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Characterization of the Bago Sub-basin Pilot implementing the EU Water Framework Directive

Norwegian Institute for Water Research

REPORT

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Summary

The aim of this report is to characterize the Bago Sub-basin, located in the Bago Region in the south-central part of Myanmar. The report presents the different characterization steps, including methods for identifying water use and water users, economic analysis of water usage, monitoring and ultimately a risk assessment of water bodies with respect to the goal of reaching good ecological status. Major pressures to the streams in this area are domestic waste water run-off, heavy garbage littering, construction of dams and other hydro morphological alternations, deforestation, sand mining and gold mining, as well as runoffs from plantations and agricultural areas. There is not much heavy industry in this area, although saw mills, fish farms/ponds, pulp industry and gold mining may influence on the water quality in some areas. A biological and water chemical monitoring program is proposed based on the occurring pressures. Based on data presented is this report, water bodies were classified as "at risk", "possibly at risk" and "not at risk" of having good status. There were uncertainties about the risk assessment in several areas because little information was available. However, the areas near and downstream the Bago City are with no doubt "at risk".

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Characterization of the Bago Sub-basin, Pilot implementing the EU Water Framework Directive

Preface

The Bago Sub-basin in Myanmar has been selected as a pilot case study by the project 'Integrated water resources management – Institutional building and training' (the IWRM project) for pilot testing the River Basin Management Approach. The objective of the River Basin Management Approach is coordination of sector and environmental authorities and involvement of Non-Governmental stakeholders within a catchment area. The rational of the approach lays in the situation that all components of a water system need to be understood in relationship with each other.

The IWRM project is a collaboration between the Norwegian Institute for Water Research (NIVA) and the Department of Forest, Ministry of Natural Resources and Environmental Conservation (MONREC). The project leader at MONREC is U Bo Ni, director of Watershed Management Division, Forest Department, and researcher Ingrid Nesheim is the project leader at NIVA. The steering group has representatives from Forest Department (FD), Irrigation and Water Utilization Management Department (IWUMD), the Directorate for Water Resources and Improvement of River Systems (DWIR) and NIVA. The project leaders have a close dialogue with the National Water Resources Committee in Myanmar. The project is part of the Norwegian – Myanmar Bilateral Environment Programme, 2015-2018, and is funded by the Norwegian Ministry of Foreign Affairs. The development goal of the IWRM project is to make a significant and positive contribution to the implementation and functioning of Integrated Water Resources Management in Myanmar, for inland waters at the national level. The objective is to establish methods and standards for Integrated Water Resources Management and to support initiation of the implementation process.

River Basin Management Plans (RBMPs) have been put forward as an important tool for securing and improving environmental status of water resources by several Integrated Water Resources Management (IWRM) frameworks such as the EU WFD, the UNESCO guidelines, and the IWRM concept co-developed by the Asian Development Bank and Asian River Basin Organizations (NARBO). Such RBMPs are prepared based on several distinct steps in a water management cycle where, characterization of the basin to get an overview of biogeographic conditions, climate, socio-economy, problems and pressures and needs are commonly prescribed as the first step towards development of a RBMP.

The main purpose of this report is to present the characterization step, including methods for identifying water use and water users, economic analysis of water usage, monitoring and ecological status classification of surface waters, and results from the Bago Sub-basin. The report has been prepared by Tor Erik Eriksen, Ingrid Nesheim, Nikolay Friberg (NIVA), Toe Toe Aung (Watershed Management Division, Forest Department) and Zaw Win Myint (Forest Department Bago Region), with input from, Ko Ko Oo (Irrigation and Water Utilization Management Department, Bago Region), Htay Aung (Directorate of Water Resources and Improvement of River Systems, Bago Region), and the three secretaries of the Non-Governmental Stakeholder Group, Dr. Hein Thant Zaw, Mg Mg Kyi, and Aung Myo Htut. The report was quality assured by Dr. Markus Lindholm (NIVA).

We hope the report will serve as useful guideline for how to characterize a basin to determine what factors influence and control water quality and quantity.

Oslo, 19. October 2017
Ingrid Nesheim

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Summary

The aim of this report is to characterize the Bago Sub-basin which is located in the Bago Region in the south-central part of Myanmar inspired to the European Water Frame directive. The report includes a description of different water users, uses and pressures, and ultimately a preliminary classification and risk assessment of water bodies with respect to the goal of reaching good ecological status. The risk assessment, is evaluated based on ecological and chemical criteria. The summary below provides the main points presented in this report.

The Bago Sub-basin includes the Bago River, which flows from the Pegu Yoma mountain range running south through meandering sections of over 331 km before it reaches the Yangon River. There is a main environmental difference with regard to topography and associated soil cover between upper and lower Bago Sub-basin. Upstream of the Bago City forested areas can be found and land use is dominated by forestry, while agriculture dominates the lower part of the Sub-basin. The lower part of the sub-basin is more populated than the upper part, hence it is expected to find water bodies of low human impact in the upper areas of the basin.

We refer for most part to the Bago District when characterizing socio-economic parameters in the Bago Sub-basin. The four townships of Bago, Waw, Thanatpin and Kawa have been selected as case study townships. In the Bago District, people mostly rely on subsistence farming and fishing for their livelihood. The main use of water in the district is for irrigation in the summer season. Utilization of water by the industry is not monitored, but it can be assumed that industrial usage in Bago Sub-basin is low due to low industrial activity. For domestic water usage, the provision of the public water supply system is about five percent. Inhabitants depend on rainwater and shallow wells, the river, or drinking water reservoirs. Sewage is collected from septic tanks in the city, but there is no treatment of sewage or waste water in the district.

A brief economic analysis is provided as recommended by the EU WFD. The purpose is to understand the situation of the different economic actors in the basin to enable development of effective policies and incentives for efficient use of water.

The report provides an overview of pressures. A pressure impact analysis is important to prioritize a preliminary monitoring program as the program. A monitoring program needs to cover sampling sites in water bodies being at risk of not meeting the environmental objectives. This overview of pressures is also important as a basis for where to target abatement measures.

In the project, the Bago Sub-basin Area Committee has been formed to serve as a coordinating arena for sector and environmental authorities as part of pilot implementing the River Basin Management Approach in the Lower Sittaung River Basin Area. The Bago Non-Governmental Stakeholder Group was formed to provide input to the discussion and the decision making of the Committee. During their discussions of pressures in Bago Sub-basin, the practice of disposing garbage and sewage into the river were identified as prioritized pressures. Another pressure discussed and emphasized as causing problems is sand mining in Bago River. Erosion is a general problem in the region. The areas alongside the Bago River around the Bago City Area and downstream Bago City River, have little vegetation cover causing runoff of soils, phosphorus, and nitrogen from agricultural areas to the river. Furthermore, concurrently, invasive species of shells are destroying local rice fields.

The evaluation of ecological status must include biological quality elements (such as macroinvertebrates, fish, algae, plants) physico-chemical supportive elements (such as nutrients and

biological oxygen demand) and any river basin-specific pollutants (such as heavy metals), and hydro-morphological degradation. Chemical status is based on environmental quality standards for prioritized substances in the river basin, specified by a maximum concentration that cannot be exceeded.

Information on water users and usage, have been provided using available literature, as well as interviews and direct information from relevant departments in Myanmar. The assessments of geological and land use patterns provided in this report has been undertaken by using available, open source GIS maps. A monitoring program was established to investigate the status of surface waters in the Bago River basin. Of river-basin specific pollutants were copper (Cu), chromium (Cr), manganese (Mn), iron (Fe) and arsenic (As). Physico-chemical quality elements and parameters were: pH, turbidity, suspended solids, alkalinity, calcium (Ca), potassium (K), chloride (Cl), magnesium (Mg), sodium (Na) and sulfate (So), total nitrogen, nitrate, phosphate, total phosphorus, ammonia. Attempts were also made to include analysis of bacteria (Escherichia coli; E. coli), as well as chemical and biological oxygen demand. However, because these samples require the initiation of analysis usually within 24 hours, and there are long travelling distances to the sample sites, these parameters are not analyzed routinely. The EU's priority substances analyzed in as part of the project were mercury (Hg), cadmium (Cd), zinc (Zn), nickel (Ni) and lead (Pb).

Water quality criteria for these perturbations do not exist in Myanmar, and therefore class boundaries for chemical substances (metals and nutrients) have not been defined. Therefore, to make a preliminary classification and risk assessment, we adopted criteria from Europe to do a preliminary classification and risk assessment. Our results show that areas in forested areas with no or few human settlements are "not at risk", whereas areas in the Bago City and downstream are "at risk". There were uncertainties about the status in several places and these are classified as "possibly at risk".

<u>The report gives the following conclusions and recommendations:</u>

1. Population density in a river basin is an important parameter for evaluating water needs and the human impact on water quality and quantity. Information on socio-economic groups and the types of economic activities that are found in the basin is important for risk assessment of water bodies with reference to identified environmental aims.
2. Rarely however, are socio-economic data available within the boundaries of basins; there is a need in most cases to estimate information on the basin level, based on information available from administrative units.
3. As part of characterizing water bodies in the basin, it is recommended to provide a register of protected areas – identified as areas requiring special protection under existing national or regional legislation or with reference to specific water use criteria, or for the conservation of habitats or species that directly depend on those waters
4. A major incident of non-point source pollution into rivers and streams is related to the monsoon season, as heavy precipitation acts as surface wash-off for various pollutants.
5. We believe that it will be possible to create an ecological status evaluation system based on the biological quality element benthic macroinvertebrates in Myanmar streams. However, more data is needed from stream reaches along gradients of anthropogenic degradation, from non-impacted to very perturb, to see whether the creation of a five-class system is possible. Such data can also be used to suggest class boundaries for physico-chemical supportive elements, such as nutrients and biological oxygen demand, as well as chemical substances like heavy metals. We therefore support that the chemical and ecological

monitoring continues. However, we support that more emphasis is put on organic pollution, nutrients and bacteria because this seems so be the main pressures and stressors acting on streams in this region.

6. Based on data presented is this report, water bodies were classified as “at risk”, “possibly at risk” and “not at risk” of having good status. There were uncertainties about the risk assessment in several areas because little information was available. However, the areas near and downstream the Bago City are with no doubt “at risk”.

1 Introduction

River Basin Management Plans (RBMPs) have been put forward as an important tool for securing and improving environmental status of water resources by several Integrated Water Resources Management (IWRM) frameworks such as the EU Water Framework Directive (European Commission, 2000), the UNESCO guidelines (UNESCO, 2009), and the IWRM concept co-developed by the Asian Development Bank and Asian River Basin Organizations (NARBO) (ADB, 2001). Such RBMPs are prepared based on several distinct steps in a water management cycle where, characterization of the basin to get an overview of biogeographic conditions, climate, socio-economy, problems and pressures and needs are commonly prescribed as the first step towards development of a RBMP. The RBMP typically summarizes the ecological and chemical status of the water bodies, sets environmental goals and abatement measures and forms a basis for local, regional and national authorities' activities by administering water resources with a holistic approach, and as the concept indicates, all within the river basin. The rationale of the river basin management approach is based on the concept that all components within a catchment area are linked through the hydrological cycle and hence the component parts of a water system need to be understood in relationships with each other (See report; Zaw Lwin Tun et al. 2016).

Myanmar has adopted the vision that: *In 2020 Myanmar will become a water efficient nation with well-developed and sustainable water resources based on fully functional integrated water resources management systems (NWRC, 2014)*. Furthermore, the principle of the river basin management approach is emphasized as an important objective for Myanmar in both the National Water Framework Directive (NWFD) (Appendix G, H) and the National Water Policy (NWP).

Under this frame, the Bago Sub-basin has been selected as a pilot case study by the project 'Integrated water resources management – Institutional building and training' (IWRM project). The IWRM project is a collaboration between the Ministry of Natural Resources and Environmental Conservation (MONREC, previously MOECAF) and the Norwegian Institute for Water Research (NIVA) under the Norwegian – Myanmar Bilateral Environment Program 2015 – 2018. The project aims to make a significant contribution to the implementation of well-functioning Integrated Water Resources Management (IWRM) for inland waters at the national level for Myanmar. The pilot implementation of the river basin administrative approach in Myanmar in this project, is inspired by the EU WFD, and specifically for this report, Article 5 (European Commission, 2000). It is acknowledged that there is need for a close consideration of the Myanmar context. Among other considerations, this refers to the current and historical practice of coordination of water management tasks and decision-making in the country (Nesheim and Platjouw 2016).

The purpose of this report is to characterize the Bago Sub-basin using the principles of the EU WFD. Chapter 2 in this report provides a general description of the Bago Sub-basin, Chapter 3 presents an overview over pressures in the area, a first attempt of an ecological classification of the Bago Sub-basin based on preliminary data is provided in Chapter 4, Chapter 5 suggests a monitoring program for the Bago Sub-basin and Chapter 6 presents recommendations and remarks. This report mainly draws on, Mjelde et al. 2017; Water usage and introduction to water quality criteria for lakes and rivers in Myanmar, Preliminary report.

2 The Bago Sub-basin general description

2.1 Introduction

This chapter aims to set the scene for water resources management in the Bago District with reference to biogeographic and climatic conditions, water users and uses, history, and trends of environmental problems in the area. Such information contributes to the overall characterization phase within the water management cycle (Figure 2.1) of the EU WFD. Such information is also important in an initial step of most water management frameworks, as it provides information for where monitoring sites should be placed in the river basin. The network of monitoring sites needs to consider human impacts regarding the extent of point-source and diffuse pollution within the basin, and - nature's vulnerability to pollution based on geology, vegetation cover and landscape formations, and precipitation patterns. The purpose of such initial characterization is identification of water bodies that might be at risk of not meeting environmental aims, or at risk of not meeting specified water-use criteria linked to specific water uses (Mjelde et al. 2017). A general approach to risk characterization is to prepare a dataset of identified water bodies and human activities (pressures) within each respective water body, and then model the likely impact of these land-use activities on water quality. Data availability in Myanmar is however limited, hence expert judgment is heavily relied upon to assess the impact of pressures. Information from opinions of local elders, the general public and political discussions in local and national governments may provide a good indication of pressing environmental issues. The information is based on discussion with sector and environmental authorities in the sub-basin and with Non-Governmental stakeholders.

As part of the characterization step, the EU WFD also requires economic analysis of water usage on a river basin level. The purpose an economic analysis of water usage, is to provide a basis for: (i) identification of relevant water pricing policies as incentives for efficient use of water, and (ii) a fair contribution from the different water users to recover costs for water services – as is in accordance with the 'polluter pays' principle. However, an economic analysis is also intended to inform the principle of balancing environmental interests with those who depend on the resource (Nesheim and Platjouw 2016).

The Myanmar National Water Framework Directive (NWFD) (Appendix G,H)[1] and the National Water Policy (NWP) refer to economic instruments like water pricing and the polluter pays principle, and the Environmental Conservation Law enables the use of economic instruments. Yet current application of economic instruments in Myanmar is in its infancy and experience on the use of such instruments are limited. A thorough economic analysis of water usage has not been prepared as part of this report as access to the necessary data is limited. There is no register of water abstraction by different actors and economic data on water use has not been available. In this context, an overview of the different water users and usage is presented. A short description of what an economic water analysis entails is provided in this chapter.

[1] In Myanmar reformation of water legislation is presently an ongoing process, which is guided by the recently adopted National Water Policy (NWP, February 2014), and the National Water Framework Directive (NWFD, December 2014). These two policies[1] are complementary, but both aim for an integrated water management of watersheds, rivers, lakes and reservoirs, groundwater aquifers and coastal and marine waters of all of Myanmar. The NWP aims to develop, share and manage the water resources of Myanmar in an integrative, holistic and socially inclusive manner using a river basin management approach, while the primary aim of NWFD is good status of Myanmar waters (NWP, February 2014). These two policies set terms for a holistic water law and operational procedures under development.

The assessments of land use patterns provided in this report has been undertaken by using freely available GIS data and analyzed in ArcGIS (version 10.1). The catchment area for each sampling site was estimated, as was the relative land use degradation, by the application of orthophotos (Google Earth; Landsat/Copernicus) and open source maps (https://www.arcgis.com). Geological composition of soils was done by applying a soil map of 1: 5,000,000 (http://www.fao.org/; Digital Soil Map of the World; version 3.6). A digital elevation model (DEM) was provided by the Directorate of Water Resources and Improvement of River Systems (DWIR) of Myanmar. Maps showing infrastructure, settlements and land cover were acquired from Myanmar Information Management Unit (MIMU; http://www.themimu.info; retrieved 20.5.2017).

Information on water users and usage, have been provided using secondary literature, and interviews and direct information from relevant departments in Myanmar. Section, 2 of this chapter provides an overview of biogeography and climate, Section 3 describes water users, and usage, Section 4 describes economic analysis of water, and Section 5 lists various types of protected areas.

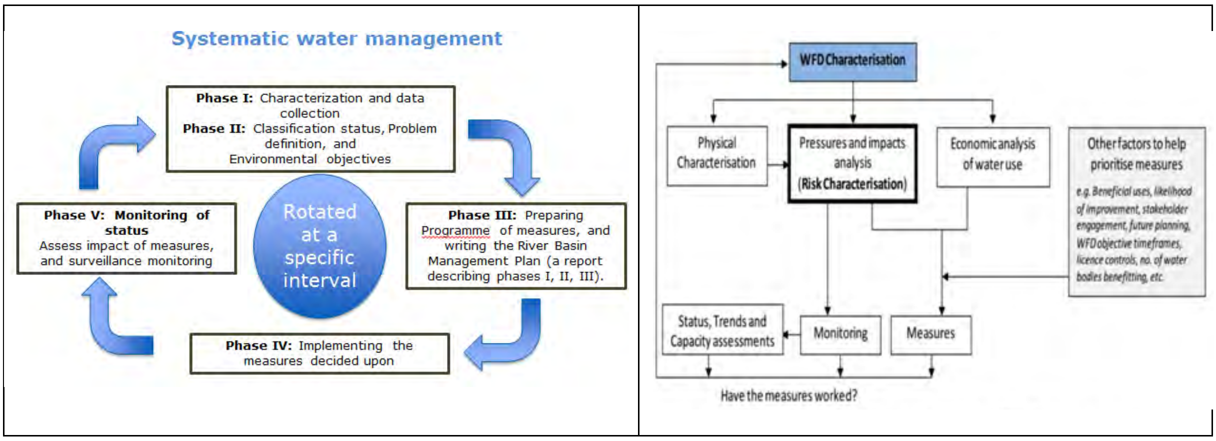


Figure 2.1 Left, Systematic water management with reference to the EU Water Framework Directive; right, Water Framework Directive Characterization, (Source: EPA, 2015).

