this nutrient-rich *rama*. This set up is left for 2 to 6 months. During the *panagburak*, family and friends carefully disassemble the *kunukun* then secure all the fish in a net. The net with the fishes is tied and then laid on the ground. Once the harvest is complete, the folks share on the catch through a feast.

Figure 4.32 Pray over of a sector leader on the Municipal Officials of Vintar.

Figure 4.33 “Panagyaman” performance from FCIS Dancers.

Figure 4.34 Release of Tilapia fingerlings to the river for more production of fish.

4.11 The Imalawa Tribe

In the year 2000, a research on the Imalawa Tribe of Vintar was conducted. According to this research, the name Imalawa was formed by adding a prefix i- meaning “dweller of” to the name of their ancestral home- “Malawa” which means vast. It was known that this group of indigenous people once resided in a place called “Malawa” near a creek at the foot of Mt. Gamamatan, a mountain encompassing the boundaries of Ilocos Norte and Apayao. It is said that some tribe members who climbed up the mountain were amused by the magnificent view and vastness of the mountains and the rivers. It is with unanimous agreement that the place is indeed “malawa”.

From “Malawa”, some tribal leaders moved and settled in a place called Dalugoc where they were eventually advised by the DENR to go down the mountain as the trees were being cut down by the tribe, causing erosion in the mountain and flooding the lowland farms. The Imalawa/Isneg dutifully went down where they were able to clear and flatten the area for rice paddies and for planting fruit trees beside the mountain. Currently, they are residing in Barangays Canaam and Isic-isic in Vintar with an estimated population of 427 and 290, respectively (National Commission on Indigenous People - Region 1, 2014)

Many written accounts were discovered on how the rivers play role in the livelihood and culture of the Imalawa. One notable account was on their burial rites. During the “tarabon”, the burial day of a deceased tribe member, all the people who joined the ceremony must go directly to the river and wash their hands and feet while calling for a spirit called “Idammang” from the “iput apayaw” (delta). They are to inform the spirit the name of the dead person. After they finish washing, they pick up stones from the river and throw them on the roof of the deceased person’s house to drive away the ghost.

The Imalawa Tribe is dependent on hunting and fishing for living. Though at present, they decided to settle in one place, they have been hunting and fishing from one mountain to another. The Imalawa Tribe consider themselves as the first settlers of the area.

5.1 River Styles in Valley Settings

Eight River Styles were identified in the Bislak Catchment, **three in the Confined Valley Setting** (1) Confined, Steep Headwater, Bedrock Bed River Style, (2) Confined, Gorge, Boulder Bed River Style, (3) Confined, Occasional Floodplain Pockets, Boulder Bed River Style, **three in the Partly-confined Valley Setting** (4) Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style, (5) Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Gravel Bed River Style, (6) Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style, and **two in the Laterally Unconfined Valley Setting** (7) Laterally Unconfined, Continuous Channel, Braided, Gravel Bed River Style, (8) Laterally Unconfined, Continuous Channel, Deltaic, Sand Bed River Style. Table 5.1 summarises the River Styles. River Styles Tree and maps are presented in Figures 5.1 and 5.2, respectively. Schematic cross-sections of each River Style are found after the Controls table.

5.1.1 River Styles in the Confined Valley Setting

The three River Styles found in the confined valley setting are found in the high slopes of the tributaries.

The **Confined, Steep Headwater, Bedrock Bed River Style** is found along the steep slopes of the Luzon Central Cordillera (LCC) Mountain Ranges. The mountainous areas, especially in landscapes, are the sources of sediments being fed to the catchment. While this River Style is laterally stable, vertical adjustment may occur when concentrated flow promotes bed and bank incisions. Geomorphic units include waterfalls, cascades, rapids and bedrock pools.

The **Confined, Gorge, Boulder Bed River Style** is found in the valley of the Rugged Hills of the LCC and occupies the entire valley floor. This River Style is laterally stable as there is absence of floodplains and vertical adjustment is limited to redistribution of materials.

The **Confined, Occasional Floodplain Pockets, Boulder Bed River Style** is bedrock-confined and occupies almost entirely on the floor of the narrow valleys. The channel is laterally stable and adjustment is very limited to occasional floodplain pockets.

5.1.2 River Styles in the Partly-confined Valley Setting

The three River Styles found in the partly-confined settings are divided into two, one that is bedrock margin-controlled and two that are planform-controlled.

The **Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style** occurs in the Rugged Hills landscape unit, downstream of the confined valleys where the valley has widened out allowing discontinuous floodplains to form. It is situated in sinuous valleys with the channel flowing adjacent to the valley at about 50-90% of its length. The channel tends to have an irregular shape imposed by the bedrock. Compound point-bars with ramps, chute channels and ridges are found in the concave side of the bend giving the channel an asymmetrical shape along this area. Vegetation is commonly found on riffles, bars and benches contributing to the channel roughness. Ledges are also present indicating a floodplain stripping and reworking during overbank stages.

The **Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Cobble Bed River Style** is found in the rounded foothills as the valley further widens and floodplains occupy a dominant proportion of the valley floor. Bedrock has reduced influence in this type as the channel impinges the valley margin at about 10%-50% only of its length. This wandering, low sinuosity channel splits into 2-3 channels around bars. Lateral adjustment is limited to the less stable banks and the confinement set by bedrock results in downstream translation and migration of bends. Channels tend to be asymmetrical at the bends, where compound bank-attached bars occur on the concave side of the bend, and uniform along points of inflection. The channel also has a compound shape where benches and ledges occur; this indicates that the channel is contracting and expanding. Vegetation adds roughness to the channel and increase stability of the instream and floodplain geomorphic units.

The **Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style** occurs in the depositional zones. There are only two rivers with this style, uncharacteristically found in between confined valley settings. In planform, the channel divides the discontinuous floodplains as it abuts the valley margin. Based on the geologic and structural map (Figure 4.5), these rivers lie along fault zones where shearing may have weakened the rocks exposing them to enhanced weathering and erosion. This may possibly explain the presence of built crop terraces in the site/area. There is no persistent presence of bars which may be due to the upstream location of the river in the catchment and the limited available discharge. The channel seems to have limited capacity to adjust as agriculture and enhanced weathering of the rocks may have resulted in cohesive banks.

5.1.3 River Styles in the Laterally Unconfined Valley Setting

The two River Styles found in the laterally unconfined valley setting are situated on the downstream 12 km of the Bislak River where the channel does not abut the valley margin.

The **Laterally Unconfined, Continuous Channel, Braided, Gravel Bed River Style** begins where the valley bottom margin widens and the channel no longer impinges the confining margin. The channel splits into more than three channels around bars and islands in low sinuosity. Continuous floodplains are formed along both banks. This river normally has a high capacity to adjust in most areas, but further downstream, more flood dikes are built in river corridors where settlements are found. These anthropogenic structures serve as the margin of the channel at overbank stage. Compound bank-attached and mid-channel bars with a number of chute channels and vegetated ridges are dominant in this River Style. This River Style is prone to thalweg shift and active channel migration.

The **Laterally Unconfined, Continuous Channel, Deltaic, Sand Bed River Style** is found at the delta where the Bislak River drains to the West Philippine Sea. The multi-channelled river enclosing flood basins has moderate to limited capacity to adjust. Adjustments are possible but in slow rates due to the cohesive nature of the sediments. Avulsions are common in this River Style as channels slowly accrete within floodplains/islands or reoccupy old pathways. Some channels are stabilised by islands while presence of less stable bars promote channel shifts.

Table 5.1 Summary of distinguishing attributes of River Styles in the Bislak Catchment.

	River Style	Valley Setting	River Character			River Behaviour
			Channel Planform	Geomorphic Units	Bed Material Texture	
1	Confined, Steep Headwater, Bedrock Bed River Style C_StHw_Brbed	Confined	Single channel, low sinuosity, highly stable	waterfalls, cascades, rapids, bedrock pools, riffles, bedrock outcrops	bedrock, boulder, cobble	Steep, bedrock-controlled rivers with high channel-hillslope connectivity. Irregular channel cross-section with straight valley. Flushes out sediments downstream. Has very limited capacity for adjustment.
2	Confined, Gorge, Boulder Bed River Style C_Gge_Bbed	Confined	Single channel, low sinuosity, highly stable	cascades, bedrock steps, riffles, pools	bedrock, boulder, cobble	Bedrock-controlled rivers with sculpted geomorphic units. Sediments are mostly from upstream and flushed readily downstream but can store sediments when there is oversupply. Channel is laterally stable and vertical adjustment is limited to redistribution of materials.
3	Confined, Occasional Floodplain Pockets, Boulder Bed River Style C_OccFp_Bbed	Confined	Single channel, low sinuosity, highly stable	rapids, pools, runs, boulder bars, occasional floodplain pockets, benches, ledges	bedrock, boulder, cobble	Bedrock-controlled rivers in narrow valley. Floodplain pockets formed by vertical accretion are evident. They serve as temporary sediment storage sites. Lateral adjustment is restricted on where the floodplains occur.
4	Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style PC_BrMc_DcFp_Cbed	Partly-confined	Single channel, sinuous valley alignment, moderately stable	pools, riffles, runs, compound bank-attached bars, mid-chanel bars, benches, ledges	bedrock, boulder, cobble, gravel, sand	Bedrock-controlled rivers in sinuous valleys where they abut the valley margin 50-90% of its length. In these transfer zones, sediment input and output are balanced over time. Depositional bank-attached bars and discontinuous floodplains are found in the concave sides of the bends while erosion occurs along the concave bends.

5	Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Cobble Bed River Style PC_PC_Wan_DcFp_Cbed	Partly-confined	Single channel, irregular valley, low sinuosity channel	pools, riffles, runs, compound bank-attached bars, mid-channel bars, benches, ledges	boulder, cobble, gravel, sand	Planform-controlled rivers which are terrace-constrained. Wandering type with a main channel that splits into 2-3 channels around mid-channel bars. In these transfer zones, compound bank-attached and mid-channel bars are present. Floodplains are prone to reworking and stripping.
6	Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style PC_PC_LSin_DcFp_Gbed	Partly-confined	Single channel, irregular valley, low sinuosity channel	pools, riffles, runs, benches, ledges	boulder, cobble, gravel, sand	Planform-controlled rivers with low sinuosity. Divides floodplain into discontinuous sections. Abrupt widening of the valley results to this planform-controlled river. Lateral adjustment is moderate due to the presence of floodplains. There is no persistent presence of bars but ledges and benches may be present. Lateral adjustment is limited due to cohesive banks.
7	Laterally Unconfined, Continuous Channel, Braided, Gravel Bed River Style LU_C_Braid_Gbed	Laterally unconfined	Single to multiple channels, low sinuosity, low to moderate stability	pools, riffles, runs, compound bank-attached bars, compound islands, benches, ledges, paleochannels	cobble, gravel, sand	Laterally unconfined rivers located at the downstream and urban part of the catchment. Channel is continuous and braid around bars. Valley margin is set back giving this river a space to move but some sections are confined with anthropogenic structures such as settlements, flood protection dikes and gabions.
8	Laterally Unconfined, Continuous Channel, Deltaic, Sand Bed River Style LU_C_Delta_Sbed	Laterally unconfined	Multiple channels, continuous, low to moderate stability	compound bank-attached bars, compound islands	gravel, sand, silt, clay	Continuous channel. Avulsions are common and new channels are formed on the floodplain or reactivation of old channels.

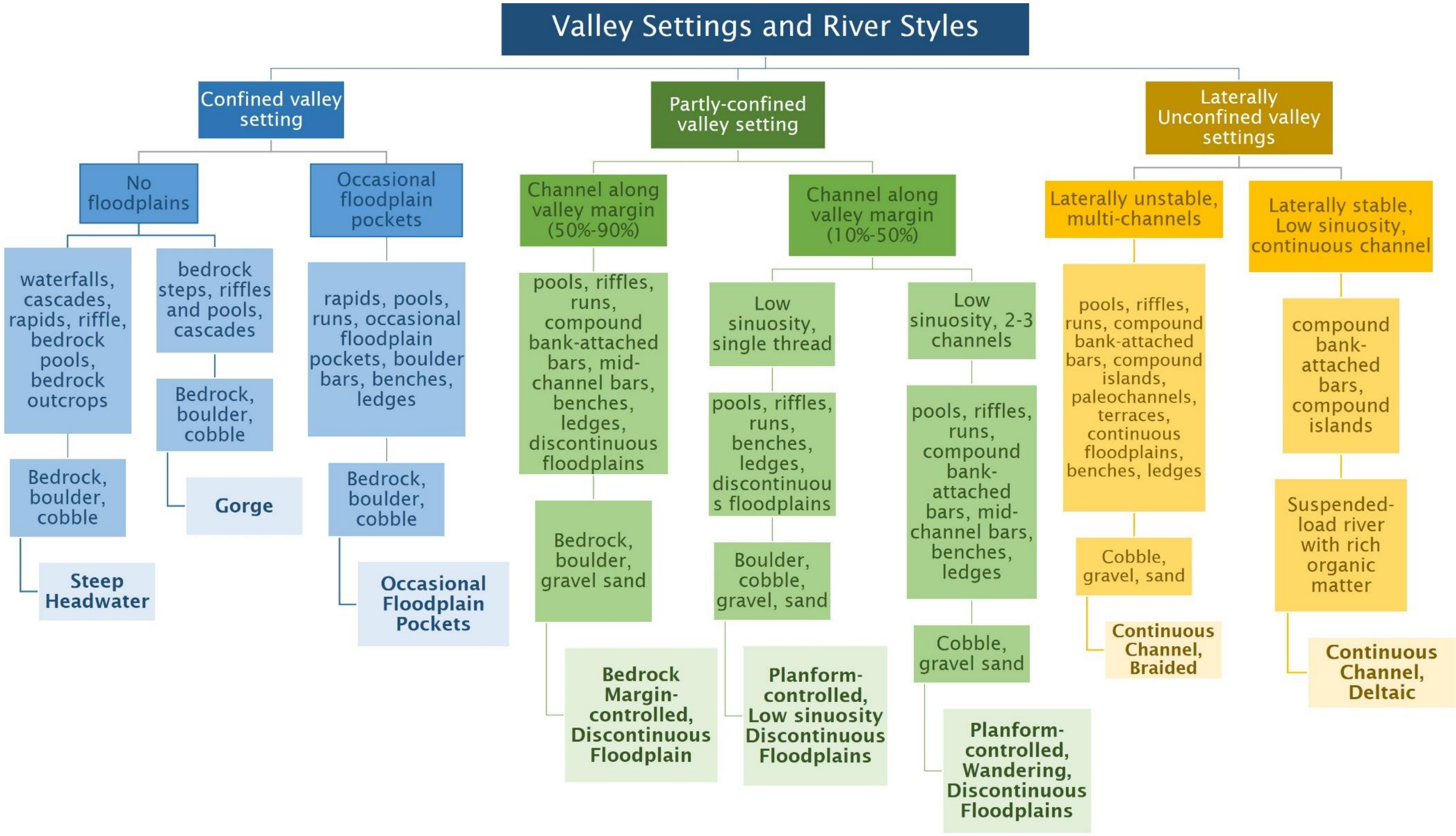


Figure 5.1 River Styles Tree for the Bislak Catchment.

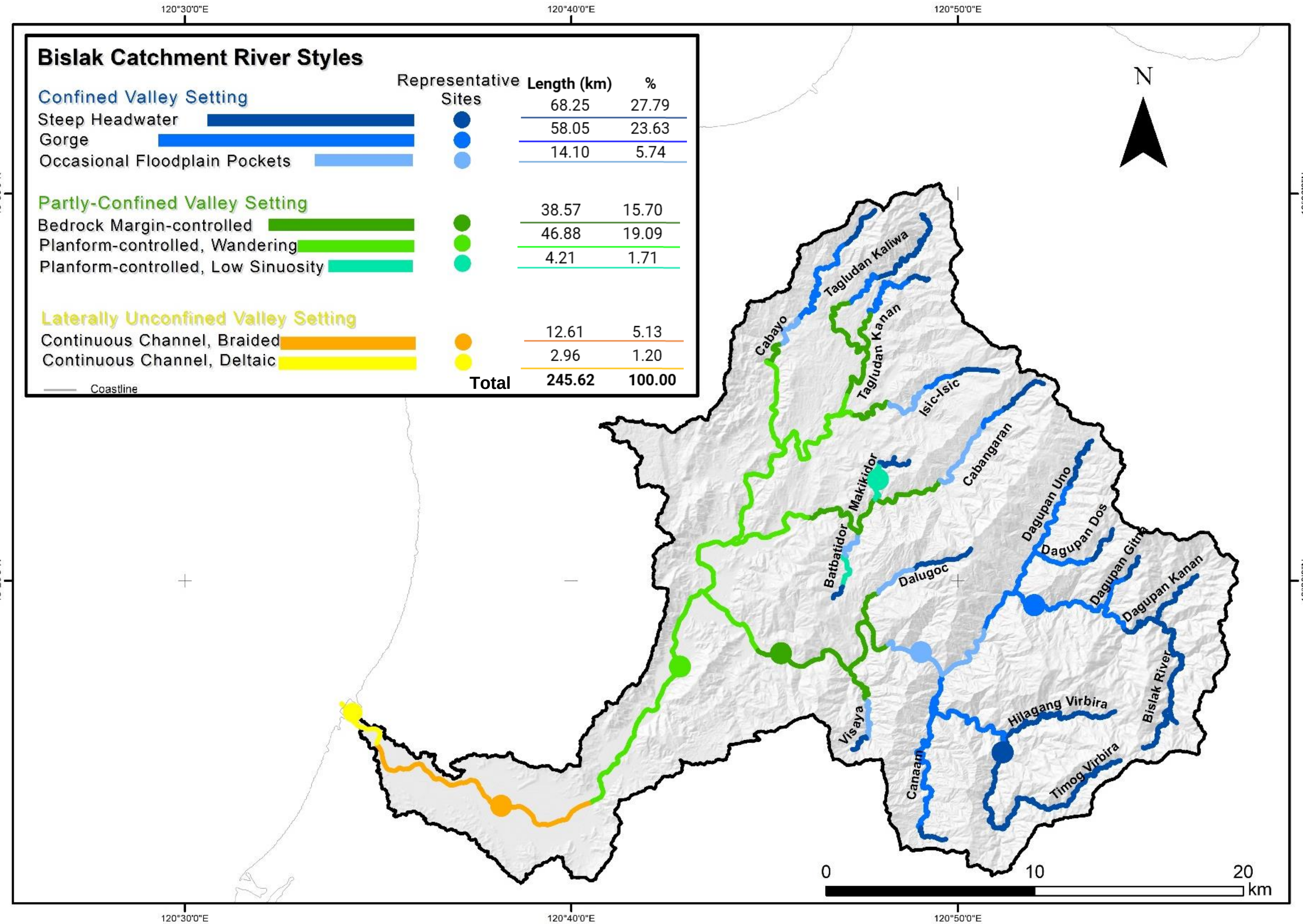


Figure 5.2 Distribution of River Styles in the Bislak Catchment. Circles represent locations of respective River Styles. Lengths in kilometer and % length are displayed.

5.2 River Styles Proformas

Confined [C] Steep Headwater [StHw] Bedrock Bed [Brbed] River Style

Defining Attributes of River Styles: This River Style is found in steep, confined valley settings proximal to headwaters which constrain channel width to the same width as the valley margin. Hillslopes are typically densely vegetated and bed slopes are very steep (mean 0.085). Channel planform in this River Style is single-threaded and with low sinuosity, while cross-section is generally irregular due to the presence of large boulders and exposed bedrock. Geomorphic units are mostly sculpted, erosional bedrock and boulder units, prominent of which are step-pools and cascades, as well as bedrock outcrops. Due to its confined nature, the channel has little capacity to adjust laterally.

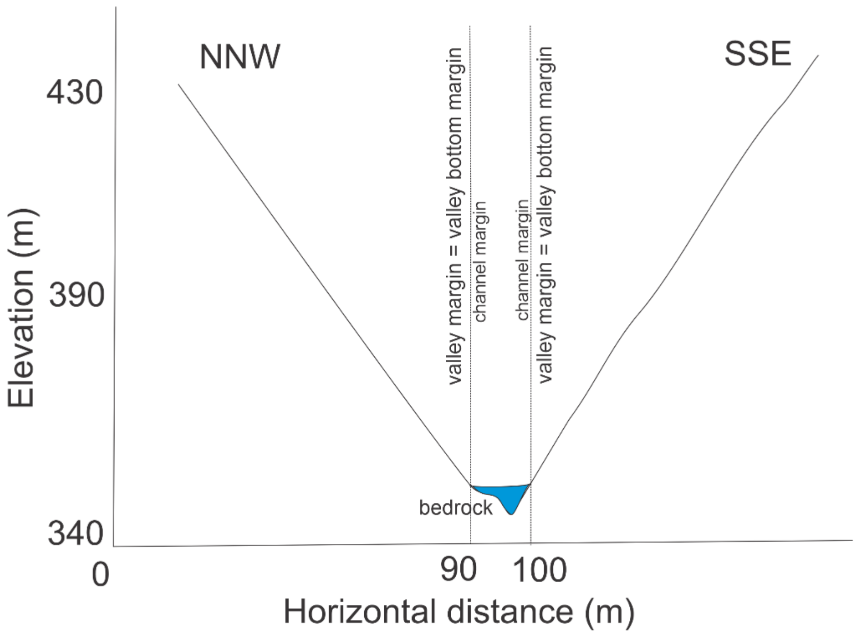
DETAILS OF ANALYSIS
Representative sites: Timog Virbira Steep Headwater Map sheets air photographs used: Date: 11/10/2018 Coordinates: 18.260506°N, 120.852855°E

RIVER CHARACTER	
Valley-setting	Confined
River planform	The reach has a low sinuosity, single-threaded channel that follows the valley margin. Lateral stability is high due to the confined nature of the valley. No floodplain occurs in this reach.
Bed material texture	Bed material is dominantly boulders and bedrock. Large boulders are abundant in the reach along with exposed bedrock features, indicating highly connected hillslopes.
Channel geometry	Channel cross-section is irregular, bedrock and large boulders control the cross-sectional shape of the channel. Low flow channel width (m) [Min: 10, Mean: 12.74, Max: 30]; channel depth (m) [no data].
Geomorphic units	This River Style is dominated by sculpted, erosional bedrock and boulder geomorphic units wherein the most prominent are cascades and step-pool units formed by large boulders. Bedrock outcrops are commonly observed along the banks. **Instream** **Bedrock step** – Channel-wide drops where flows fall near-vertically, separating backwater pools from plunge pools. Width may reach up to 7 m.

