Hydrological Characteristics Assessment of Jalaur River System and Its Bottom Sediments, Province of Iloilo, Panay Island

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Rivers are important to civilization because river water can be diverted for agricultural irrigation, industry, hygiene, and related uses. Most rivers have varied hydrological characteristics like water depth, flow rate and volume discharges when measured during the wet and dry season. In addition, rivers do carry dissolved minerals and organic compounds. A hydrologic monitoring was done in strategic sampling points along the river to cover the upstream (Banban, Pequeño, Calinog), midstream (Moroboro, Dingle) with sub-points before and after the dam (Imbang Pequeño—near Passi Sugar Central and Licuan, Dingle next to the National Power Corporation) and downstream (Nabitasan, Leganes) sections of the Jalaur River. Sampling was done three times per season (dry and wet seasons) at each of the five sampling sites.

Water level and flow rate variations were observed during the occurrence of a tropical storm and torrential rains brought by a typhoon. Depth ranges from 0.45 meters (dry season) to 6.0 meters (wet season). The river current in the upstream station was greater than the mid and downstream stations at a rate of 2.5, 0.22 and 0.33 m/sec in the wet season and 0.37, 0.2 and 0.08m/sec in the dry season, respectively. River discharges were also higher (108.5, 41.04, and 19.99 m^3/sec) during the wet season than in the dry season (3.89, 29.40, and 28.08 m^3/sec) for the upper, middle, and downstream stations. Water transparency during the wet season ranged from 5-15 cm whereas 31-55 cm was recorded during the dry season. Color of the water changed from murky brown to brown during the wet season and from clear to light green during the dry months from Calinog down to Leganes except in Imbang, Pequeño-San Enrique site with very undesirable color (black) and odor (ammoniacal) during dry months (milling season). Highest precipitation of 317.24 mm in the wet season and barely 5.2 mm during the dry season was recorded. Bottom sediments were found to be sand to sandy loam, to silty loam from upstream to downstream, respectively. Soil pH was neutral to slightly basic (7.10-8.17). Available phosphorus measurements were higher (11.22-30.50 ppm P) in soils from Calinog to Leganes while the amount of available iron (Fe) increased as the concentration of acetate soluble sulfate decreased, except in Moroboro, Dingle and Nabitasan, Leganes that showed an abnormal increase twice the initial value. The organic matter content of the sediments taken from all sampling sites yielded a wide range of 1.31—4.53 % that decreased to 0.04 from 2.46 % in all sampling sites from wet to dry season. Highest value was in the midstream with values ranging from 4.53—2.46 %.

The results of this study show that sediment agitation by recreational activity and storm surges associated with the dry-cold season are responsible for the impact on water quality and not recreational users directly. This implies that a follow up study and continuous monitoring is needed to ensure the safety of all end users of the river system, otherwise its use in the future will be limited to quarrying of concreting and embankment materials for civil work projects.

KEYWORDS: hydrology, Iloilo, Panay Island, river system

INTRODUCTION

A river system usually consists of a main channel and tributaries that flow into it. It can be divided into three subsystems: a collecting system, a transporting system, and a dispersing system.

Rivers are important to civilization because river water can be diverted for agricultural irrigation, industry, hygiene, and related uses. Most rivers also carry dissolved minerals and organic compounds. Some communities depend on the fish that live in or travel along rivers. Rivers can facilitate transport but can also be barriers to land transportation. They can be crossed by ferries, bridges, and tunnels. Because of the difficulty of crossing rivers, they have often become territorial boundaries. In another aspect, a dam can raise the level of a river to provide pressure for electrical generation. Some rivers are also known for their recreational and aesthetic value (River Basin Report, 2003; River Systems of the World, 2007).

Human demands on the available freshwater supplies continue to grow as the global population increases. In the endeavor to manage water to meet human needs, the needs of freshwater species and ecosystems have largely been neglected, and the ecological consequences have been tragic. Healthy freshwater ecosystems provide a wealth of goods and services for society, but our appropriation of freshwater flows must go together with better management if we hope to sustain these benefits and freshwater biodiversity (Hirsch, Walker, Day & Kallio, 1990). A framework must be prompted for developing an ecologically sustainable water management program, in which human needs for water are met by storing and diverting water in a manner that can sustain or restore the ecological integrity of affected river ecosystems. The six-step process includes: [1] developing initial numerical estimates of key aspects of river flow necessary to sustain native species and natural ecosystem functions; [2] accounting for human uses of water, both current and future, through development of a computerized hydrologic simulation model that facilitates examination of human-induced alterations to river flow regimes; [3] assessing incompatibilities between human and ecosystem needs with particular attention to their spatial and temporal character; [4] collaboratively searching for solutions to resolve incompatibilities; [5] conducting water management experiments to resolve critical uncertainties that frustrate efforts to integrate human and ecosystem needs; and [6] designing and implementing an adaptive management program to facilitate ecologically sustainable water management for the long term (Rahaman & Varis, 2005).

Locks and dams regulate water surface elevations and flow, enabling commercial navigation to continue year round. The water regime could be regulated to maintain navigation and improve conditions for native plants and animals without increasing flood damages (Hendriks, 2010).

Climate change and land-use change can significantly affect the hydrology of a river system including the drainage basin. The magnitude and direction of changes in stream flow are sensitive to watershed size and land-use scenarios. Smaller watersheds with higher proportion of impervious surfaces exhibit greater impacts than larger watersheds with relatively smaller urban areas. Assessing local hydrologic impacts of climate change and land-use change is thus important to identifying subtle changes in stream flow and to establishing future water-management strategies (Haller, 2004).

The effects of climate change on average annual runoff depend on the ratio of average annual runoff to average annual rainfall, with the greatest sensitivity in the driest catchments with lowest runoff coefficients. The greater the concentrations of a given annual rainfall change in rainy season, the greater the effect of that change on runoff. Several different empirical formulae will yield results inconsistent with those from the monthly water balance model (Tang, Haller, Baik, & Ryu, 2009).

Changes in monthly runoff are controlled by catchment geology and the current balance between rainfall and potential evapotranspiration. A catchment where summer rainfall is currently close to potential evapotranspiration shows the greatest proportional change in runoff in summer, while flows in catchments with large groundwater storages may be maintained even during warmer, drier summers if rainfall increases (Baconguis, Daño & Dumlao, 1987).