2.2 Biogeographic, climate and waterflow conditions in the Bago Sub-basin

The Bago Sub-basin lays in the southern central part of Myanmar. It includes the Bago River, which flows from the Pegu Yoma mountain range at an elevation of 800 m.a.s.l. in the north, running south through meandering sections of over 331 km before it reaches the Yangon River near Yangon City (Haruyama 2013). The Sub-basin being relatively small, 5,359 km^2, is located between 95°53´ 30"E – 96°43´30" E longitudes and 16°43´ 15" N – 18°26´17" N latitudes, with the Sittaung River on the east and the Ayeyarwaddy and the Myintmakha Rivers on the west. The Bago Sub-basin is connected to the Sittaung River Basin by a 61-km long canal built in 1878 to regulate flooding (see Figure 2.3 and Appendix B). The canal is currently an important supplier for local irrigation. Almost two thirds of the Bago River, the main river in the Bago Sub-basin lie in the Bago District of the Bago Region, while only a small portion (the river mouth) falls under the Yangon Region. The Bago Sub-basin is therefore administratively and politically mainly located within the Bago District in the Bago Region. According to the River Basin Management (RBM) approach, the whole country should be divided into River Basin Areas, which again may be divided into smaller Sub-basin Areas to facilitate for practical management tasks and the development of River Basin Area and Sub-basin Area Management Plans (Zaw Lwin Tun et al. 2016). As part of a project workshop in Bago in 2015 (Zaw Lwin Tun et al. 2016), three Sub-basin Areas within the Sittaung River Basin Area were recommended; (i) the Lower Sittaung Sub-basin Area, (ii) the Middle Sittaung Sub-basin Area, and (iii) the Upper Sittaung Sub-basin Area. According to this approach, the Lower Sittaung Sub-basin Area includes the following administrative units: the townships of, Bago, Kawa, Thanatpin, Waw, DaikU, Nyaung Lay Bin, and Shwe Gyin Township in Bago District, and in Mon State the Kyaik Hto and Bilin townships within the Thaton District. This alternative was considered due to the Sittaung canal combining the Sittaung River with the Bago River. This report however, mainly focuses on characterizing the Bago Sub-basin (mostly the Bago District), and not the whole Lower Sittaung Sub-basin Area.

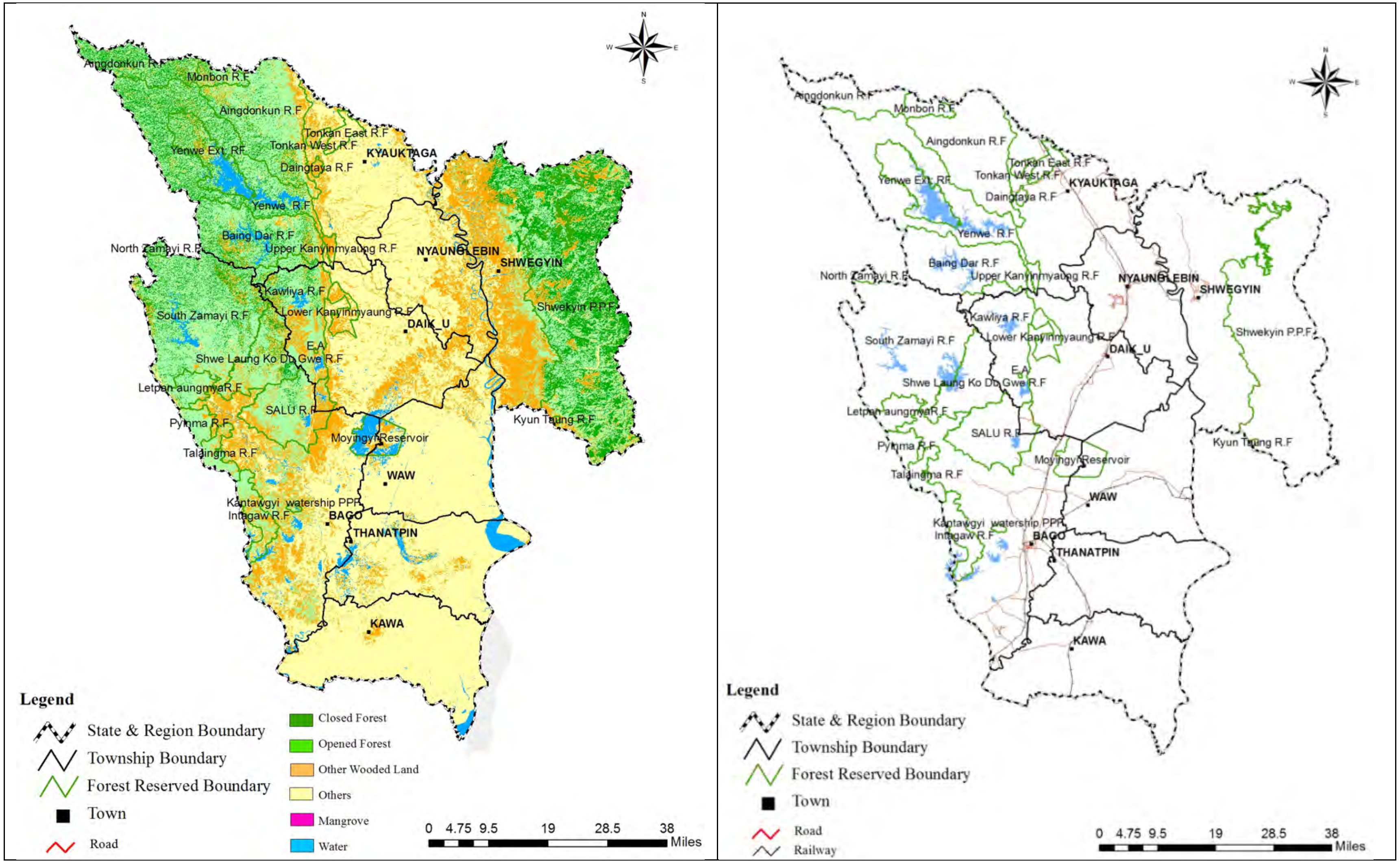


Figure 2.2 Left side, land use, land cover map, Bago District; right side, Bago District administration (Source: Maps 2015; GIS and Remote Sensing Section, Forest Department, MONREC).

The climate in the Bago Sub-basin is tropical monsoon with distinct wet and dry seasons. The cold season lasts from November to January, followed by a dry season from December to April, and a wet season from May to October. Meteorological data from 1955-2004 shows that December and January are the coldest months (T_{mean} 23.7°C in the Bago River at Bago City), whereas April is the warmest (T_{mean} 30.5°C) (Haruyama, 2013). From 1975-2009, the average temperature in the Bago River at Bago and Zaungtu stations were 26.6 °C, and from 1990-2009 the average annual precipitation was 3185 mm and 2746 mm, respectively (Shrestha and Ye Htut 2016), see also Table 2.1 presenting statistics of meteorological paramters in Bago. The study area has four meteorological stations namely Bago, Zaungtu, Kabaraye, and Hmawbi and two hydrological stations: Bago at the outlet of the basin and Zaungtu in the middle of the Bago River.

Climate studies in the Bago Sub-basin by Ye Htut et al. (2014), Shrestha and Ye Htut (2016) and Shrestha et al. (2017) show that changes in temperature and precipitation are expected to significantly affect the hydrological processes in the Sub-basin. The studies predict that mean annual Tmax and Tmin in the basin will increase, while a large uncertainty is observed when predicting future precipitation. The studies indicate a decrease in precipitation in the 2020ties and then an increase in the long-term scenario (see Ye Htut et al. 2014 and Shrestha et al. 2017). Shrestha and Ye Htut (2016) argue that climate change together with land use change is threatening socio-economic development in the area, that annual rainfall has decreased and that seasonal stream flows are reduced, particularly during the summer season. They further add that climate change may have significant impacts on water resources management in Bago Sub-basin.

The average flow in the Bago River is 135 m^3/s, which can increase to 450 m^3/s during the rainy season (Shrestha et al. 2017). In the dry period, March-April when there is less water in the river, the flow of the river is reduced to a velocity ranging from 6-40 cm/s. In the rainy season, a greater quantity of water in the river at a flood level of 860 cm causes the river to regain its flowing rate of 137 cm/s, and as the flood level becomes higher to the point of 900 cm, there is an increase in the flow rate to 200 cm/s (Ye Htut et al. 2014). The Bago River flows through Bago City and it is flooded almost every year during the monsoon period. Moreover, the drainage systems of the Bago River Basin are in poor condition and a major cause of flooding.

Table 2.1 Statistic of meteorological parameters at four meteorological stations for the period 1975-2005 in the Bago River. (Source Ye Htut et al. 2014).

Station	Avg. annual rainfall (mm)	Mean Tmax (°C)	Mean Tmin (°C)	T Mean (°C)	Avg annual stream flow (m3/s)	Lat_N (degree)	Lon_E (degree)	Elevation (masl)
Bago	3185	32.6	20.6	26.6	1597.9	17.3	96.5	19
Kabaraye	2607	33.1	21.2	27.2		16.9	96.2	31
Zaungtu	2746	33.0	20.1	26.6	1412.8	17.6	96.2	37
Hmawbi	2541	33.1	21.7	27.4		17.1	96.0	22

With regard to topography and associated soil cover in the area, there is a main environmental difference between upper and lower Bago Sub-basin (Figure 2.2 and 2.3). Upstream of the Bago bridge, which is located within Bago City, the Sub-basin covers 2,610 km^2 of the catchment area (Aslaksen, 2016). In this area, dominating soil types are gleysol and nitisol, both porous soils with high clay content and in need of roots of trees to hold the soil together (Figure 2.3). Downstream of the Bago Bridge, soils include sandy sediments and the terrain is highly dissected. Terrains are low land and less than 10 m.a.s.l. in elevation; in sections, the elevation of the riverbed is lower than the mean seawater level and seawater intrudes during the dry season. Associated with this difference in soils, there is also a difference in land cover. In the upper part, forested areas can be found, and land use is dominated by forestry, while agriculture dominates the lower part of the Sub-basin (Figure 2.3). The forested areas consist of scrubland, deciduous and evergreen forests. However, the recent 15 years there has been a reduction in the forested areas due to deforestation (Haruyama 2013; personal communication Forest Department Bago Region 2015). Overall in the sub-basin, grassland is the most dominant land use type, contributing to more than 32 % of the total area, whereas open land is about 28 %. The other land use types in the basin are agriculture and forest.

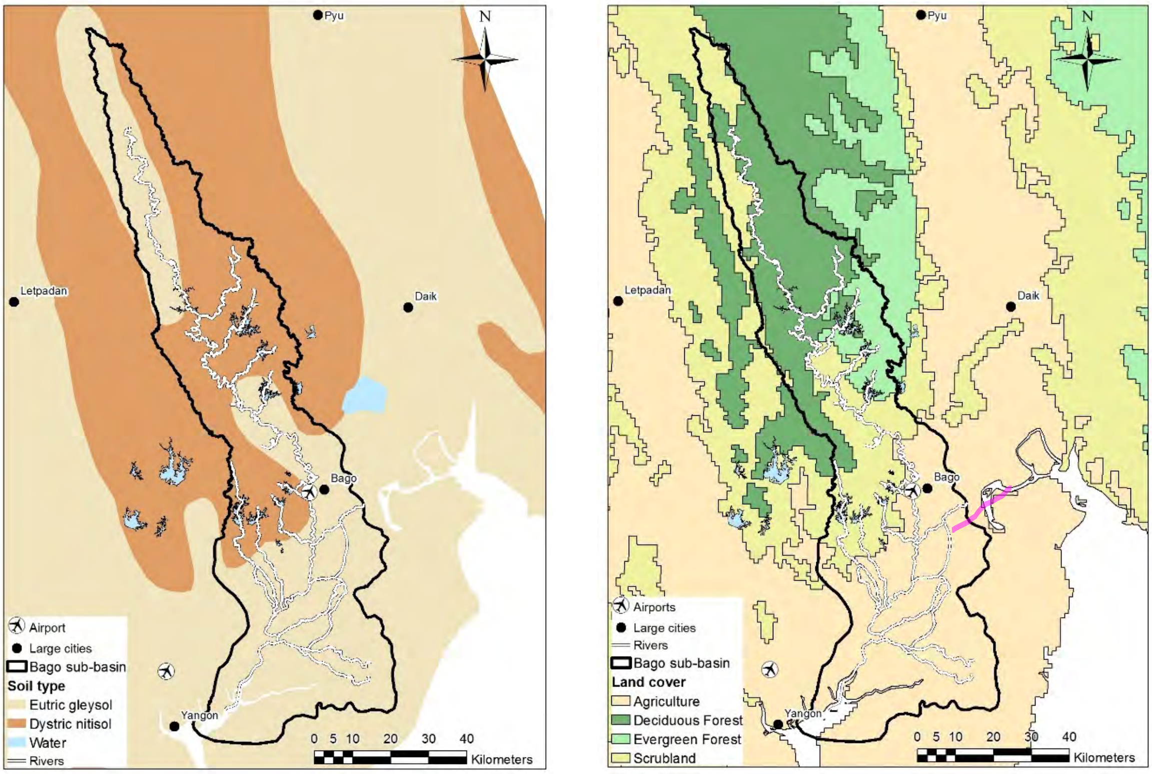


Figure 2.3 The dominant soil types (left panel) and land use (right panel) in the Bago River Sub-basin. The dominant soil types in the Bago River Sub-basin were eutric gleysols (faosoil GE37-2/3a) and dystric nitisols (faosoil Nd55-2/3b). The Bago Sittaung canal is denoted by the purple line (right panel).

2.3 Water users and uses in the Bago Sub-basin

2.3.1 Socio- economic information

Population density in a river basin is an important parameter for evaluating water needs and the human impact on water quality and quantity. Information about socio-economic groups and the types of economic activities found in the basin are important for enabling risk assessment of water bodies which may not meet identified environmental aims (Mjelde et al. 2017). Rarely however, are socio-economic data available within the boundaries of basins; there is a need in most cases to estimate information on basin level, based on information available from administrative units, such as on the region/state, district, or possibly township level. Though information may be available, it may not be accessible. Where scientific data are not available, expert and local knowledge can also be valuable for indicating water bodies at risk of not meeting environmental aims.

As the larger part of the Bago Sub-basin refers to Bago district, for most socio-economic parameters we refer to this administrative unit when characterizing the Bago Sub-basin. As the four townships of Kawa, Waw, Thanatpin and Bago have been selected as case study townships, we will provide specific information when possible for these townships.

The total population in the Bago District which covers an area of 2,909.2 km², was 1,770,785 in 2014. Among these, 73.8 % was rural and 26.2 % was urban. Population density was 133.4 inhabitants/km² (Department of Population, Ministry of Immigration and Population 2015). The Bago City is the largest city in the Sub-basin with the highest population density in the area. Considering that the case study townships are located in the lower part of the sub-basin with a higher population density than the general average in the Bago District (Table 2.2, Figure 2.4), we expect to find water bodies of relatively lower human impact in the upper areas of the sub-basin.

As a majority of the population within the district are farmers, the size of farms and the relative number of large and small farms provide some estimate of equity and socio-economic levels in the area. According to an officer from the Agricultural Department Bago Regional level, the normal farm size is 10 acres (4 ha) (50 % of the total number of farms); while about 100 persons have around 30 acres (12 ha) only few, 4 -5 farms, have over 100 acres (40 ha), while some, 4 or 5 only have 3-4 acres (1.4 ha).

Table 2.2 The case study townships in Bago District

Township	Area	Population	Population density	Number of village tracts	Number of villages
Bago	2,909.2 km²	491 434	168.9 inh./km²	65	281
Thanatpin	945.36 km²	145 287	153.7 inh./km²	60	99
Kawa	1,166.4 km²	197 363	169.2 inh./km²	89	157
Waw	951.85 km²	176 014	184.9 inh./km²	54	117

Economic activities in the Bago District reflect to some extent economic activities in the *Lower Sittaung Sub-basin Area*[2]. Considering the larger Lower Sittaung Sub-basin Area; this area includes some industrial activities, more specifically a saw mills, brick manufactories, small scale gold mining, and hydropower stations. As industrial activities in the basin are still at a low level, approximately 9000 are employed in industry (pers. com 2015). In the Bago District, people mostly rely on subsistence farming and fishing for their livelihood; with reference to district statistics, farmers represent 40 % of the local population, farming over 89,000 hectares annually; fishermen comprise 30 % of the population; 20 % are self-employed, while the remainder of approximately 40% are in government service (Ministry of Agriculture and Irrigation, 2012).

2.3.2 Water usage

Water from the Bago River is diverted for irrigation and is used to maintain the water level of the Moeyingyi wetland during the dry season through a canal. The Bago River is furthermore the source of water for hydropower generation, fisheries, and navigation. See for overview of towns, settlements, highways, in relation to land cover, Figure 2.4, and Appendix A, B and C.