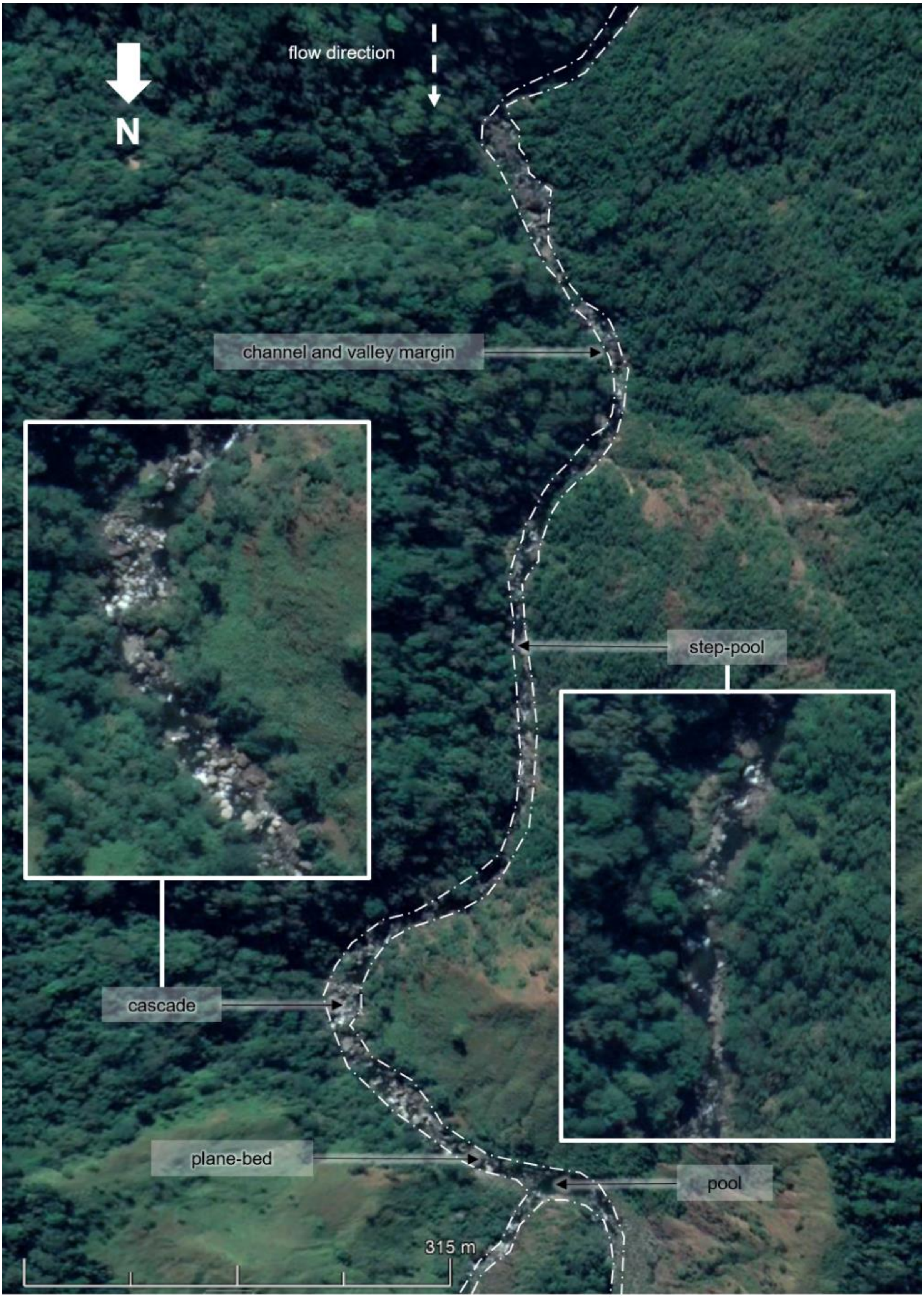
	Step-pool sequences – Stair-like features formed on steep slopes that span the channel. Comprised of bedrock or boulder materials. Each step is separated by a plunge pool. Widths that may span the channel ranges from 5 - 10 m. Distance between individual steps range between 7 - 10 m in length while whole segments of continuous step-pool features may reach up to 140 m in length. **Cascades** – Features formed by longitudinally and laterally disorganised coarse materials. Flow cascades over steps of large boulders then into calmer flow. Cascades are frequent within the steep headwater reaches with widths ranging from 7 - 11 m. **Plunge pool** – Deep and circular depressions along the channel bed formed by scouring at the base of a bedrock step. **Run/Plane-bed** – Relatively featureless bed typically at smooth flow zones found between pools. Comprised of boulder and cobble bed material. Width and length ranging from 7 - 13 m and 49 - 103 m, respectively. **Bedrock outcrops** – Common throughout the reach.
Vegetation associations	There is little to no vegetation established in the channel.

RIVER BEHAVIOUR
Low flow stage The channel is stable at low flow stage with little to no geomorphic work being done. Sculpted, geomorphic units such as cascades and step-pools are maintained by the abundance and organisation of large boulders and bedrock. Relatively smaller-sized material may be infrequently mobilised and stored behind larger materials or deposited in pools where flow velocities are reduced. Supercritical flow is present over steps while subcritical flow is present in pools.
High flow stage As a source zone, sediment is delivered into the channel through highly-connected hillslopes. The steep slopes deliver large amounts of coarse sediments into the channel, especially from mass-movements. During high flows, river width is still constrained within the bedrock valley margin, flushing small grains, as well as mobilising and redistributing coarser grains, overall restricting sediment accumulation within the channel. As such, even during high-flow events, bedrock-confined rivers have limited ability to adjust their boundaries in lateral or vertical dimensions. Most features in the reach are only being reformed and reshaped in these high-flow events. Boulders may move within geomorphic units, rearranging keystones in step-pools, while bedrock may be scoured. Movement of boulders also rework cascades. Stored gravel and smaller sized materials are flushed during high flows.

CONTROLS	
Upstream catchment area	~43 km^2
Landscape unit and within-Catchment position	This River Style can be found in the Steep Upland landscape units and is the most upstream River Style found at the headwaters, just below the drainage divide.
Process zone	Source zone with high connectivity between the channel and its hillslopes; hillslopes contribute to sediment input through mass-movement.
Valley morphology (size and shape)	V-Shaped, Symmetrical
Slope	High Min: 0.01 Max: 1.04 Ave: 0.08
Relative Stream Power	High Min: 95 W/m Max: 5520 W/m Ave: 920 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


flow direction
N
channel and valley margin
step-pool
cascade
plane-bed
pool
315 m

Confined [C] Gorge [Gge] Boulder Bed [Bbed] River Style

Defining Attributes of River Styles: This River Style is found in a confined valley setting, which restricts the formation of floodplain pockets. Hillslopes are sparsely vegetated relative to the Steep Headwaters River Style and bed slopes are relatively gentler (mean 0.023). The channel width is typically the same as the valley width (approximately 20 - 45 m). Channel planform in this River Style is single-threaded with low sinuosity and cross-section shape is generally irregular due to the presence of large boulders and exposed bedrock. Geomorphic units are mostly sculpted, erosional bedrock and boulder units, prominent of which are step-pools and cascades, as well as bedrock outcrops. Due to its confined nature, the channel has little capacity to adjust laterally.

Note: Analysis done in this River Style is based on aerial images from Google Earth.

DETAILS OF ANALYSIS
Representative sites: Bislak River Map sheets air photographs used: Aerial images from Google Earth Date: 4/4/2017 Coordinates: 18.321838°N, 120.867723°E

RIVER CHARACTER	
Valley-setting	Confined
River planform	The channel in this reach is single-threaded with low sinuosity, generally occupying the whole valley floor and following the orientation imposed by the valley margin. Lateral stability is high due to the confined nature of the valley. No floodplains occur in this reach.
Bed material texture	Bed material is dominantly composed of cobbles, boulders, and bedrock. Large boulders are common throughout the reach along with exposed bedrock features. Gravel may be present at point and lateral bars, as well as in pools and runs.
Channel geometry	Channel cross-section is irregular due to the presence of bedrock and large boulders (~8.5 m a-axis for largest boulders) which dictate the shape of the channel. Low flow channel width (m) [Min: 15, Mean: 22.70, Max: 50]; channel depth (m) [no data].
Geomorphic units	This River Style is dominated by sculpted, erosional bedrock and boulder geomorphic units wherein the most prominent are cascades and step-pool units formed by large boulders. Point and lateral bars occur at bends and relatively straighter segments, respectively, rarely with vegetation established. Bedrock outcrops are commonly observed along the banks. **Instream**

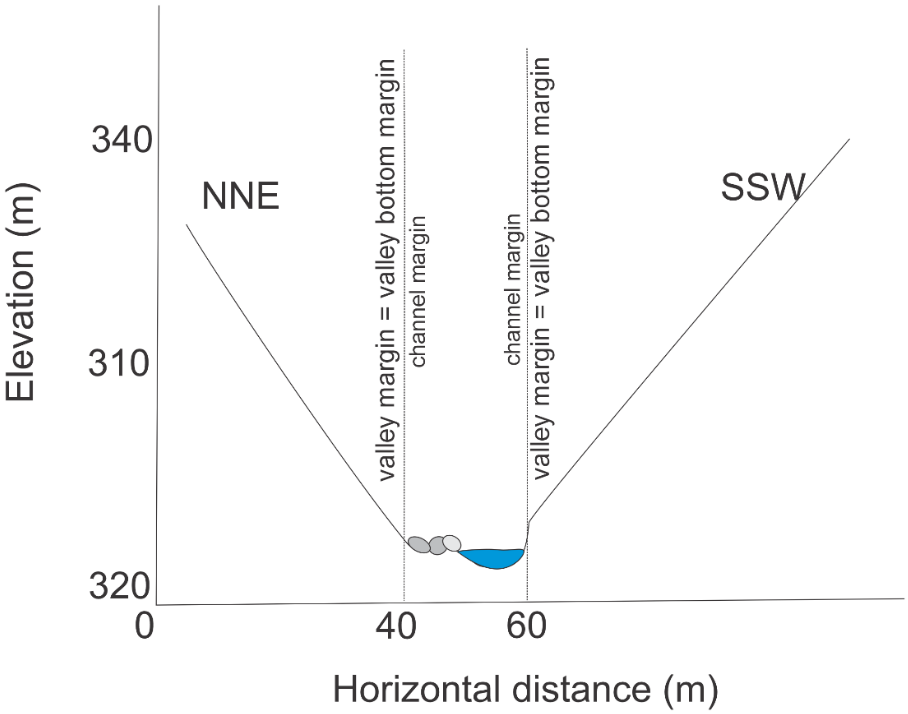
	Bedrock step – Channel-wide drops where flows fall near-vertically, separating backwater pools from plunge pools. Width is about 10 m. **Step-pool** – Stair-like features formed on steep slopes that span the channel. Comprised of bedrock or boulder materials. Each step is separated by a plunge pool. Widths that may span the channel ranges from 10 - 23 m. Individual steps range between 10-30 m in length while whole segments of continuous step-pool features may reach up to 200 m in length. **Cascade** – Features formed by longitudinally and laterally disorganised coarse materials such as bedrock and boulders. Flow cascades over steps of large boulders, falling on areas of tranquil flow less than one channel width in extent. Width and length ranges from 9 - 20 m and 22 - 52 m, respectively. **Plunge pool** – Deep and circular depressions along the channel bed formed by scouring at the base of a bedrock step. Width ranges from 6 - 13 m and length ranges from 9 - 13 m. **Rapid** – Elevated parts of the channel bed wherein individual particles break the water surface at low flow. Comprised mostly of large boulder clusters arranged in irregular transverse ribs. Found more commonly in this reach where the hillslopes are relatively less steep, near the downstream end of the reach. Width and length ranges from 13 - 20 m and 38 - 74 m, respectively. **Pool** – Depressions along the channel bed, commonly found downstream of elevated segments of the channel. Also occur in concave banks of bends where there are rare instances of point bars. May be bedrock or gravel-based and sometimes contain finer materials such as sand and mud which are eventually flushed during high flow events. More elongate in straighter segments but shallow, and shorter at bends but deep. Width and length ranges between 9 - 25 m and 8 - 50 m, respectively. **Run/Plane-bed** – Relatively featureless bed typically at smooth flow zones found between pools approaching rapids or between small segments of rapids. Comprised of finer gravel and cobble bed material. Typically long and narrow with width and length ranging from 14 - 26 m and 40 - 134 m, respectively. **Point bar** – Bank-attached feature found along the convex side of a bend. Arcuate and aligned similar to the orientation of the bend. Comprised mostly of boulders fining in the downstream direction and across, away from the channel, while also interspersed with large clasts, possibly colluvial in origin. Cobbles and gravel are also present. Width ranges between 20 - 22 m while length ranges between 34 - 68 m. **Lateral bar** – Bank-attached features found in relatively straighter segments of the channel and behind bedrock mounds. Long and narrow in this reach. Comprised mostly of boulders that fine in the downstream direction while also interspersed with large clasts, possibly colluvial in origin. Cobbles and gravel are also present. Vegetation may occur in perennially dry surfaces. Width ranges between 12 - 29 m while length ranges between 61 - 270 m.

	Bedrock outcrops – common throughout the reach at either banks.
Vegetation associations	Most bars observed have no vegetation cover. In rare instances, bars may be partially covered by shrubs and grasses. Overall, approximately 5% of the bars have vegetation established.

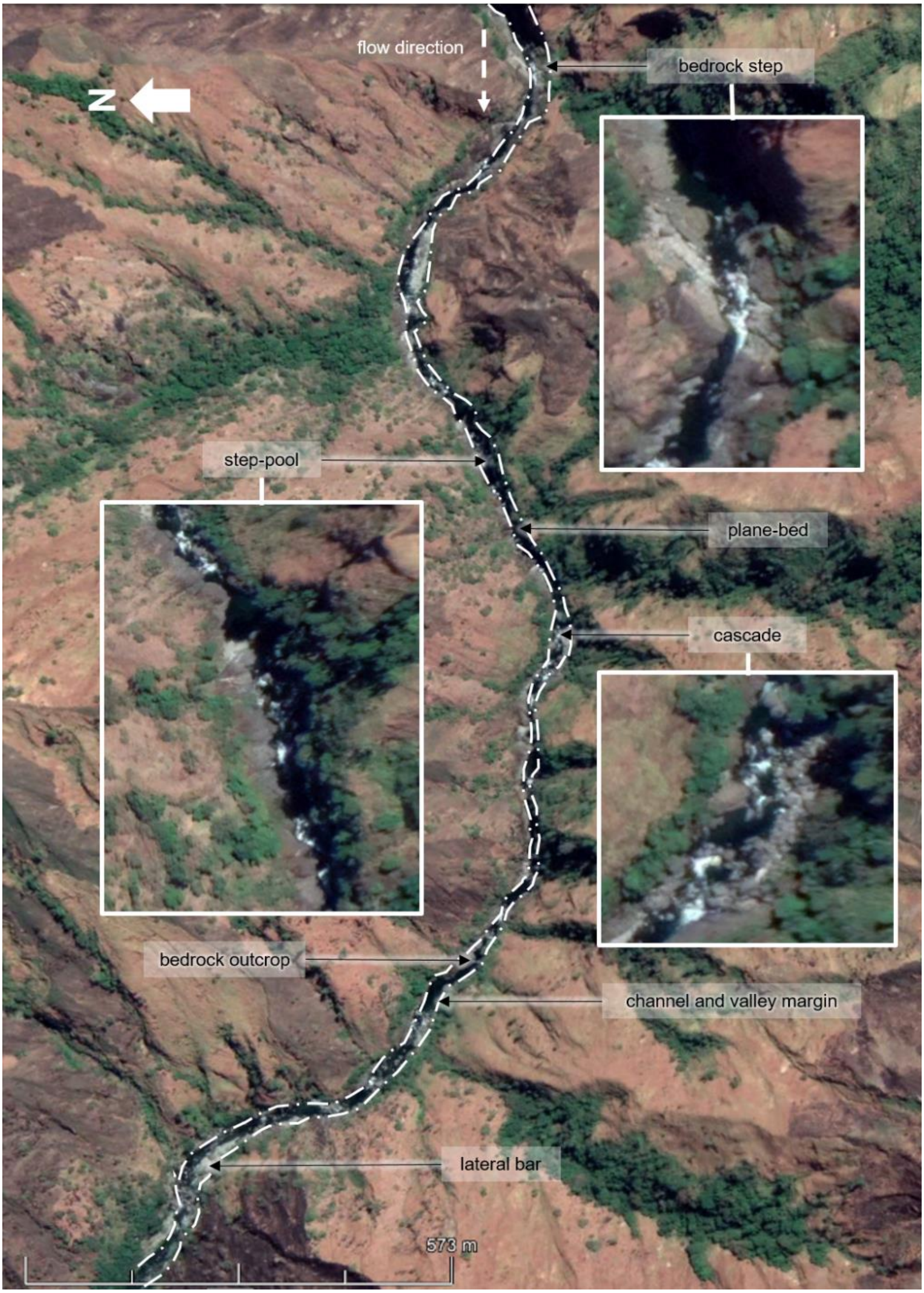
RIVER BEHAVIOUR
Low flow stage The channel is relatively stable at low flow stage with little geomorphic work being done. Sculpted, geomorphic units such as cascades, step-pools, and rapids are maintained by bedrock and the organisation of large boulders. Gravel-sized material may be infrequently mobilised and stored behind coarser material, while sand and mud may be transported as bedload and suspended load, respectively; eventually deposited in pools where flow velocities are reduced. On bar surfaces, vegetation may be established at dry areas.
High flow stage Steep hillslopes act as a source of sediments that are delivered into the channel. Large amounts of sediments can be delivered into the channel, especially from mass-movement. In addition, relatively barren hillslopes allow for easier transport of eroded materials. During high flows, river width is constrained within the bedrock valley margin and spans the valley, restricting sediment accumulation within the channel. As such, even during high-flow events, bedrock-confined rivers have limited ability to adjust their boundaries in lateral or vertical dimensions. Most features in the reach are only being reformed and reshaped in these high-flow events. Generally, coarse bed materials may be redistributed, while finer materials stored or deposited during low flow are flushed. Boulders may move within geomorphic units while bedrock may be scoured. Higher stream powers rework bed materials and reshape bars. Plunge pools are further scoured in high-flow events. Step-pools are disturbed during extreme flooding, wherein keystones may be rearranged, as with cascades which also undergo reworking. Rapids are mobilised but will reform as the flow decreases. Stored gravel-, sand-, and mud-sized materials are flushed during high flows.

CONTROLS	
Upstream catchment area	~110 km^2
Landscape unit and within-Catchment position	Starts at the lower end of the Steep Upland transitioning to Rugged Hills where the slopes begin to become relatively gentler and elevations are moderate.
Process zone	Located in confined valleys with high connectivity between the channel and its hillslopes similar to the Steep Headwater River Style; relatively barren hillslope allow for

	ready transport of eroded material to the channel in addition to landslides and mass-movement.
Valley morphology (size and shape)	V-Shaped, Symmetric
Slope	High Min: 0.008 Max: 0.24 Ave: 0.04
Relative Stream Power	High Min: 157 W/m Max: 8340 W/m Average: 1450 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


flow direction
N
bedrock step
step-pool
plane-bed
cascade
bedrock outcrop
channel and valley margin
lateral bar
573 m

Confined [C] Occasional Floodplain Pockets [OccFp] Boulder Bed [Bbed] River Style

Defining Attributes of River Styles: Found in a confined valley setting, this River Style is distinguished by occasional floodplain pockets. Despite these pockets of sediment deposition, the channel abuts the valley margin along 90% of its course. Channel planform in this River Style is typically single-threaded and with low sinuosity, while cross-section is generally irregular. Bed material includes of predominantly exposed bedrock, boulders and cobbles, with the presence of fine materials. Geomorphic units are mostly sculpted, erosional bedrock and boulder units, prominent of which are rapids - as part of riffle-pool-run sequences - and bedrock outcrops. Typically, active channel width is defined by the bedrock valley margin and the channel has little capacity to adjust laterally as with most confined settings, with the exception of local adjustment in the floodplain pockets.