Most of the sediment transported by the flood to the ocean is carried through the rivers. Sediment transport is directly related to river stage, but tidal phase (spring versus neap tides) also plays an important role. An estimated 40% of the sediment load in the river is deposited in the estuary, mostly in and seaward. The remaining sediment is deposited directly offshore during flood seasons, but much is re-suspended and carried back by subsequent storms (Brookes, 1994).

Stream flow information is important to home owners, builders and developers. It is essential in conducting foundation calculations in areas near the water. Studying the hydrologic cycle and stream flow will determine the relationships between rain, run-off and groundwater. Also, it can evaluate the impacts of environmental off-site and on-site flows originating from both naturally and human-made sources. It can assist in "water budgeting", where communities depend on stream-fed bodies of water for their municipal water supplies (Baxter & Woessner, 2003; Rantz, 1982). Natural runoff absorbing processes occur when accumulated runoff is dispersed. More obvious runoff absorbing processes are related to human activities, e.g. river water is diverted into irrigation channels and consumed among the fields. In a sense, water resources management is the way for the public to influence and manage runoff-evaporation processes (Poje & Haller, 1999).

Rainfall-runoff and runoff-evaporation processes are coexistent, but runoff-evaporation processes are largely dominating with rare precipitation and large potential evaporation. In the tropics, a river system with little precipitation and large potential evaporation coincide causing little runoff (Lange, Liebundgut, & Schick, 2000). But in some hyper-arid areas, precipitation intensity usually ranges from 10-30 millimeters per day in arid areas and below 10 millimeters in hyper-arid areas (Kedar, Leonard & Wiggins, 1990). Light rain usually cannot induce efficient runoff in dry conditions because of dry soil storage. According to the groundwater budget study in the Gansu Corridor, less than two percent of the groundwater recharge comes from precipitation (Leopold, 1994).

Soil structure refers to the way in which the sand, silt and clay particles are arranged relative to each other. Hence, soil texture is a soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil. In soil with a good structure, the particles of sand and silt are held together in aggregates (small clumps) by clay, humus and calcium (Wu, Borkovec, & Sticher, 1993). Particles are grouped according to their size into what are called soil separates (clay, silt, and sand). The soil texture class (e.g., sand, clay loam, and so on) corresponds to a particular range of separate fractions, and is represented in the formof a diagram by the soil texture triangle. Coarse textured soils contain a large proportion of sand; medium textured soils are dominated by silt and fine textured soils are primarily clay (Francesco, 1992; Romberger & Papendick, 1986).

Depending on the proportion of each type of mineral, soils can be divided into four groups: sandy soils, silty soils, clay soils and loams. Each group has distinct features. Sandy soils (light soils, yellow soils) consist mainly of coarse sand. Soils of this type are easy to work on and are well aerated and have good drainage, but are subject to leaching (of water and minerals). On the other hand, silty soils consist mainly of fine sand and silt.

Rain and watering tend to form a crust on the surface of this type of soils, making it impossible for water and air to penetrate, whereas, clay soils (heavy soils, clayey soils) contain over 25% clay. These are usually rich soils with good water- and nutrient-retention properties. Loam (loam, clay loam soils, and average soils) soils contain about 40 to 60% sand, 30 to 50% silt and 15 to 25% clay. These are highly fertile and excellent soils for growing plants, because they are well balanced in terms of aeration, drainage and water and nutrient retention (Hwang, Kwang, Dong, & Powers, 2002). The defects in sandy, clay and silty soils can be corrected by improving the soil structure and adjusting the pH, as necessary. If loamy soil dominates, it is important to maintain or improve the soil by regularly adding organic matter

(Campbell & Flury, 1999).

The specific objectives according to the three major study components were: [1] to determine the hydrological characteristics (depth, width, current flow, rainfall and erosion pattern, soil composition, and soil texture) of the river system; and [2] to elucidate the various chemical properties (soil pH, available phosphorus, available iron, acetate soluble sulfate and percent organic matter) of river bottom sediments

The results of the physico-chemical assessment of the Jalaur River should be very useful in determining the present status of the Jalaur River System specifically for its users. The basic information from these findings could serve as basis for protecting the Jalaur River system and in the promulgation of plans of action for early mitigations to preserve the present status before it worsens and becomes non-beneficial.

The proposed project was expected to generate an information database on the hydrological and physical and chemical status of the Jalaur River System, Province of Iloilo. The data includes the status and condition of the existing hydrological characteristics and some physico-chemical parameters of the river system.

Although the researchers wished to come up with a very comprehensive assessment of the Jalaur River System, certain limits were considered without necessarily sacrificing the overall quality of the study. This study did not cover the entire length of the river but instead covered only sampling points identified as upstream (Calinog), midstream (Moroboro, Dingle) with additional sampling point before and after the dam (at Imbang Pequeño, San Enrique-near Passi Sugar Central and Licuan, Dingle after the National Power Corporation), and downstream (Leganes). Sampling for data collection for all the components of this study (hydrological characteristics and physico-chemical features) was based on these pre-identified sampling points. These data were collected from the river and from the immediate environs of the river within the different sampling points.

MATERIALS AND METHODS

A hydrologic monitoring was done in strategic sampling points along the river to cover the upstream (Banban, Pequeño, Calinog), midstream (Moroboro, Dingle) with sub-points before and after the dam (Imbang Pequeño, San Enrique-near Passi Sugar Central and Licuan, Dingle

after the National Power Corporation) and downstream (Nabitasan, Leganes) sections of the Jalaur River. Sampling was done three times per season (dry and wet seasons) at each of the five sampling sites.

Hydrological Parameters

Hydrological characteristics like velocity, discharge, high and low level stages and other measurable parameters on site were taken at once (start and end of study period). The stream flow, or discharge, is the volume of water passing a single point in the stream over time. It was measured by determining the cross-sectional area and velocity (speed and direction) of the flowing water.