[2] The lower Sittaung Sub-basin Area includes the following administrative units: the townships of Bago, Kawa, Thanatpin, Waw, DaikU, Nyaung Lay Bin, and Shwe Gyin Township in Bago District, and in Mon State the Kyaik Hto and Bilin townships within the Thaton District.

Irrigation
The main use of water in the district is for irrigation, and 34.000 acres (13759 Ha) /year used for summer rice are irrigated from around the third week of November / first week of December until April/May.

If the onset of rains is late, irrigation also occurs for rain-fed paddy at the beginning of planting in June / July. When the onset of rain is early, irrigation often also occurs in September October of rain-fed paddy (personal communication with U Ko Ko Oo, IWUMD, 2017). Actual irrigation demand varies within the area and among crops (See also, Table 2.3). There are plans to have 100% irrigation of crops. As a general estimate of water requirements for irrigation, 6 acre/feet is needed to irrigate 1 acre of land (statistical data from the Irrigation Department, 2014). See overview of reservoirs, and irrigation canals on map in Appendix A and Appendix B.

Fisheries
The Department of Agriculture informed 2015, that fish are released in the river canals, reservoirs, river and dams through June – August every year. Fish species released are mainly: Common carp, Indian carp, and Tilapia. It was informed that in 2015, 22000 fish had been released in the paddy fields as a source of food. There are 2470 acres of paddy field and about 500 fish/acre are commonly released. There has been an increased amount of fish during recent years.

Table 2.3 Overview of crops in Bago District (Source: Director of Agricultural Department, Bago Region 2015.)

Crops summer	**Acres**	**Crop monsoon season**	**Acres**
Rice, summer paddy	34.000 acres	Corn	2991
Sesame		Peanut	61182
		Sesame	124528
		Rice, monsoon paddy	270111
		Green ground	1028
		Soya bean	1749
		Pigeon pee	18430
		Chili	3077
		Vegetables	41982

Industrial water use
Utilization of water for industry is not monitored, but it can be assumed that industrial usage in the Bago Sub-basin is rather low due to the low level of industrial activities. Industries occurring in the Sub-basin using water in their production processes include saw mills, and brick production in Bago Township. In Shwe Gyin Township there are unofficial gold mine activities and a hydropower station. No information is available on economic production of these industries.

Domestic water use, drinking water and sewage
With regard to domestic drinking water usage, the penetration ratio of the public water supply system is only about five percent. Inhabitants depend on rainwater and shallow wells and many also get water from the river or from drinking water reservoirs. A few use groundwater, but natural arsenic contamination is a problem for groundwater usage. There are no public drinking water treatment plants in the area, but some households treat their drinking water by boiling the water. In the dry season, when the supply of drinking water is scarce, drinking water is supplied by the Township Municipality Committee to the Bago City area. About 30% of the Bago City Area receive

drinking water from the Kan Taw Gyi reservoir. It is the Department of Rural Development which is responsible for provision of drinking water to the rural areas. Funding for rural water supply when there is scarcity of water is coming from the regional parliament which receive budget from Union level Rural Development Department. These services however, are not systematic and not all households are covered.

Availability of drinking water is a recurrent problem in the dry season for all the case study townships, and also in the whole Lower Sittaung Sub-basin Area.

Sewage; Most of the people in the Bago District, around 70 %, use water sealed pit latrines. Traditional pit latrines and buckets are used by 14 % of the population and 10 % of the population do not use any of toilet (Department of Population 2015). Constructed small houses and toilets with tubes for discharge into the river can be observed alongside the Bago River, and quite densely observed around Bago City area. The sewage system is the responsibility of the Bago Township Municipality Committee, and in Bago City sewage is collected from septic tanks by the Township Development Committee, but there is no treatment of sewage in the district.

There are plans for funding of a waste water treatment plant in Bago by Japan International Cooperation Agency (JICA), but the timeline for this project is not known.

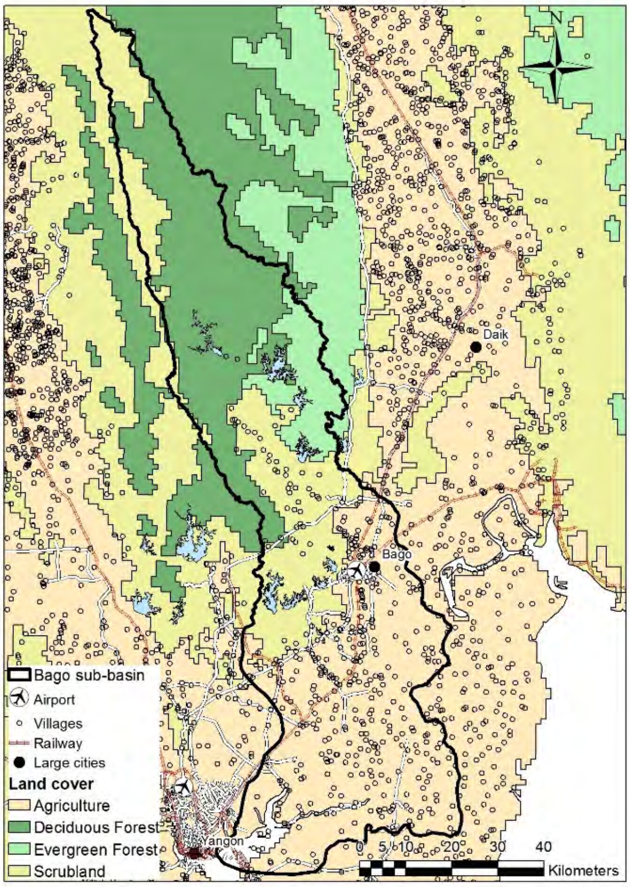


Figure 2.4 Overview of towns and settlements, highways, railways and airports in relation to land cover in the lower parts of the Bago River and Sittaung Sub-basins.

2.4 Economic analysis of water

As part of the characterization step, economic analysis of water usage at the river basin level is recommended by the EU WFD. The purpose is to understand the different economic actors in the basin, to enable development of policies and incentives that promote efficient use of water to avoid over-use, and for the preparation of rules so water users will pay for costs of water services. Paying for costs of water services, also referred to as the 'recovery of costs for water services' follows from the 'polluter pays' principles a central principle in the WFD. The polluter pays principle denotes that the party responsible for polluting, is responsible for managing it or paying for its negative impact on society or the environment. This principle comprises land, water and air pollution, and has also been applied to the emission of greenhouse gases that escalate climate change. Cost recovery is achieved through prices that the water service consumer has to pay to the provider directly or as part of a tax, charge or levy that is imposed on the service (see Arcadis, 2012). The principle of recovery of the costs for water services includes environmental and resource costs. Environmental and resource costs are defined as damage costs that water users impose on the environment and ecosystems (including non-use values) and those who use the environment (Wateco 2002). Another possible definition of environmental costs is the cost of future actions to achieve the adequate status required (Schaltegger and Burritt 2000). There is however, a need to be aware that many practical difficulties exist for defining, measuring and implementing pricing for full cost recovery. Employing water pricing for cost recovery may pose some problems for industrial, hydroelectric and urban users. Pricing and cost recovery can also be highly controversial for agricultural users. In Myanmar and in other developing countries (and in some developed countries) water management is always framed within the general development discourse. This is also recognized in particular in the National Water Policy, which embraces broader additional objectives of poverty alleviation and economic development.

The purpose of providing an overview of socio-economic value of water using sectors is related to prioritization of water allocation among sectors (WATECO, 2003; Arcadis, 2012). An economic analysis is also intended to inform the principle of balancing environmental interests with those who depend on them (Nesheim and Platjouw 2016). When deciding on the most appropriate measures to achieve environmental objectives, this involves balancing the interests of various water user groups. The EU WFD requires integration of measures in a way that achieves the best possible balance between the protection and improvement of the water environment and the interests of those who depend on it for their prosperity and quality of life.

2.4.1 An approach to economic analysis of water

To undertake an economic analysis of water, data need to be collected for identification of current and projected economic benefits and costs associated with utilization of water resources. More specifically with reference to the EU WFD, there is a need to present:

- Overview of socio-economic importance of key water uses referring to economic usage of water and domestic usage of water
- Assessment of costs and cost recovery of water services; supply of water and treatment of wastewater
- Projections of demand, supply capacity, and costs of water services

To estimate socio-economic importance of water use sectors, the following parameters are relevant: establishment calculations, gross output values, gross value, employment data, and wages and salaries. If data is not available from institutions, a survey of local authorities can be organized and combined with user-specific water consumption estimates adapted from values in other studies. The combination of the economic impacts and water-use values describe the socio-economic importance of water use in a basin. National economic impact data and local water-use value data may be presented via geographic information system (GIS) mapping techniques. See also Table 5 for an overview of different methods for estimating economic value of different types of water use. It must be noted however, that monetary values do not always reflect the values people equate to their water use, see also the paragraph on ecosystem service framework below (MA 2005; Martin-Lopez 2012; Klain et al. 2014).

We present below the main water use sectors in Bago and we provide an indication of methods which may be applied for estimating socio-economic value.

Overview of key water use sectors in Bago

The domestic sector is a key water use sector, and its water use is commonly prioritized before other uses, (Nesheim and Paltow 2016). Estimating the economic value of domestic water is a complex process since using water for domestic water does not contribute directly to an economic production while most of its value comes from the extrinsic values (Al-Assa'd et al 2013). The value to users of water is a key component of the extrinsic values that can be measured using the willingness to pay approach which could be expressed by the cost of water on users.

Key water-using sub-sectors are defined as those where the volume of water use is high, and where there is absence of suitable substitutes. Table 2.4 presents the main water user sectors and sub-sectors contributing to economic production in the Lower Sittuang Sub-basin Area (includes the township of Bago, Kawa, Thanatpin, DaikU, Nyaung Lay Bin, and Swhe Gyin Townships in Bago District, and Kyaik Hto and Bilin Townships in Thaton District, Mon State).

The agricultural sector is the most important water using sector in Bago with reference to the number of household engaged in agricultural production, and with regard to the volume of water use. To estimate the socio-economic value of water for the agricultural sector, the Production Method, (Table 5; http://www.ecosystemvaluation.org/productivity.htm) could be applied. It may be relevant to also consider estimating socio-economic value of agricultural sub-sectors and water use of each subsector as the difference between crops and water demand can be large.

Hydropower sector: There are in total five multipurpose dams which include production of hydropower in the Bago District. The largest of these is Zangtu Hydropower Plant in Bago Township. The socio-economic importance of the hydropower sector can be estimated by considering the amount of electricity produced related to demand for each specific hydropower plant, and for the whole sector in an area. It is relevant to consider the demand of electricity production and contribution related to security of supply to such as hospitals, industry, and city areas.

Other manufacture industries: The other industries in the Bago District are currently relatively small.

To estimate the socio-economic importance of industries, the economic turnover of each industry is often presented. It may be assumed that an industry with high economic turnover has socio-economic importance in an area (related to other sectors). Another possible indicator of socio-economic importance is considering the number of employees in an industry. A high, or relatively high number of employees will have value related to provision of employment in the area.

Table 2.4 Key water-using sub-sectors in the Lower Sittaung Sub-basin Area.

Agricultural Sub-sectors	**Industrial Subsectors**	**Miscellaneous Subsectors**
Rice, monsoon paddy	Small scale gold mining in Shwe Gyin Township	Forestry
Rice, summer paddy	Beverage, distilleries,	Inland commercial fishing
Betel nut	Pulp, paper	Aquaculture
Sugarcane (irrigation dependent)	Sugar factory in Phyu, and Yedashe	
Maize	Hydroelectric power generation	
Sunflower, beans and pulses, cotton, sesame, ground nut, tobacco, water melon, fruits and vegetables	Rubber plantation and production, Bago district,	
Cattle and cattle products	Ceramics	

Cost recovery of water services

Water services refer to the supply of water for domestic, industrial or agricultural uses, and the collection, treatment and disposal of wastewater. Provision of the service may be for instance through a piped centralized system, or by tanker trucks for distribution or collection. Both water supply and wastewater collection, treatment and disposal are very costly due to the processes involved and the significant impacts in case of mismanagement. Various chemical processes such as disinfection through chlorination are used to improve the final output of wastewater, however processes and subsequent discharges vary between and within countries. Underfinanced or managed poorly, polluted wastewater from water or wastewater processing are in many cases discharged into rivers, lakes or the ocean.

The ‘recovery of costs’ typically relates to fixed costs (capital and personnel costs) and less often to variable costs that depend on the quantity of water consumed (mainly energy and chemicals). These economic parameters need to be provided from a number of different government, Non-Governmental organisations and industry sources to calculate costs of water usage. There are three types of cost recovery: (i) operational, (ii) full service (including maintenance), and (iii) environmental costs (including negative externalities). When wastewater of poor quality is discharged into aquatic ecosystems, it is the ‘externalised cost’ imposed on people and ecosystems without compensation.

It is possible to deduce that if future investment in wastewater treatment services is less than or equal to the monetary value of the environmental, economic and social benefits of an unpolluted waterway, then it is worth improving cost recovery systems to enable the investment. In many countries, only parts of these water service costs are charged to users while the remainder is financed through direct or indirect subsidies from local, regional or national governments. Globally, there is little information on cost recovery of externalities associated with polluted wastewater discharges.

Bago-Sub-basin cost recovery of water services

There is no cost recovery of water services in Bago Sub-basin. The Township Municipal Committee will have an overview of costs of water services in Bago City. The Rural Development Department will have information of costs of water services in rural areas; in the rural areas costs of water services refers to provision of water in the dry season when lack of drinking water. Financial costs of water services primarily include those associated with the provision of potable water supply and wastewater treatment.

Bago Sub-basin projected water demand
It is projected that abstractive water demand for Bago will increase due to increased urbanisation, increased irrigation of crops, and industrial development. An irrigation system is being constructed with loans from OPEC, to irrigate 88500 acres of farmland in the Bago Region (PYIDH NLM 2011-03-29). With regard to industrial development in the region, there are plans for the development of a Specialized Textile and Garment Zone (STGZ) in Shwe Taung within Bago Region (Union Minister for Industry, 2017).

Frameworks for Ecosystem Services and their valuation
As well as being crucial for broad ecosystem functioning, freshwater ecosystems provide society with goods and services that very important to human wellbeing. Informed decisions about freshwater ecosystem usage can only be made when understanding and estimations of the system's value occurs. A river for instance, provides a host of benefits to society including such as; food, water for domestic, agricultural or industrial use, plants for eating or medicinal purposes, nutrient cycling, water cycling, climate regulation, transportation and energy. The variety of services are emphasized and presented in the Millennium Ecosystem Assessment (MA, 2005) and in The Economics of Ecosystems and Biodiversity (TEEB, 2008) frameworks.

The Millennium Ecosystem Assessment (MA, 2005) was the first major international effort to explore the linkages between ecosystem services and human well-being (Pandeya et al., 2016). The ecosystem services are according to the MA framework split into the following four value categories:

- provisioning (products obtained from ecosystems such as water and food),
- regulating (benefits obtained from regulation of ecosystem processes, such as climate regulation),
- supporting (services necessary for production of all other ecosystem services, such as nutrient cycling), and
- cultural (non-material benefits such as recreation or historical experiences).

In response to the lack of economic perspective of biodiversity loss and ecosystem degradation in the MA framework, The Economics of Ecosystems and Biodiversity (TEEB) emphasized more on joint efforts of ecologists and economists in ecosystem services valuation (TEEB 2008). The value components of the TEEB approach sum up to the 'Total Economic Value', which provides a comprehensive description of the sources of economic value for a good or service (TEEB 2008).

The TEEB framework focuses on:
- Direct uses (e.g. abstraction for public supply, agriculture, industry etc.);
- Indirect uses (e.g. ecological services provided by water such as provision of habitats for species, pollution abatement, etc.);
- Preferences for ensuring future uses of water; and
- Reasons that are independent of use, including ensuring a sustainable water environment for others to use, for future generations, and for the sake of a sustainable environment.

Methods to estimate the monetary value of these services exist, through both market and non-market values. Economic estimations are however criticized for taking a reductionist point of view to an extremely complex system. Table 2.5 presents an overview of methods for economic evaluation of ecosystem services.

Table 2.5 The table gives an overview of the most common quantitative evalution methods used, their constraints and limitations. Adapted from Barbier, E.B, Acreman, M and Knowler, D. 1996. Economic valuation of wetlands: A guide for policy makers and planner. Ramsar Convention on wetlands; King, D. and Mazzota 1999. Ecosystem valuation website (www.ecosystemvaluation.org); Struip, M.A.M, Baker, C.J. and Oosterberg, W. 2002. The socio-economics of wetlands, Wetlands International and Riza, The Netherlands.

Method	**Applicable to**	**Description and importance**	**Constraints and limitations**
Marked Price method	Direct Use values, especially wetland products	The value is estimated from the price in commercial markets (law of supply and demand)	Market imperfections such as subsidies, lack of transparency.
Damage cost avoided, Replacement Cost, Substitute Cost methods	Indirect Use Values, coastal protection, avoided erosion, pollution control, water retention.	The value of organic pollutant or any other pollutant's removal can be estimated from the cost of building and running a water treatment plant (substitute cost). The value of flood control can be estimated from the damage if flooding would occur (damage cost avoided).	It is assumed that the cost of avoided damage or substitutes match thhe original benefit and the method may therefore lead to under or over estimates. .
Travel cost method	Recreation and tourism	The recreational value of a site is estimated from the amount of money that people spend on reaching the site.	This method only gives an estimate. Over-estimates are easily made as the site may not be the only reason for traveling to the area. Requires a lot of quantitative data.
Hedonic pricing method	Some aspects of indirect use, future use and non-use values	The method is used when wetland values influence the price of marketed goods. Clean air, water large surface areas may increase the price of houses or land.	This method only captures people's willingness to pay for perceived benefits. If people are not aware of the link between the environmental attribute and benefits to themselves, the value will not be reflected in the price. The method is data intensive.
Contingent valuation method	Tourism and non-use values	This method asks people directly how much they would be willing to pay for specific environmental services.	There is controversy over whether people would actually pay the amounts stated in interviews.
Contingent choice method	For all wetland goods and services	Estimate values based on asking people to make tradeoffs among sets of ecosystems or environmental services.	Does not directly ask for willingness to pay as this is inferred from tradeoffs that include cost attribute.
Benefit transfer method	For all wetland goods and services	Estimates economic values by transferring existing benefit estimates from studies already completed for another location or context.	Often used when it is too expensive to conduct a new full economic valuation for a specific site. Can only be as accurate as the initial study. Extrapolation can only be done for sites with the same gross characteristics.