DETAILS OF ANALYSIS
Representative sites: Bislak River Map sheets air photographs used: Aerial images from Google Earth Date: 4/4/17 Coordinates: 18.302343°N, 120.815239°E

RIVER CHARACTER	
Valley-setting	Confined
River planform	This reach is limited to a single-threaded channel with low sinuosity, generally occupying the whole valley floor and following the orientation imposed by the valley margin. Lateral stability is high due to the confined nature of the valley. Floodplain pockets occur in localised segments which allows for very limited space to laterally adjust.
Bed material texture	Bed material is dominantly composed of boulders and cobbles. Patches of exposed bedrock also occur commonly along the reach.
Channel geometry	Channel cross-section is irregular due to the presence of bedrock and large boulders (~6 m a-axis for largest boulders). Downstream segments where bends occur tend to be asymmetrical, as controlled by the bedrock-imposed bank at the concave side and the depositional area at the convex side of these bends. Low flow channel width (m) [Min: 15, Mean: 69.47, Max: 100]; channel depth (m) [no data].
Geomorphic units	**Instream** This River Style is dominated by sculpted, erosional bedrock and boulder geomorphic units wherein the most prominent are rapids, adjacent to narrow lateral bars and wider point bars. Lateral bars occur on straighter segments of the channel while point bars are typically in bends - compound features comprised of ramps, chute channels, and vegetated ridges within the bar

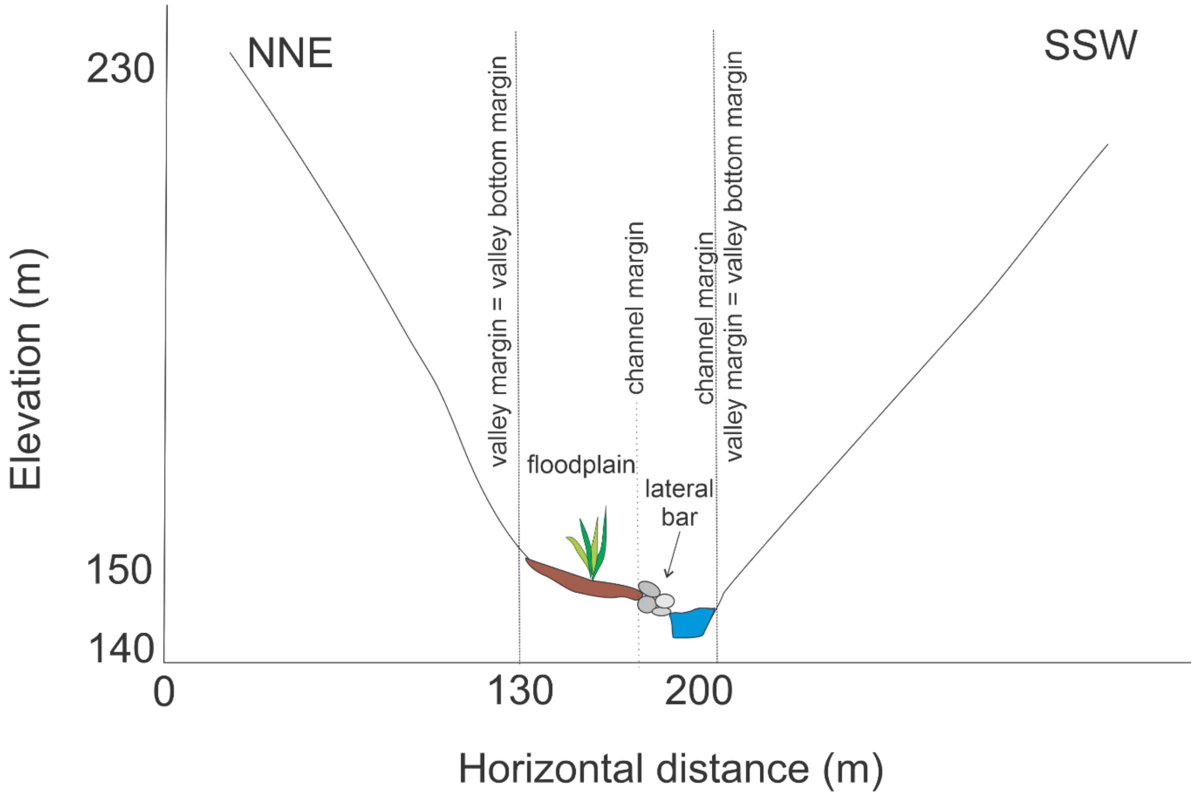
	surface. Where there are floodplain pockets, benches or ledges are noted. Bedrock outcrops are be observed along the banks. **Rapid** –- Elevated parts of the channel bed. Comprised mostly of large boulder clusters wherein individual particles break the water surface at low flow. Tend to be long and contiguous at straighter segments of the channel. Width and length ranges from 14 - 38 m and 25 - 500 m, respectively. **Pool** – Depressions along the channel bed, commonly found at bends for these reaches. May be bedrock or gravel-based and sometimes contain finer materials such as sand and mud which are eventually flushed during high flow events. More elongate in straighter segments but shallow, and shorter at bends but deep. Width and length ranges between 17 - 41 m and 47 - 180 m, respectively. **Run** – Relatively featureless bed typically found between pools approaching rapids, as well as inflection points of bends. Comprised of finer gravel and cobble bed material. Typically long and narrow with width and length ranging from 25 - 35 m and 53 - 100 m, respectively. **Point bar** – Bank-attached feature found along the convex side of a bend. Arcuate and aligned similar to the orientation of the bend. Comprised mostly of boulders fining down-bar and across, away from the channel. Cobbles and gravel are also present. May contain ramps, chute channels, and vegetated ridges within. Width ranges between 80 - 85 m while length ranges between 108 - 128 m. **Lateral bar** – Bank-attached features found in relatively straighter segments of the channel. Typically long and narrow in this reach. Comprised mostly of boulders that fine the downstream direction. Cobbles and gravel are also present. Vegetated ridges are often present. Width ranges between 5 - 60 m while length ranges between 140 - 415 m. **Bench** – Stepped, bank-attached features found adjacent to depositional bars where there are floodplain pockets. Arcuate in planform in this reach due to its common location at convex banks of bends. Slightly elevated above the point bar comprising of gravel and distinct presence of sand and clay. Approximately 7 to 12 m in width and 120 – 230 m in length. **Ledge** – Stepped, bank-attached features at erosional banks. Typically elongate in this reach, occurring at relatively straighter segments where there are floodplain pockets. Comprised of floodplain materials, including boulders and cobbles forming a step-like feature adjacent to the floodplain. Approximately 6 - 8 m in width and 200 - 210 m in length. **Bedrock outcrops** – Common throughout the reach but most prominent at concave banks of bends.
Vegetation associations	The few point and lateral bars are partially covered by vegetation (approximately 60 - 75% coverage), with vegetation established at elevated and relatively dry portions of the bar surface. The vegetation is generally comprised of grasses and shrubs, but occasional trees may be seen.

	Floodplain vegetation includes grasses, shrubs, and woody trees.

RIVER BEHAVIOUR
Low flow stage The channel is relatively stable at low flow stage with little geomorphic work being done. Rapids are maintained by exposed bedrock and the organisation of large boulders. Gravel-sized material may be infrequently mobilised, while sand may be transported as bedload and suspended load, respectively; eventually deposited in pools where flow velocities are reduced. On bar surfaces, relatively elevated and dry portions promote vegetation establishment and chute channels are exposed. Floodplain pockets remain stable with negligible lateral movement of the channel.
Bankfull and Overbank Stage Due to the lack of readily definable banks and floodplains, bankfull and overbank behaviour is interpreted for flows that inundate all instream surfaces. River width is maintained by the bedrock valley margin and spans the valley, restricting sediment accumulation within the channel. As such, even during high-flow events, bedrock-confined rivers have limited ability to adjust their boundaries in lateral or vertical dimensions. During these high flow events, most features in the reach are only being reformed and reshaped. Generally, coarse bed materials may be redistributed, while finer materials stored or deposited during low flow are flushed. Boulders may move within geomorphic units while bedrock may be scoured. Higher stream powers rework bed materials, reshape bars and new chute channels may be formed. Rapids can be mobilised but will reform as the flow decreases. However, there is some possibility for localised lateral adjustment at floodplain pockets where there may be scouring of ledges and banks, floodplain reworking, or floodplain stripping. While fine materials are flushed in high flows, vertical accretion on floodplain pockets occur in the waning stages of overbank flows.

CONTROLS	
Upstream catchment area	~ 210 km^2
Landscape unit and within-Catchment position	Starts at the upper end of the Rugged Hills landscape unit where the slopes continue to become relatively gentler and elevations are moderate.
Process zone	Sediments are sourced from adjacent colluvial hillslopes but is dominantly a bedload transfer zone. Sediment storage occurs in floodplain pockets.
Valley morphology (size and shape)	V-Shaped, Symmetric
Slope	Moderate to High Min: 0.005

	Max: 0.09 Ave: 0.02
Relative Stream Power	Moderate to High Min: 159 W/m Max: 4303 W/m Average: 1250 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


N
flow direction
rapid
pool
run
lateral bar
valley margin
channel margin
ephemeral stream
floodplain
406 m
ledge

Partly-confined [PC] Bedrock Margin-controlled [BrMC] Discontinuous Floodplain [DcFp] Cobble bed [Cbed] River Style

Defining attributes of the River Style: The channel has a low sinuosity (1.06) and abuts the valley margin along 60-80% of the length (partly-confined valley setting). In this transfer zone, the main geomorphic units are bank-attached compound bars and pool-riffle-run sequences. Bed material size is mainly cobbles to boulders, with some sand-gravel deposits in pools and runs. Lateral adjustment of the channel occurs along floodplain banks which are discontinuous along the River Style length. There is evidence for human activity, with irrigation canals, rice and corn fields and a flood defence which protects the community of Sitio Dimamaga, Brgy. Masasaduel.

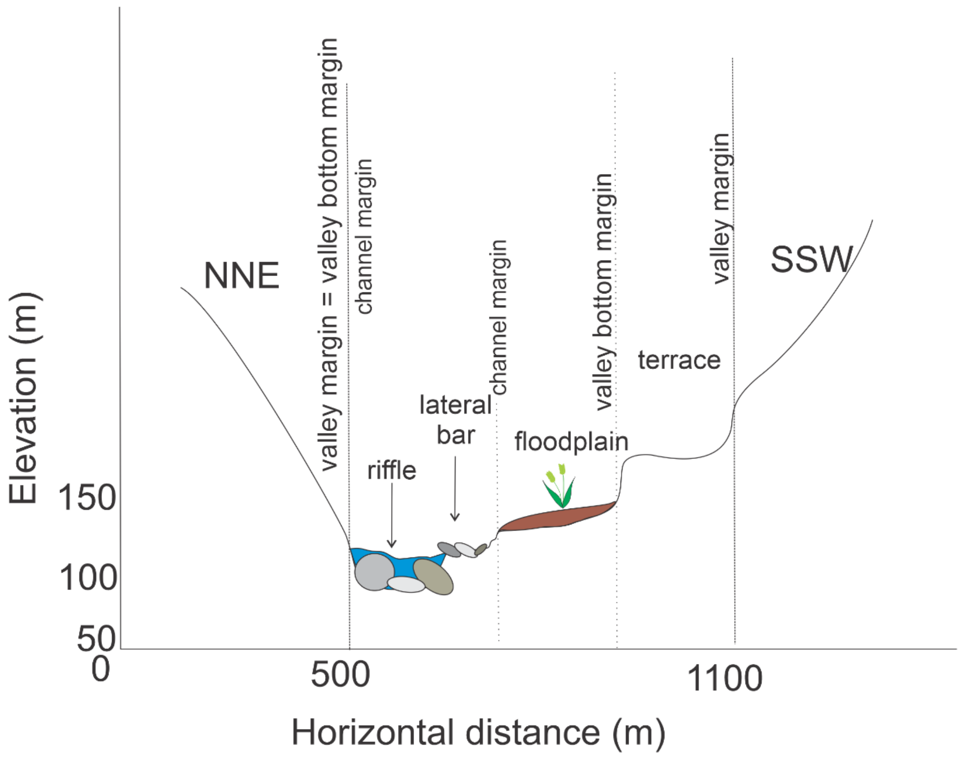
DETAILS OF ANALYSIS
Representative sites: Bislak River at Masadsaduel Map sheets air photographs used: Date: 4 April 2017 Coordinates: 18.303265°N, 120.757394°E

RIVER CHARACTER	
Valley-setting	Partly-confined.
River Planform	The channel is a single thread with a low sinuosity (at Masadsaduel 18.303265°N, 120.757394°E, sinuosity is approximately 1.06), but splits around bars as the valley widens. The channel follows the orientation of the valley margin and abuts the valley margin along >50% of its length. Lateral adjustment is possible where there are floodplain pockets.
Bed material texture	Bed material is cobble to boulder size with zones of exposed bedrock. Sand and gravel beds are observed in some pool units. Bank material is cobble to boulder size in depositional zones, whereas exposed bedrock is observed in erosional zones.
Channel geometry	Channel geometry is irregular along this river style. The channel cross-section tends to be asymmetrical along bends adjacent to lateral bars, point bars, and floodplain; with complex topography. In the downstream direction, channel width increases. Low flow channel width (m) [Min: 70, Mean: 138.96, Max: 380]; channel depth* (m) [Min: 0.095, Mean: 0.043, Max: 0.335]. *Insufficient bathymetry points
Geomorphic units	The most common geomorphic units are compound bank-attached point and lateral bars. These compound features include ramps, chute

	channels and ridges with vegetation. Bedrock outcrops are observed along the banks. **Pool** – Depressions along the channel bed, typically located in bedrock sections where the channel abuts the valley margin. Pools have finer bed material than riffles, from coarse sand to gravel. Deep and narrow at concave bank of bends, shallow and elongate at straighter segments. Width ranges from 12 - 40 m, length ranges from 30 - 70 m. **Riffle** – Elevated parts of the channel bed, typically located before a pool and where the channel width narrows at the head of bars. Comprised mostly of cobble to boulder clusters where a sheet of water flows over at low flow stage. Width ranges from 10 - 70 m while length ranges from 10 - 360 m. **Run** – Featureless and flatbed where flow is smooth. Found at inflection points of bends and at relatively straighter segments of the channel, commonly before riffles. Bed material sizes include coarse sand to gravel. Typically long and narrow in planform; widths range from 13 - 55 m and lengths range from 60 - 300 m. **Compound point bar** - Bank-attached feature at the convex side of a bend. Consequently, point bars are aligned parallel to the bend. Bed material sizes fine - from boulders to cobbles to gravel - in the down-bar direction and across stream direction. Most point bars in the reach are large and compound features; widths range from 40 - 180 m and lengths range from 0.13 - 1.2 km. **Lateral bar** – Bank-attached feature at straighter sections of channels. Bed material size ranges from gravels to boulders. They are compound features with vegetated ridges; widths are approximately 50 m and lengths < 1 km.. **Diagonal bar** – Mid-channel feature orientated diagonally to banks in dissected riffle. Bed material size is sand to gravel. Width is approximately 20 m, length is approximately 50 m. **Bench** – Bank-attached depositional feature behind point bars, arcuate in planform. Slightly elevated above the point bar. Material mainly gravel sized, but presence of sand (and possibly clay). **Ledge** – Bank-attached erosional feature flanking the banks and forming a step-like feature adjacent to the floodplain. Material size is cobbles to boulders; units are 1 - 2 m wide and 100 m long. **Bedrock outcrops** – common along the bends.
Vegetation associations	Vegetation on instream geomorphic units covers 5-10% of the lateral and point bars. Riffles are covered by grasses and shrubs. Floodplain vegetation ranges from grasses to woody trees. There are crops (rice, corn), fruit-bearing trees (banana, mango, tamarind), and woody trees (acacia, figs etc).

RIVER BEHAVIOUR
Low flow stage At low flow stage, the channel is relatively stable and has limited capacity for lateral adjustment. Pool and run or riffle sequences are generally stable along this reach. Bed transport and deposition is limited to pools (sand to gravel bed material) while runs and riffles (coarser bed material) are only infrequently mobilised. At this flow stage, there has little to no impact on bank erosion especially adjacent to bedrock margin. The complex topography results in exposure of small longitudinal bars and other depositional mid-channel features. Diagonal bars are observed at locations of gradual sediment deposition. Low flow promotes the growth of vegetation like shrubs and grasses along ridges, including more established trees on mid-channel islands.
Bankfull stage At bankfull stage, channel migration is observed towards less stable segments of the reach as flow alignment shifts toward erosional surfaces. Channel expansion is observed along with activation of secondary channels that results in a compound structure. Where the channel narrows, bar stripping and erosion is more likely as coarser material is transported; thus bed incision and aggradation can occur. However, lateral erosion is limited by the bedrock margin. Diagonal bars and small longitudinal bars are reworked and are submerged. For larger compound lateral and longitudinal bars, ridges may remain elevated beyond the water surface, but remaining sections are submerged and reworked in the process. Bar heads are reformed and reshaped depending on their channel elevation. Pools and riffles are also reworked in the process. Vegetation is stripped at low elevation ridges, while shrubs and grasses on low elevation bars are submerged. At segments with floodplains, adjacent benches serve as the margin and additional deposition of bench may occur while erosion of floodplain banks results in formation of step ledges.
Overbank stage At overbank stage, instream and floodplain geomorphic units are formed and/or reworked. While vertical adjustment of the bed is highly likely (erosion and accretion), the channel has a reasonable lateral stability because of the dominant bedrock margin. This triggers floodplain stripping and bank erosion on less stable portions of the channel and flow alignment is highly influenced by the valley margin rather than the channel. In this case, sculpting of bedrock is possible. Ledges are reworked and formed as portions of the banks are being eroded and new benches are formed at depositional areas. Pools and riffles are most likely to be scoured. Positions of instream geomorphic units may change, depending on their location in the reach. Less stable banks that are eroded are converted to bank-attached bars while previous gravel and cobble bars are likely to be converted to new floodplains. Instream vegetation are likely to be uprooted while riparian trees and croplands on adjacent floodplains could be vulnerable. Vegetation roughness from the floodplain dissipates some stream energy at the overbank stage. Fine material may be deposited through vertical accretion during the waning stage of the flood event. There is possible destruction of irrigation canals and in extreme cases, floodplain stripping. There could be damage to properties among floodplain communities.

CONTROLS	
Upstream catchment area	~ 100 km^2
Landscape unit and within-Catchment position	Rugged Hills – found in upstream portion of the catchment where floodplains occur more often.
Process zone	Transfer Zone – the increasing area that it drains and moderate slope allow sediments to move and flow.
Valley morphology (size and shape)	U-Shaped, Asymmetric
Slope	Moderate to Low Min: 0.002 Max: 0.03 Ave: 0.008
Relative Stream Power	Moderate Min: 157 W/m Max: 2516 W/m Ave: 945 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


flow direction
compound lateral bar
N
vegetated ridges
valley margin
diagonal bars
channel margin
terrace
floodplain
riffle
pool
run
ledges
floodplain
compound point bar
benches
chute channel
valley margin &
channel margin
827 m


Floodplain
Riffle
Pool
Run
Compound Point Bar

Partly-confined [PC] Planform-controlled [PC] Wandering [Wan] Discontinuous Floodplain [DcFp] Cobble bed [Cbed] River Style

Defining Attributes of River Styles: The channel is set within a partly-confined and relatively straight valley. It has a low sinuosity (1.13) and a moderate capacity to adjust planform laterally as it impinges 10-50% of the valley margin along its length. While still a transfer zone, the reach has a higher width/depth ratio and reduced lateral stability especially in sections with floodplains. Characteristic instream geomorphic units include pools, riffles, runs, compound point, lateral and longitudinal bars. Primary floodplain geomorphic units include vegetated ridges and palaeochannels. Bed material ranges in size from gravels to cobbles with occasional boulders. Several anthropogenic structures are present and include irrigation canals, flood defences, houses and community buildings.

DETAILS OF ANALYSIS
Representative sites: Bislak River at Dipilat (also observed in Tagludan Kaliwa and Tagludan Kanan) Map sheets air photographs used: Orthophotos from LiDAR Survey (March 2019), Aerial images from Google Earth (4 April 2017) Date: March 2019 Coordinates: 18.297084°N, 120.714127°E

RIVER CHARACTER	
Valley-setting	Partly-confined.
River Planform	The channel splits into two around longitudinal bars, has low sinuosity (1.08) and is a wandering type of river. Discontinuous floodplains are formed on both banks. The channel has moderate capacity to adjust, where terraces and the valley margin may restrict lateral adjustment, thus translation or progressive downstream movement of the bends may be observed locally over time. There is evidence for a meander shift or extension where that channel has sufficient space to do so.
Bed material texture	Bed material is coarse (gravels to cobbles). There are some boulders deposited in riffles and finer materials in pools.
Channel geometry	The cross-sectional channel shape along this River Style is asymmetrical along the bends and more symmetrical between bends. Low flow channel width (m) [Min: 200, Mean: 286.50, Max: 400]; channel depth (m) [Min: 0.16, Mean: 0.48, Max: 3.24].
Geomorphic units	The most common features in this River Style are bank-attached compound point and lateral bars found in the concave side of the bends. Vegetation covers a large proportion of bar surfaces. Chute channels are also evident

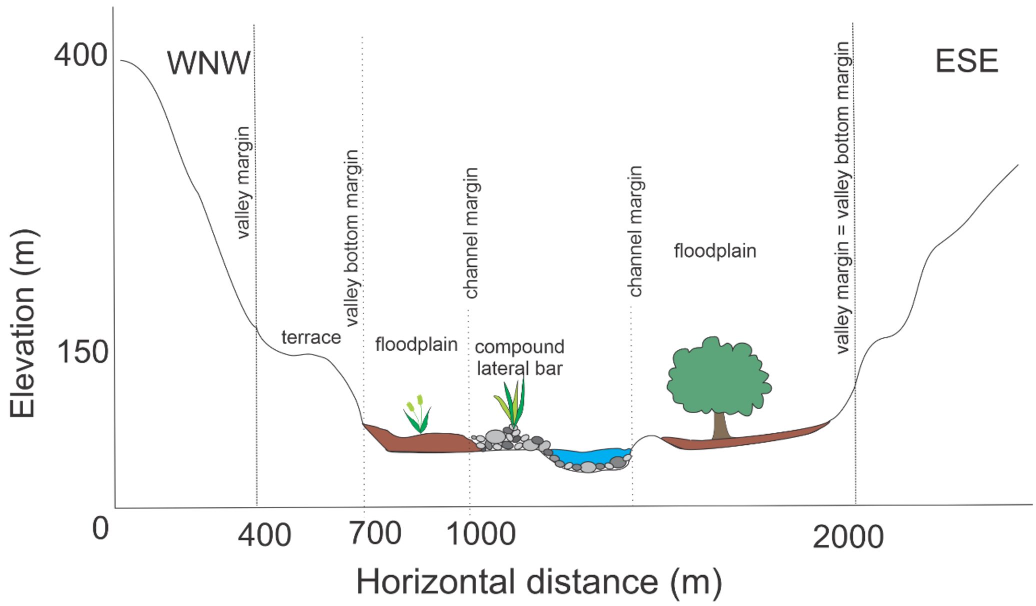
	depicting a recurring flood event. Pool-riffle-run sequences are stable over time and maintain the hydraulic diversity in this River Style. **Pools** – Depressions along the channel bed following a riffle or a run. Have finer bed materials, from coarse sand to gravel. Deep and narrow at concave bank of bends, shallow and elongate at straighter segments. The average width is 20 m while the length ranges from 50 - 80 m. **Riffle** – Elevated parts of the channel bed, typically located before a pool and where the channel width narrows at the head of bars. Comprised mostly of cobble to boulder clusters. Width ranges from 10 - 30 m while length ranges from 40 - 80 m. **Run** – Featureless and flat bed where flow is smooth. Found along inflection points of the bend and at relatively straighter segments of the channel, commonly in between riffles and pools. Comprised of a mixture of sands and gravels. Typically long with widths ranging from 50 - 80 m and lengths from 30 – 100 m. **Compound point bar** – Bank-attached arcuate-shaped features found along the convex side of a bend. Form follows the alignment of the bend. Composed of occasional boulders and cobbles to gravels fining down-bar and laterally. These compound point bars range between 100 – 500 m wide and 300 m - 1.2 km long. Further units that can be found on these compound bars include chute channels, ramps and vegetated ridges. **Compound lateral bar** – Bank-attached feature found along straighter segments. These compound features are composed of gravels and boulders, with further units of chute channels and vegetated ridges. Width is about 100 m and lengths can reach up to 2.5 km. **Ledges** – Erosional stepped-like bank features found on the convex side of the bends. It can reach up to 400 meters and follows the perimeter of the channel. Some steps have vegetation cover while others are composed of exposed bank materials. **Benches** – Stepped depositional areas inset along a bank which can promote floodplain formation. Comprised of bed materials which are different from the adjacent floodplain. Its length reaches up to 600 m. **Mid-channel bar** – Mid-channel features that fine from gravel to sand down-bar, with vegetated ridges. Their width is about 100 m and their length ranges from 350 m - 700 m. **Bedrock outcrops** – observed occasionally (e.g. 18.300678°N, 120.711506°E.) Floodplains in this reach are highly modified and utilised for agriculture. Palaeochannels are present. Anthropogenic structures such as settlements, flood protection dikes, irrigation canals and roads are also found in these floodplains.