1. River water depth

A graduated rope with sinkers at the end of the rope was used for measuring manually the water depth (Figure 1). The graduated rope

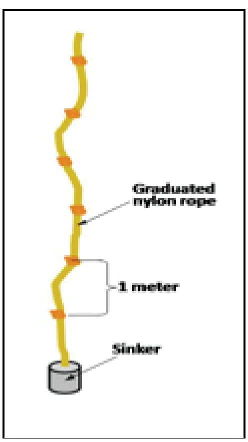


Figure 1. Improvised graduated nylon rope with sinker used to measure the water depth.

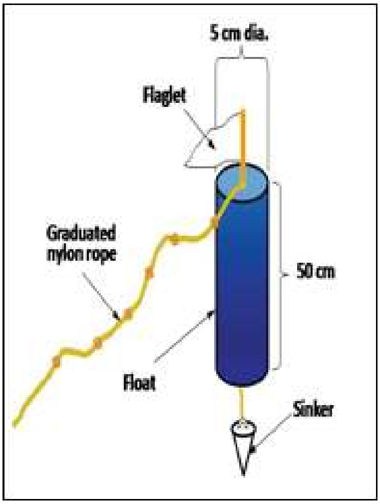


Figure 2. The float made of 50 cm PVC pipe (5 cm diameter), with sinker used to determine the flow rate or river water velocity.

was plunged into the water until the sinker touches the bottom of the river and the water depth was recorded. There were 6-8 observations done across the river. Mean was taken as the river water depth.

2. *Water Velocity/River Current*

Water flow or river current was determined using the float method. The float was made of a PVC tube 5 cm in diameter), 50 cm in length and closed at both ends (Figure 2). At lowest end a sinker was attached so that the float will be standing straight when carried by water current. The weight was enough to hold the float in a vertical position with only a very small portion of its length seen above the surface of the water. Small red flags were installed at the upper end of the tube floats to make them visible in the water. Strict measures were made to ensure that the PVC tubes have free floatation.

3. *Water transparency*

A Secchi disk is a standard way to measure visibility in water or simply water transparency. The disk measures 20-25 cm in diameter and is painted black and white in opposing quarters (Figure 3). A simple disk can be made from a round can lid. The disk is attached to a wooden stick or a rope marked off or graduated in centimeters. The water transparency was measured by lowering the disk into the water with the back of the observer to the sun while viewing the disk from

Figure 3. Instruments used to measure Hydrologic parameters velocity.

directly above. The depth at which the disk just disappears from sight is the Secchi disk reading.

4. Rainfall

Reliable rainfall data acquisition calls for rain gauges and rainfall data loggers proven to perform under harsh conditions. Rainfall data loggers and rain gauges are appropriate for rooftop weather monitoring, agriculture, site assessment, green building and renewable energy systems monitoring, indoor air quality assessment, and scientific research.

Daily rainfall data were obtained from Iloilo State College of Fisheries (ISCOF) at their Automatic Weather Station based in San Enrique Hydrometer Station San Enrique, Iloilo while the average rainfall data was provided by the AgroMet-PAG-ASA Weather Station in Dumangas, Iloilo for the period covered by this study.

5. Bottom Sediments

Bottom sediment samples were collected with an improvised hand corer. Composite soil samples from the five stations were brought to the laboratory for particle size determination using a set of sieves and the pipette method for soil texture analysis for the remaining samples

Figure 5. The sieve series used in grain-size analysis to determine the soil composition

from the receiver (less than 0.250 mm). Dry sieving was done for the grain-size analysis using U.S. sieves of mesh sieve series numbered #10(1.98 mm), # 40 (0.417 mm), # 60 (0.246 mm), #100 (0.150 mm). This sieve series was assembled from the coarsest at the top to finest at the bottom (Figure 5). Dry samples were placed on the top most sieve and shaking the whole sieve series for about 3 to 4 minutes (ASTM, 1961).

The topmost (coarsest) sieve was removed and shaken separately but directly over sieve until no more material passed through the succeeding screen. The procedure was repeated in the same manner with other sieves. Materials retained by each sieve were weighed in bulk and the percent by weight of materials passing individual sieves was calculated (Gee & Bauder, 1986).

Size classification of bottom sediments (grain-size analysis) was limited to the following size scales based on the Wentworth's Size Classification:

Very coarse sand (VCS)	= greater than 1 mm
Coarse Sand (CS)	= 1 mm to 0.5 mm
Medium Sand (MS)	= 0.5 mm to 0.250 mm
Fine Sand (FS)	= 0.250 mm to 0.062
Silt (SL)	= 0.062 mm to 0.0039 mm
Clay (CL)	= less than 0.0039 mm/

Pipette method was used in segregating fine sediments from the remaining samples in the receiver.

Soil classification	**Clay Soil**	**Loam Soil**	**Sandy soil**
Percent clay	40-100%	7-27%	1-10%
Percent silt	0-40%	28-50%	1-15%
Percent sand	0-45%	23-52%	85-100%

A more precise way to determine soil texture is by using the soil triangle from the percent sand, silt and clay (Figure 6).

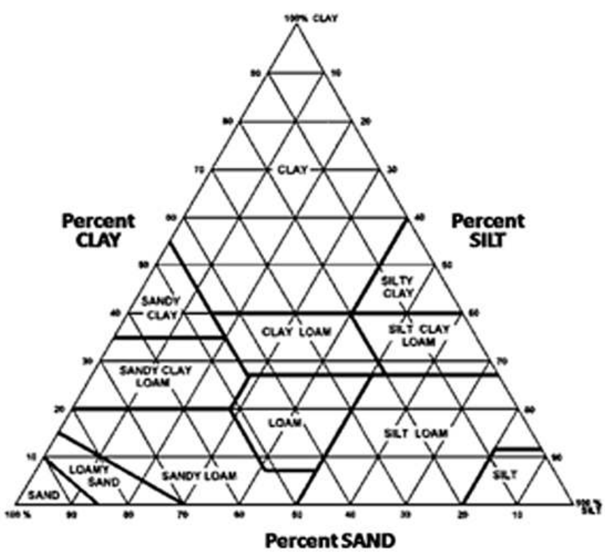


Figure 6. The soil triangle used to reveal the type of \soil according to its percent composition.

Figure 7. The portable pH meter used to measure soil pH.