Method	Applicable to	Description and importance	Constraints and limitations
Productivity method	For specific wetland goods and services; water, soil, humidity in the air.	Estimated the economic value for wetland products or values that contribute to the production of commercially marketed goods.	The method is straight forward and data requirements are limited but the method only works for some goods and services.

2.5 Protected areas

As part of characterizing water bodies in the basin, it is recommended to establish a register of protected areas – identified as areas requiring special protection under existing national or regional legislation or with reference to specific water use criteria, or for the conservation of habitats or species that directly depend on those waters. The purpose of such a register is to enable and facilitate for their consideration in river basin planning and in monitoring programs. Protected areas require as part rules established for each protected area, particular management procedures (Myanmar Wetland policy, draft version 2017).

The register may consist of an inventory of protected area sites representing the protected area categories as exemplified below:

- Water bodies used for the abstraction of drinking water
- Water bodies used for irrigation
- Water bodies designated to protect economically significant aquatic species
- Areas designated for the protection of habitats or species: where the maintenance or improvement of the status of water is an important factor in their protection.

Protected areas in the Bago District:
Protected areas for the management of biodiversity and ecosystems cover two percent of the land in Bago Region.

Moeyungyi Wildlife Sanctuary (RAMSAR site since 2004) was constructed in 1978 and was originally built as a reservoir for flood control (Figure 2.5). This wetland is also used to supply water to the Bago–Sittaung canal during the dry season as a source of irrigation water for rice. The wetland also serves as a habitat for various species and acts as a resting place for migratory birds and in 2005 it was declared as a Ramsar Site. The Moeyingyi wetland lies in the Bago and Waw townships of Bago district and covers an area of 103.6 sq. km. Around 65 species of water birds, 60 species of terrestrial birds, 30 species of fishes and 29 species of reptiles and amphibians are commonly observed in the Moeyingyi wetland. The Bago River is one of the major sources of water to the Moeyingyi wetland. Around 8.5 m3/s of water is diverted to the Moeyingyi wetland through the Zangtu weir at the Bago River. Similarly, water is diverted during the monsoon season (May–October) to prevent flooding in Bago city situated on the banks of the Bago River. The Moeyingyi wetland is managed by the Forestry Department, Ministry of Environmental Conservation and Forestry, whereas the sluice gates are controlled by the Irrigation Department, Ministry of Agriculture and Irrigation Livestock and Fisheries.

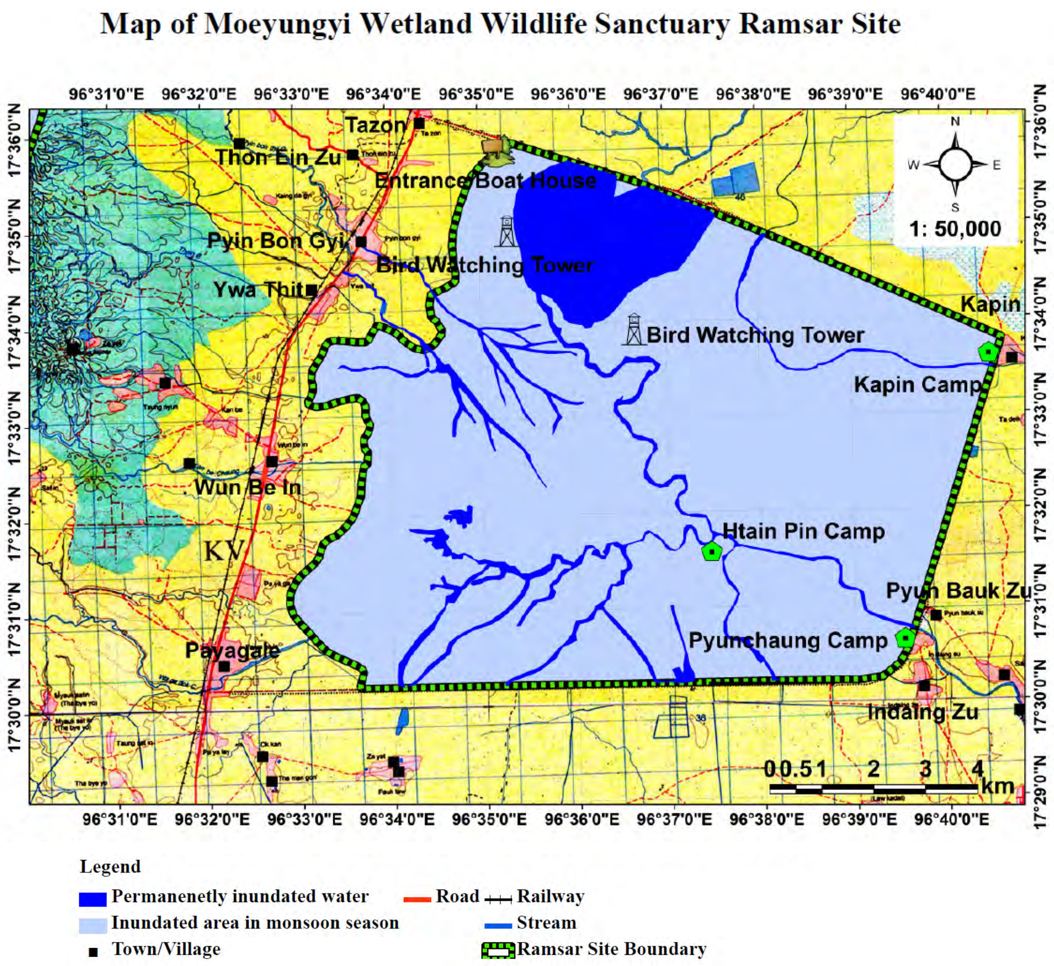
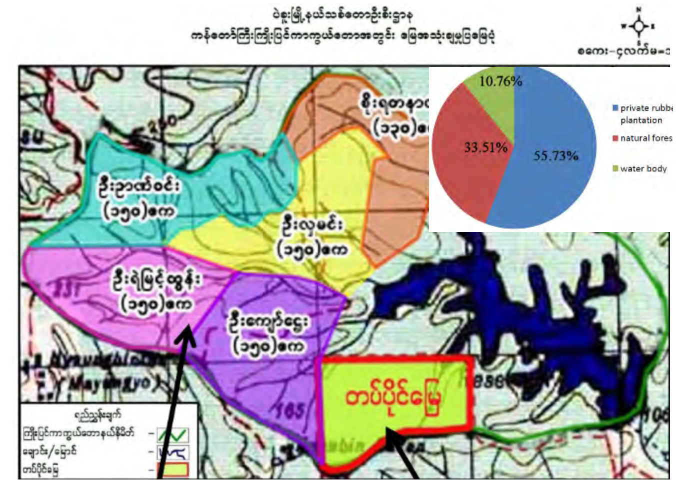


Figure 2.5. The Moeyingyi wetland area. The red circles indicate possible areas for water sampling (Source: Ramsar information service 2017).

Shwekyin and Kantawgyi are protected public forests. The watershed area of Kantawgyi is protected to enhance water flows into the Kantawgyi Lake, to sustain water supply for agriculture and to reduce sedimentation rate. The protected watershed area of Kantawgy was established in 1997 and covers 1310 acre (Figure 2.6). It was protected to enhance water flows into the Kan Taw Gyi Lake, to sustain water supply for agriculture, to reduce sedimentation rate and to protect biodiversity. However, since 2012 private rubber plantations have been established within the area leading to concerns about potential impacts on water quality (Forest Department, TBago Region 2017).

No	Content	Area (Acre)	(%)
1	Private rubber plantation	730	55.73
2	Natural forest	439	33.51
3	Water body	141	10.76
	Total	**1310**	**100**



Private Rubber Plantations | Degazetted area for Defence services

Figure 2.6 Land use in the Kan Taw Gyi protected public forest (Forest Department Bago Region, MONREC, 2017).

According to the Myanmar Forest Department, additional forest reserves and protected public forests of approximately 514.000 acres are planned to be established in the Bago Region within the next 10 years (MONREC 2017).

Dams and reservoirs used for irrigation: There are restrictions on land use upstream dams and reservoirs used for irrigation. Reservoirs are protected by prohibiting mining industries on first and second tributary upstream reservoir area; Table 2.4 (IWUMD, personal communication 2016).

Table 2.6 List of dams and reservoirs in Bago District

	Name of dams and reservoirs	Location	Water Body (Acres)	Purpose of dams and reservoirs
1	Zaung Tu	Bago Township	8328	Hydropower 20MW, irrigation, flood control
2	Zalat Htaw	Bago Township	1380	
3	War Ka Toke	Bago Township	3098	Flood control, and irrigation summer paddy
4	Shwe Pyi (3)	Bago Township	860	
5	Shwe Laung	Bago Township	4174	Flood control, and irrigation summer paddy
6	Salu	Bago Township	4750	Flood control, and irrigation summer paddy
7	Pyinpon	Bago Township	528	
8	Mazin	Bago Township	3700	Irrigation
9	Alaing Ni	Bago Township	2060	
10	La Gun Pyin	Bago Township	2316	
11	Kodu Kwe	Bago Township	6607	Flood control, and irrigation summer paddy
12	Kawliya	Daik Oo Township	4570	
13	Bawni	Daik Oo Township	1400	
14	Ye New	Kyauk Township	18745	Hydropower (25 MW)
15	Baida	Kyauk Township	17162	

	Name of dams and reservoirs	Location	Water Body (Acres)	Purpose of dams and reservoirs
16	Kyun Chaung	Shwe Kyin Township	8864	Hydropower (60 MW)
17	Shwe Kyin	Shwe Kyin Township	28160	Hydropower (75MW)

3 Pressures

3.1 Introduction

This chapter provides an overview of pressures and an analysis of their impact on the ecological status of surface waters. Identification of pressures is important to prioritize a preliminary monitoring program as it needs to cover sampling sites in water bodies being at risk of not meeting environmental objectives. This overview of pressures is also important as a basis for where to target abatement measures. In this chapter, the described impact these pressures have on water quality and quantity are based on review of known effects from scientific literature. The overview of pressures represents a risk screening exercise; a thorough assessment of pressures requires access to extensive data sets to allow the necessary analyses, which is outside the scope of this report. Provided below is an initial presentation of pressures in the Bago Sub-basin according to Article 5 of the EU WFD, which requires an analysis of:

- point source pollution, such as effluent from waste water treatment works and industrial discharges
- diffuse source pollution – including run-off from farmland, sewage from scattered dwellings and urban areas
- abstraction and flow regulation – including abstractions of water for irrigation, human consumption and industrial purposes; and impoundment of water by dams for a range of uses such as hydropower, irrigation, and navigational purposes;
- morphological alterations – embankments, channel alignments, substrate excavation, draining etc. to claim land for various purposes such as agriculture, housing etc. as well flood protection and provision of resources for the construction industry
- alien species – introduced species which can result in a loss of natural biodiversity.

For the current assessment of pressures, limited quantitative information has been available and risk assessments have relied on predicted impacts (but see Chapter 4 on a preliminary classification of ecologic status of the Bago River). Assessments of land use patterns have been undertaken using freely available GIS data (version 10.1) (see also sub-section 2.1). An online survey was made to find sources of data, including local, regional, and international databases for relevant data sources. Relevant GIS data was analyzed in the GIS program Arc-GIS (version 10.1). The overview of land-use patterns, along with data on settlements have been used to indicate diffuse source pollution locations. Identification of point source pollution was provided from the Forest Department, Bago Region. As part of this project we have used water quality information obtained from initial monitoring. Data on water abstraction and modification of hydromorphology has been assessed using maps and by a pilot field survey in which data on hydromorphological quality, using a modified approach of the Morphological Quality Index (MQI; Rinaldi et al. 2013). Several field assessment systems for hydromorphology have been developed in recent years in Europe and include the loss of river dynamics as opposed to most previous systems. MQI allows rivers to be assigned by quality classes based on the hydro morphology status, and is therefore in complete agreement with the approach used for both biological and chemical quality elements.

The amount and quality of available data and information should improve in future cycles of water management, making later assessments more comprehensive and robust. This first analysis provides a basis for developing monitoring programs, taking into consideration important pressures indicated. The difficulty of obtaining data refers to the lack of a national register of abstractions. It is recommended to establish a national database with information on water quality and water flow.

3.1.1 Pressures as identified by the Bago Sub-basin Area Committee and by the Bago Non-Governmental Stakeholder Group

The River Basin Management (RBM) approach involves managing different water uses in an integrated way within the boundaries of the catchment. The argument for this approach is that water is best managed along hydrological boundaries, and the tool to enable RBM is development of a coordinated River Basin Management Plan (RBMP). A Sub-basin Area Committee based in Bago was formed to serve as a coordinating arena for sector and environmental authorities as part of pilot implementing the River Basin Management Approach in the Lower Sittaung River Basin Area, and a Non-Governmental Stakeholder Group was formed to provide input to the discussion and the decision making of the Committee (Zaw Lwin Tun et al. 2016). The Chair of the Sub-basin Area Committee is the Minister for The Ministry of Natural Resources, Environmental Conservation, and there are three elected secretaries in the Committee; the director of the Bago Region Forest Department, the director of the Bago Region Irrigation and Water Utilization Management Department, and the director of the Bago Region Directorate of Water Resources and Improvement of River Systems. As part of these meetings, members of the Committee, and also members of the Non-Governmental Stakeholder Group discussed pressures in the Bago Sub-basin (see Figure 2.1, and Table 3.1).

The downstream townships of Kawa, Thanatpin and Waw share similar issues, whereas Bago Township is viewed different to the others, due to the location of the Bago City, and also because upstream in Bago the population density upstream is rather low. There are however a few villages with relatively higher population density. The impact of erosion is particularly high in the townships of Kawa, and Thanatpin. In this sub-section we first highlight the pressures as emphasized in the Committee and Group meetings organized. In the following sub-sections, we describe the main types of categories of pressures i.e. point pollution sources, diffuse pollution sources, and abstraction and flow regulation, hydromorphological alterations, and alien species, and their impact on the environment.

Disposal of garbage and sewage: The Committee members and the Non-Governmental Stakeholder Group members agreed that disposal of garbage and wastewater into the river is a problem. It was emphasized that it is necessary to raise awareness and improved law enforcement related to garbage disposal. It was however, also emphasized that there is lack of places for disposal of garbage, "except for in the river". People dwelling around the rivers, streams and lakes continue to discharge sewage into waterbodies. International health organizations have introduced ventilated pit latrines. Disposal of garbage and sewage is the most critical issue to be addressed to create a healthy ecosystem in Bago River.

Sand mining: Pyinbongyi sand from the banks of Bago River is renowned for its high quality; investment in sand mining is therefore a profitable industry in the region. The sand mining has caused riverbank erosion, and in a few serious cases, villages have needed to be resettled: a problem frequently reported in the media. Local authority support is urgently required to reduce harmful impacts of sand mining in the region. In the past, the General Administration Department issued sand mining permits based on comments the following departments: DWIR, IWUMD, and ECD. This issue is the responsibility of the Bago DWIR. Clear environmental rules and regulations are lacking.

Erosion is a general problem in the region. Bago, Thanatpin and Kawa Townships experience problems with excess sedimentation due to erosion upstream. The problem is exacerbated by the salt water intrusion from the sea, having an impact on the Thanatpin and Kawa Townships. The areas alongside the Bago River, around the Bago City Area and also downstream Bago City River, have little vegetation cover causing runoff of soils, phosphorus and nitrogen from agricultural areas to the river. The combined impact of these problems affects economic conditions of local communities.

Polluted groundwater in the area is also an issue reported on: locals in Thanatpin Township have produced a special report on their *groundwater* turning red in color (personal communication, 2016). Monitoring activities and analysis are planned by the current project to find the cause of the issue, as limited observations have been made to-date.

Industrial waste is another issue identified as a potential challenge in meetings, but as industrial activities in the Sub-basin are low, industries are not the most important challenge, but laws, rules and guidelines issued by the Environmental Conservation Department need to be adhered to for future industrial activities.

There are other general issues in the region, such as that of fish farming. Fish farmers culture common or desirable species, which has led to the disappearance of indigenous species. Gold mining has decimated some species, and electro fishing others. Electro shock fishing is a problem in the Bago area. In the study area's four districts, 93 instances of electro fishing were reported 2016, with 6 fishermen caught (Bago Forest Department, 2017). Fishing in the spawning period is also not allowed.

Table 3.1 Meeting for the discussion of prioritized management issues in Bago (September 2016).