Vegetation associations	Vegetation on instream geomorphic units covers a larger area, about 20-30% of the lateral and point bars in this River Style. They are mostly herbaceous plants but it is very important to note that woody trees also exist on bars. Shrubs and grasses can be seen on ridges and riffles but there are also areas where they are placed as breeding ground of freshwater fishes. Floodplain vegetation ranges from grasses to shrubs and woody trees. There are crops (rice, corn), fruit-bearing trees (banana, mango, sampaloc), and woody trees (acacia, figs etc).

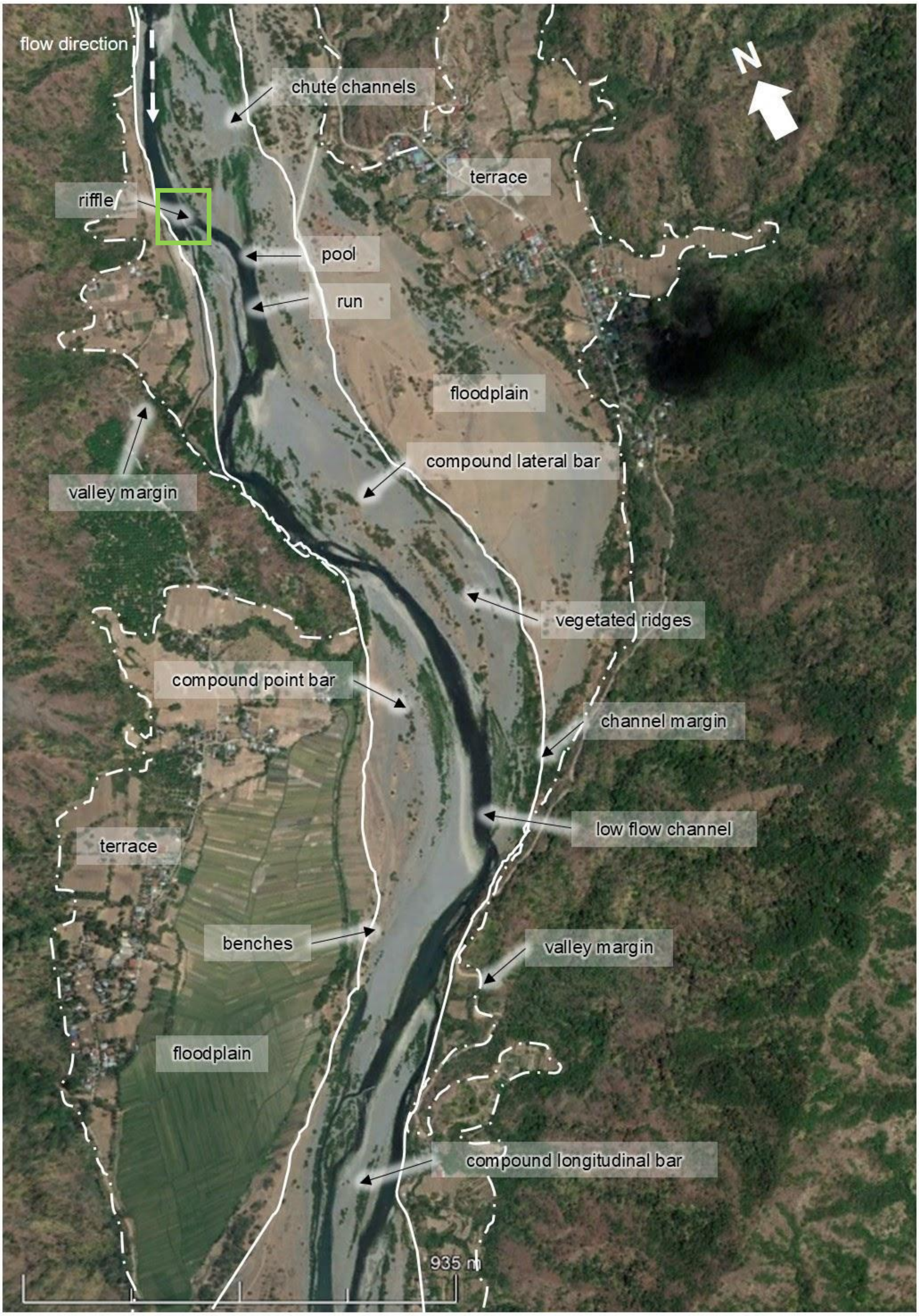
RIVER BEHAVIOUR
Low flow stage At low flow stage, the pool-riffle-run sequences are maintained. Fine-grained sediments accumulate in pools while sediments along riffles and runs are relatively stable. Hydraulic diversity is induced by textural segregation of instream geomorphic units. This low flow has minimal impact to bank erosion and almost none when the channel abuts the bedrock margin depending on the material. Inlet and chute channels can be observed in compound depositional bars. At this stage, growth of vegetation along the ridges of exposed and bank-attached bars is promoted. No adjustment of the channel along the valley floor is expected at this stage.
Bankfull stage At bankfull stage, instream geomorphic units are formed and reworked. Riffles may be reworked and pools are further scoured. Bar stripping and erosion is likely to occur as well as barhead reshaping and reformation. Flow energy dissipated along channel margins may rework bank-attached depositional/erosional features. This may give the channel a compound shape with the development of stepped-like features such as benches (depositional) and ledges (erosional). The formation of these features allow lateral adjustment of channels through contraction and expansion, respectively. The channel tends to be narrow and deep submerging vegetation on bars. Chute channels may be activated. Along asymmetrical channels, flow may erode the concave side of the banks and deposit sediments on the convex side. Based on the past, this channel is prone to downstream movement of the bend and migration along the valley floor.
Overbank stage At overbank-stage, instream and floodplain features are both formed and reworked. The flow energy is no longer concentrated along the channel but dissipated on the floodplains. Flood channels may be scoured or infilled as flow is now dictated by the valley alignment. Palaeochannels may be reactivated and floodplain stripping occurs. Movement of the channel is still constrained along where the channel abuts the bedrock-margin but may laterally adjust towards less stable banks. Pool, riffles and runs may be scoured and relocated. In the waning stage of an event, fines are likely to be deposited on the floodplains. There is also an observed downstream translation of bends and lateral migration of the channel along the valley floor. The flood defences and anthropogenic structures such as irrigation canals may be breached due to

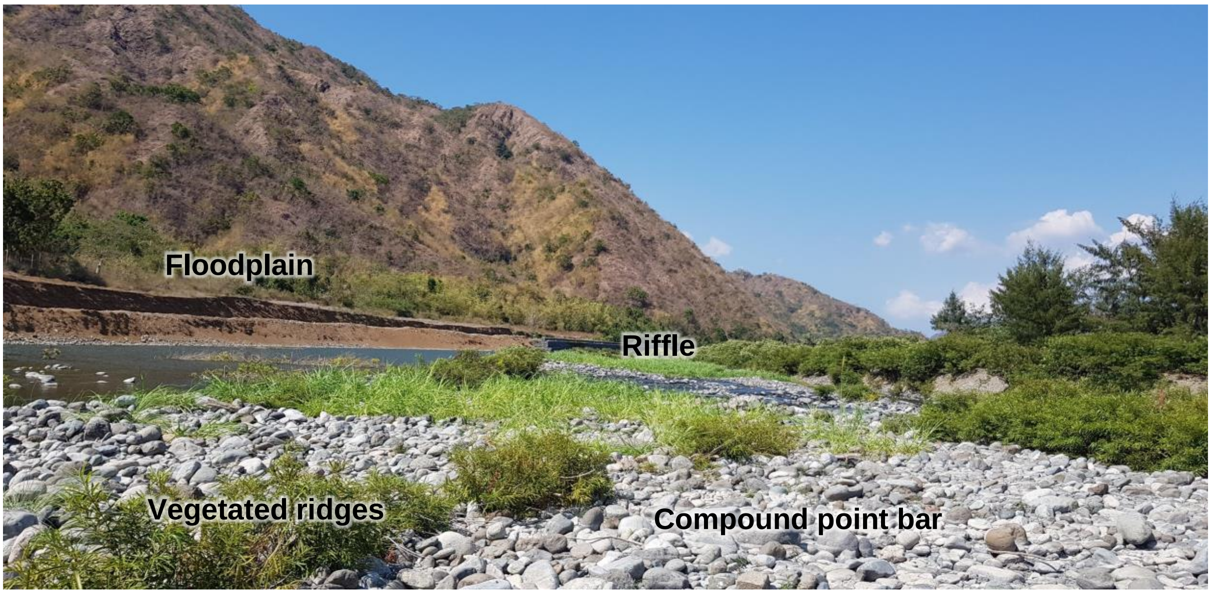
high energy of the channel, floodplain communities are also susceptible to flooding at this stage.

CONTROLS	
Upstream catchment area	~ 250 km^2
Landscape unit and within-catchment position	Rugged Hills transitioning to Lowland Plains - situated at low elevation and mid-catchment It is worth noting that the Tagludan Kaliwa and Kanan exhibit this River Style while being situated in the upper part of the catchment.
Process zone	The depositional and erosional features in this River Style signify its being a transfer zone.
Valley morphology (size and shape)	Asymmetrical
Slope	Moderate to Low Min: 0.001 Max: 0.005 Ave: 0.002
Relative Stream Power	Moderate Min: 87 W/m Max: 2640 W/m Ave: 1070 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


flow direction
N
chute channels
terrace
riffle
pool
run
floodplain
compound lateral bar
valley margin
vegetated ridges
compound point bar
channel margin
low flow channel
terrace
benches
valley margin
floodplain
compound longitudinal bar
935 m


Floodplain
Riffle
Vegetated ridges
Compound point bar

Partly-confined [PC] Planform-controlled [PC] Low Sinuosity [LSin] Discontinuous Floodplain [DcFp] Gravel bed [Gbed] River Style

Defining Attributes of River Styles: The channel is set within a partly-confined relatively straight valley. It has a low sinuosity (1.07) and abuts 10-50% of the valley margin along its length. Shearing zones due to fault activities may have weakened the rocks along the valleys of this river. This may offer an explanation on the unusual presence of floodplains in between confined valleys. There is no persistent presence of bars which may be due to the upstream location of the river in the catchment and the limited available discharge. The channel seems to have limited capacity to adjust as agriculture and enhanced weathering of the rocks may have resulted in cohesive banks.

Note: Analysis done in this River Style is based on aerial images from Google Earth.

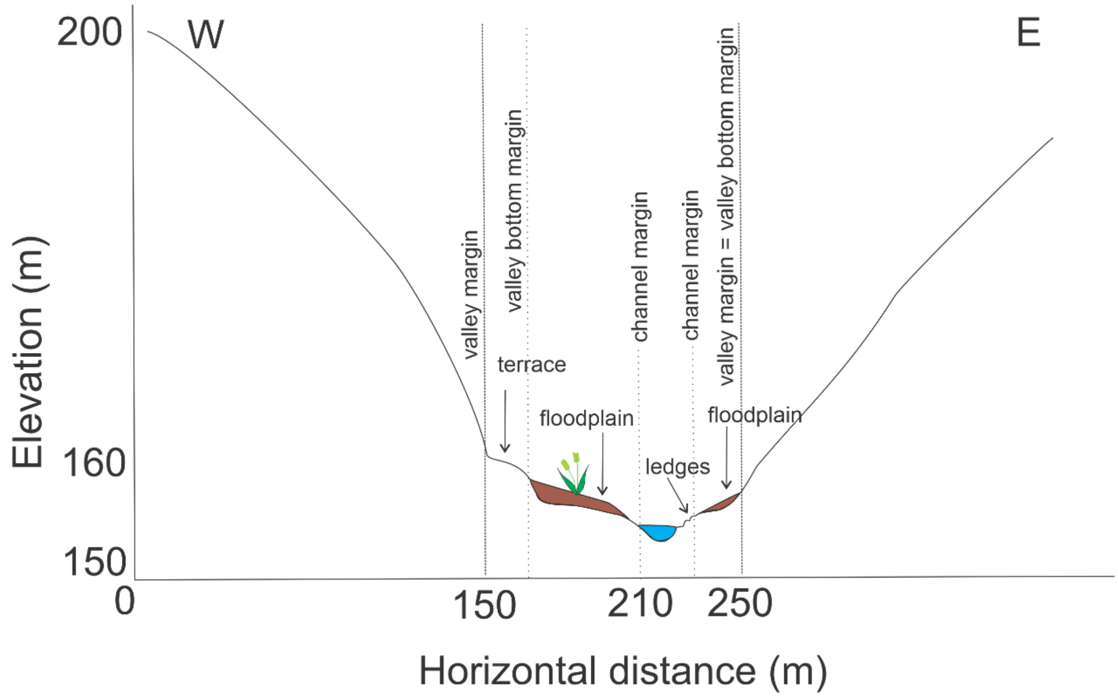
DETAILS OF ANALYSIS
Representative sites: Makikidor Map sheets air photographs used: Aerial images from Google Earth 2020 Date: 4/4/2017 Coordinates: 18.378176°N, 120.798888°E

RIVER CHARACTER	
Valley-setting	Partly-confined.
River Planform	The low sinuosity (1.07), single channel in planform dissects the floodplains as the channel abuts the valley margin in an alternating manner. Lateral stability appears high as the banks are more pronounced, this suggests that the banks are more cohesive.
Bed material texture	Bed materials are dominated by gravels in a sandy matrix. Sediment is mostly from hillslopes in sites where colluvial fans are present.
Channel geometry	The cross-sectional channel shape along this River Style is generally symmetrical at segments where floodplain margins abut both channel banks and where one side abuts the valley margin, wetted cross-section tends to be asymmetrical. Low flow channel width (m) [Min: 10, Mean: 14.31, Max: 20]; channel depth (m) [no data].

Geomorphic units	The most common features in this River Style are the discontinuous floodplains which are converted to crop fields. The banks are stabilised by the presence of established vegetation. Instream geomorphic units are limited to sculpted runs, scour pools and bank-attached bars. **Instream** **Pools –** Depressions along the channel bed found in expansion zones where the channel exits from more confined sections. Acts as storage zone in this River Style. The average width is 10 m while the length ranges from 20-100 m. **Sculpted run** – Featureless and flat bed where flow is smooth. Found along inflection points of the bend and at relatively straighter segments of the channel, commonly in between riffles and pools. Comprised of a mixture of sands and gravels. Typically long with widths ranging from 50 - 80 m and lengths from 30 - 100 m. **Lateral bars –** Bank-attached features which serve as local depositional areas in this river which is about 5 – 10 m wide and 10 – 20 m long. **Benches** – Stepped features which are areas of deposition where the channel contracts. Found in the concave side of the bends with an average width of 15 m and length of 100 m. Some steps have vegetation. **Ledges** – Eroded features where local scouring of the banks occur. About the same size of the benches found on the convex side of the bends where the floodplains are slowly eroding. Floodplains in this reach are highly modified and utilised for agriculture. Stripped floodplains form ledges. Flood runners are depressions in the floodplains that convey water during overbank stage which are about 5 m wide and 40 – 50 m long.
Vegetation associations	Instream vegetation is mostly limited to shrubs, grasses and water plants along bank-attached features as there is absence of mid-channel features. Floodplain vegetation is dominated by man-made terraces of agricultural croplands of rice, corn, and other high value crops. The banks are lined with shrubs and trees that promote bank stability across the reach.

RIVER BEHAVIOUR
Low flow stage At low flow stage, the channel maintains a uniform flow dictated by the slope of the bed. Pools and runs are being maintained at this state. Reworking at this stage of the limited number of instream geomorphic units is limited to deposition of fine sediments in pools and bed material organisation. Vegetation growth is also promoted at this stage.
Bankfull stage At bankfull stage, banks are relatively resistant to erosion because of the vegetation protection. As the flows reach critical level, pools, sculpted runs and laterals bars are further reworked. Concentrated flows further scour the pools while deposition occurs on areas with higher roughness like lateral bars and on benches along channel margin. As the channel expands, incision of beds and banks may occur and ledges are formed.
Overbank stage At overbank-stage, flow energy is dissipated on the floodplains. Irrigation canals and crop plots may be totally submerged. Communities settled in the floodplains may also be affected. The channel normally has the capacity to move where floodplains occur but observing through Google timeline, there is negligible lateral channel movement. Alluvial fans hold the channel in place giving the channel its high lateral stability. Nevertheless, at any point, the channel may shift as floodwaters short circuit the floodplains and form floodrunners. At the waning stage of an event, vertical accretion of the floodplains occur as fine sediments are deposited, deposition along channel margins leads to formation of stepped morphology attached to floodplains.

CONTROLS	
Upstream catchment area	Catchment area is relatively small being located upstream of the area, at an average of 3 km^2.
Landscape unit and within-Catchment position	Rugged Hills, mid-catchment.
Process zone	Draining a small area with limited discharge, this may be a source zone and flushing out hillslope sediments during high flows.
Valley morphology (size and shape)	U-shaped valley, 10 - 30 m
Slope	Moderate Min: 0.009 Max: 0.02 Ave: 0.01
Relative Stream Power	Low Min: 73 W/m Max: 222 W/m Ave: 127 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


Confined Valley Setting
N
flow direction
channel margin
benches
colluvial fan
ledges
valley margin
floodplain
terrace riser
terrace
floodplain
391 m


Channel
Benches
Colluvial fan
Floodplains
Ledges
Terrace riser
Terrace

Laterally Unconfined [LU] Continuous Channel [C] Braided [Braid] Gravel bed [Gbed] River Style

Defining Attributes of River Styles: This River Style is found in a laterally-unconfined valley (low lying plains) with a low sinuosity of approximately 1.1. There is a single, continuous, low flow channel that splits and forms into a braided river channel planform. The diverse range of instream geomorphic units include compound point bars, lateral bars, islands, pools, runs, riffles, benches, and ledges. Paleochannels are also located along the continuous floodplain. Lateral stability of the channel is very low; channel migration and expansion are likely to happen at overbank stage. Bed material is dominantly cobble with patches of gravel and sand bed in pool areas and still waters.

DETAILS OF ANALYSIS
Representative sites: Bislak River at Vintar Poblacion Map sheets air photographs used: Aerial images from Google Earth April 4, 2017, orthophotos from LiDAR Survey acquired on March 2019 Date: 4/4/2017 Coordinates: 18.237451°N, 120.635731°E

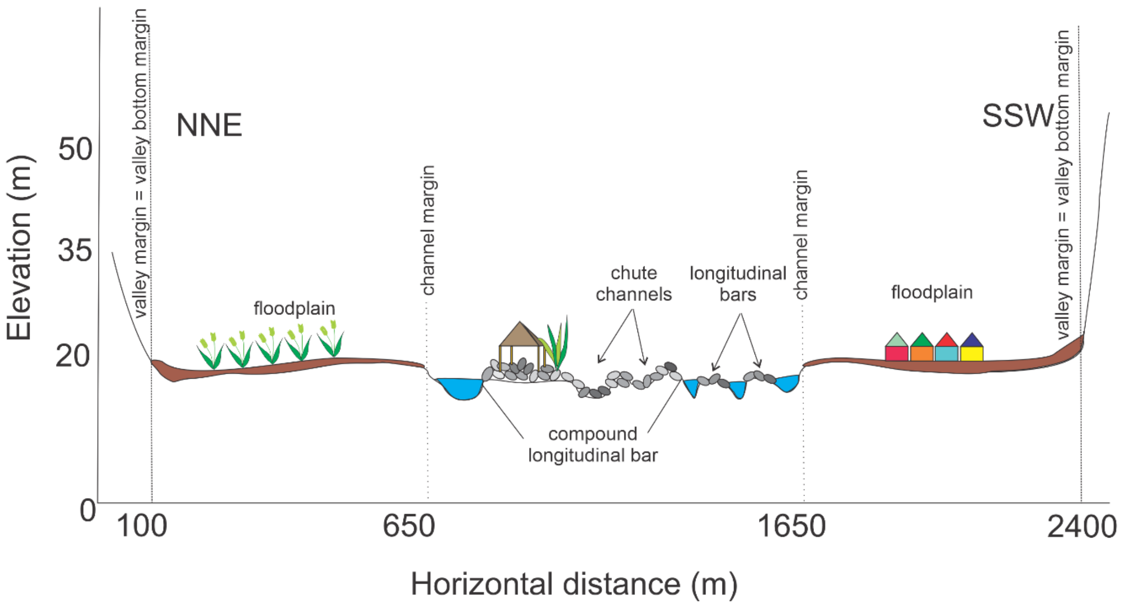
RIVER CHARACTER	
Valley-setting	Laterally Unconfined
River planform	The channel is a continuous composed of a single channel that splits up to multiple channels. It has a low sinuosity of approximately 1.1. The floodplain is continuous at both sides of the channel. Elevated islands and mid channel bars also control channel planform at low flow stage. There are multiple anthropogenic structures (including flood defences) that could force planform geometry.
Bed material texture	Bed material is predominantly cobble with a mixture of sand to coarse gravel in still water areas.
Channel geometry	The channel has asymmetrical cross-section along meander bends and in areas where the opposite bank is constrained by anthropogenic structures and flood defences. Where there are multiple channels, the cross section is compound and irregular. Low flow channel width (m) [Min: 300, Mean: 613.86, Max: 1050]; channel depth (m) [Min: 0.1, Mean: 0.69, Max: 2.02].
Geomorphic units	A diverse array of geomorphic units are observed in this River Style. Several lateral and longitudinal bars are present. A large compound mid-channel island is evident at the braided section. Chute channels and paleochannels are also present. Benches are formed in depositional areas while ledges are present as eroded portions of the floodplain. Pool-riffle-run sequences also dominate this river type. **Instream**

	Pool – Instream feature in sequence with riffles or runs. They are observed in either straighter segments or in areas where the channel abuts anthropogenic margins. This feature has fine sand to gravel materials and has width and length of 45 m and 120 m respectively. **Riffle –** Occurs at the elevated parts of the channel bed which transitions to pool feature. They are mostly comprised of cobble to gravel material. Their width ranges from 30 - 50 m and length from 50 - 200 m. **Run –** Located at the straighter sections of the river before or after pools and riffles. They are typically shallow and planar features composed mainly of gravels and sands. Their width ranges from 50 - 100 m and length from 100 - 600 m. **Compound bank-attached bar –** Bank attached compound point bars or compound lateral bars. Compound lateral bars are mostly dominated by cobble to gravel sediments with occasional vegetation and lined with chute channels. Large lateral bars also transition to mid channel bars and islands when secondary and chute channels are activated at high flow events. Along this feature, aquaculture is evident from the abundance of constructed fish pens. Man-made huts are also observed especially at low flow stage that temporarily serve as shelters. Point bars in this River Style are also compound features composed of cobble and gravel material, vegetated ridges and chute channels. They could span a width of up to 450 m and length of 1.7 km. There is downstream fining in point bar materials from mixed cobble and gravel to finer materials. Vegetation is mainly grasses and shrubs. The bank-attached bars in this area are hotspots for gravel extraction and other anthropogenic activities and construction. These specific point bars also have constructed dikes at the upstream portion that serves as flood protection to the municipalities. **Compound mid-channel island** - A compound mid-channel feature of varying morphology composed of cobble and gravel to sand material, vegetated ridges, chute channels and dissection features. This is usually stable at low flow but is highly prone to reworking and formation of smaller geomorphic units during bankfull and overbank stage. Portion of high vegetation promotes its stability and capacity to store instream sediments during high flows. This compound island has a width and length of approximately 800 m and 2.2 km respectively. **Diagonal bar –** Mid-channel features that are comprised of cobble, and gravel to sand material. This feature is present at the braided portion of the reach oriented diagonally to banks which is 100 m wide and 500 m long. **Bench –** Stepped morphology observed at the depositional areas adjacent to the bank that serves as additional protection and margin at bankfull stage. Some of the benches are vegetated and have finer material while some have gravel to cobble-size material. They have width and length dimensions of 250 m and 900 m respectively. **Ledge –** bank-attached erosional feature which is adjacent to the floodplain and is observed at the convex side of a bend. It is approximately 200 m wide and 700 m long. **Floodplain**

	Paleochannel – Long and sinuous remnant channel which is located on the floodplain and represents the position of the old channel. It has finer materials with vegetation. **Terrace** – elevated feature adjacent to the floodplains which lines the valley margin.
Vegetation associations	Instream vegetation includes grasses, shrubs at ridges. The elevated island also has small trees and shrubs. Local plants and crops are also planted adjacent to the channel banks. Floodplain vegetation is dominantly agricultural croplands (rice, corn) and plantations (mango, banana, sampaloc) with occasional shrubs and grasses.