Soil pH *(by pH meter)*

Measurement was done by the use of a pH meter (previously calibrated in a Buffer solution with pH 4, 7 and 10), wherein the glass electrode of the meter was dipped into a water suspension of 1:1 soil-water ratio (Figure 7).

Organic Matter *(Walkley and Black)*

The organic matter content of the soil was determined by Walkley and Black method. The method involved measuring the reducing power of soil organic matter under specified conditions.

The total soil organic matter was estimated by measuring organic carbon content. Organic matter can reduce a compound such as $K_2Cr_2O_7$ because it is a reducing agent. In this process, organic matter is itself oxidized, largely to CO_2 and water. It is a wet oxidation procedure and back titration to measure the amount of unreacted dichromate. The extent of oxidation of organic matter by $K_2Cr_2O_7$ under suitable conditions provides an index to organic matter content.

Available Phosphorus (*Olsen's Bicarbonate Extraction*)

The most common way of determining P availability was to mix a small amount of soil with an extracting solution. Sodium bicarbonate (0.5M $NaHCO_3$) was the extracting solution at pH 8.5. It removed adsorbed phosphate from the soil while precipitating calcium ions into carbonates, while aluminum and ferric ions as hydroxides. The extracting solution and soil were separated by filtration and the amount of P extracted was determined. The original procedure required a 5 g dried soil shaken for 30 min in 100 mL extracting reagent containing 1 teaspoon of acid washed activated carbon. The use of carbon black eliminated the color of the extract. Method of measurement was by use of UV-VIS spectrophotometry employing 660 wavelength after 10 minutes and the blue color developed after adding ammonium molybdate and stannous chloride.

Available Sulfur *(Turbidimetry Method)*

Sulfur (S) exists in soil in the form of sulfides, sulfates and organic sulfur. Sulfate anions (SO_4^{2-}) are the primary form absorbed by plants, although S being released from primary minerals (sulfides) and soil organic matter will contribute to that available to plants. Organic sulfur is believed to become available primarily through microbial conversion to sulfates.

The method described herein assumes that available sulfur is primarily in the form of sulfates. Acetate soluble sulfate (SO4) ion was extracted aided by activated carbon from a 10 gram air dried soil using 0.5M ammonium acetate – 0.25M acetic acid as extractant. Sulfates were precipitated by barium chloride and "seed solution" and the turbid white solution produced was measured in a spectrophotometer at 420 nm wavelength.

Iron *(Colorimetry)*

This element is relatively abundant in soils. It exists in soil as exchangeable cation (ferric and ferrous). It is ferrous under anaerobic conditions and ferric under aerobic conditions that can be detected. Iron was extracted by treating the soil with 1 N ammonium acetate solution at pH 4.8. Iron was analyzed from the extract by atomic absorption spectrophotometry or by reduction with hydroxylamine hydrochloride and development of the ferrous orthophenanthroline color. Absorbance was measured against the solution without orthophenanthroline reagent at wavelength of 510nm.

RESULTS AND DISCUSSION

Owing to the different physiographic conditions of the Jalaur River System and its watershed, assessment and monitoring of the hydrological features and some physico-chemical parameters of sediments in tributaries were done at least three times per season at each of the five sampling sites during the rainy season (July-September 2009) and the dry season (January-March 2010).

Hydrological characteristics like velocity, discharge, high and low level stages and other measurable parameters were taken on site during rainy and dry months of the year. Moving from upper stream to lower stream along the river, some hydrological processes and physico-chemical characteristics of the river system and sediments were encountered: abnormalities in the water depth, flow rate, color and transparencies were obviously observed on the midstream sampling sites and lower stream particularly towards the end of study period (dry season). Water level and flow rate variations were observed on July 25 sampling due to the occurrence of a tropical storm and torrential rain brought by typhoon Jolina.

1. Water Depth

The water depth in the Jalaur River System particularly at the five sampling stations as measured during the wet and dry season (Table 1) shows the maximum depth of 6 meters observed in the downstream station during the rainy season that dropped to 4.5 meters towards the dry season. This can be attributed to the early on-set of the El Niño phenomenon in Panay Island. The minimum water depth during the wet season was observed in the upstream station with only 1.4 meters, however this dropped tremendously to as low as 0.45 meters during the last sampling (March 13, 2010). Moreover, during the dry season a remarkable decrease in water depth was observed in all stations. In the downstream station a water depth of 4.5 meters and 0.45 m in the upstream station were observed. Water depth in midstream station also decreased slightly during the dry season (Plate 1).

2. River Current and Flow Rate

Results for the river current and computed flow rate (discharge) (Table 1) indicate that the river current in the upstream station during

Plate 1. Jalaur River in July 2009 (wet season) when water level was measured at midstream sampling station (Moroboro, Dingle).

the rainy season was greater than the mid and downstream stations as shown by the value of 2.5, 2.2 and 0.33 m/sec, respectively. The high speed at the upstream can be attributed to the topography or elevation. However, the slack movement of water at the midstream (Moroboro, Dingle) was due to the presence of the dam that regulated the volume and flow of river water for irrigation purposes. The velocity slowed down (0.37, 0.20 and 0.08m/sec for the upper, mid and downstream) as the volume of water decreased towards the drier months. Likewise, the river current and volume discharges were also higher (108.5, 41.04, and 19.99 m^3/sec) in the wet season than in the dry season (3.89, 29.40, and 28.08 m^3/sec) for the upper, middle, and downstream. The increase of water depth (19.99 to 28.08 m^3/sec) at the downstream (Nabitasan, Leganes) was due to the occurrence of high tide during sampling.

Table 1.