Bago township	Thanatpin township	Kawa township	Waw township
Sewage Garbage Sand mining Industrial waste River Bank Erosion and Sedimentation	Salt water intrusion Invasive shell species destroying paddy fields High concentration of phosphorus and nitrogen Groundwater pollution Riverbank Erosion and Sedimentation	Salt water intrusion Invasive shell species destroying paddy fields High concentration of phosphorus and nitrogen Riverbank Erosion and Sedimentation	Salt water intrusion Invasive shell species destroying paddy fields High concentration of phosphorus and nitrogen Riverbank Erosion and Sedimentation

3.1.2 Point source pollution

Point source pollution can be defined as a single identifiable source of air, land, or water pollution. Typical examples of point source pollution include, domestic sewage and industrial wastewater discharges, whereby pollution is discharged via a pipe or drain. Industrial wastewater can come from the following industries: textiles, pharmaceuticals, leather, plastics, chemicals, electrical equipment, pulp, and paper mills, and more. Sewage and wastewater are commonly discharged to rivers, lakes, and oceans. Discharges can also occur from leakage during heavy rainfall, where storm water runoff mixes with sewage, resulting in sewer overflow (untreated sewage directly discharged to water bodies). Problems for society and the environment result when the content of these discharges are deleterious. Unregulated discharges from point sources can contain high nutrient levels or toxic chemicals and heavy metals that lead to water pollution endangering human health (via contact with or ingestion) or wide-scale ecosystem damage (See also Mjelde et al. 2017). The impact on the aquatic environment is determined by chemical type, concentration, timing of release, weather conditions and the type of organism in the discharge area. Regulating the quality of effluents discharged is one way of reducing risk, however there has been a shift in emphasis in recent years from focusing on end of pipe measures to changing the mode of production, to cleaner, more modern technologies.

Point source pollution in the Bago Sub-basin

In the Bago Sub-basin Area point pollution sources as informed by the Forest Department Bago Region, includes the following type of industries (Figure 3.1).

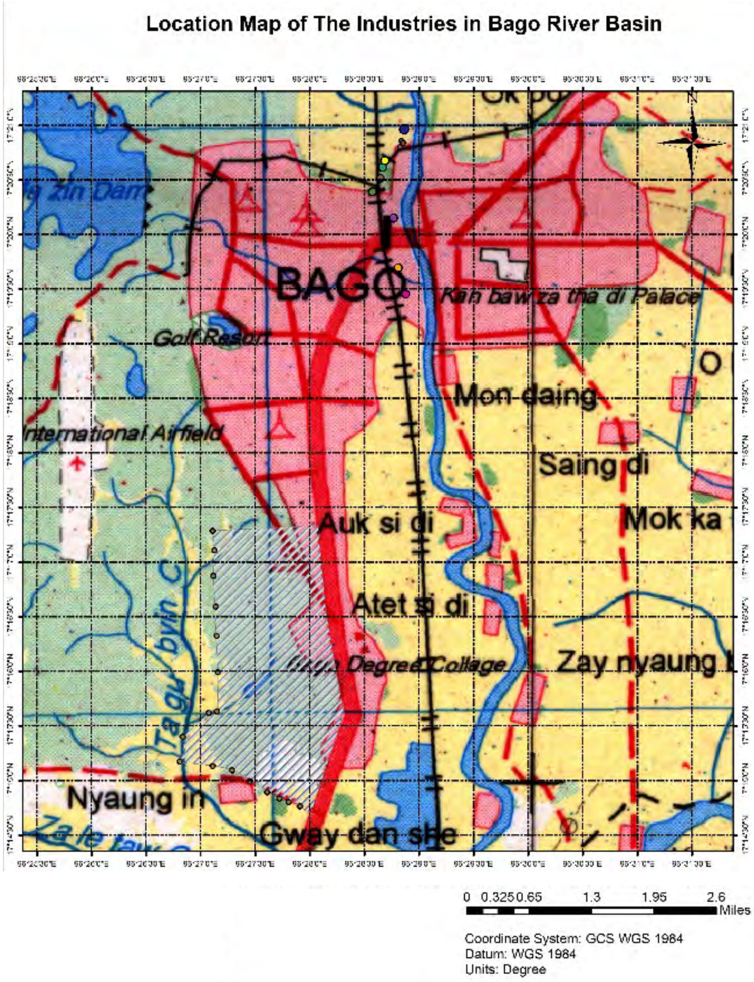
- Sand mining in Bago River (Bago Township)
- Saw mills
- Brick manufacturing (in most villages)
- Small scale gold mine in Shwe Gyin Township (Bago District)

Sand mining: there has been an increased demand for river sand as a source of construction material in the Bago Region. This has resulted in a mushrooming of river sand mining activities, which have given rise to various problems that require urgent action by authorities. These include riverbank erosion, river bed degradation, river buffer zone encroachment, and deterioration of river water quality. Over-mining frequently occurs which jeopardizes the health of the river and the environment in general. Sand mining was emphasized as an important problem at both Bago Sub-basin Area Committee meetings, and also at Bago Non-Governmental Stakeholder Group meetings.

Sawmill: Wastewater discharges from pulp and paper mills contain solids, nutrients and dissolved organic matter such as lignin. They also contain alcohols, and chelating agents and inorganic materials like chlorates and transition metal compounds. Nutrients such as nitrogen and phosphorus can cause or exacerbate eutrophication of fresh water bodies such as lakes and rivers. Organic matter dissolved in fresh water, measured by biological oxygen demand (BOD), changes ecological characteristics. Wastewater may also be polluted with “organochloride compounds, some of which naturally occur in the wood. One of the persistent problems with sawmill operations is disposal of waste, as is also the situation in Bago. However, the saw mills are far from the rivers, hence there is no discharge to rivers. Few negative impacts of sawmills are reported in the area.

Brick manufacturing: brick manufacturing is a water-intensive industry requiring large quantities of water to be consumed to produce bricks. Impact on water quality may refer to increased turbidity due to clay suspensions. Impact on water quantity may be considered in the dry season. Most manufacturing industries use additives like barium carbonate. Still, brick manufacturing is almost a chemical-free industry that uses raw products clay and sand. Nearly every village has brick manufacturing, but production levels are low. Brick manufacturing occurs close to paddy fields and near rivers for water availability. Rice husk is used for fuel and it creates air pollution. A few villagers complain to the regional government. Soil degradation and erosion is problematic. The significance varies depending on the area.

Gold Mining: The extraction of minerals demands large amounts of water, and mining through discharged mine effluent and seepage from tailings and waste rock impoundments pollute waters downstream. The impact of mining on water quality depends on the sensitivity of local terrain, the composition of minerals being mined, the type of technology employed, and the skill, knowledge, and environmental commitment of the mining company. Mining activities may impact on water quality through: acid mine drainage, heavy metal contamination; processing chemicals pollution; erosion and sedimentation (for more details on potential impact, see Mjelde et al. 2017). There has been reported some unofficial small-scale gold mining in Shwe Gyin Township. Because of gold mining there is sedimentation in the Shwe Gyin River. Environmental degradation is reported in this area, but the degree of impact degree is not known. Water sampling will be initiated in this area.



Bago 1	Daw Kyi Kyi Wai (Saw Mill)
Bago 2	U Win Thein (Saw Mill)
Bago 3	Daw New New Oo (Saw Mill)
Bago 4	U Tun Tun Win (Bean-curd (Tofu) Business)
Bago 5	Bago Market
Bago 6	Daw Aye Sandar Myint (MontHinkhar Business)
Bago 7	U Kyaw Lin Mg (Brick Manufacturing Business)
Bago 8	U Aung Than (Brick Manufacturing Business)
Bago 9	U Chit Brick Manufacturing Business)
Bago 10	Zarni Mg (Bean-curd (Tofu) Business)
Bago 11	Sand Budiness
Bago 12	Industrial zone (482.15 acre)

Figure 3.1 The figure presents the location of industries in Bago District.

3.1.3 Diffuse pollution

Diffuse pollution refers to run-off from land-use activities, both rural and urban that are dispersed across the basin and which are not related to well-defined point of discharge. It is the sum of many, often small, pollution sources that collectively result in a significant environmental impact. Examples of diffuse pollution to groundwater and/or surface waters include the loss of excess nutrients and sediment from farmland, run-off from domestic activities such as sewage from scattered dwellings and small townships, and from water contaminated with pollutants from vehicle emissions from hard surfaces towns. A major incident of non-point source pollution into rivers and streams is related to the monsoon season, as heavy precipitation acts as surface wash-off for various pollutants. The main type of diffuse pollution in developing countries is from agricultural areas and drainage from agricultural fields often continue to pollute streams for some time after the monsoon is over.

Below we present the main types of diffuse pollution present in the Bago Sub-basin: from agricultural areas; related to deforestation; and from townships and villages. Diffuse or non-point source pollution has both spatial and temporal heterogeneity being correlated with land-use conditions, terrain, vegetation cover and hydrological characteristics. Diffuse pollution can be estimated by various modelling approaches if loss of nutrients/pollutants from different types of land-use is known. Source apportionment can be done by comparing transport of, for example, nutrients in catchments dominated by nature/least impacted land-use with transport in primarily deforested catchments, agricultural catchments, and urban catchments with few point sources.

Agriculture

Lower Bago Sub-basin consists of a flat agricultural landscape, where the main crop is rice. Almost all the land, 96.6% to 99.0 % is used for paddy fields in this area (Figure 2.4, Appendix A). There are commonly two cropping cycles in a year, and fields are fertilized around sowing times; that is for rain-fed crops around June/ July and for summer crops around last week of November / first week of December. If plant growth is weak, fertilizers are applied during the whole growing season. According to the Director of Bago Region Agricultural Department (personal communication, 2015), 89446,91 tons of fertilizer are applied on paddy (monsoon) rice (2761549 acres), and 3700 tons of fertilizer are applied on summer rice (264700 acres) in the Bago Region. The usage of pesticides varies between farmers; according to personal communication with the Bago Region Agricultural Department, usage is low. Pesticides are mostly applied by wealthier farmers during the growing season of crops. Irrigation mainly occurs during the summer season from about last week of November until April / May (see also section 2.3).

Animal husbandry includes cattle for meat and draft animals, while dairy production in Bago is limited and only for domestic purposes. Hogs and poultry are common in all villages (Table 3.1).

Table 3.1. Husbandry in the *Bago Region* as provided by the Bago Agricultural Department (2015).

Type	Number
Cattle	1.572.288
Buffalo	332.621
Pig	1.157.793
Sheep and goat	76.476
Poultry	38.797.611
Duck	9.449.084
Goose	148.212

The amount of fertilizers (referring mainly to nitrogen and phosphorus) used in the agricultural plains of Bago Sub-basin can affect surface water eutrophication, which may cause toxic algal blooms and reduce oxygen; both of which are harmful for aquatic organisms. When fertilizers are applied to farmland excess nutrients (nitrogen and phosphorus) will eventually end up in the river, especially under rainfall events. Nitrogen is more mobile than phosphorus, which will be bound harder to soil particles, and consequently, most nitrogen will be dissolved when it reaches the river, while a large proportion of the phosphorus will be particle bound and less bioavailable. If phosphorus and nitrogen fertilizers are applied during times of rain loss can be substantial, although with relatively little effect in the river itself as most will be transported downstream at a high rate. However, the nutrients can have significant eutrophication effects in lakes, reservoirs, and coastal areas. These nutrients will have the largest effect in the river itself at low/stable flow conditions, where a large biomass of algae can be accumulated causing charges to habitat conditions and oxygen levels.

Pesticides used in agriculture will show a similar pattern in terms of transport routes to the river. Loss will be highest when pesticides are applied just before, or during, high precipitation events. Depending on chemical properties of pesticides used, they will either be transported dissolved in the soil water (hydrophilic pesticides) or sediment bound (hydrophobic pesticides). Most pesticides are easily photodegradable, or broken down in the soils, but this process will be slower in water. Hydrophobic pesticides adsorbed to particles can remain active for long periods and can cause toxic effects on aquatic biota. Levels of pesticide use are however apparently low.

Forests and deforestation
Available GIS data clearly show substantial forest cuts during the last 15 years in the central and northern part of the Sub-basin (Figure 2.2). Forest cover have decreased significantly between 2010 and 2015 with reduction in 21 % for open forests and 10 % for closed forests (Regional Forest Department, MONREC 2017).

Deforestation is known to affect water quality in various ways. It causes soil erosion and increased sediment transport as the binding capacity of the forest floor is substantially reduced with removal of forests. Damage to the forest floor by large trucks removing logs further increases soil erosion. Eventually sediments end up in rivers, causing downstream sedimentation which may clog the canal. Leaching of nutrients such as nitrogen and phosphorus can be activated during deforestation and contribute to eutrophication or increasing the nutrient content downstream. This can be important in areas that have substantial inter-annual precipitation patterns (Ellison, 2012).

Currently, the Bago Region government has prohibited logging for the next 10 years to stop deforestation. It is recognized however, that illegal logging continues to some extent, despite controls. The Bago Region Forest Department prepares weekly and monthly reports, including information on planting of trees, forestry status, and illegal logging. Every day the FD has new information on illegal logging; “it is a huge problem” (Personal communication, Forest Department 2016).

To counter deforestation and degraded forests, a new reforestation and rehabilitation program in charge of the Bago Region Forest Department will be carried out in Bago Yoma, upper Bago Region. Among the planned actions include planting new, and regenerate existing forest plantations with a particular focus on community forestry and planting valuable species such as teak. The program will also support existing forests with regeneration and enrichment planting. Some of the community forests in Bago Region, will be combined with agriculture (MONREC 2017).

Local residents have voiced concerns about Private rubber plantations within the Kan Taw Gyi Watershed and Protected forests since 2012. It is estimated that around 55 %/ 730 acres of the Kan Taw Gyi Protected Public Forests consist of private rubber plantations. The rubber plantations use chemicals which may pollute the drinking water and have harmful impacts on biodiversity. The regional government has recently approved a ban on further establishments of plantations within the area (MONREC 2017).

Mines
Shwe Gyin Township in the upper part of the Bago District engages in the economic activity of gold mining. Because of gold mining there is sedimentation in the Shwe Gyin River. Environmental degradation is reported in this area, but the degree of impact degree is not known. Water sampling will be initiated in this area.

Both diffuse and point source pollution are related to mining activities (see above on point source pollution, and Mjelde et al. 2017).

Townships and sewage
Bago Region has a total of about 4.8 million inhabitants (data from 2014) with 22 % living in urban areas (Department of Population 2015). The main pressure from urban areas is the sewage from human feces and the lack of proper sewage treatment. 73 % of the population use water sealed pit latrines, which have been recently implemented in the region. Traditional pit latrines and buckets are used by 14 % of the population and 10 % of the population do not use a toilet of any kind (Department of Population 2015). Houses with toilets and tubes for discharge into Bago River can be observed when travelling by boat on the river. As part of a meeting with the Bago Municipality Township Committee in 2015, it was stated that: "Water quality in the river is bad. Sewage from households and agriculture is the main problem. Sewage management is the household's responsibility, they dig pits for 'septic tanks'. When one pit is full they just dig a new one." (Personal communication with the Bago Municipality Township Committee, 2015). During the meeting the staff informed that JAICA is preparing a plan for a sewage treatment plant and they hope to start the construction process in 2016.

The sewage problem in the lower part of the Bago Sub-basin can cause severe effects on water quality. The lack of proper sanitation will lead to deteriorating water quality, in particular hazards for human health in the town. Pathogens such as *Escherichia coli* (hereafter *E. coli*), *Clostridium perfringens, Campylobacter* and *Salmonella* are common in human and animal fecal and are hazardous to human health. Contamination from sewage to the Bago Sub-basin becomes even more concerning due to crop irrigation used in eastern parts of the lower basin. High amounts of pathogens in the water used for irrigation can damage crops and be a liability for human health as the crops become unsuitable for human consumption.

3.1.4 Abstraction, flow regulation and flooding

Water is abstracted from rivers, canals, reservoirs, or underground rocks (aquifers) to provide public water supplies and serve industry and agriculture (see Appendix A, B and C). The main challenge in managing abstraction is to meet the reasonable needs of water users, while leaving enough water in the environment to conserve river and wetland habitats and their species.

Low flow is more detrimental to the river's ecology than high flows and flooding. The reason for this is that low flow conditions create a range of stressors on the biota such increased temperature, decreased oxygen levels, increased sedimentation, habitat loss and an increased risk of toxic algae blooms. Changes in flow regimes and related alterations in water quality, e.g. in connection with dam releases, can also impact the biota negatively. High flows can also be harmful, but the river biota is evolutionary well-adapted and resilient to such events, and recovery is normally fairly rapid if events are not extreme. It is therefore important that river discharge is monitored regularly and that flows recorded are related to water use as well as climatic conditions. Water stage can be measured and related to measurements of discharge to create Q/H curves that can be used to continuously estimate the flow regime.

Another important aspect is that water abstraction involves smaller dams and weirs that create migration barriers for biota (See Appendix A, B, C). A large proportion of the river biota, and in particular fish, are highly dependent of migration. If barriers prevent migration, this can lead to the loss of species and lowering of ecological status. Abstractions need to be mapped as well as their possible effect on migration of important species. A hydropower plan with its turbine is a barrier in many rivers. Height of the barriers, current velocity over the barrier and if they are permanent in time (or passable at e.g. high floods) are important features to consider in the context of the biology of important species (e.g. swimming speed). The impact of flow alterations and modifications to natural running waters will have a substantial effect of the aquatic biodiversity. Alterations in flow regimes change life cycles of river biota, in species interactions and food web structure (Poff, 2007). In the Bago Sub-basin, controlled flow will affect biodiversity, fish species and natural areas as the dams built are a result of flooded forest areas (Appendix A, B, C). Biodiversity loss in the form of fish migration can also have substantial effects on micro scale economics as the altered flow paths and barriers hinder fish to migrate along Bago River.

Five hydropower multipurpose plants are located in Bago River and on tributaries to the Bago River. According to communication with the secretaries of the Bago Sub-basin Area, there is no significant negative impact on water availability (but see impact on hydromorphology below).

In Bago Sub-basin the water volume requirement is dependent on the irrigation water requirement as other industrial activities are still at a low level. Then there is the situation that there is no registration of water utilization for the industry. Water abstraction from the Bago River feeds large agricultural areas. The water requirement for the monsoon season is satisfied by the rain-fed water requirement for the summer paddy as the irrigation water requirement. Since the irrigation system in the survey area is not improved, the cultivable area for summer paddy is still 744 ha in the four townships. Water abstraction can result in more concentration of hazardous substances in the river due to the reduced dilution effect that water abstraction causes. It also needs to be noted that irrigation of crops downstream in Bago city can cause health concerns due to sanitation issues and pathogen spread from fecal contamination.