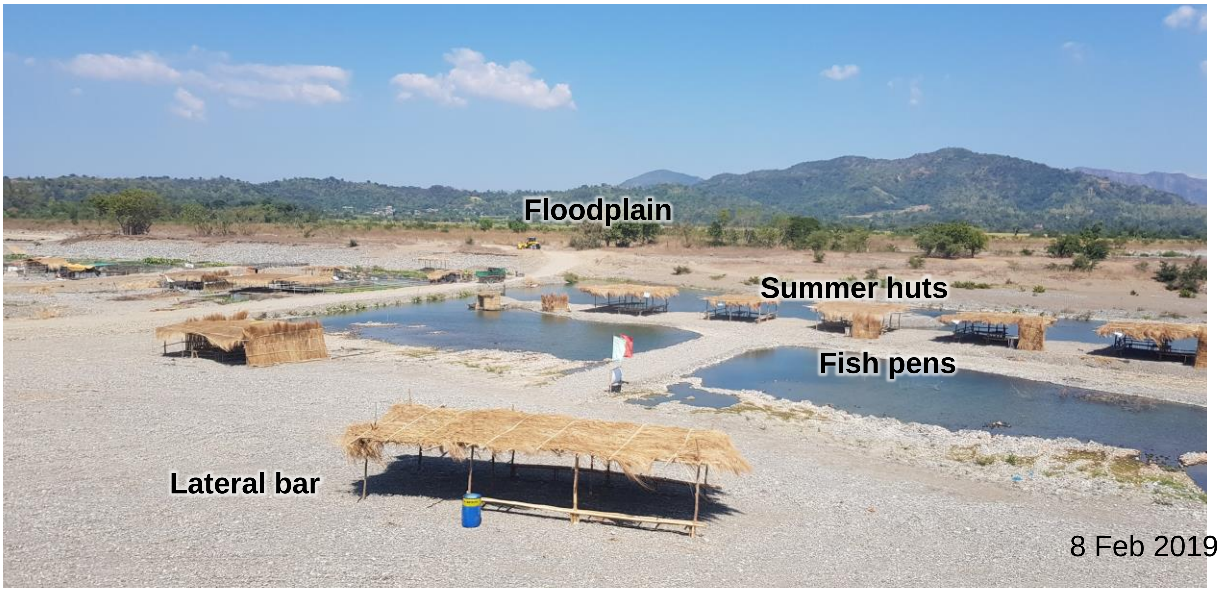
RIVER BEHAVIOUR
Low flow stage At low flow stage, flow is controlled by the lowest elevation of the main channel. Multiple channels are present, driven by local topography. Instream geomorphic features of pool-riffle-run sequences are maintained. Runs and riffle of coarser cobble material are infrequently mobilised and deposition of fine grained material occurs at pools. Mid-channel bars and islands are exposed with vegetation ridges, shrubs and grasses. There is promotion of aquaculture evident with makeshift huts and fishing pens along the channel. During this stage, there is little to moderate impact on lateral movement of the channel. Furthermore, makeshift bamboo bridges and dirt roads are also observed within the channel for bank to bank transportation.
Bankfull stage Instream geomorphic units are formed and reworked during high flow events. Lateral bars, longitudinal bars, and islands will be fully submerged resulting in uprooting and flushing of instream vegetation features. Floodplains of eroded banks will form ledges and deposition of material will result to formation of benches. Pools will be scoured and fines are flushed downstream. Lateral stability is very low and channel expansion and migration may occur depending on the erodibility of banks and beds. Floodplain and anthropogenic flood defences will serve as the margin during the bankfull stage.
Overbank stage At overbank stage, anthropogenic structures such as flood defences serve as the margins of the reach, but in extreme cases, these defences may be breached and adjacent communities may be flooded. Croplands and plantations are flooded and results in high damage to properties. Instream and floodplain geomorphic features are both formed and reworked and paleochannels may be reactivated. Riffle-pool-run sequences are scoured and relocated depending on the magnitude of the high flow event. Lateral bars, longitudinal bars, and islands are also reworked and relocated in this stage. Floodplain stripping occurs at less stable banks resulting in formation of ledges while deposition to channels adjacent to the banks results in the formation of new benches. Floodplain vegetation is most likely to be vulnerable to being uprooted. Wholesale adjustment of the channel is observed and new channels are formed. Flow energy is dissipated along the floodplain and vertical accretion of fine sediments will occur at the waning stage of the flood event.

CONTROLS	
Upstream catchment area	585 km^2
Landscape unit and within-Catchment position	This reach is present at the Lowland Plains where continuous floodplains abuts both channel margins. The wide laterally unconfined valley permits the formation of a diverse array of instream and floodplain geomorphic units.
Process zone	Given the varying nature of relative stream power that ranges from low to high, both transfer and accumulation processes of sediment are active in this reach with the latter being dominant. The process zones are also dynamic depending on the stage flow and the substantial amount of anthropogenic activities happening within this reach.
Valley morphology (size and shape)	Asymmetrical, Irregular
Slope	Very Low Min: 0 Max: 0.002 Ave: 0.001
Relative Stream Power	Low to High Min: 0 W/m Max: 2268 W/m Ave: 1065 W/m



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


compound lateral bar
flow direction
chute channel
N
bench
riffle
paleochannel
channel margin
run
chute channel
valley margin
out of page
compound lateral bar
riffle
floodplain
pool
floodplain
lateral bar
chute channels
longitudinal bar
compound island
diagonal bar
vegetated ridges
run
riffle
compound point bar
valley margin
out of page
chute channel
pool
1112 m


Floodplain
Summer huts
Fish pens
Lateral bar
8 Feb 2019

Laterally Unconfined [LU] Continuous Channel [C] Deltaic [Delta] Sand bed [Sbed] River Style

Defining Attributes of River Styles: This River Style is found in a laterally-unconfined, wide alluvial plain adjacent to the coastal area. It has a continuous, multiple channel planform with highly variable sinuosity of individual channels draining to the West Philippine Sea. Instream geomorphic units include pools, large compound bank-attached features and stable, vegetated islands. The channels are separated by large floodplain segments formed by vertical accretion during overbank stages. The low energy flow of the setting promotes the lateral stability of the channel and these moderately resilient rivers have localised capacity for adjustment. Bed material is a mixture of cohesive fine sands, silts, and clays with organics.

DETAILS OF ANALYSIS
Representative sites: Bislak River Delta Map sheets air photographs used: Google Earth Date: April 4, 2017 Coordinates: 18.272316°N, 120.573441°E

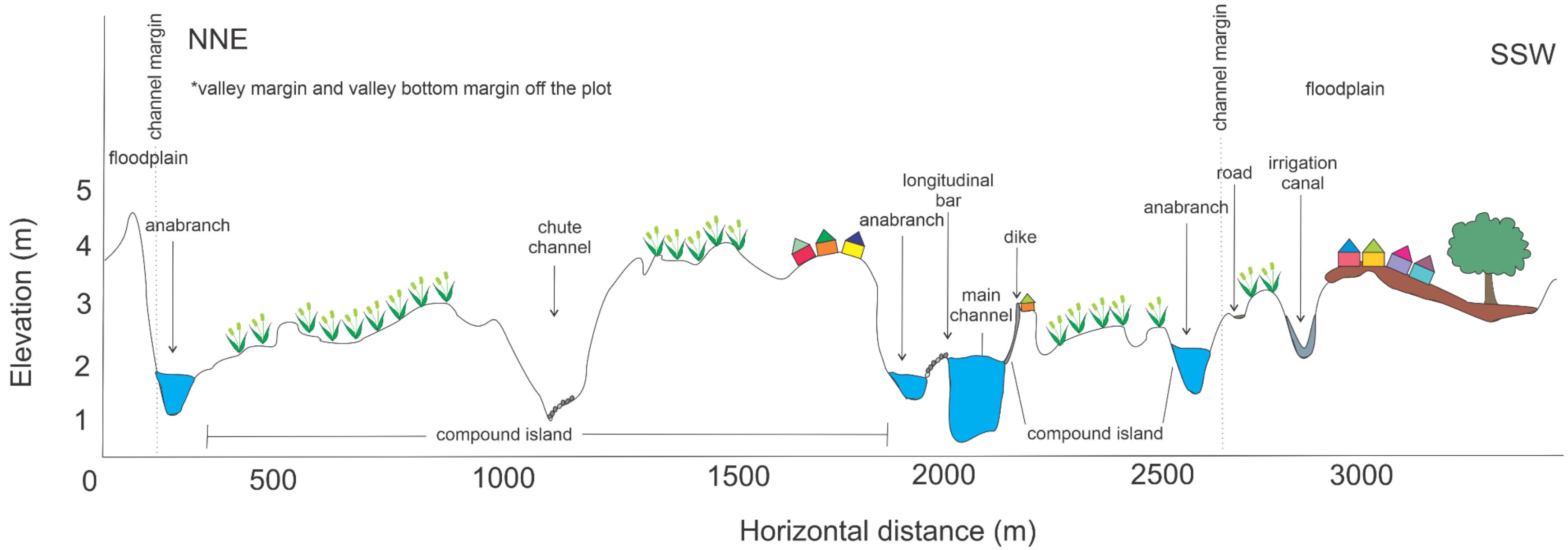
RIVER CHARACTER	
Valley-setting	Laterally Unconfined
River planform	The river planform is multichannel with varying sinuosity of individual channels. The River Style is characterised by vertically accreted floodplain of cohesive, fine-grained banks with dense vegetation cover along the reach. The low energy is insufficient to induce bank erosion, thus resulting in laterally stable channels.
Bed material texture	Bed material is dominated by deposited suspended sediment and cohesive fine-grained materials like silt, clay, and sand. Occasional cobble and gravel materials are also found along the reach.
Channel geometry	The channel mostly has low width/depth ratio and is commonly symmetrical with exception to segments with anthropogenic flood defences. Low flow channel width (m) [Min: 630, Mean: 1613.06, Max: 2300]; channel depth (m) [Min: 0.13, Mean: 0.88, Max: 2.94].
Geomorphic units	A limited array of geomorphic units are observed in this River Style. Large compound mid-channel island and compound bank-attached features dominate the reach and occasional longitudinal bars are also observed especially on low flow. Pools and riffles are also observed in this River Style. **Instream** **Pool** – instream features observed in either straighter segments or in areas where the channel abuts anthropogenic margins. Pool areas in this River Style are also observed with aquaculture and fishing activities because of its proximity to the coastal area. This feature has cohesive

	fine sand to gravel materials and has a range of width and length of 30 - 300 m and 150 - 600 m respectively. It has depth that can reach up to 4 m. **Riffle** – occurs at short segments along elevated parts of the channel bed which transitions to pools. They are mostly comprised of cobble, gravel, and sand material. They have width and length of 25 m and 150 m respectively. **Compound bank-attached bar** – bank attached features dominated by cobble to fine sediments with dense vegetation and secondary channel. They have width that ranges from 130 - 550 m and length that could reach up to 1.7 km. **Compound mid-channel island** - a compound mid-channel feature of varying morphology composed of cobble to sand material, with highly dense vegetation, chute channels and dissection features. Areas of relatively high elevation are home to local communities and are converted to agricultural lands and plantation. They are 0.45 - 1.2 km wide and 1.4 - 1.8 km long.
Vegetation associations	Instream vegetation includes grasses, shrubs at ridges. Elevated islands have agricultural crops, large trees and shrubs. Aquatic plants like water hyacinth and kangkong (swamp cabbage) also dominate the areas adjacent to the channel banks. Floodplain vegetation is dominantly agricultural croplands (rice, corn) and plantations (mango, banana, sampaloc) with dense vegetation.

RIVER BEHAVIOUR
Low flow stage At low flow stage, cohesive sediment limits hydraulic diversity. Multiple channels are present across the reach and instream geomorphic features of pools and riffles are maintained. Pools are partially infilled with suspended load sediments. Large areas of vegetation and agricultural croplands are present on large compound islands. Compound bank-attached features are exposed with ridges with vegetation such as shrubs and grasses. Aquaculture and fishing structures are also prominent during this stage. While this River Style is present in laterally unconfined areas, the low energy setting is unable to generate sufficient energy for erosional processes on banks resulting in stable channels.
Bankfull stage During bankfull stage, secondary channels would be activated and areas of low elevation will be fully submerged. However, channel adjustment is also limited because of the cohesive bank sediments. There is moderate to little formation and reworking of geomorphic units caused by

the lack of bedload-calibre material. During the waning stages, these fine sediments will eventually accumulate via accretion on channel banks and bank-attached bars.
Overbank stage During overbank stage, islands will be dominated by vertically accreted silt and clay resulting in damage to crops and communities. This is also the case for the adjacent structures in the proximal floodplains. Pools will be scoured and reworked. Low levees and backswamps may form on different parts of the reach and changes in flow direction results in channel abandonment or channel infilling.

CONTROLS	
Upstream catchment area	>585 km^2
Landscape unit and within-Catchment position	This River Style is found at the most downstream part of the river specifically at the delta where wide alluvial plains define this reach.
Process zone	Given its low energy and low slope nature, this reach is an accumulation zone where fine-grained sediments of sand, clay, and silt are deposited and dominate both bed and banks.
Valley morphology (size and shape)	Asymmetrical, Irregular
Slope	Very Low
Relative Stream Power	Very Low



valley margin = bedrocks that confine the channel
valley bottom margin = channel margin + floodplain
channel margin = wetted channel + instream geomorphic units


compound longitudinal bar
chute channels
flow direction
pool
bench
floodplain
channel margin
riffle
compound lateral bar
pool
Laterally Unconfined Braided River
chute channels
valley margin
out of page
compound island
vegetated ridges
chute channels
floodplain
riffle
ledge
valley margin
out of page
chute channel
chute channels
compound island
compound island
compound island
longitudinal bar
pool
1701 m


WEST PHILIPPINE SEA

Section 6. Assessment of controls on the character, behaviour and downstream patterns of River Styles in the Bislak Catchment

Five downstream patterns are determined from examining the downstream succession of River Styles in the Bislak Catchment. The difference in patterns are explained through changes in the imposed boundary conditions, including geology, lithology, topography through elevation and slope, and upstream catchment areas. The main flux boundary condition controls on the river character and behaviour are presented by plotting relative stream power onto longitudinal profile-catchment area plots. Figure 6.1 shows the distribution of the downstream patterns and landscape units in the catchment. Figure 6.2 presents a tree-like diagram of the different downstream patterns of River Styles until they connect to the trunk stream and the list of tributaries under each pattern.

All headwaters of the Bislak Catchment initiate in the Steep Upland landscape unit, with a downstream sequence from Steep Headwaters through Gorges through confined valleys with Occasional Floodplain Pockets. These highly connected (high hillslope-channel coupling), V-shaped and irregular valleys are the primary sources of sediment in the catchment. Sediment storage is very limited in floodplain pockets, meaning that sediment is rapidly flushed through these zones. At the base of the Rugged Hills, the confined rivers transition to partly-confined valleys that are bedrock margin-controlled through to planform-controlled, wandering. In these mixed-load transfer zones, accumulation of sediment is mainly observed at the convex banks of bends (forming multiple geomorphic units) while erosion occurs along the concave side. Sediment is easily transported from bar to bar. When the river reaches the Lowland Plains, the high energy continuous channel braids around longitudinal bars. Further downstream where the slope and elevation fall close to zero, fine sediment starts to accumulate in the suspended load river. Distributary channels are formed along the delta where the river exits to the West Philippine Sea. Moving downstream, the catchment area and discharge increases, and there is progressive change in slope, widening of both the channel and valley as the river traverses through the landscape units from the Steep Upland through the Rugged Hills through the Lowland Plains. This downstream pattern, **Pattern 1**, is the dominant configuration, observed in 11 out of 17 tributaries listed in Figure 6.2. Two subsets of this pattern, **Patterns 2 and 3**, where the former has less resistant banks upstream relative to other tributaries due to their differences in lithology, and the latter is a relatively short tributary resulting in the absence of either a Confined, Occasional Floodplain Pockets, Boulder Bed River Style or a Confined, Gorge, Boulder Bed River Style, respectively. **Patterns 4 and 5** occur in tributaries which begin in the Steep Upland then abruptly at the base of the Rugged Hills where the reduced control of bedrock margins set a planform-controlled river in between more confined valley settings.

Table 6.1 lists the controls on the character and behaviour of each River Style including the catchment area, slope, elevation, river width and relative stream power which will be discussed along with the controls on the downstream patterns (diagrams are shown in Figures 6.4, 6.6, 6.8, 6.10 and 6.12) of the representative tributaries (maps are shown in Figures 6.5, 6.7, 6.9, 6.11 and 6.13)

Discussion of Pattern 1 considers the entire connected river length, covering the entire succession of River Styles in the Bislak River, until the outlet with the West Philippine Sea. To avoid repetition, discussion of Patterns 2-5 until their confluence with another tributary. Figure 6.4 shows the longitudinal profile and the diagram of controls of Bislak River.

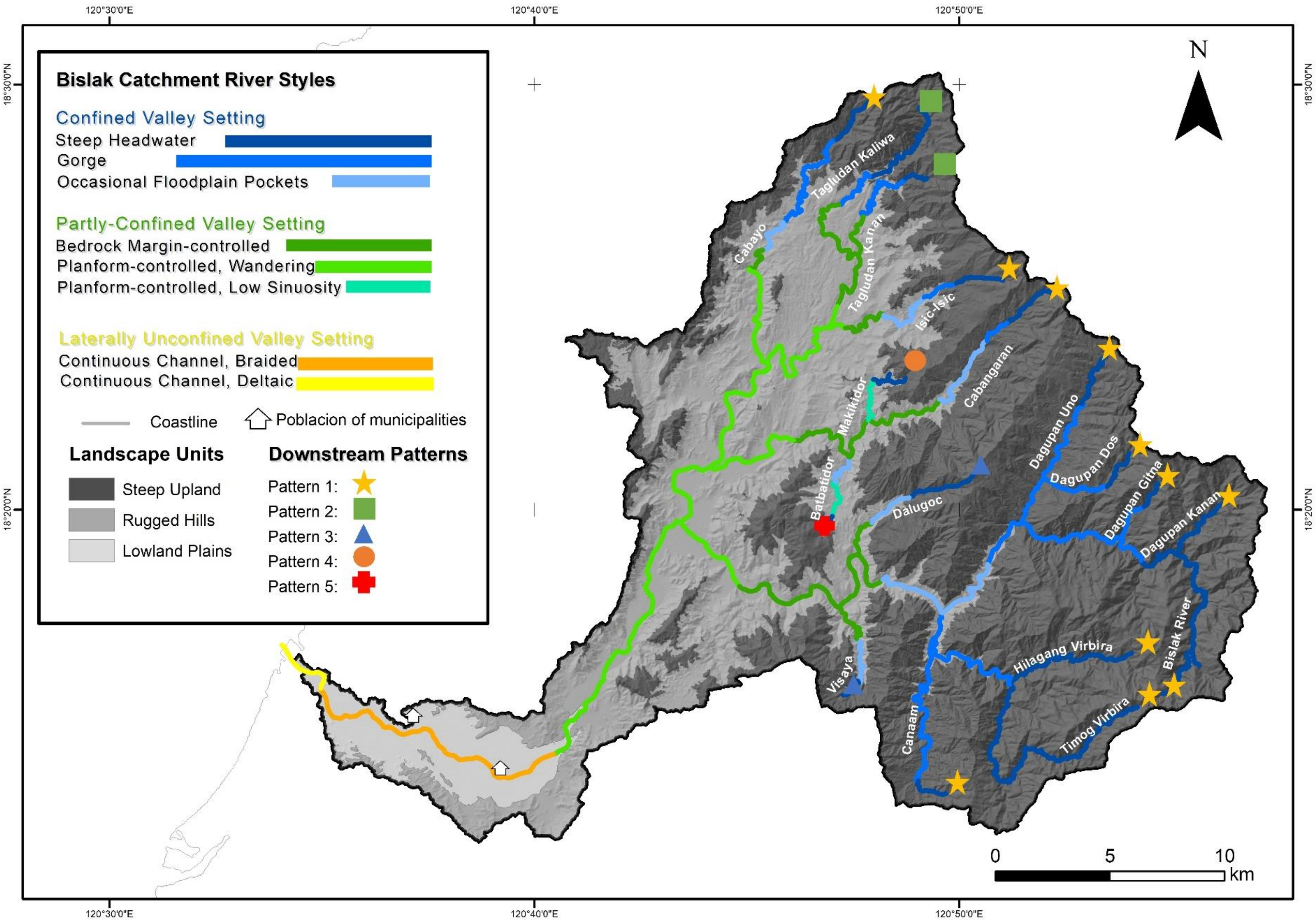


Figure 6.1 Distribution of downstream patterns through the landscape units in the Bislak Catchment.