Hydrological characteristics of Jalaur River during the months of July 2009 to March 2010

Sampling Site	River width (m)	Water depth (m)	Water transparency (cm)	Flowrate (m/sec)	Volume discharge (m^3/sec)	Water color
Banban Pequeño, Calinog	36.8	1.40 - 0.45	5 - 32	2.5 - 0.37	108.5 - 3.89	murky brown - clear
Imbang Pequeño, San Enrique	40.0	1.35 - 0.45	10 - 35	2.2 - 0.67	100.0 - 12.06	murky brown - black
Licuan, Dingle	80.0	1.35 - 1.50	10 - 55	1.2 - 0.09	85.0 - 6.32	brownish green
Sampling Site	**River width (m)**	**Water depth (m)**	**Water transparency (cm)**	**Flowrate (m/sec)**	**Volume discharge (m^3/sec)**	**Water color**
Moroboro, Dingle	71.0	2.6 - 2.1	12 - 32	0.22 - 0.20	41.04 -29.40	brown - yellowish green
Nabitasan, Leganes	89.6	6.0 - 4.5	15 - 31	0.33 - 0.08	19.99 -28.08*	brown - light green

* High tide period during sampling

3. Water transparency and Color

Water transparency during the wet season ranged from 5–15 cm from the upstream in Calinog down to the lower stream sampling station in Leganes, whereas, the water transparency reading obviously increased from 31–55 cm with a mean value of 37 cm during the dry season. The low transparency during the wet season can be attributed to high turbidity brought about by soil erosion during heavy rains and flooding. Towards the dry season the water transparency became

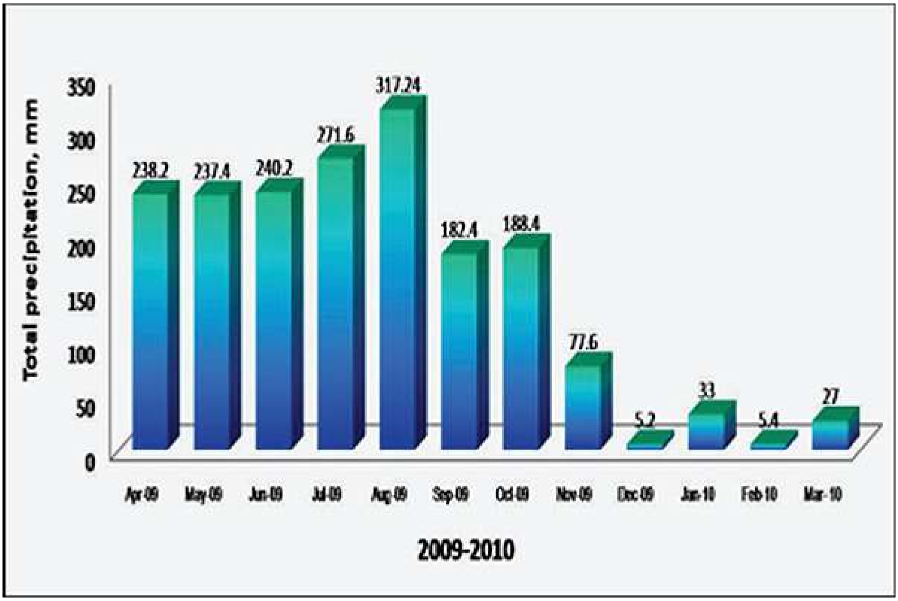


Figure 8. Average rainfall data collected daily for the period covering April 2009 to March 2010 by the AgroMet-PAG-ASA Weather Station in Dumangas, Iloilo.

higher indicating lower turbidity.

Color of the water changed from murky brown to brown during the wet season and clear to light green during dry months from Calinog (upstream) down to Leganes (downstream) except in Imbang Pequeño, San Enrique site where very undesirable color (black) and odor (ammoniacal) during dry months (milling season) were observed (Table 1).

4. Rainfall

The average rainfall data provided by the AgroMet–PAG-ASA Weather Station in Dumangas, Iloilo illustrated the trend of precipitation for the period April 2009 to March 2010 (Figure 8). High precipitation was recorded between months of July to August 2009 when tropical storms started to occur to include the area where this study was conducted.

Furthermore, daily precipitation was recorded for the period when the study was conducted (Figures 9 and 10). The data were obtained from Iloilo State College of Fisheries (ISCOF) at their Automatic Weather Hydrometer Station in San Enrique, Iloilo. Similarly, high

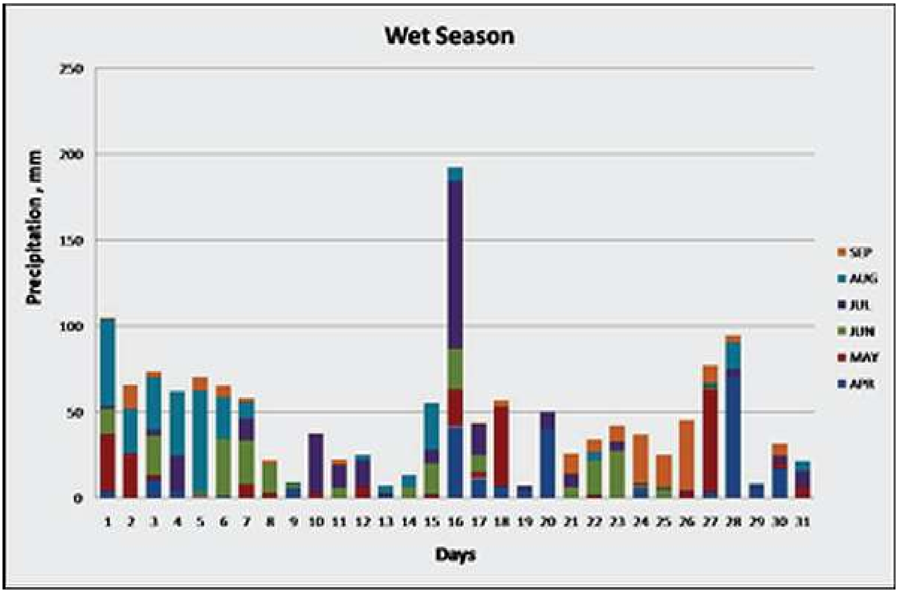


Figure 9. Daily rainfall data collected by ISCOF at their Automatic Weather Hydrometer Station in San Enrique, Iloilo for the wet season, period covering April to September 2010.