As the lower parts of the eastern region are strongly irrigated, the amount of freshwater moving into the estuaries of Yangon River can be substantially reduced. Basically, there is a need to ensure flow level of the river to avoid saltwater intrusion of water from the sea. Considering the irrigation requirement as estimated as part of the 2-10 Data Collection Survey on Water Resources Potential for Thilawa Special Economic Zone and Adjoining Areas follows applying the equation of (cropped area) × (required irrigation water depth 6 feet).

Flooding and salt water intrusion

Deforestation and the high number of dams combined contribute to high sediment transport and bed levels are rising in the lower reaches of the Bago River (see also Manh et al. 2014). Sedimentation in the rivers further contributes to increased flooding and navigation is problematic. Sedimentation and water abstraction cause reduced discharge rates, and the combined effect cause intrusion of sea water into the lower reaches of the Bago and Sittaung Rivers. Intrusion of seawater can be a larger problem in the future related to climate change, as rising sea levels will increase the salinity of the freshwater and make is unusable for drinking water consumption or irrigation. Figure 3.2 shows flooding in Bago in 2015, due to heavy rainfall that affected large parts of the eastern lowlands where irrigation is used for crops and rice fields.

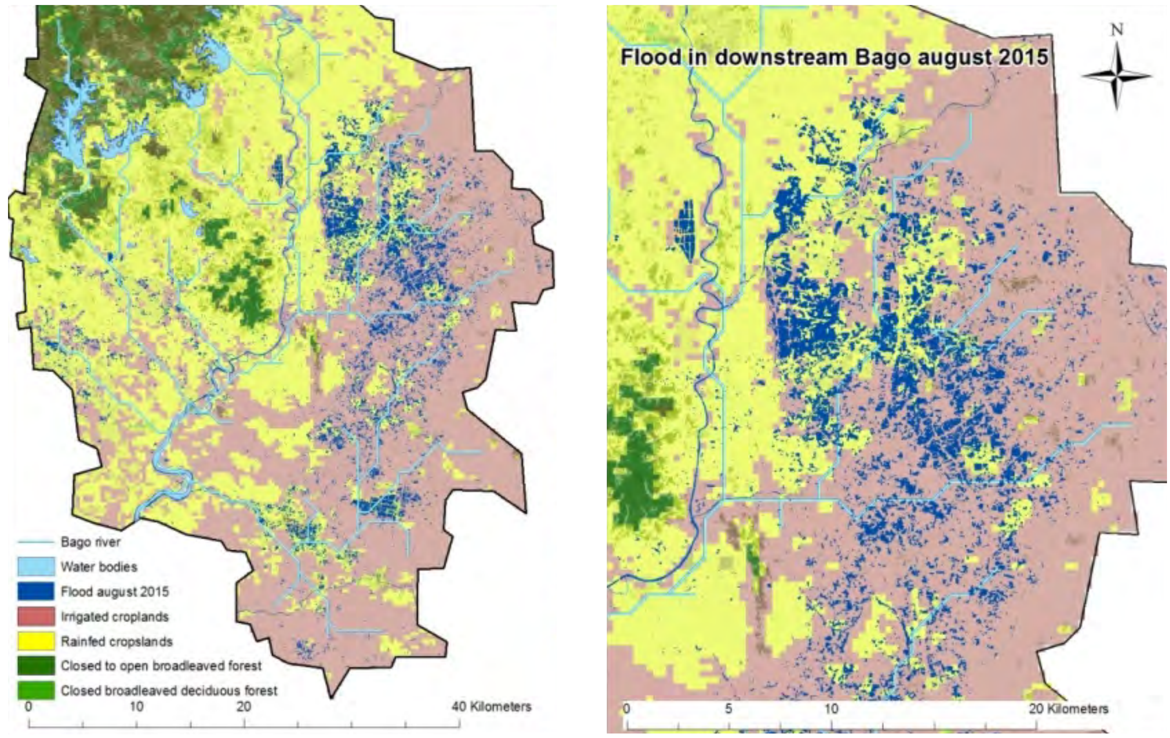


Figure 3.2 Illustration of the 2015 flooding in lower Bago River basin (Source Aslaksen, 2016).

3.1.5 Hydromorphological alterations and assessment of impact

Hydromorphology is an important supplementary component in determining the ecological status of running waters, and is defined as the hydrological and geomorphological conditions of rivers and streams. Degradation and loss of physical complexity in rivers are common features through, for instance, embankments, channelization, dredging and wood removal etc. In addition, sediments and siltation with fine particles is a major problem in many rivers, especially in areas with changed land-use (deforestation) and agriculture.

Weirs, dams, and barrages can alter water and sediment movements, in addition to act as migration barriers as mentioned above, may influence the hydromorphological frame conditions.

Changed hydromorphology impacts the biota negatively directly through reduced availability of important habitats, which limit both biomass and abundance of a number of species. Indirectly, a degraded hydromorphology may affect oxygen conditions, food supply for the stream food web and decrease the tolerance towards pesticides. Ways of mitigating impacts of hydromorphological degradation are related to various types of restoration, which could be both nature-based solutions by e.g. rehabilitating riparian vegetation, or by removing embankments and change channel platforms using more traditional engineering approaches. It is furthermore important to minimize the extent of the hydromorphological modification in pristine rivers, as the negative impacts will often last for a long period and restoration is costly.

Construction of dams and water reservoirs

A total of 17 dams and reservoirs exist in Bago District (Table 2.6; Appendix B); the main usage of these are for hydropower, drinking water and irrigation. The dams, linked to forest clear cuts, have flooded large land areas in upstream Bago and artificial lakes have been created. Based on available data, no natural lakes are present on the upstream Bago River. In the Bago River Basin and adjacent area, including the eastern bank of the Sittaung River, there are various scales of reservoirs. Most of the dams have been constructed for irrigation purposes and flood control, some have been constructed for multipurpose use including hydropower production, and a few only for hydropower production (Table 2.6). 11 reservoirs are located in the tributaries of the Bago River, three (3) of which are in the east bank, four (4) in the west bank, and the other four (4) are located in the bordering basin of the Sittaung River. Though the there is no negative impact on availability of water, the reservoirs are barriers for fish migration as there is no fish passage. This situation has a negative impact fishing and biodiversity in the area.

There are no reservoirs downstream on the Sittaung River.

Environmental flow and downstream water user rights have never been considered in the catchment. Water flow regulation is claimed to be poorly managed. The reservoirs provide water for local people when the local stream is dry, but the reservoirs also disturbs the natural flow of water causing increased sedimentation rate. This again may lead to salt water intrusion in the delta areas.

Embankments

Embankments are made to protect built to protect river banks from erosion and the adjacent land area from flooding. They will therefore block the lateral connectivity between the river and its floodplain. Naturally functioning floodplains are important for biodiversity and for ecosystem services such as storage of water under floods. Embankments will impair this function and have a negatively impact on biodiversity. Furthermore, when rivers are not able to flood their banks, the excess energy under flooding cannot be dissipated, which lead to increased shear stress in the channel itself. This will increase sediment transport and maybe result in incision in addition to increase the hydraulic stress on the freshwater biota.

Embankments may also lead to lower ground water levels and threats to organisms that have naturally adapted to episodic floods.

Around Bago city there are build levees in several places to prevent flooding. There are more embankments on the east portion of the river because it is situated at lower altitude relative to the western part. Along the eastern bank, there is a river terrace of 13 km in length stretching between the Bago City Bridge to the Tawa Village in the South (Haruyama 2013). Furthermore, there are in several places build embankments to river banks in smaller streams and ditches to prevent erosion (Figure 3.4).

Figure 3.4 Embankments made to the Mazin Chaung in upper parts (upper) and the Eastern bank of the Bago River Between the Bago City and Tawa Village (lower).

3.1.6 Alien species

According to the EU WFD, Monitoring programmes need to be established to provide a coherent and comprehensive overview of water status within each river basin district; this also include assessment of alien species.

A high impact invasive alien species is expected to have a significant adverse effect on the ecological quality of any part of the water environment in which it becomes established. Alien species have been deliberately or accidentally introduced by humans and there is growing evidence that they can cause a major threat to native flora and fauna. They can result in loss of natural biodiversity and may have significant economic impacts. Waters in which one or more of the species have become established cannot be classed as high ecological status. Instead they are classed as good, moderate, poor, or bad status, depending on the extent and severity of the impact they have on the other plants and animals present.

A list of what are considered to be invasive species in Myanmar should be produced. The list need to
dynamic and will change as new species arrive and/or new risk assessments are completed. In the Bago Sub-basin people complained about invasive shell species.

4 A preliminary classification of the Bago sub-basin

While the first part of this report has identified the main pressures in the Bago Sub-basin, the aim of this chapter is to do a preliminary classification and a risk analysis of the probability of achieving good status, based on an initial assessment of water quality and the biological quality element macroinvertebrates.

4.1 Introduction

The vision of the Myanmar National Water Framework Directive (NWFD) is to become a water efficient nation with well-developed and sustainable water resources based on fully functional integrated water resources management systems within 2020, applying concepts like the European Water Framework Directive (WFD, EC (2000). The objective of the WFD is to maintain or achieve good status (chemical and ecological) for all surface waters and ground waters. Status, *sensu* the WFD, is divided into the following five classes: high, good, moderate, poor and bad, and water bodies that do not achieve at least good status must be restored. High status means no or insignificant perturbation by humans (natural state), good status means only minor deviations from this state, while moderate, poor and bad status are categories of unacceptable conditions by this legislative. The evaluation of ecological status must include biological quality elements, such as macroinvertebrates, fish, algae and plants. In addition, the evaluation makes use of supportive elements: physico-chemical parameters (nutrients), any river basin-specific pollutants (such as heavy metals), as well as hydromorphological degradation (Figure 4.1). In combination, the element with the worst status decides the total status. However, if the status of the biology is high or good, the supportive elements can only degrade the total status down to moderate. Therefore, biology is the most decisive element in classifications. Chemical status is based on environmental quality standards for prioritised substances in the river basin, specified by a maximum concentration that cannot be exceeded (yes/no instead of a five-class system). If the set threshold concentration for one of the prioritised substances are exceeded, the water body will not be classed as having a good status. 33 substances or groups of substances are on the list of priority substances for which environmental quality standards were set by the EU in 2008, including selected existing chemicals, plant protection products, biocides, metals and other groups like Polyaromatic Hydrocarbons (PAH) that are mainly incineration by-products and Polybrominated Biphenylethers (PBDE) that are used as flame retardants. A complete list of substances can be found at (http://ec.europa.eu/environment/water/water-framework/priority_substances.htm).

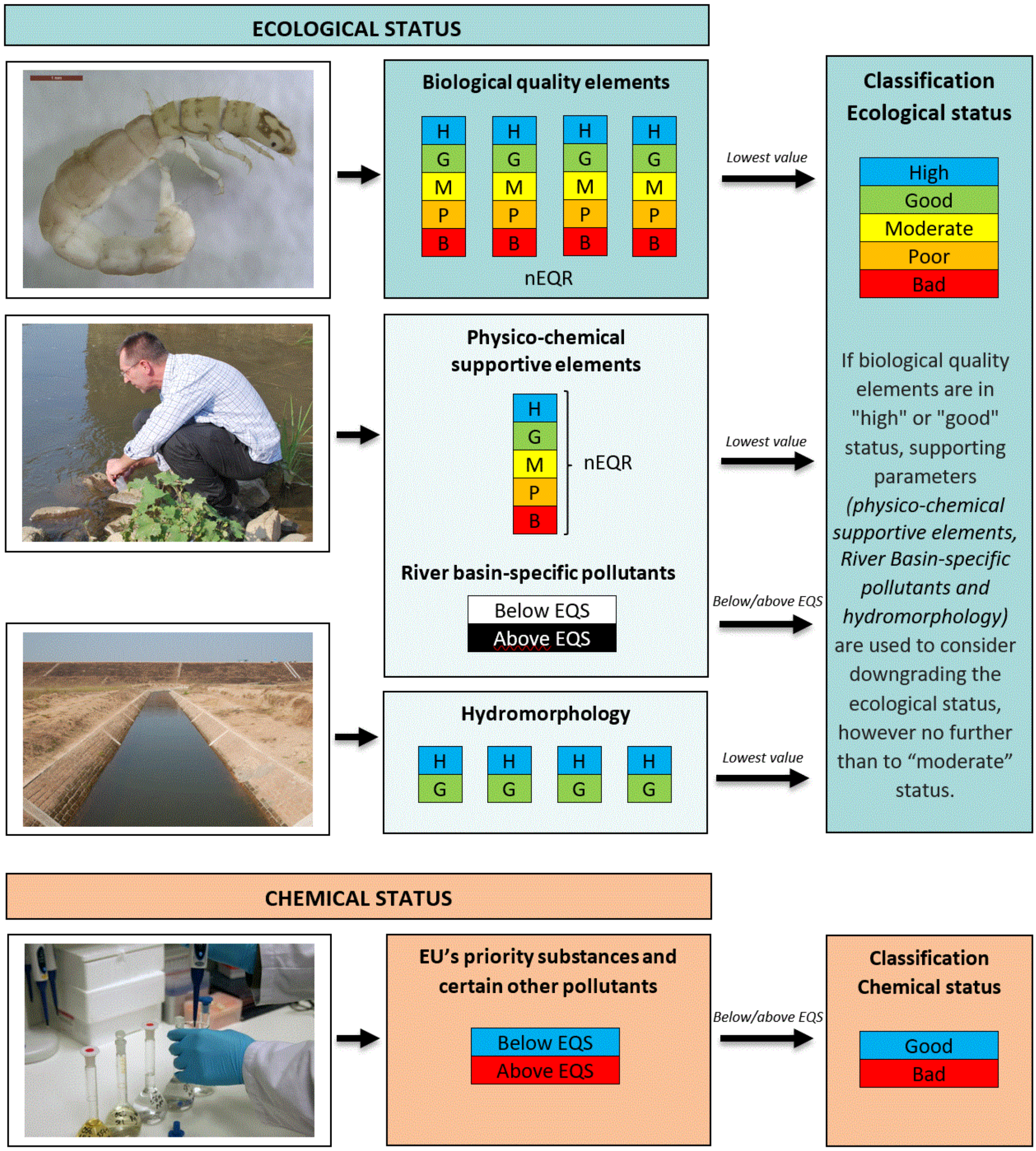


Figure 4.1. Flow chart showing the concept behind ecological and chemical status classification.

4.2 Methods

4.2.1 Water body division

Ecological assessment, as per the WFD must be "type specific", i.e. water bodies must be characterized based on their physical and morphological attributes, such as geology, salinity, alkalinity, catchment size and altitude. Water bodies are defined as the units for reporting and assessing compliance with the environmental objectives per a future national water legislation. A water body may consist of one or several lakes or river segments and must consider only natural boundaries (not political). Furthermore, a water body need to be exposed to similar types of pressures and have similar ecological status. The rationale for this approach is that the physico-geological properties of the catchment will affect the physico-chemical properties of waters and ultimately have consequences for status classifications. Like shown in the characterization part of this report, there were two dominating soils types in the Bago Sub-basin (gleysol and nitisol soils). In initial phases of delineating water bodies, all information necessary for an operational division of individual water bodies might not exist. This, together with logistic and financial constraints, means that the final division of water bodies in the Bago Sub-basin could change from what is presented here. Since evaluation criteria may be dependent on the water body type, a detailed water body division may give more precise evaluations and may be especially important in areas with little previous experience with monitoring ecological status. The initial division done in the Bago Sub-basin was done in rigorous manner according the criteria given in the WFD. Based on information from local management and available GIS data, division into 35 water bodies were proposed (Figure 4.2).

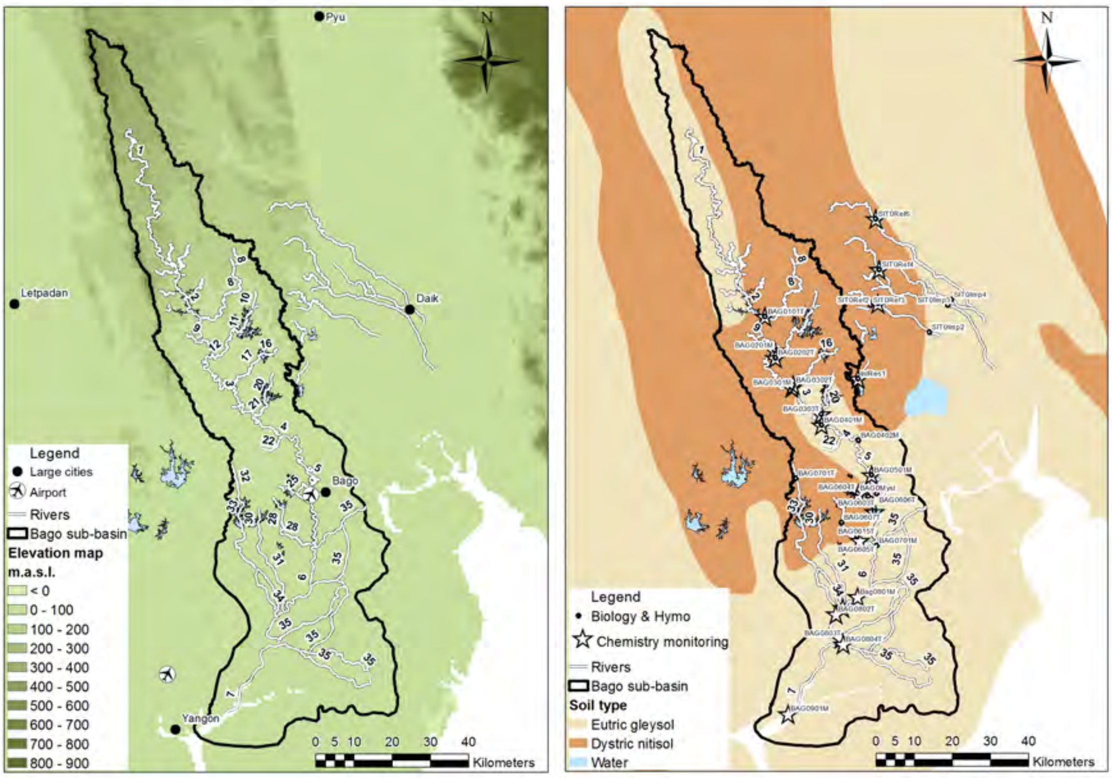


Figure 4.2. The proposed 35 water bodies for the Bago River Sub-basin (left). Locations for data collection in 2016 and 2017 are also shown (right). Note that some streams in the Sittaung Sub-basin are included to acquire reference data points. A total of 32 water bodies were sampled as part of this sampling campaign with three water bodies left out due to logistic constrains.