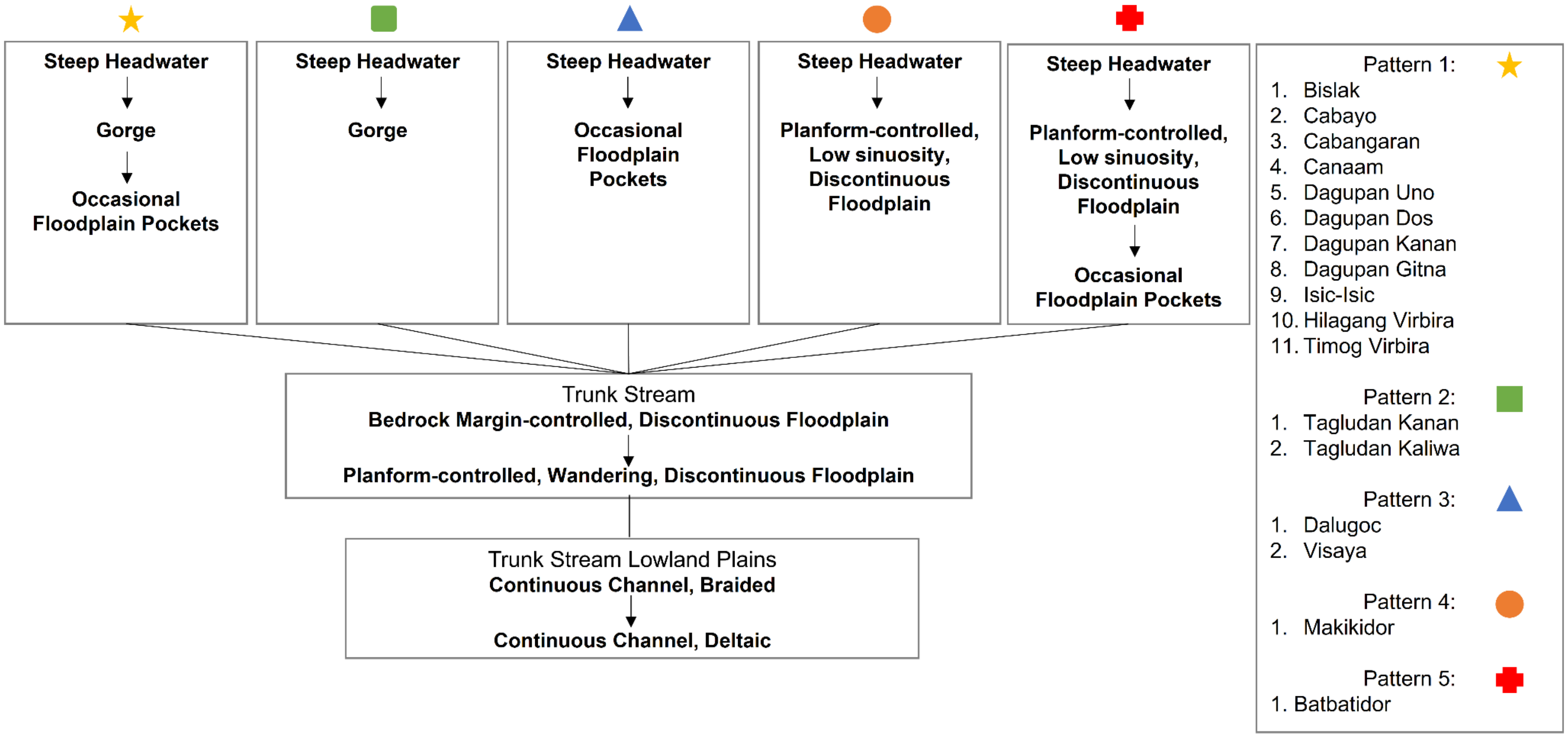


Figure 6.2 Downstream pattern of River Styles in the Bislak Catchment.

Table 6.1 Controls on the character and behaviour of each River Style.

River Style	Catchment Area (km^2)	Elevation (m)	Slope (m/m)	Valley Width (m)	Relative Stream Power (W/m)
Confined, Steep Headwater, Bedrock Bed River Style	< 45	185 - 1455	0.01 - 1.04	10 - 30	95 - 5520
Confined, Gorge, Boulder Bed River Style	2 - 115	140 - 780	0.008 - 0.24	15 - 50	155 - 8340
Confined, Occasional Floodplain Pockets, Boulder Bed River Style	3 - 215	115 - 370	0.005 - 0.09	40 - 120	160 - 4305
Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style	10 - 255	75 - 210	0.002 - 0.03	110 - 420	160 - 2515
Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Gravel Bed River Style	20 - 550	25 - 100	0.002	300 - 1450	85 - 2640
Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style	2 - 10	130 - 200	0.009 - 0.03	80 - 200	75 - 220
Laterally Unconfined, Continuous Channel, Braided, Gravel Bed River Style	550 - 585	2 - 25	0 - 0.002	1200 - 3200	0 - 2270
Laterally Unconfined, Continuous Channel, Deltaic, Sand Bed River Style	> 585	0.2 - 2	0	> 2000	- *

*****Relative stream power in the Deltaic River Style could not be calculated due the zero slope value.

Pattern 1: Bislak River

The small contributing catchment area in the headwaters produce low relative stream powers (average 1199.40 W/m) in the **Confined, Steep Headwater, Bedrock Bed River Style** of the Bislak River despite the very steep slopes (average 0.081). The majority of the stream network flows over resistant metavolcanic rocks of Bangui Formation, limiting the potential for deep river incision within the confined setting, and producing narrow valley width (25 m). Mass movements are a major source of sediment input to the reach. There is also limited bedrock incision which results in forced morphologies brought about by bedrock and boulders.

A peak in the slope (1.04) and relative stream power (3350 W/m) at 0.43 km from the headwater is caused by a waterfall. After this waterfall, the longitudinal profile follows a smooth concave-upwards form. The river then enters a short valley underlain by the Pasaleng Quartz Diorite Formation as it reaches its confluence with Dagupan Kanan, its first major tributary. The tributary adds a substantial input of contributing area (13.53 km^2), which allows for locally high relative stream powers (average 4130 W/m), especially at points where there are abrupt increases of slope immediately downstream of the confluence, after which the River Style transitions into a Confined, Gorge, Boulder Bed River Style.

In the **Confined, Gorge, Boulder Bed River Style**, the slope falls as the river flows over less resistant lithology (sandstone, shale and reef limestone of the Laoag Formation). The first peak of relative stream power (3520 W/m) within this River Style is observed 200 m downstream the confluence with Dagupan Gitna wherein an immediate increase in slope contributes to the increase in relative stream power. The river has maximum relative stream power (6780 W/m) over Pattern 1 at its confluence with Dagupan Uno, a relatively longer tributary and joined upstream by Dagupan Dos, where the catchment area has increased from 65.51 - to 104.16 km^2 and after which the valley begins to widen and further reduces its slope (average 0.024), coinciding with the transition to a Rugged Hills landscape. Sparsely vegetated hillslopes define this reach. Decreased vegetation cover allows for some fine materials to enter the channel. The process zone is defined mainly as a source zone, but some transfer will occur. Mechanical breakdown of coarse sediment sourced from upstream will decrease the bedload size, with large boulders more readily transported and spatially organised.

Still situated within the Rugged Hills landscape unit, relative stream power steadily decreases (average 1245.30 W/m) and occasional floodplain pockets can form. **Confined, Occasional Floodplain Pockets, Boulder Bed River Style** start to appear as the valley starts to gradually widen, permitting the deposition of small floodplain formations which are prone to reworking and stripping in the confined valley setting. The transfer zone begins to dominate the process zone at this bedload-dominated reach, where point and lateral bars are also able to form readily. Midway along the reach, slope is further reduced from an average of 0.013 to 0.005 starting from the confluence of Bislak with Timog Virbira (24 km distance), creating riffle-pool sequences with relatively long runs in straighter segments. For relative stream power, the reduction in slope downstream of confluence attenuates the increase in catchment area (from 123.22 km^2 to 201.98 km^2).

Within similar landscape and geological settings, the river shifts from confined valleys to partly-confined valleys, allowing the development of discontinuous floodplains on both banks, and characterising the **Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain,**

Cobble Bed River Style. In this reach, the river is situated in sinuous valleys where the river abuts the valley margin approximately 60 - 80% of the reach's length. Moderate relative stream power is maintained between 2050 - 2444 W/m as the river traverses low slopes (average 0.004) along with gradually increasing catchment area. Downstream of the confluence with Visaya, a slight decrease in relative stream power is observed which can be attributed to the continuous decrease in slope. Due to the configuration of the river, compound point bars are common along this reach. Longitudinal bars also begin to be observed within this River Style. This suggests that some sediment accumulation is beginning to occur, although the dominant process remains transfer.

As the valley continues to widen, allowing formation of wider and longer floodplains and creating a planform-controlled setting, the underlying lithology changes into sandstone, shale and conglomerates of the Bojeador Formation. In such a setting, the river exhibits a **Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Gravel Bed River Style**. In this River Style, the wider valley results in further decrease in relative stream power and slope (average 1790 W/m and 0.003, respectively) until it reaches the confluence with Cabayo, a long tributary originating from the northern region of the catchment. The confluence almost doubled the catchment area (from 278.18 to 507.155 km^2) and hereafter the river reaches a steady relative stream power (average 2270 W/m) with localised increases that does not exceed 2700 W/m throughout the remainder of the partly-confined valley. The abundant supply of gravel, and sustained moderately high relative stream power, allows for the formation and reworking of large compound bars, both bank-attached and mid-channel. Channel planform enables lateral migration with the downstream shift of bends and the lateral adjustment of the channel; except in areas where bedrock is exposed and flood defence structures such as embankments and gabions act as a localised sources of anthropogenic confinement.

Midway towards the outlet at the West Philippine Sea at 59.10 km distance from the source, the Bislak River transitions to a **Laterally Unconfined, Continuous Channel, Braided, Gravel Bed River Style** as it enters the Lowland Plains landscape and the valley becomes laterally unconfined, where the sidewall retreats and now approximately 500 m wide. This coincides with the boundary of the extensive Quaternary reefs that extends until the outlet. The very low slope (average 0.0009) results in a decreasing relative stream power (average 1060 W/m). This allows for sediment to be more readily stored within the reach and promote the diverse array of depositional geomorphic observed within this reach. This reach is dominantly a transfer zone at the upstream portion but transitions into an accumulation zone further downstream once slope and relative stream power fall. In this downstream area, sediment supply is greater than sediment output. Channel planform is dynamic as lateral stability is very low. The relatively wider and shallower channel (238 m at its narrowest point), and the abundant supply of sediment maintain the braided form of the channel. Along this reach, flood protection dikes (Figure 6.3) are present along the left bank where the community built houses and buildings on the floodplains. The river is then confined by dikes on both sides at the approach of the Bacarra Bridge (approximately 65.90 km distance). Further downstream, the river is confined by dikes on the right bank to protect the Poblacion (center) of the Municipality of Bacarra.

Approximately 2.5 km from the coastline, the river forms a delta in a **Laterally Unconfined, Continuous Channel, Deltaic, Sand Bed River Style** which eventually exports sediment into the West Philippine Sea. This portion of the river is an accumulation zone and is dominated by suspended load due to the very low relative stream power and slope. Sediment accumulates, forming stable islands, and distributary channels are formed where flowpaths become established. Large events easily shift channels and islands may be reworked.

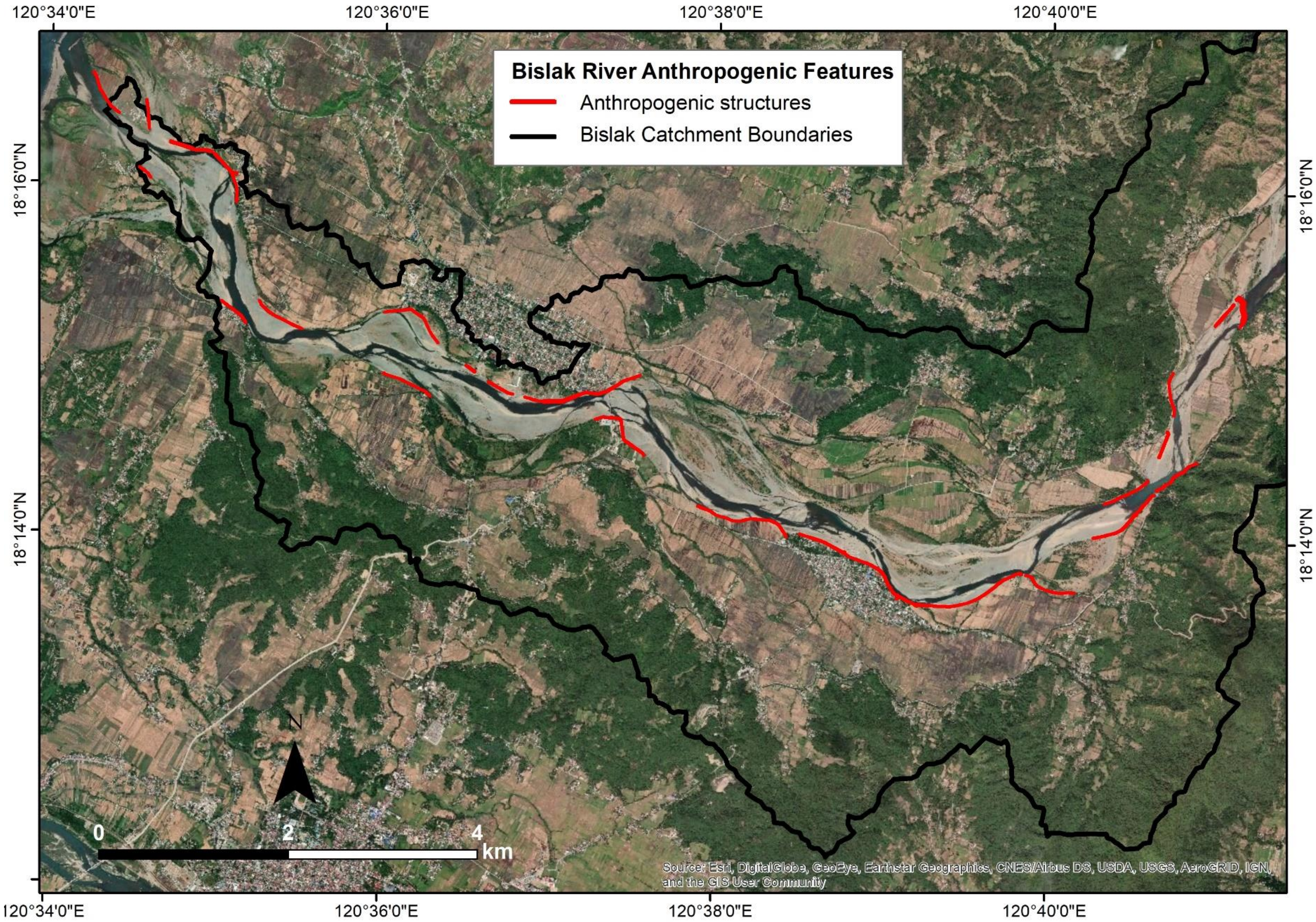


Figure 6.3 Anthropogenic structures in the downstream portion of Bislak River (16km from the outlet)

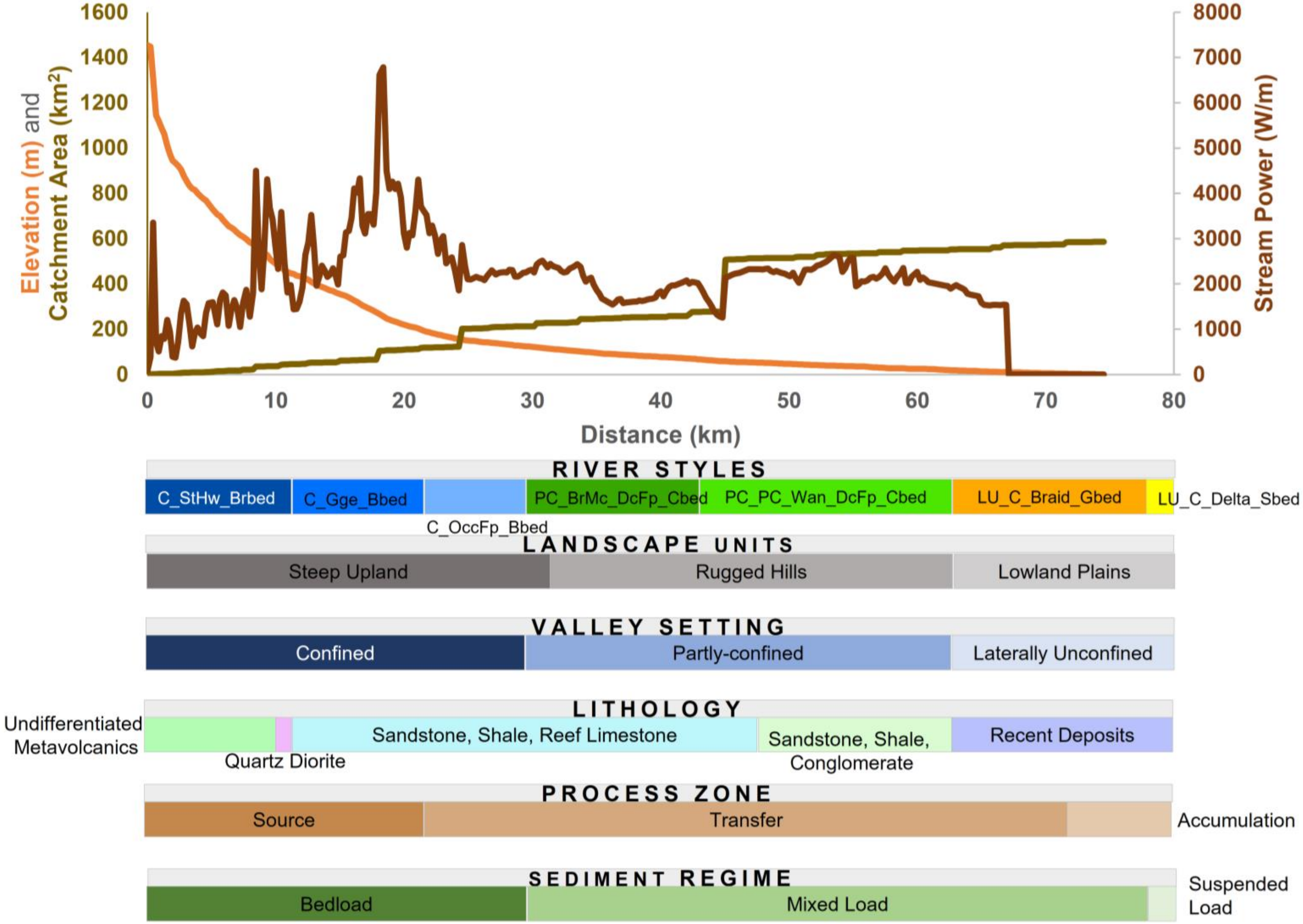


Figure 6.4 Diagram of controls on the character and behaviour of Bislak River.

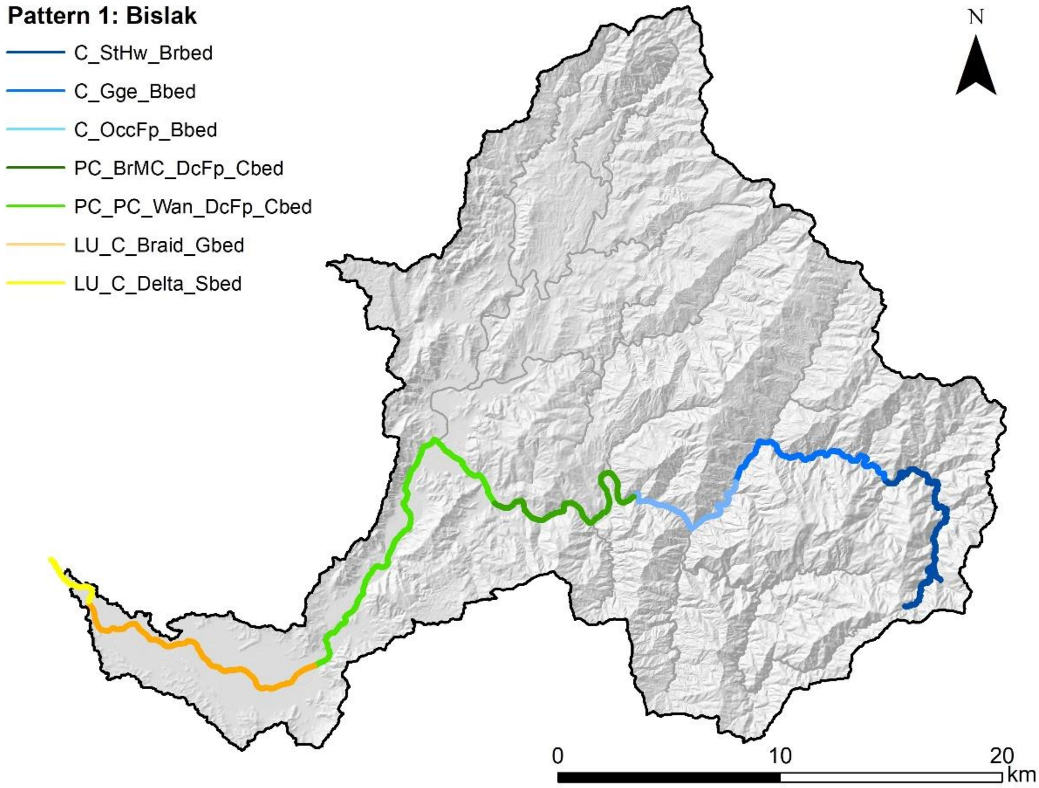


Figure 6.5 Distribution of Bislak River in the Bislak Catchment.