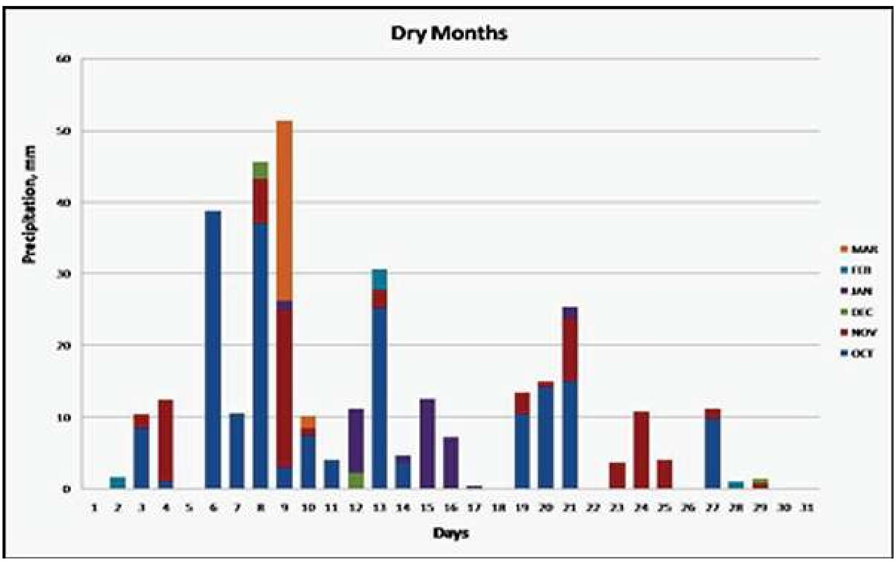


Figure 10. Daily rainfall data collected by ISCOF at their Automatic WeatherHydrometer Station in San Enrique, Iloilo for the dry season, period covering October 2009 to March 2010.

rate and volume of rain took place in the second half of July towards the end of August. On the other hand, rainfall seemingly drew closer to an end in the last quarter of November 2009 when the El Niño phenomenon came about earlier than forecast, possibly indicating the worsening situation of climate change.

Highest precipitation of 317.24 mm in wet season and barely 5.2 mm during dry season was recorded.

Rainfall also affects soil pH. Water passing through the soil leaches basic nutrients such as calcium and magnesium from the soil. They are replaced by acidic elements such as aluminum and iron. For this reason, soils formed under high rainfall conditions are more acidic than those formed under arid (dry) conditions. Sulphates of iron and ammonium, elemental sulphur and organic matter are used to lower the pH (increase acidity) of the soil (Daniel, Carton, & Magette, 1997).

5. Bottom Sediments

Soil texture helps us to understand how a soil will perform. Thus, a better understanding of soil physical properties can benefit several sectors of society from common laypersons to scientists. This type of knowledge is crucial when evaluating soils. For example, a soil that is high in silt and clay will pack tighter and drain slower than a sandy soil. Consequently a fine textured soil may be highly desirable for an embankment but not as a good as agricultural soil. A simple approach to determining texture will not work if the soil contains a lot of gypsum which is normally pinkish white in color.

Bottom sediments were subjected to mechanical size analysis. Result of the particle size, distribution, and soil texture analysis showed that the sediments in upstream station was sandy while those sediments taken from the midstream and downstream stations were found to be sandy loam to silty loam, respectively (Table 2).

Soil texture, in this case clay content, exerts a major control on the amount of slow moving sediments and therefore influences the storage and deposition of heavy sand and silt while decreasing the dynamic flow of the river water. Very coarse sand and medium sand dominated the upstream station while a higher percentage of mixed fine sand, silt and clay comprise the soil structure of sediments in the midstream and downstream stations. Changes in season during the course of the experiment barely brought alterations, and neither did they cause transformations on the structure and texture of sediments examined. Silt and clay deposition in the downstream (Nabitasan,

Table 2.

Soil texture and composition of sediments taken from sampling sites along the Jalaur River during the duration of experiment (July 2009–March 2010).

Sampling Site	Wet Season (July—September)				Dry Season (January—March)			
	Percent			Classification	Percent			Classification
	Sand	Silt	Clay	Texture	Sand	Silt	Clay	Texture
Banban Pequeño, Calinog	89.24	7.69	3.07	Sand	89.80	7.14	3.06	Sand
Imbang Pequeño, San Enrique	90.70	8.14	1.16	Sand	83.10	4.08	2.82	Sand
Licuan, Dingle	56.08	40.54	3.38	Sandy Loam	87.94	11.56	0.50	Sandy Loam
Moroboro, Dingle	39.07	58.94	1.99	Silty Loam	11.06	84.33	4.61	Silty Loam
Nabitasan, Leganes	38.12	60.00	1.88	Silty Loam	36.49	61.00	2.51	Silty Loam

Leganes) showed some differences but not so remarkable after series of flooding typhoon and torrential rains.

Discharge-sediment concentration can be correlated to the total suspended solids (TSS) results of the water samples taken simultaneously. This situation results from the combination of the different hydrological regimes in the upper, middle and lower streams of the Jalaur River System. The results reflect the influence of the upper stream tributaries (high discharge and high silt content during rainy days, whereas the dry season sampling months (January to March) show the effect of early on-set of El Niño occurrence on the river system's hydrological characteristics particularly water depth, flow rate, and transparency.

Soil pH or soil reaction is an indicator of the acidity or alkalinity of soil and is measured in pH units. An acid solution has a pH value of less than 7. While a basic solution always has a pH larger than 7, an alkaline solution (i.e., a solution with positive acid neutralizing capacity), can also be defined as the negative logarithm of hydrogen ions in the soil (Smith, Peoples, Keerthisinghe, James, Garden, & Tuomi, 1994). It therefore does not necessarily have a pH larger than 7. Soils tend to become acidic as a result of: [1] rainwater leaching away basic ions (calcium, magnesium, potassium and sodium), [2] carbon dioxide from decomposing organic matter and rain water forming weak organic acids, and [3] decay of organic matter and ammonium and sulfur contents. The pH value of a soil is influenced by the kinds of parent materials from which the soil was formed (Eliason, 1999). Soils developed from basic rocks generally have higher pH values than those formed from acid rocks (http://www.smartgardening.com)

The range of the physico-chemical characeristics of the sediments taken from the different sampling sites of Jalaur River (Table 3) shows soil pH was neutral to slightly basic.