4.2.2 Sampling and evaluation of new data

Water chemistry

In February 2016, a sampling campaign was made to the Bago Sub-basin to collected data on water chemistry, macroinvertebrates and hydromorphology, from Dawe in the north to Yangon in the south (Figure 4.2; Appendix D). In September 2016, NIVA together with the Irrigation and Water Utilization Management Department (IWUMD) and Forest Department initiated a water chemical monitoring program for the Bago River Sub-basin and the South-Eastern part of the Sittaung River basin. Here, based on the proposed water body division, a set of monitoring stations, one in each water body, were monitored monthly for water chemical parameters, starting from November 2016. Locations for data collection was selected to cover as much of the river basin as possible.

Water quality parameters that are known to be sensitive to human pressures and have ecological impacts as well, was chosen for the monitoring program in some cases, a negative influence on human health. Physico-chemical parameters were: pH, turbidity, suspended solids, alkalinity, calcium (Ca), potassium (K), chloride (Cl), magnesium (Mg), sodium (Na) and sulfate (So), total nitrogen, nitrate, phosphate, total phosphorus, ammonia. River-basin specific pollutants were: copper (Cu), chromium (Cr), manganese (Mn), iron (Fe) and arsenic (As). The EU's priority substances were mercury (Hg), cadmium (Cd), zinc (Zn), nickel (Ni) and lead (Pb). Attempts were also made to include analysis of bacteria (*E. coli*), chemical and biological oxygen demand. However, because these samples require the initiation of analysis usually within 24 hours, and there are long travelling distances to the sample sites, these parameters are not analyzed routinely but it is recommended that they will be a part of a future monitoring program (see also chapter 5).

Water samples were collected by taking water samples in bottles to conduct laboratory analysis, as well as in situ measurements using field instruments (Figure 4.3). The data have been analyzed partly in Yangon at the laboratory of the IWUM and partly at NIVA in Norway as well as in the newly rehabilitated laboratory at the Forest Research Institute at Nay Pyi Taw.[3] The data are available through the projects database: http://www.niva.no/myanmar/water-quality-database-system.

Figure 4.3. Water chemistry sampling in a bottle (left and center) and with a oxygen probe and pH-meter (right).

All nutrient analyses were conducted at the NIVA laboratory. Water quality criteria for metals and nutrients have not been defined for Myanmar, and we also did not manage to find such criteria for neighboring countries. Because preliminary data indicated low levels of these substances, like Northern Europe, we adopted criteria from Norway as a first approach (see Mjelde et al 2017; Table 4.1-4.2).

[3] The rehabilitation and instrumentation of the water quality laboratory at FRI is an activity within the IWRM project.

The toxicity of metals to aquatic organisms are usually not proportional to the total chemical concentration in a stream environment, but varies with different forms that have different bioavailability. When background concentrations of particulate bound metals are high (typically for copper), additional inputs of toxic forms will be difficult to separate from natural variations. For this reason, water samples can be filtrated through a filter prior to analysis (0.45 µm mesh sizes) to remove the particulate bound metals. This may be especially useful if there are a lot of sediment particles in the water, which is often the case in many of water bodies in the Bago Sub-basin. This process is therefore an estimate of the dissolved metals, which are crucial for biological communities. For metals, there are both filtrated (0.45µm) and un-filtrated samples. Samples that were transported to Norway were conserved applying acids. The conservation was done in the field, immediately following collection. For nutrients 1% sulfuric acid (4 molar) was applied to the collected water sample, while 1% nitric acid (7 molar) was applied to water samples for heavy metals. Any filtration was conducted prior to conservation.

Table 4.1. Water quality criteria for river basin specific pollutants and EU prioritized substances (*) metals in freshwater (filtrated samples) from Norway. Class 2/AA-EQS = upper limit for chronical exposure effects. Class 3/MAC-EQS = upper limit for acute toxic effects.

	Water quality criteria for freshwater (µg/l), filtrated samples				
Parameter	Class 1	Class 2	Class 3	Class 4	Class 5
EQS	Background	Good AA-EQS	Moderate MAC-EQS	Poor	Bad
Lead (Pb)*	0.02	1.2	14	57	> 57
Nickel (Ni)*	0.5	4	34	67	> 67
Mercury (Hg)*	0.001	0.047	0.07	0.14	> 0.14
Copper (Cu)	0.3	7.8	7.8	15.6	> 15.6
Zink (Zn)*	1.5	11	11	60	> 60
Arsene (As)	0.15	0.5	8.5	85	> 85
Chromium (Cr)	0.1	3.4	3.4	3.4	> 3.4
Cadium (Cd)	0.003	Depends of the hardness of water (CaCO3)			

Cadmium	**Water quality criteria for freshwater Cadmium (µg/l), filtrated samples**				
Water hardness	Class 1	Class 2	Class 3	Class 4	Class 5
EQS	Background	Good AA-EQS	Moderate MAC-EQS	Poor	Bad
< 40 mg CaCO3/L	0.003	≥ 0.08	≥ 0.45	≥ 0.45	≥ 0.45
40 - < 50 mg CaCO3/L	0.003	0.08	0.45	0.45	0.45
50 - < 100 mg CaCO3/L	0.003	0.09	0.6	0.6	0.6
100 - < 200 mg CaCO3/L	0.003	0.15	0.9	0.9	0.9
>200 mg CaCO3/L	0.003	0.25	1.5	15	15

Table 4.2. Water quality criteria for nutrients in rivers (un-filtrated samples), proposed for gleysol soil streams (<200 m.a.s.l., Calcium <4 mg/l, TOC <5) and nitisol soil streams (<200 m.a.s.l., Calcium 4-20 mg/l, TOC <5). The class boundaries will probably need revision.

Gleysol soils	**River typology: <200 m.a.s.l., Calcium <4 mg/l, TOC <5***					
	Reference	**H**	**G**	**M**	**P**	**B**
Total phosphorus (µg P/l)	6	11	17	**30**	60	> 60
Total nitrogen (µg N(l)	200	325	475	**775**	1350	> 1350
Ammonia (NH4+NH3 µg N/l)	10	10	30	**60**	100	160

Nitisol soils	**River typology: <200 m.a.s.l., Calcium 4-20 mg/l, TOC <5***					
	Reference	**H**	**G**	**M**	**P**	**B**
Total phosphorus (µg P/l)	9	15	25	**38**	65	> 65
Total nitrogen (µg N/l)	275	425	675	**950**	1425	> 1425
Ammonia (NH4+NH3 µg N/l)	10	10	30	**60**	100	160

Benthic macroinvertebrates

Aquatic, benthic macroinvertebrates is a diverse group of bottom-dwelling organisms that inhabit most surface waters (Figure 4.4). They lack a backbone (invertebrate) and are usually visible with the naked eye (macro). Their differentiated responses to many types of perturbation, in addition to low mobility, has made them excellent indicators of water quality. Because they have wide distributions, and are easy to collect and identify to an operational level, benthic macroinvertebrates are used indicators of water quality worldwide. Compared with both plants and fish, riverine macroinvertebrates are widely accepted to be most well-proven biological quality element and useable in a wide range of geographical regions. Therefore, macroinvertebrates were selected to classify ecological status in the Bago Sub-basin.

Figure 4.4. Macroinvertebrates from streams in the Bago Sub-basin. Trichoptera (left), Ephemeroptera (middle) and Gastropoda (right).

Macroinvertebrates were collected in the dry season in 2016 and 2017 by kick-sampling, following CEN standard protocol (NS-EN-16150:2012 ; NS-EN-ISO-10870:2012). The hand net had a frame opening of 25 x 25 cm and 0.25 mm mesh sizes. The sampling net was held in the direction of flow while 1 m of substratum was stirred for a total of 20 seconds, allowing animals to drift into the net (Figure 4.5). This procedure was repeated 9 times, and leads to a total sampling time of 3 minutes, and the total area covered was approximately 2.25 m^2. All 9 subsamples were pooled, preserved in 96 % ethanol, and later analyzed using magnification in a laboratory for species composition.

Applied literature for taxa identifications were mainly Sangpradub and Boonsoong (2006) and Dudgeon (1999).

Figure 4.5. Sampling of macroinvertebrates in rivers. The samples were collected by disturbing the substratum allowing animals to drift into the sampling net.

For a preliminary classification, the data has been evaluated qualitatively based on expected pollution tolerances at the family level in Europe and Thailand (Armitage et al. 1983; Mustow 2002). In this first phase of evaluation, these characteristics were used to qualitatively separate between no/low impact and high impact. NIVA initiated a PhD-project in 2017 to develop a classification system based on riverine macroinvertebrates in Myanmar that will study this topic further until 2021.

Hydromorphological data

Hydromorphological degradation means that humans have altered the way that a river naturally flows and operates in the ecosystem. The term hydromorphology was introduced by the WFD in Europe and signifies how important physical features are in determining the ecological status of running waters, and is defined as the hydrological and geomorphological conditions of rivers and streams. Degradation and loss of physical complexity in rivers has been massive in most parts of the world through, for instance, channelization, siltation, dredging and wood removal etc. (Friberg 2014). The channel pattern of the Bago River has previously been reported to be more meandering in the northern portion than the southern portion, while the river morphology is more channelized in lower parts because of engineering works under colonial period for flood prevention (Haruyama 2013).

Hydromorphology was assessed using a modified version of MQIHydromorphological features are visually assessed in the field and combined to score which can be translated into quality classes. The version applied here was simplified to test its potential application in Myanmar and results cannot be compared directly with results obtained with the original MQI method. However, the modified MQI used in Bago River can give a good indication of the degree hydromorphological degradation in the Sub-basin as well as an impression of its potential use in future.

4.3 Results

Water chemistry
Our data support that streams in (eutric) gleysol soils have lower pH, alkalinity, conductivity and calcium levels than (dystric) nitisols (Figure 4.6). Gleysol soils had relative low levels of calcium (< 4 mg/l) and alkalinity (<1 mmol/l). BAG0606T, on the contrary, had high levels of calcium and TOC. This was probably a result of inputs of sewage effluents. Total organic carbon (TOC) was generally below 5 mg/l across soil types. Levels of suspended sediments were quite similar across soils, however, lower parts of the Bago River (BAG0801M and BAG0901M) had notably higher levels than upper parts. Furthermore, levels of TOC were also elevated here. This may indicate that there are inputs or both inorganic and organic matter in this part of the river system. pH and conductivity were both higher in streams draining dystric nitisols than eutric gleysols, reflecting natural differences in the geology. Furthermore, there was a tendency for higher levels of suspended sediments in streams draining dystric nitisols that probably reflects a combination of land-use impacts and natural differences in erodibility between soil types.

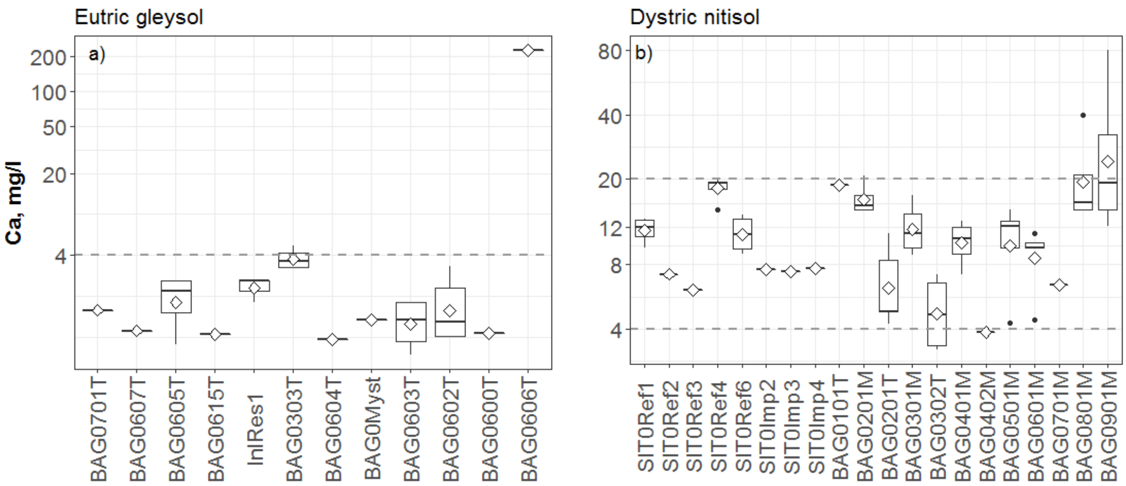


Figure 4.6. Physico-chemical properties of streams in the Bago and Sittaung River-basins. Left panels are from eutric gleysol soils and right panels dystric nitisol soils. Station names are shown on the x-axis (Figure 4.2; Appendix D). Within each boxplot, the thick, horizontal lines represent the median, the top and bottom of the boxes represent the 75th and 25th percentiles, the dashed error bars extend to the most extreme data point which is no more than 1.5 times the interquartile range from the box, and separate points represent outliers. Dashed horizontal lines denote possible boundaries for water body type divisions.

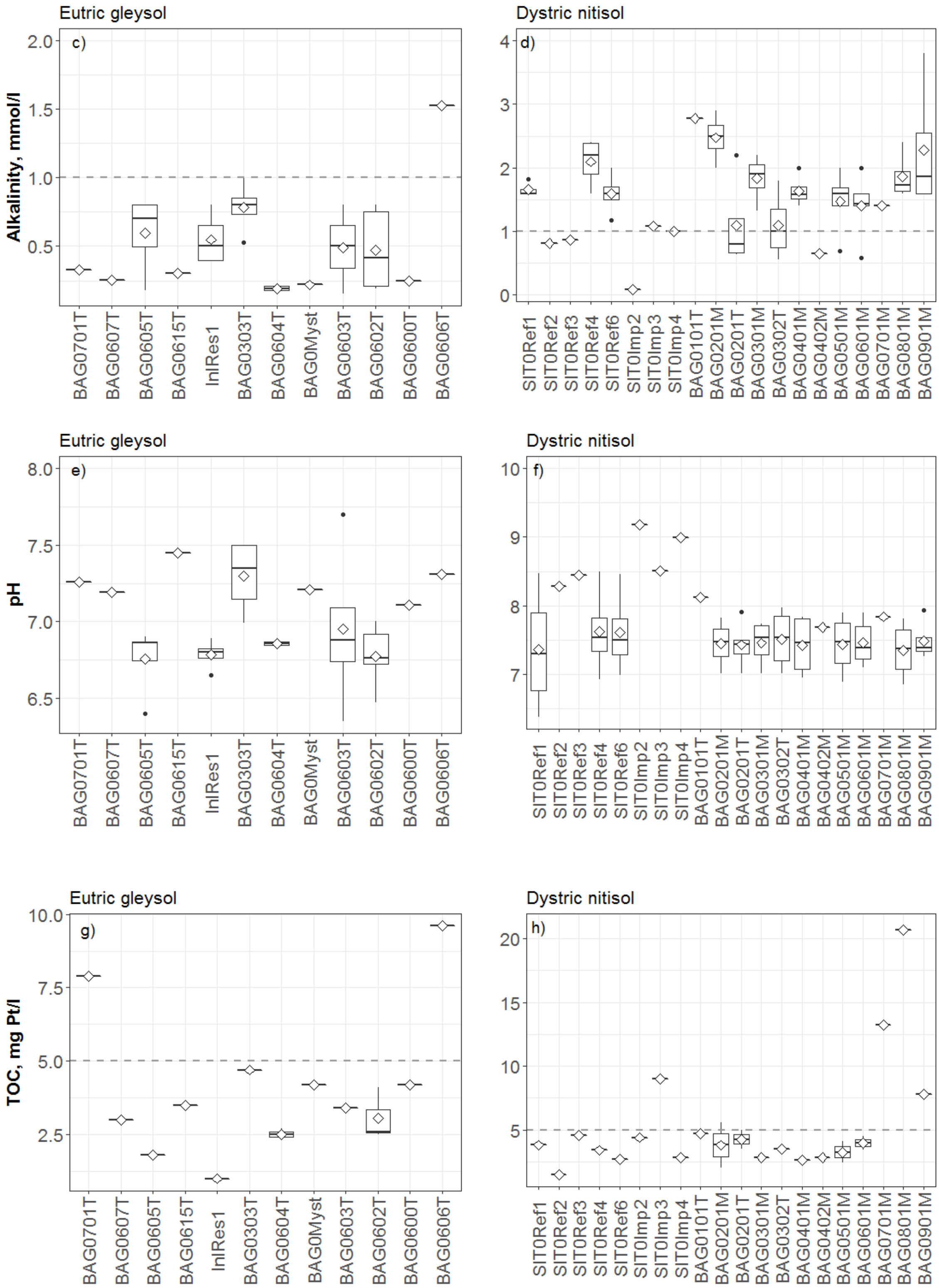


Figure 4.6. continued.