Pattern 2: Tagludan Kaliwa

Pattern 2 follows a similar downstream configuration of River Styles as with Pattern 1 but with the absence of Confined, Occasional Floodplain Pockets, Boulder Bed River Style. Only 2 tributaries out of 17 exhibit this pattern. The unique characteristic of this pattern is that the river is underlain by the Bojeador Formation characterised by sandstone, shale and conglomerates throughout the entire river. The **Confined, Steep Headwater, Bedrock Bed River Style** is observed to begin with the highest slope (0.09) of Tagludan Kaliwa where the small contributing catchment area produces a low relative stream power (281 W/m). The slope generally decreases, moving along the confined valleys, but relative stream power increases as the effects of slope are offset by increases in contributing catchment area. Locally, abrupt increases in slope also produce corresponding peaks in relative stream power. At a downstream distance of 3.44 km, the river attains its maximum relative stream power (629 W/m) resulting from the sudden increase in slope (0.029 to 0.038). The remaining course of the Steep Headwater enters the Rugged Hills landscape where slope decreases (0.021 to 0.018) as the River Style transitions into a **Confined, Gorge, Boulder Bed River Style**. The relatively gentle slopes (average 0.014) result in a low and decreasing relative stream power (average 386 W/m) in the Gorge Confined, Gorge, Boulder Bed River Style. There is high hillslope-channel connectivity along this reach where sediments are readily supplied to the channel. This is mainly a source zone but transfer of eroded sediments also occurs.

The valley then widens allowing for discontinuous floodplains to form on both banks, producing the **Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style**. The presence of bars in this reach allows the sediments to transport from bar to bar. The immediate setting back of valley margin and the short extent of the confined valley (8.7 km) are probably the reasons for the absence of Confined, Occasional Floodplain Pockets, Boulder Bed River Style. Along the partly-confined valley setting, the relative stream power increases reaching a local peak (476 W/m) caused by the slope increase (0.013 to 0.016). From this point, the relative stream power steadily decreases (average 324 W/m) and with occasional peaks until it is joined by the Tagludan Kanan Tributary increasing both relative stream power (322 W/m) and catchment area (from 21.40 km^2 to 35.53 km^2). The relative stream power becomes relatively "stable" (average 300 W/m) after the confluence.

Further widening of the valley allows wider floodplains on both banks and a planform-controlled setting transitioning the River Style to a **Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Gravel Bed River Style**. The relative stream power had a steep decrease along this transition (from 302 W/m to 184 W/m) and maintains an average relative stream power (189 W/m) and slope (0.002) until it joins the Isic-isic Tributary which then joins Cabayo Tributary which drains to the Bislak River.

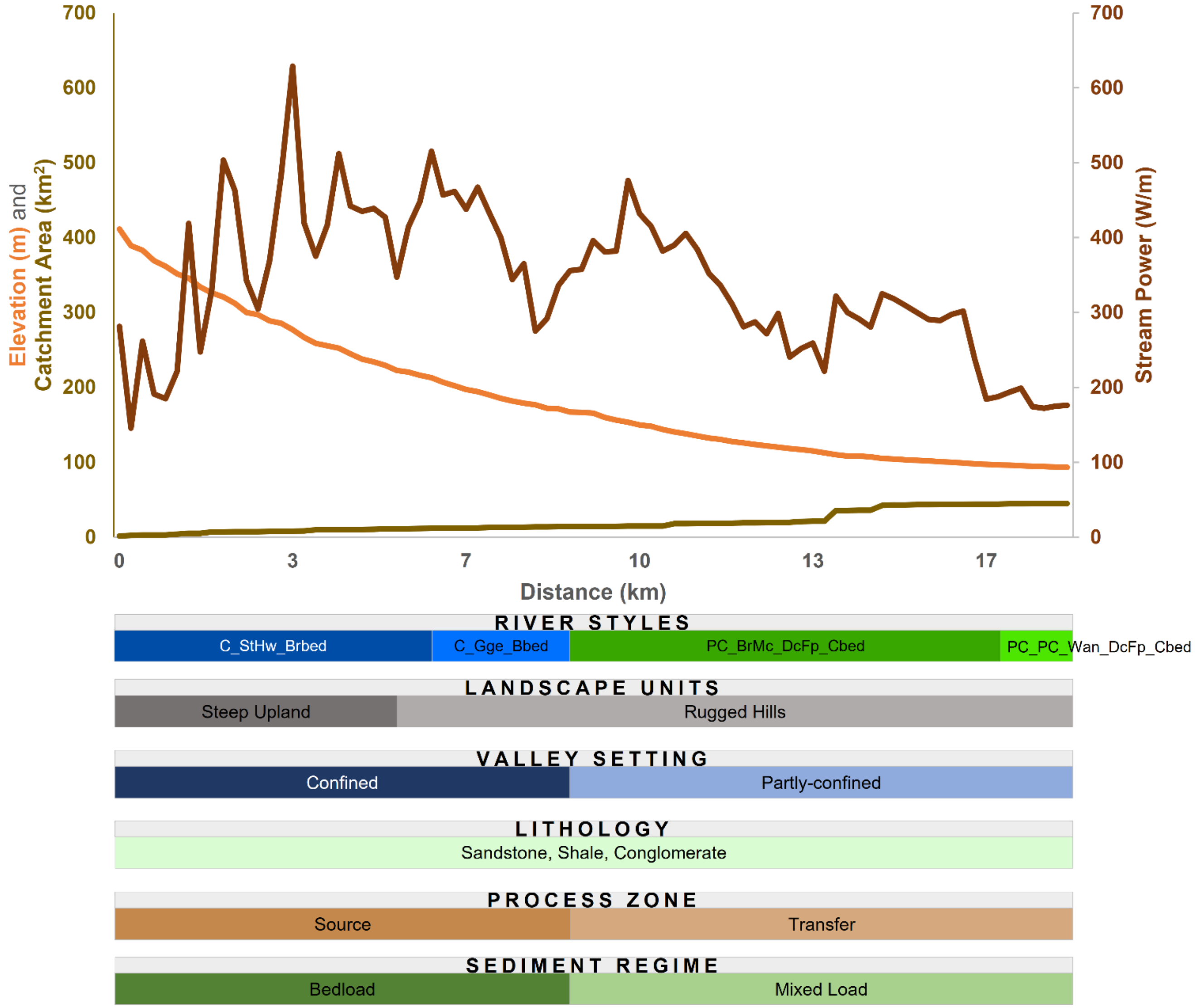


Figure 6.6 Diagram of controls on the character and behaviour of Tagludan Kaliwa River.

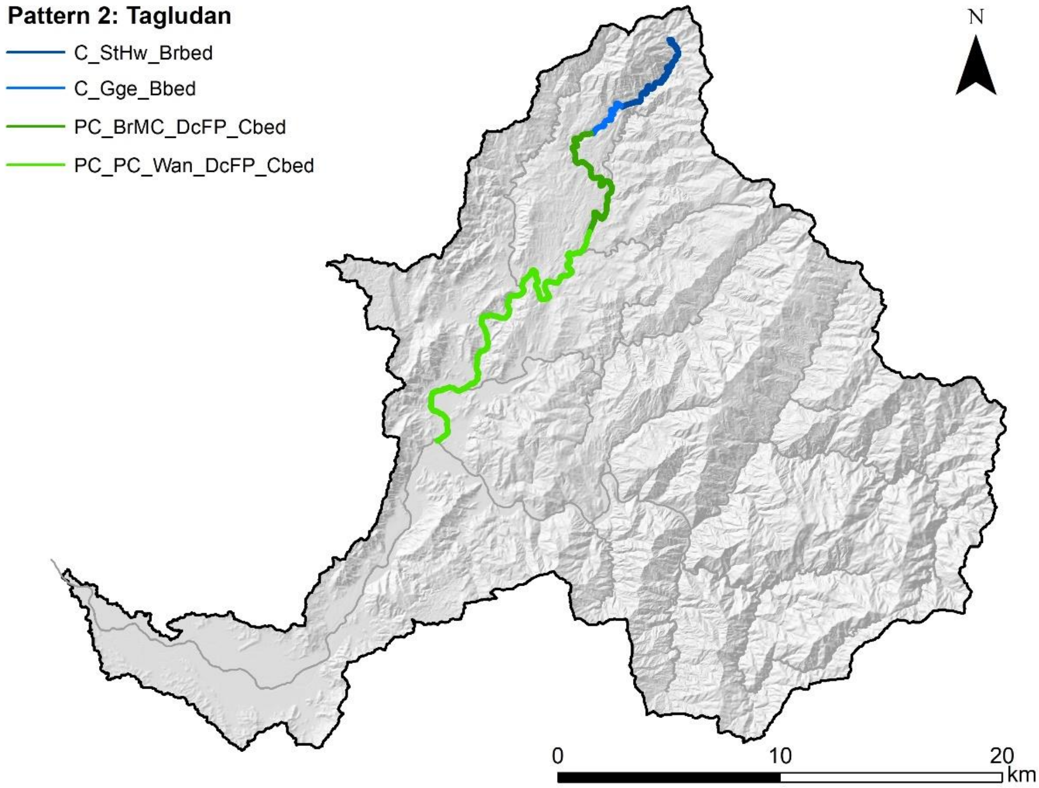


Figure 6.7 Distribution of Tagludan Kaliwa River in the Bislak Catchment.

Pattern 3: Dalugoc

This pattern is a subset of Pattern 1 notable for its absence of Confined, Gorge, Boulder Bed River Style. It is exhibited by only 2 tributaries, Dalugoc and Visaya, both relatively short in length (5.81 and 5.46 km, respectively) and found mid-catchment underlain by sandstone, shales, and reef limestone of the Laoag Formation. The **Confined, Steep Headwater, Bedrock Bed River Style** of Dalugoc is located at the Steep Upland where a break in the decreasing slope caused a peak in both slope (0.23) and relative stream power (924 W/m). This high relative stream power (average 748 W/m) is maintained by the moderately steep slopes (average 0.18) until the River Style transitions to an **Confined, Occasional Floodplain Pockets, Boulder Bed River Style**as it enters the Rugged Hills and gradually decreasing slopes. Storage is limited in this confined valley setting.

Discontinuous floodplains begin to occur on both banks as the valleys begin to widen, producing the **Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style,** where both slope (average 0.014) and relative stream power (average: 336.80 W/m) steadily decrease until it joins the trunk stream. The presence of floodplains also transitions the sediment regime from bedload-dominated to a mixed-load river where stripping contributes fine sediments to the reach.

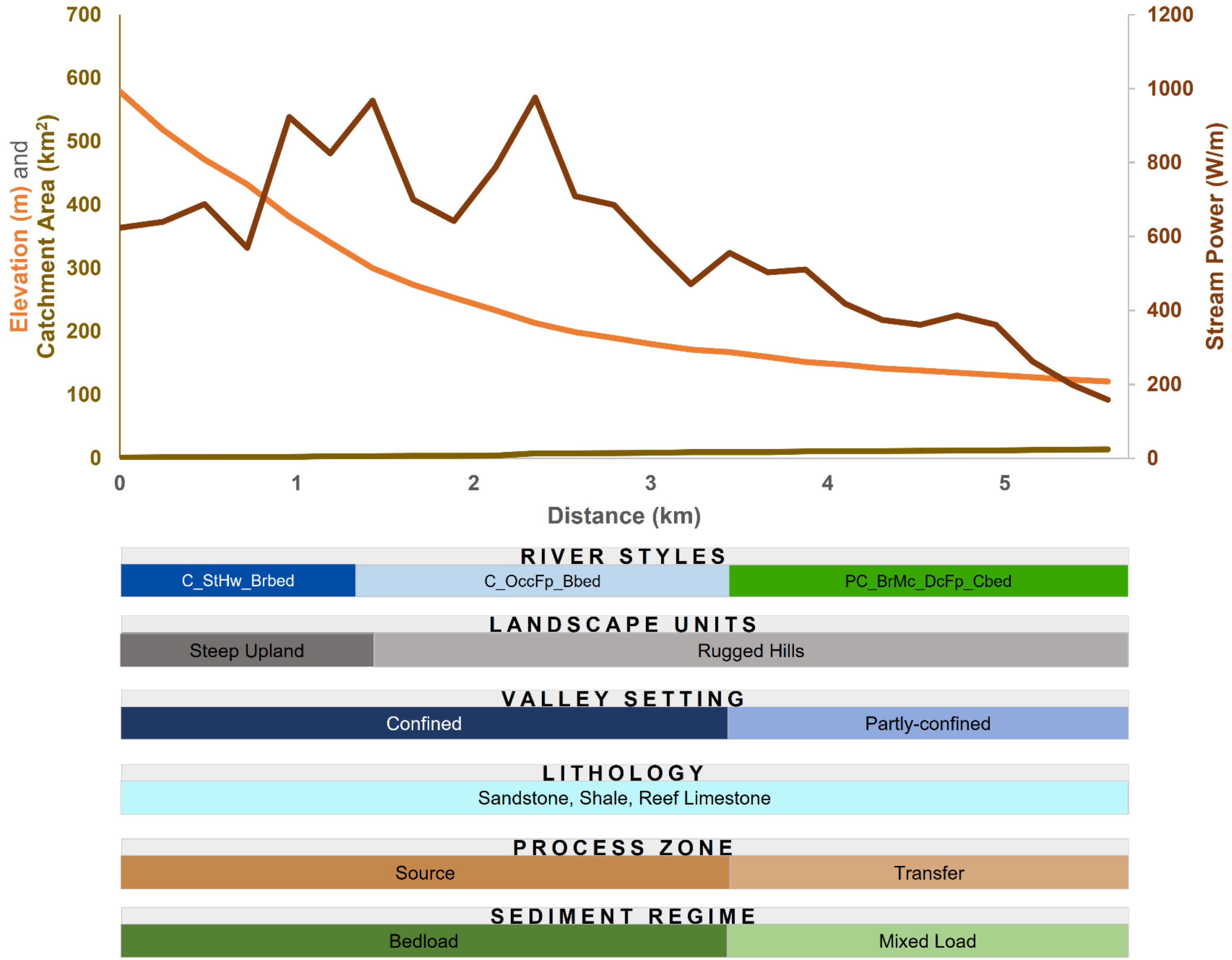


Figure 6.8 Diagram of controls on the character and behaviour of Dalugoc River.

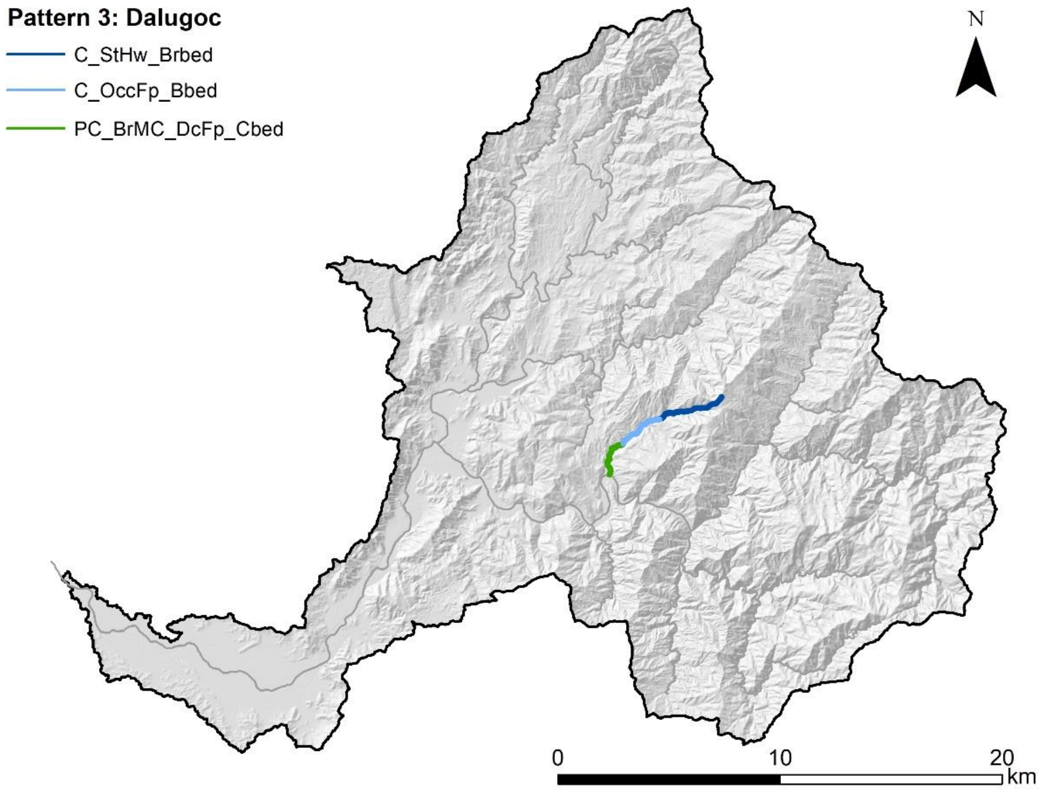


Figure 6.9 Distribution of Dalugoc River in the Bislak Catchment.

Pattern 4: Makikidor

This pattern is unique to the short Makikidor Tributary that only occurs at a mid-catchment location underlain by sandstone, shales, and reef limestone of the Laoag Formation. The river begins at the Rugged Hills where moderate slopes (average 0.05) and the small catchment area along the confined valleys in the **Confined, Steep Headwater, Bedrock Bed River Style** generate very low relative stream powers (average: 166 W/m). Maintaining slightly lower magnitude of relative stream power (average 118 W/m) and gentler slopes (average 0.01), the river directly enters a partly-confined valley where the River Style also transitions to a **Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style**. This change in River Style also changes the sediment regime from bedload to mixed-load and the process zone from source to transfer. The abrupt decrease in relative stream power is possibly due to a decrease in confinement brought about by a nearby fault along the eastern side of the valley. As a result, the slope becomes relatively gentler and discontinuous floodplains are able to form. The river then joins the Cabangaran Tributary at a low relative stream power (100 W/m) and slope (0.009). The low relative stream power allows the channel to remain single-threaded along this reach and while the slopes are relatively lower than the steep headwaters, it is still high enough to maintain a low-sinuosity channel.

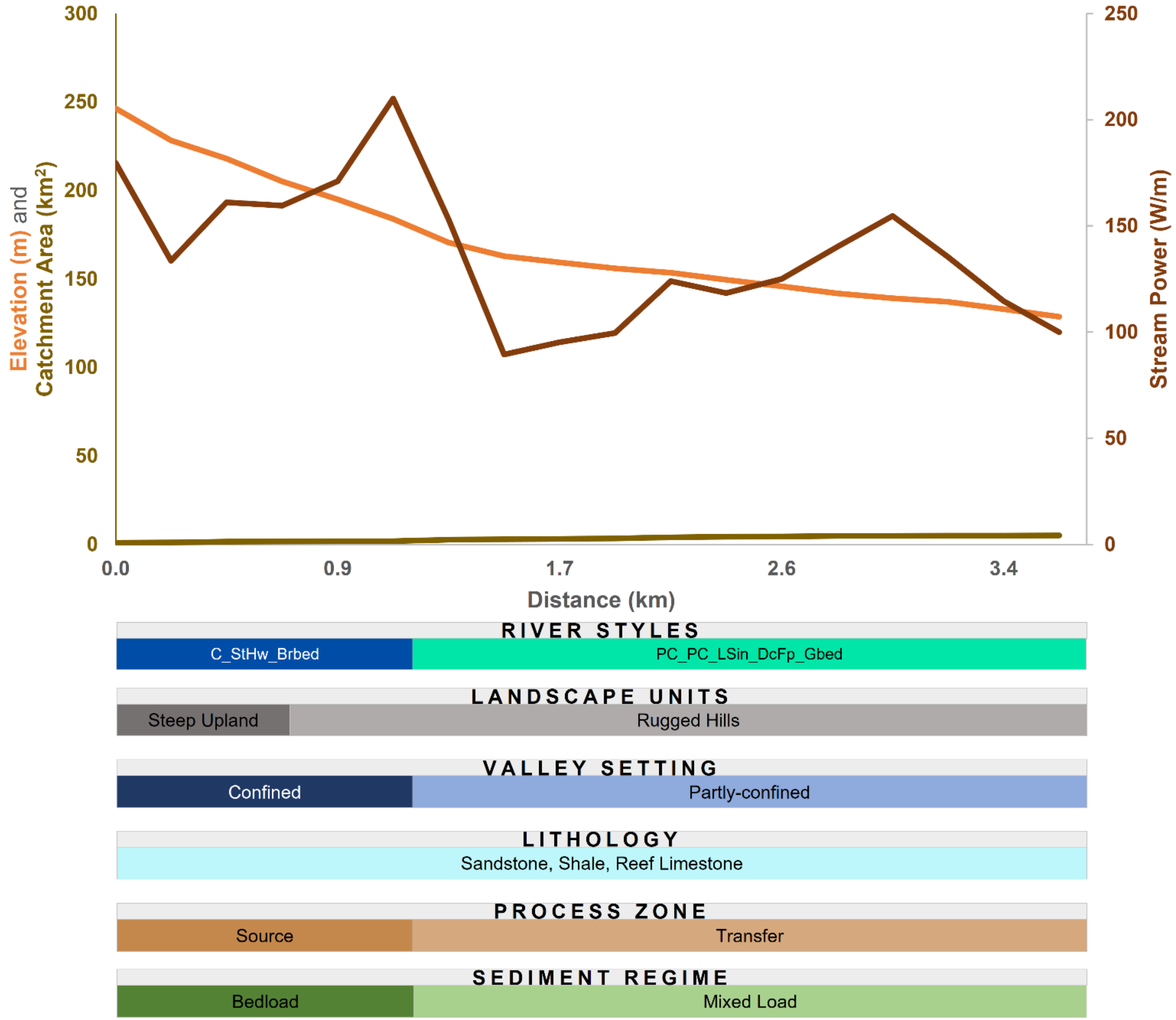


Figure 6.10 Diagram of controls on the character and behaviour of Makikidor River.