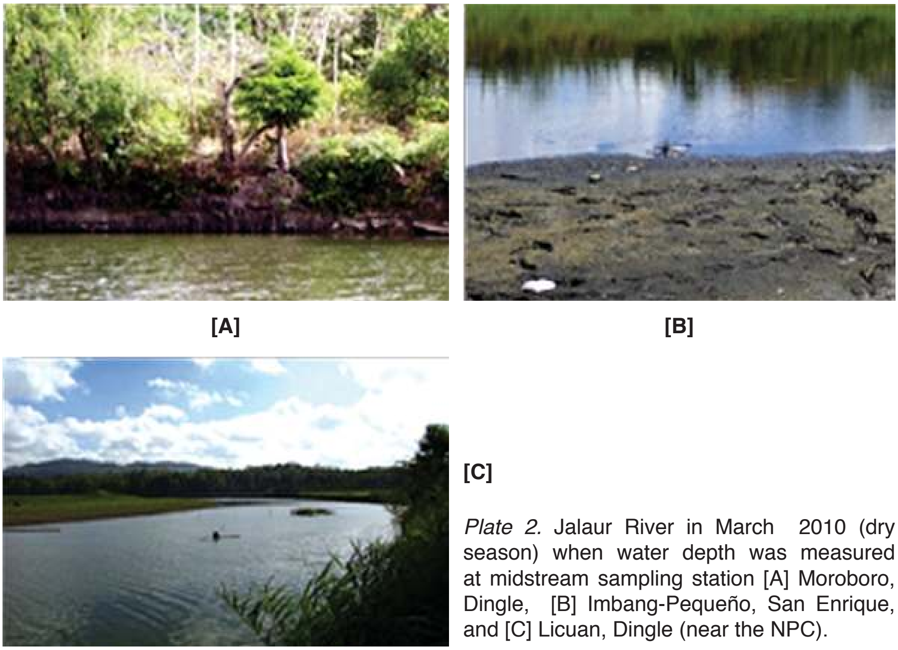
Phosphorus is one of the three nutrients generally added to soils in fertilizers. The concentration of P is usually sufficiently low in fresh water so that algae growth is limited. When lakes and rivers are polluted with P, excessive growth of algae often results. High levels of algae reduce water clarity and can lead to decreases in available dissolved oxygen as the algae decays, conditions that can be very detrimental to game fish populations. Many phosphate compounds are not very soluble in water; therefore, most of the phosphate in natural systems exists in solid form. However, soil water and surface water (rivers and lakes) usually contain relatively low concentrations of dissolved (or soluble) phosphorus S. Depending on the types of minerals in the area, bodies of water usually contain about 10 ppb or more of dissolved P as orthophosphate. This is usually estimated by a chemical test that is designed to measure the dissolved P and the particulate P that are easily available (APHA 1989). In soils, P may exist in many different forms, however, P in soils can be thought of existing in 3 "pools": [1] solution P pool, [2] active P pool, and [3] fixed P pool.

The solution P pool is very small, usually in the orthophosphate form. The active P pool is P in the solid phase which is relatively easily released to the soil solution. The **fixed P pool** of phosphate will contain inorganic phosphate compounds that are very insoluble and organic compounds that are resistant to mineralization by microorganisms in the soil. Phosphate in this pool may remain in soils for years without being made available to plants and may have very little impact on the fertility of a soil. Some slow conversion between the fixed P pool and the active P pool does occur in soils (Korol & Rattray, 1999).

Phosphorus in soils is almost entirely associated with soil particles. When soil particles are carried to a river or lake, P will be contained in this sediment. When the sediment reaches a body of water it may act as a sink or a source of P in solution. In either case, it is a potential source of P that may eventually be released (Maguire, Sims, & Coale, 2000). Most soils have a large capacity to retain P. Increasing the amounts of phosphate in soils results in increased levels of phosphate in soil solutions. This will generally result in small but potentially important increases in the amounts of phosphate in water that passes over or through soils (Sui, Thompson, & Shang, 1999).

Phosphorous (P) exists in various forms in mineral soils, being equally divided between that in soil organic matter and that in various inorganic forms. The latter P forms are primarily mixtures of aluminum, iron, and calcium phosphates. Under acidic conditions, phosphates combine with iron and aluminum and under alkaline condition it is present as calcium phosphate. Consequently, the extraction procedure for the measurement of plant-available P will be governed to a large degree by soil pH. The highest phosphorous availability is in the pH range of 6–7. Phosphate in mud is released in large amounts to the water when iron and aluminum dissociate under reduced condition. Phosphorous in mud is important in regulating phytoplankton productivity.

Available phosphorus was lower (11.22–15.68 ppm P) in soils during the wet season compared to a range value of 14.04–30.50 ppm P in the dry months in all sampling stations. This can be attributed



[A] [B]

[C]

Plate 2. Jalaur River in March 2010 (dry season) when water depth was measured at midstream sampling station [A] Moroboro, Dingle, [B] Imbang-Pequeño, San Enrique, and [C] Licuan, Dingle (near the NPC).

to human activities observed during sampling such as laundering, quarrying and fishing. But a most peculiar situation was observed in midstream (Imbang, Pequeño-San Enrique, Moroboro and Licuan, Dingle) where Sugar Mill and National Power Corporation effluents are discharged indiscriminately (Plate 2). Available P in wet season could have been due to dilution, erosion and leaching process brought about by amount of rain received thus increasing water volume and depth.

Iron is essential for many plant functions. However, iron toxicity is primarily pH related and occurs where the soil pH has dropped sufficiently to create an excess of available Iron (Tisdale, Nelson, Beaton, & Havlin, 1993). Iron toxicity can also occur when Zinc is deficient, or the soil is in a "reduced" condition caused by very wet or flooded conditions. Potassium (K) appears to play a very specific, but poorly understood role in the utilization of Fe. Some research indicates that low K availability can result in increased Fe uptake (Daniel, Carton, & Magette, 1997), whereas iron deficiency can be induced by the presence of the bicarbonate ion in the soil (saline and alkali conditions). Iron presents some difficulties for plant analysis also because [1] it is often a contaminant on samples that have any dust on them, [2] Fe can exist in a leaf in a non-functional form, and

Table 3.

The various physico-chemical parameters of sediments taken from five sampling sites of Jalaur River evaluated during the wet and dry seasons

Sampling Site	pH (pH meter)	Available Phosphorus (Olsen's Bicarbonate Extraction), ppm P	Available Iron (Colorimetry) ppm Fe	Acetate Soluble Sulfate (Turbidimetry Method) ppm SO_4^{2-}	Organic Matter Content (Walkleyand Black), %
Banban Pequeño, Calinog	7.44 - 8.17	12.02 - 14.04	18.31 - 20.40	153.06 - 55.86	2.54 - 0.04
Imbang Pequeño, San Enrique	7.73 - 7.61	11.22 - 30.50	25.81 - 52.36	133.83 - 80.46	0.30 - 0.26
Licuan, Dingle	7.12 - 7.80	13.67 - 16.14	2.05 - 36.01	148.52 - 100.30	1.40 - 0.26
Moroboro, Dingle	7.10 - 7.92	14.21 - 21.34	7.31 - 84.91	135.25 - 126.49	4.53 - 2.46
Nabitasan, Leganes	7.88 - 8.07	15.68 - 19.90	17.32 - 89.83	172.01 - 385.91	1.31 - 0.65

[3] a crop may respond to foliar Fe due to a low Fe:Mn ratio in the tissue, even when Fe is adequate by "critical level" standards (Van Cappellen & Wang, 1996).

Consequently, the amount of available Iron increased during the dry season (20.40–89.83 ppm Fe) as compared to the rainy season as shown in the values ranging from 2.05 to 25.81 ppm Fe in all sampling stations. The iron content increase can be attributed to the rapid absorption by the sediments during high rate of evaporation and oxidation parallel to slow discharge rate and low volume of the river system.

Sulphur used as an amendment is available in powder (micronized sulphur) or granular form. It is used to acidify soil. Sulphur has a medium- and long-term effect on soil. This means that it should be applied one or two years before planting (Alam, Prasad, Singh, Nath, & Kumar, 2000). Granular sulphur works more slowly than powdered sulphur, but is longer-lasting. It is also easier to apply, leaches out of the soil more slowly and produces less dust. Iron sulphate is very useful for lowering soil pH quickly, especially when plants show signs of an iron deficiency (Brar, 1998).

The forms of sulphur in soils determine their availability for plants, while the method for determination of available S in soil has a relationship between available sulphur and plant growth. Soil organic sulphur is the main source and supplement of soil available sulphur and needs to be considered in the evaluation of plant available S in soils (Chensuin & Yien, 1951).

Results (Table 3) also clearly showed higher values of 133.83–172.01 ppm SO_4^{2-} during the wet season that decreased to 55.86–126.49 ppm SO_4^{2-} during the dry months in all stations except at the downstream (Nabitasan, Leganes). Likewise, as the amount of available Fe increased in the dry season, the concentration of acetate soluble sulfate decreased except in Nabitasan, Leganes that abnormally increased twice the initial value. The increase in SO_4^{2-} at the downstream can be ascribed to the intrusion of seawater normally high in sulfates and chlorides owing to a salinity value of 6 ppt. Soluble sulfates become abundant in soils submerged in brackish to seawater.

Organic Rich Bottom Sediment

Correspondingly, the organic matter content of the sediments taken from all sampling sites yielded a wide range of higher values (0.30–4.53 %) during the wet season that decreased to 0.04 from 2.46 %

Plate 3. Sources of fecal pollution in upstream and midstream stations (grazing ruminants and other natural animal populations and human activities).

Plate 4. Possible future human activities in the event of total degradation of the Jalaur river bottom sediments and its implications to biota.

in dry months from upstream to downstream. Sediments from the midstream (Moroboro, Dingle) marked out to have the highest value of 4.53–2.46 % (wet to dry months) as detected. Sediment accumulation and decaying materials that had flowed in and got trapped before the dam constructed on the site can be one of the reasons for this high value observed. However, most storage can occur in organic matter pools with turnover times less than a decade but not as fast as a year's time. More work is required to assess the export potential for periodically inundated or submerged soils.

Without a doubt, organic matter is the most important soil component. It provides food and shelter for the flora and fauna in the soil. As it is broken down by microorganisms, it releases the nutrients that are essential to plants. Humus binds the soil particles together, allowing them to form stable aggregates and to improve the soil structure (Lehmann, Bernasconi, Barbieri, & McKenzie, 2002; Meyers, 1994). A soil test will tell you exactly how much organic matter soil contains. Healthy soil contains at least 5% organic matter. Compost and composted manure are the main sources of organic matter. A high load of organic matter is sometimes found in the bottom sediment of a river system. This is a typical example of the poor water management imposed in the area. This is partly due to the lack of understanding of water quality in the river. Organic rich bottom sediment is a "silent killer" for aquatic plants and animals because it may cause high levels of toxicity that diffuse from the sediment and enter into the water column. To overcome this problem, the organic rich sediment must be removed or processed to reduce the organic content (Ganeshram, Calvert, Pedersen, & Cowie, 1999; Twichell, Meyers & Diester-Haass, 2002).

CONCLUSION AND RECOMMENDATIONS

This report summarizes the results of monitoring on hydrological data and physico-chemical parameters of sediments obtained from five sampling sites done in Jalaur River with some details of the stream flow and rainfall data studied. Also, the sediments taken from the river at the different sampling points were used to determine the various physico-chemical characteristics of the Jalaur River bottom sediments.

The results of this study show that sediment agitation by recreational activity and storm surges associated with the dry-cold season are responsible for the impact to bottom sediment quality and not recreational users directly, as revealed by test results. We have analyzed that for a relatively short timescale (1 year), the mixing regimes and rainfall within sampling sites had only slight dependence on height and flow discharge. Dispersion or sediment texture change was not evident from one season to another. A fairly wide range of sediment's physico-chemical parameter values allows us to conclude that the results of the present study are beneficial to the end users of Jalaur River System and its attributes. The Jalaur River and its sediments can still offer parameters for good agriculture and fisheries activities. However, it is important to describe the effects of present human activities in order to formulate better monitoring and mitigations to preserve and maintain the integrity of the river for future use.

This implies that a follow up study and continuous monitoring is needed to ensure the safety of all end users of the river system otherwise its only use in the future will be for quarrying of concreting and embankment materials for civil work projects.

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