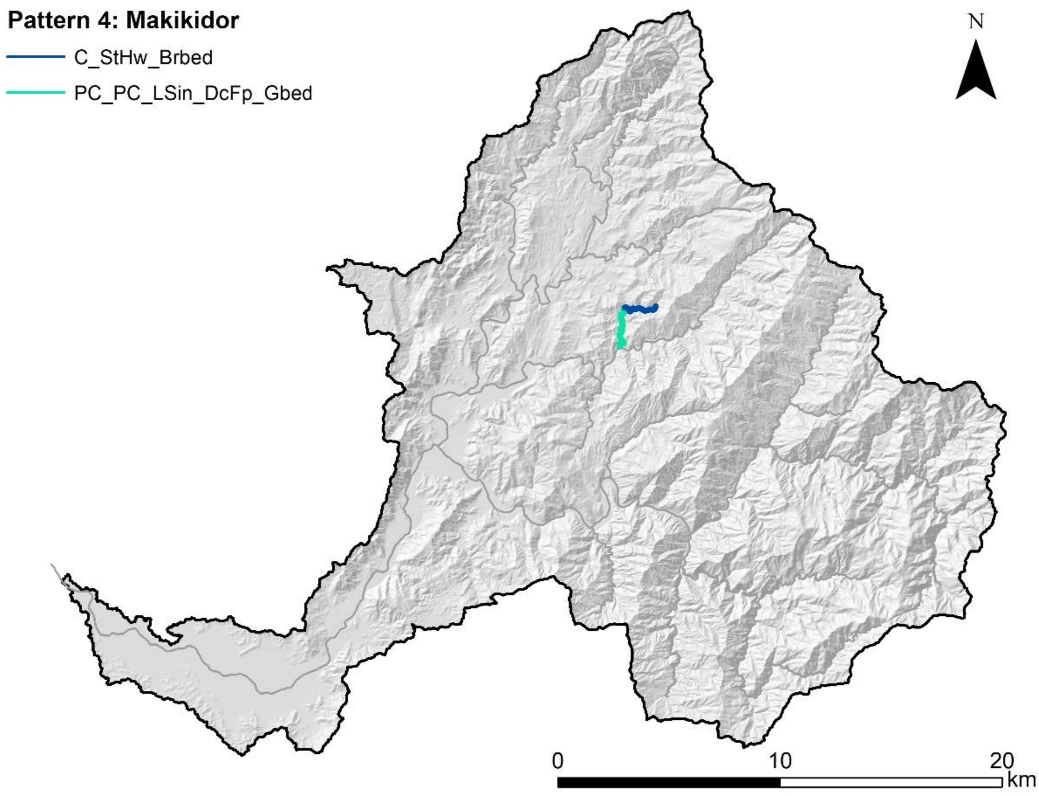


Figure 6.11 Distribution of Makikidor River in the Bislak Catchment.

Pattern 5: Batbatidor

This pattern is unique to the north-trending Batbatidor Tributary and similar to the pattern exhibited by the Makikidor Tributary (Pattern 4) but is set apart by the disruption to such pattern caused by a confined valley setting downstream of a partly-confined river. The very steep slope (average 0.05), low catchment area and low relative stream power (average 193 W/m) generate a **Confined, Steep Headwater, Bedrock Bed River Style**. This reach is situated at the Rugged Hills underlain by Laoag formation characterised by sandstone, shale and reef limestones. Slope becomes gentler (average 0.01) as the River Style becomes **Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style** resulting in further decrease in energy and occurrence of floodplains. Further downstream, the river is set back to a confined valley in **Confined, Occasional Floodplain Pockets, Boulder Bed River Style** and halfway through this, the steep slope at 0.09 and abrupt peak of the relative stream power of about 1710 W/m is caused by the steep descent of the river on a resistant bedrock waterfall. After this, the slope and relative stream power are abruptly set low at 0.01 and 219 W/m respectively as it joins the Cabangaran Tributary in Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style.

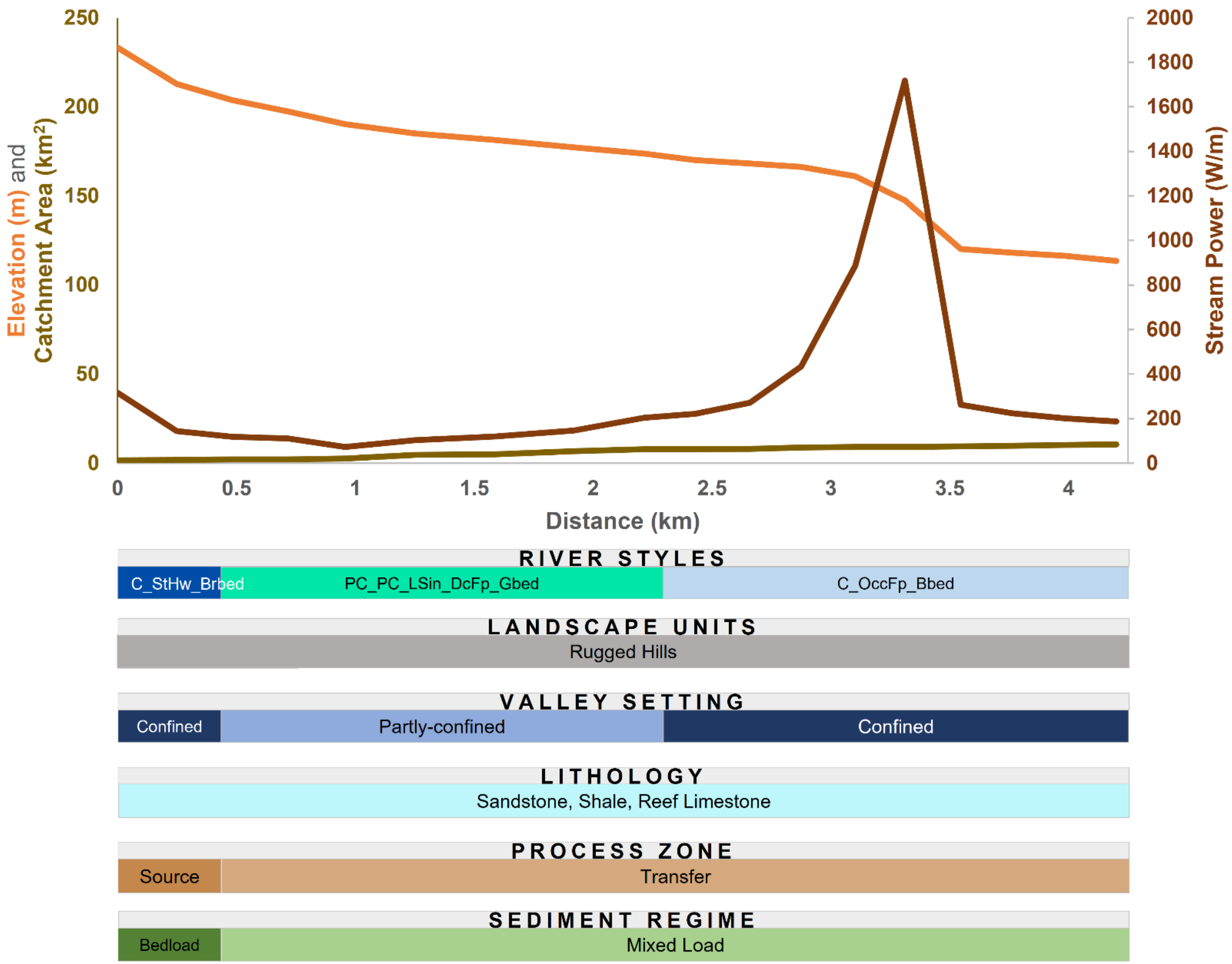


Figure 6.12 Diagram of controls on the character and behaviour of Batbatidor River.

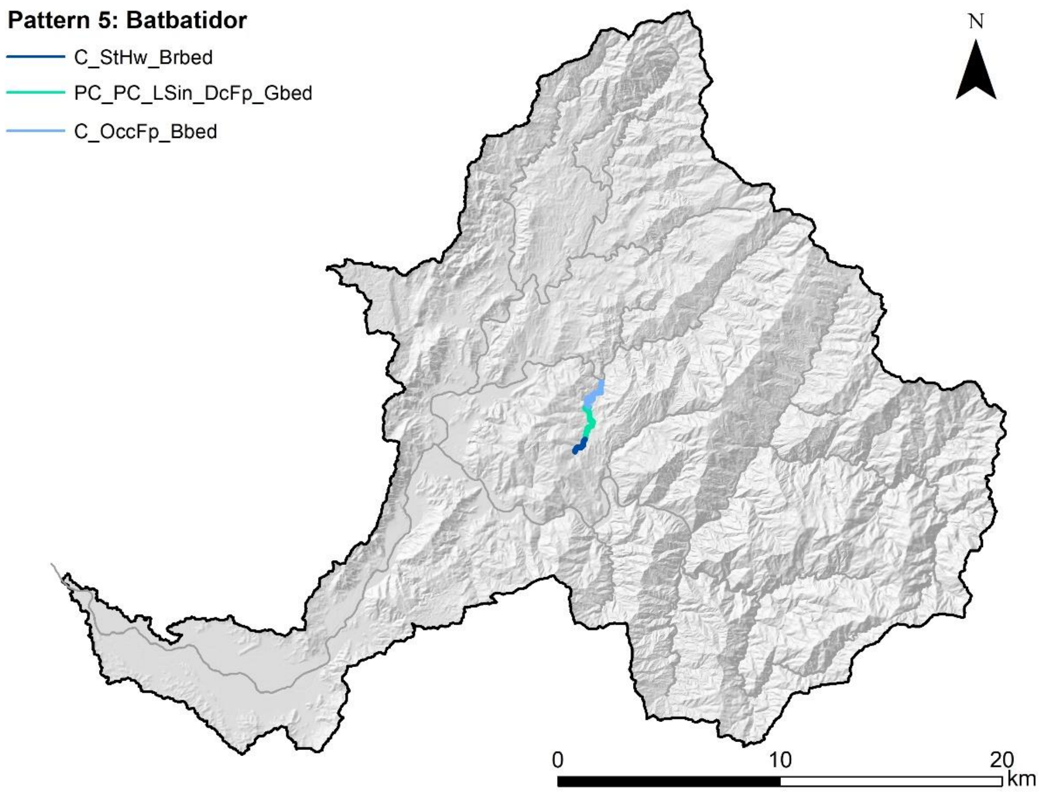


Figure 6.13 Distribution of Batbatidor River in the Bislak Catchment.

Section 7. Summary and Conclusions

7.1 Summary of Findings

Stage One of the River Styles Framework has proved to be effective in identifying the different types of rivers in a catchment through its nested hierarchical approach. This initial stage started by laying out the boundary conditions at the catchment scale such as geology, climate etc. Assessment of valley setting and confinement came after and provided the entry point of defining the different River Styles. The different controls were then analysed by looking at the downstream patterns of the River Styles through representative tributaries.

The eight distinct River Styles identified in the Bislak Catchment are the:

1) Confined, Steep Headwater, Bedrock Bed River Style
2) Confined, Gorge, Boulder Bed River Style
3) Confined, Occasional Floodplain Pockets, Boulder Bed River Style
4) Partly-confined, Bedrock Margin-controlled, Discontinuous Floodplain, Cobble Bed River Style
5) Partly-confined, Planform-controlled, Wandering, Discontinuous Floodplain, Cobble Bed River Style
6) Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain, Gravel Bed River Style
7) Laterally Unconfined, Continuous Channel, Braided, Gravel Bed River Style
8) Laterally Unconfined, Continuous Channel, Deltaic, Sand Bed River Style

These River Styles form under the combination of different imposed boundary conditions by landscape units, lithology, and valley-setting, as well as flux boundary conditions such as water and sediment transport regimes that affect stream power (as a function of slope and contributing catchment area) and process zone distribution.

The influence of these controls were elucidated by the downstream patterns of River Styles along different tributaries in the Bislak River. There are five downstream patterns that were identified, represented by the Tributaries of Bislak, Tagludan Kaliwa, Dalugoc, Makikidor, and Batbatidor, all of which eventually converging into the pattern present in the Bislak River. The majority (11 out of 17) of the tributaries follow the pattern represented by Bislak, most of which are situated in the distinctly high relief present in subcatchments to the east. Successions in River Style along longitudinal patterns generally follow breaks in slope, changes in underlying lithology, or abrupt changes to valley confinement. In addition, changes in relative stream power determine the formation of distinct geomorphic units within the channel. A notable disruption in downstream patterns due to fault activity in the area is found where a Partly-confined, Planform-controlled, Low Sinuosity, Discontinuous Floodplain River Style transitions downstream into confined settings.

7.2 Limitations

This report is limited to a desk top level of interpretation on some of the identified River Styles; not all Styles have been visited in the field. The hydrologic dataset was relatively sparse compared to the catchment wide analysis of topography. The land cover dataset from the year 2010 is ten years old so is likely to be indicative rather than accurate for 2020. A lack of recorded history and annotations on land and river use of early settlements limits the interpretation to the contemporary land and river use in the Bislak Catchment.

7.3 Implications

In the Philippines, where rivers are characterised and classified based on the quantity and quality of water, the River Styles framework offers a template to identify the features and assess the processes involved in the formation and reworking of geomorphic units, the core and basis for river classification. Interpretation of the genetic linkages of the geomorphic units provides information on the range of character and behaviour along a certain river type. Identification of the different River Styles of the Bislak Catchment already hints towards a clearer picture on the diversity of Philippine rivers. Assessment of the interplay of controls on their respective character and behaviour sheds light on how dynamic Philippine river may be.

The whole process walks us towards a better understanding of our dynamic rivers. Stage One is just a starting point but not far from the realisation of the catchment-scale vision which is to be supplemented and further amplified by the succeeding stages. Needless to say, this is already a big step for the Philippines movement towards a geomorphologically-informed and sustainable river management. The succeeding stages of the framework emphasising on river evolution and assessment of geomorphic conditions to predict its future trajectories and trends are essential in understanding river recovery towards a better river management/intervention.

All things considered, this study enables us to champion the concepts of:

- **River Futures and Proactive River Management Plans**
  Geomorphology is fundamental in conducting risk assessments and prioritising of interventions (flood mitigation, infrastructure protection, etc.)
- **Respecting River Diversity**
  Acknowledgement of the different river types and process-form relationships allow us to manage rivers effectively.

It is not possible to conserve our resources and preserve the quality of life it supports without understanding the inner workings of a river system.

7.4 Recommendations

Sustainable river management is not independent from geomorphic insight, but rather made more coherent by it. While land use plans acknowledge geomorphology as part of a comprehensive assessment, they remain lacking in the integration of the principles of fluvial geomorphology into plans. Stage One of the River Styles Framework ensures the familiarisation with the contemporary river.

In the Philippines, geomorphology is often overlooked in river management plans. As this report recognises the potential of adapting the River Styles Framework, the Philippines should begin to incorporate the principles of fluvial geomorphology into evidence-based and catchment scale river management. The report offers a template in assessing other catchments consequently providing insights on the nature and needs of our rivers.

The responsibility for land and water management is divided among 38 agencies additional to the multiple political boundaries. The absence of a central body integrating the plans and approaches of the national government agencies and local government units insinuates a weak institutional framework. These fragmented and conflicting strategies on river management yield more problems than it answers. To address this issue, systematic and integrated plans between all the stakeholders should be spearheaded.

The Philippines is still trapped in the traditional "control the river" and reactive approach towards river management by building hard flood defences and repairing them regularly after the typhoon season. After realising the key underpinnings of the River Styles Framework, it comes to light that these habitual uninformed practices impose more harm and the repairs only add up to impairment of the river. In a sense, we settle with "band-aid solutions" confining us in a cycle of wasted efforts and resources. As a developing country, river restoration/rehabilitation may be challenging to achieve due to lack of resources, knowledge, and possible disputes in properties. In this type of scenario, avoidance or prevention of further disruption is a more plausible option.

Another recurring activity in Philippine rivers that is often uninformed and mismanaged is gravel extraction. It is commonly done as an economic activity which also serves as a flood mitigation option. It is carried out without a geomorphic understanding for sediment and flow dynamics. Educating planners and regulators on the role of sediment in river management, and the potentially negative effects of extraction, would be beneficial.

Any management projects could not function without technical and financial assistance. Support from funding agencies (e.g. DOST-PCIEERD) and cooperation from the encompassing local government units of the catchment will be needed in the implementation of this integrated framework. Its application should be imposed to the projects dealing with rivers then later on transfer the best practices to the mandated agencies for full implementation.

With all the previous analyses and interpretation laid out from the Stage One of the River Styles Framework, carrying out the succeeding stages is highly recommended. The next steps of the River Styles Framework include assessing the evolution of the river and its current geomorphic condition, ultimately presenting an effective approach in managing rivers.

References

Brierley, G., Fryirs, K., Outhet, D., and Massey, C. (2002). Application of the River Styles framework as a basis for river management in New South Wales, Australia. *Applied Geography 22 (1),* 91 - 122.

Brierley, G.J., and Fryirs, K.A., (2005). Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publications, Oxford, UK. 398 pp.

Citizen's Disaster Response Center. (2018, September 17). Typhoon Ompong: Impact on Ilocos Region - Situation Report #4. Citizen's Disaster Response Center Disaster Alerts. https://www.cdrc-phil.com/typhoon-ompong-impact-on-ilocos-region/

Coronas J. (1920). The climate and weather of the Philippines. Bureau of Printing. 25, 1903-1918 pp.

Fryirs, K.A,. and Brierley, G.J., (2013). Geomorphic Analysis of River Systems: An Approach to Reading the Landscape. John Wiley and Sons, Chichester, UK, 345 pp.

Fryirs, K., and Brierley, G. (2018). What's in a name? A naming convention for geomorphic river types using the River Styles Framework. *PLOS ONE, 13 (9)*: e0201909. https://doi.org/10.1371/journal.pone.0201909

Grafil, L., and Castro, O. (2014). Acquisition of IfSAR for the Production of Nationwide DEM and ORI for the Philippines under the Unified Mapping Project. *Infomapper, 21,* 12 - 13 and 40 - 43.

Holden, W.N., and Marshall, S.J. (2018). Integrating Disaster Science and Management: Global Case Studies in Mitigation and Recovery. Elsevier Inc. https://doi.org/10.1016/C2016-0-02482-8

Lazaro, Freddie. (2019, August 24). Laoag City, Vintar town declared under state of calamity due to 'Ineng'. Philippine Information Agency – News Center. https://pia.gov.ph/news/articles/1026371

Maeda, Y., Siringan, F., Omura, A., Berdin, R., Hosono, Y., Atsumi, S., & Nakamura, T. (2004). Higher-than-present Holocene mean sea levels in Ilocos, Palawan and Samar, Philippines. *Quaternary International, 115 - 116*, 15 - 26. https://doi.org/10.1016/S1040-6182(03)00093-4

Maxwell, K., Ramos, N., Tsutsumi, H., Chou, Y.C., Duan, F., Shen, C.C. (2018). Late Quaternary uplift across northwest Luzon Island, Philippines constrained from emergent coral reef terraces: Late Quaternary uplift across northwest Luzon Island, Philippines. *Earth Surface Processes and Landforms, 43 (15)*, 3114 - 3132. https://doi.org/10.1002/esp.4474

Mines and Geosciences Bureau. (2010). Geology and mineral resources of the Philippines (2nd ed.). Manila, Philippines: Mines and Geosciences Bureau.

Mines and Geosciences Bureau – Regional Office No. 1. (2017). Directory of Operating Mines and Quarries as of December 2017. http://www.region1.mgb.gov.ph/images/MGBRO1_FILES/MINERALS_STATISTICS/DIRECTORY/DIRECTORY_OF_OPERATING_MINES&QUARRIES/2017/directory_of_operating_mines_and_quarries_update_2017.pdf

National Economic and Development Authority – Regional Office 1. (2017). Ilocos Regional Development Plan 2017 - 2022. San Fernando City, La Union, Philippines: National Economic and Development Authority Regional Office 1.

National Commission on Indigenous People - Region 1. (2014). Ancestral Domain Situationer Region 1. https://ncipr1.com/wp-content/uploads/2014/10/Ancestral-Domain-SITUATIONER.pdf

Paringit, E.C. and Pascua, C. (Eds.). (2017). *LiDAR Surveys and Flood Mapping of Bacarra River*. Quezon City, Philippines: University of the Philippines Training Center for Applied Geodesy and Photogrammetry, 250 pp.

Philippine Atmospheric, Geophysical and Astronomical Services Administration, 2005

Philippines Statistics Authority. (2012). Census of Agriculture and Fisheries 2012: Agriculture - Ilocos Region. https://psa.gov.ph/sites/default/files/CAF2012Agri_Reg1.pdf

Peña, R. (2008). *Lexicon of Philippine Stratigraphy*. Mandaluyong City, Philippines: Geological Society of the Philippines.

Pinet, N., and Stephan, J.F. (1990). The Ilocos Foothills and western Central Cordillera : a key region for the understanding of the geodynamic evolution of the eastern eurasian margin in Luzon area (Philippines). In Aubouin and Bourgois (Eds.), *Tectonics of the Circum-Pacific Continental Margins* (pp. 165 - 180). Utrecht, the Netherlands: VSP.

Pinet, N., and Stephan, J.F. (1990). The Philippine wrench fault system in the Ilocos Foothills, Northwestern Luzon, Philippines. *Tectonophysics, 183 (1 - 4),* 207 - 224.

Ramos, N.T., Maxwell, K.V., Tsutsumi, H. Chou, Y.C., Duan, F., Shen, C.C., and Satake, K. (2017). Occurrence of 1 ka-old corals on an uplifted reef terrace in west Luzon, Philippines: Implications for a prehistoric extreme wave event in the South China Sea region. Geoscience Letters, 4. https://doi.org/10.1186/s40562-017-0078-3

Spencer, J., Fryirs, K., Keating, D., and Brierley, G. (2004). River Styles in the Upper Hunter Catchment. Macquarie University, Sydney, Australia.

Tolentino, P. L. M., Poortinga, A., Kanamaru, H., Keesstra, S., Maroulis, J., David, C. P. C., & Ritsema, C. J. (2016). Projected impact of climate change on hydrological regimes in the Philippines. PLoS ONE, 11(10). https://doi.org/10.1371/journal.pone.0163941

Vintar Municipal Planning and Development Office. (2009). Vintar Comprehensive Land Use Plan (Period 2009-2018). http://www.vintar.gov.ph/solid-waste-management-program/

Vintar Municipal Planning and Development Office. (2019). Vintar Forest Land Use Plan (Period 2020-2029). http://www.vintar.gov.ph/solid-waste-management-program/

Catchment Project