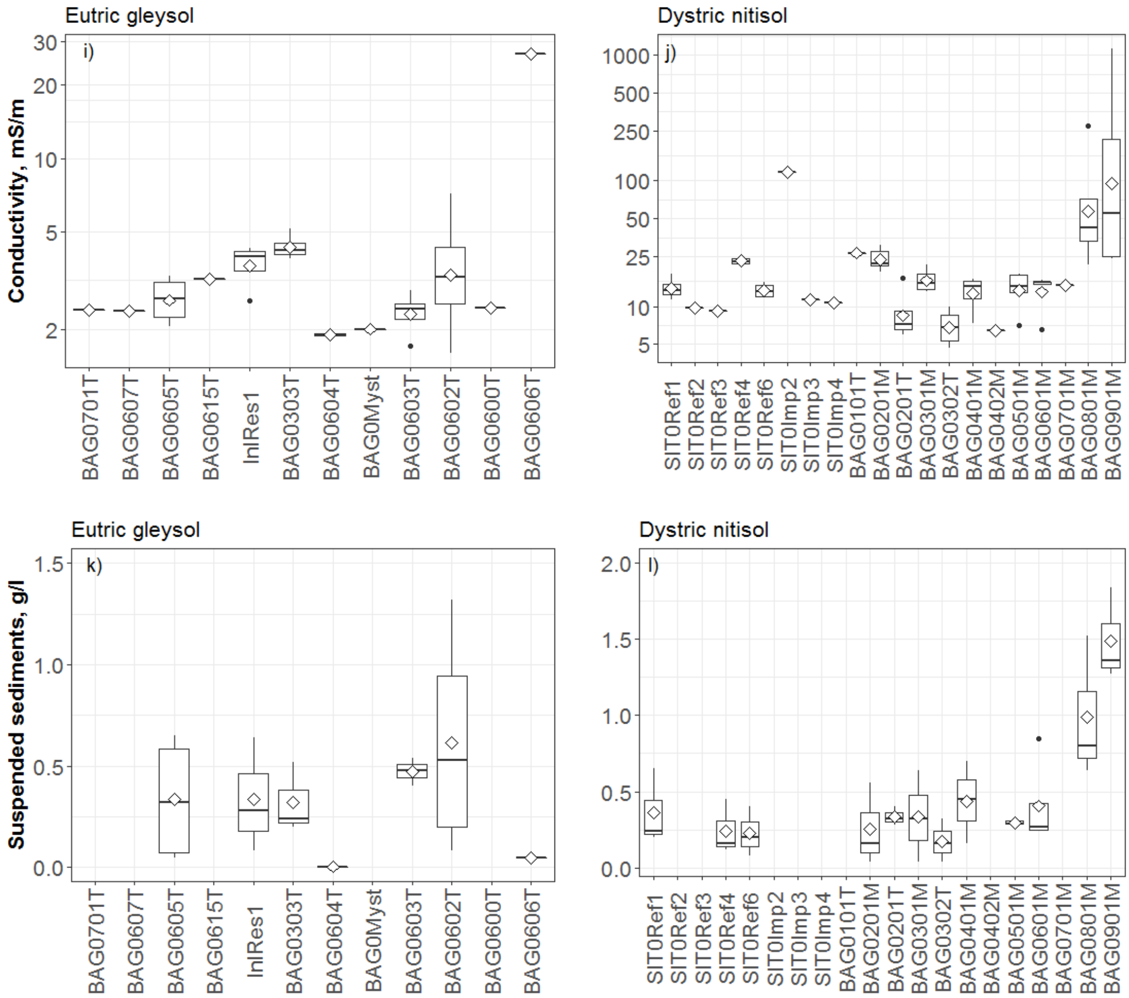


Figure 4.6. continued.

With regard to heavy metals and based on data from reference localities, as well as the Northern Europe criteria, there seem to be no, or very little perturbation by these in the Bago Sub-basin (Figure 4.7 a-j). This result was expected because there are no known significant sources of heavy metal pollution here (usually entering as run-offs from mines and heavy industry) as revealed by the analysis of pressures (Chapter 3). The background levels for heavy metals (filtrated) seem to be in accordance with expected levels from Europe. Because all levels are generally low, it is at present not possible to comment on the G/M, M/P and P/B class boundaries. Our data show support that copper is a highly particulate bound metal, and therefore the proposed class boundaries requires filtration to interpret (0.45 µm filters). The other metals were in low concentrations in the un-filtered samples as well. Nevertheless, filtration should be applied to all metals for the application of this system, and will be conducted in future monitoring. Some unexplainably high levels were sometimes recorded, for instance for total mercury (Hg; Figure 4.7 j). This may be related to analysis error but could also be related to possible mining activities or other acute pollution. Such records should be investigated further.

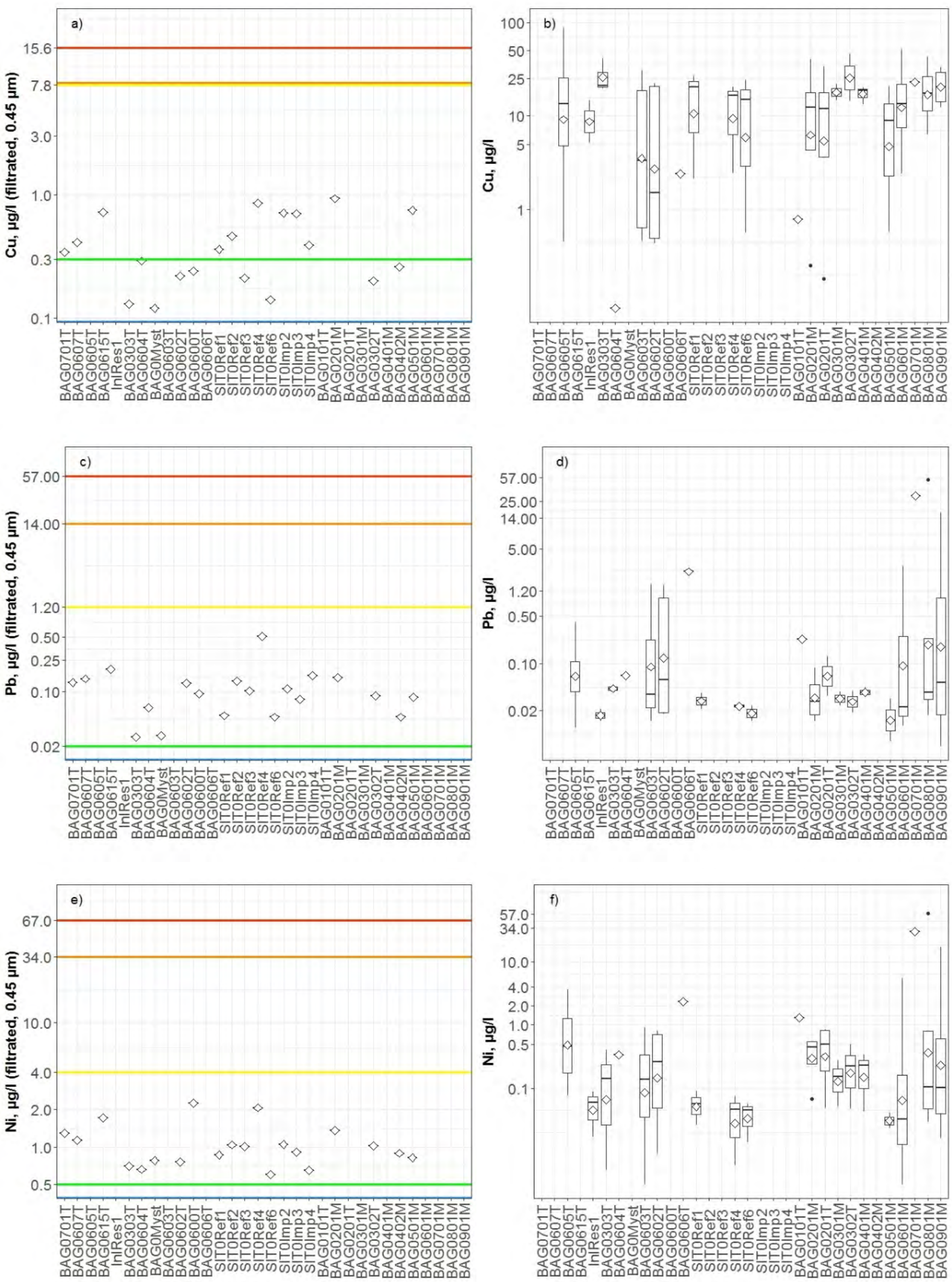


Figure 4.7. Levels of metals from water samples taken from of streams in the Bago River and Sittaung River-basins. Horizontal lines represent proposed class boundaries based on suggested criteria: the area between blue and green lines represents high status, green-yellow = good, yellow-orange = moderate, orange-red = bad and red and above = poor status. For more details about the plots, see description of Figure 4.6.

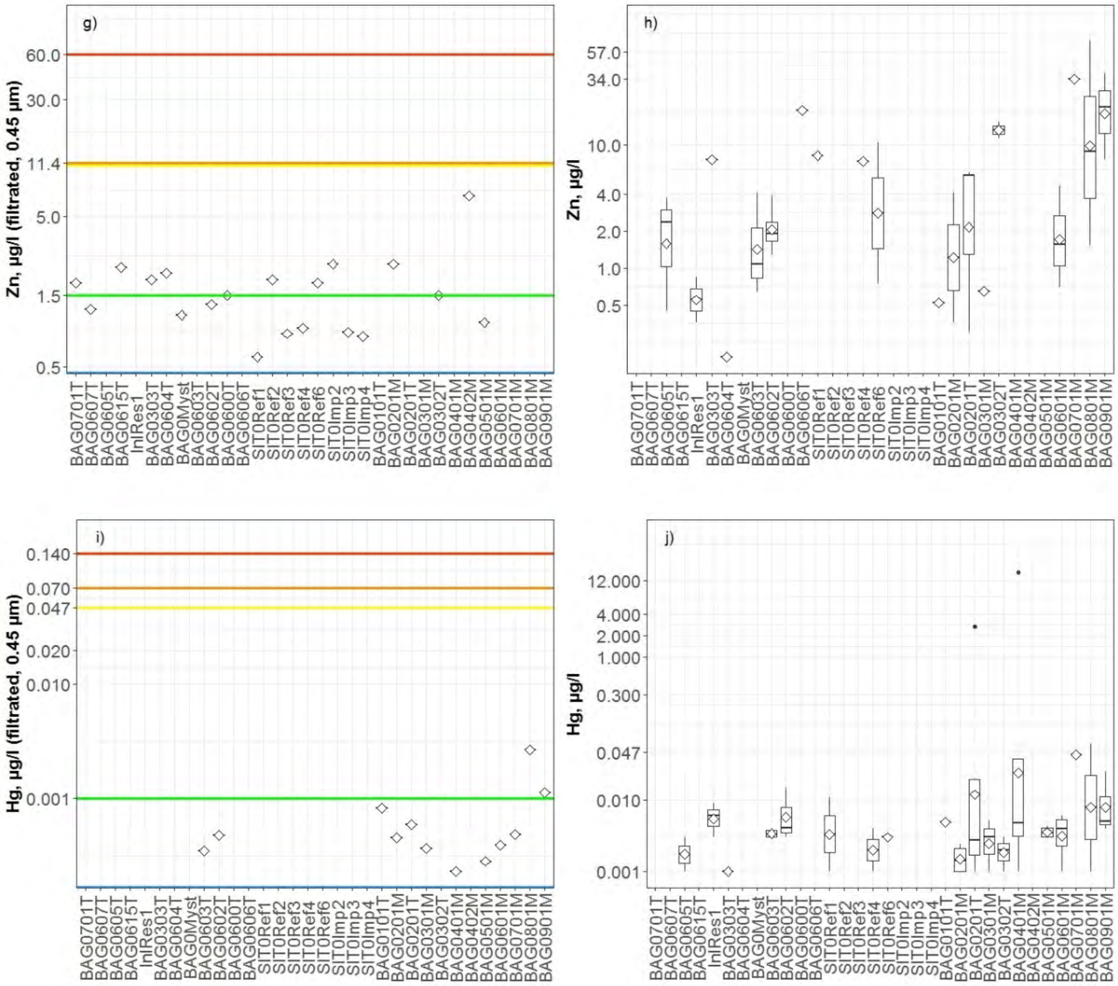


Figure 4.7. continued.

For nutrients, there was generally one to three available samples from each site. This makes evaluation of these parameters difficult at this stage and more data is required to identify relevant nutrient levels in the 35 water bodies. Adding to this uncertainty, some sites we believed to have no or little impact, showed relatively high levels of phosphorus (SIT0Ref1 and SIT0Ref4), as well as nitrogen (SIT0Ref4). Some trends were, however, clear. The lower parts of the Mazin Chaung (BAG0603T, BAG0602T, BAG0600T), which originates from the Mazin Dam and flows though Bago City, had elevated levels of phosphorus relative to the upper parts (BAG0604T and BAG0Myst). The lower parts apparently receive sewage inputs from the city, where sewage runs openly in ditches and small streams and eventually enters the Bago River (Figure 4.9). One such small urban tributary stream was investigated (BAG0606T) and here levels of phosphorus and phosphate reached approximately 1 mg/l, which indicates high levels of pollution. The level of dissolved oxygen was 0.72 mg/l and saturation of 9.3 %, clearly indicating saprobic conditions. Furthermore, the downstream reaches of the Bago River (BAG0601M-BAG0901M) appear for the very preliminary sampling to have elevated levels of nutrients relative to upstream (BAG0501M) (Figure 4.10). For bacteria, there were challenges related to traveling distances, and so far, there is only data from two sampling sites on one occasion (BAG0601M and SIT0Ref1). From BAG0601M the bacteria *E. coli* was recoded, further supporting inputs of sewage.

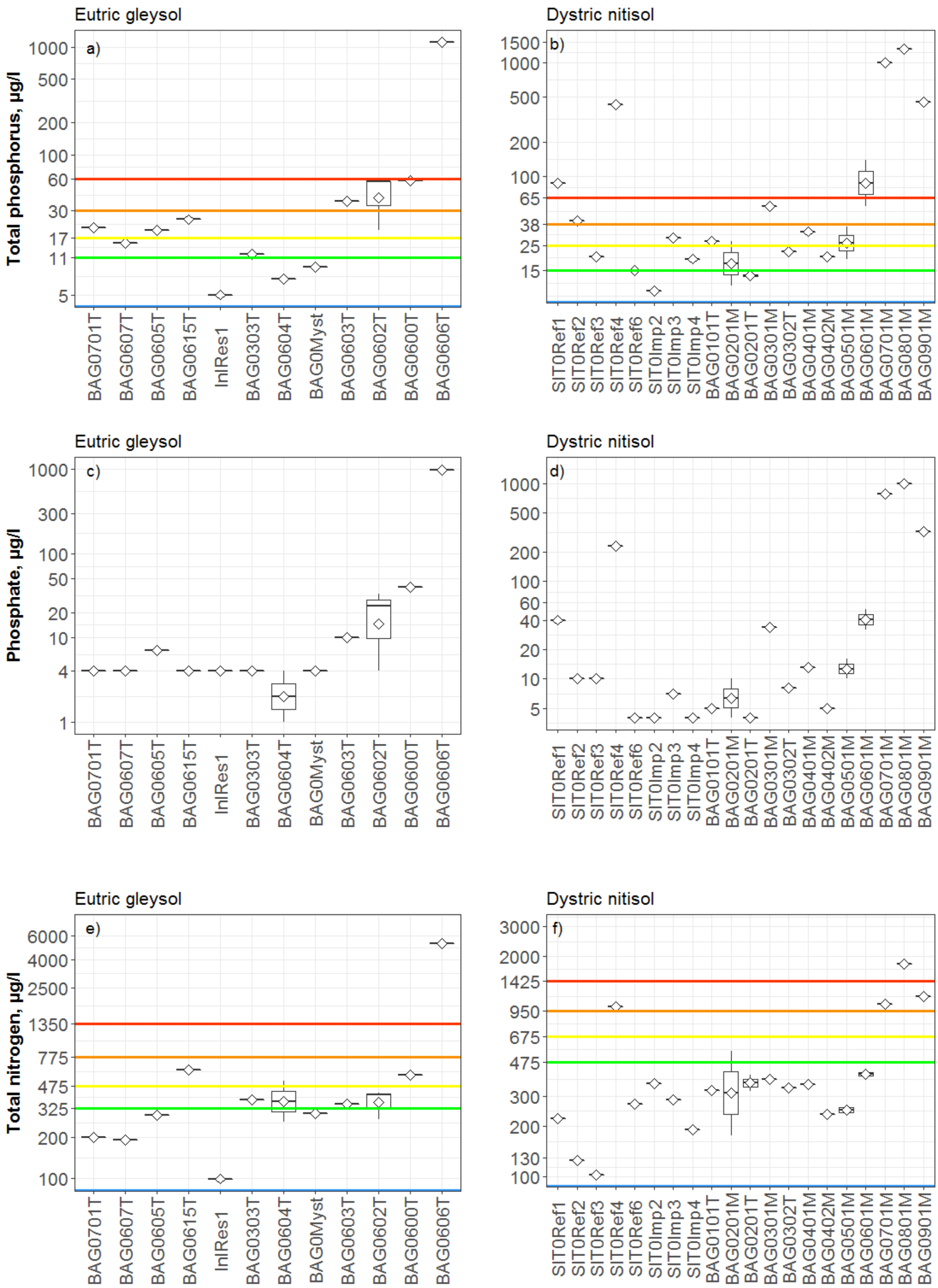


Figure 4.8. Levels of nutrients from water samples taken from streams in the Bago and Sittaung River Sub-basins. Horizontal lines represent proposed class boundaries based on European criteria: the area between blue and green lines represents high status, green-yellow = good, yellow-orange

= moderate, orange-red = bad and red and above = poor status. For more details about the plots, see description in Figure 4.6.

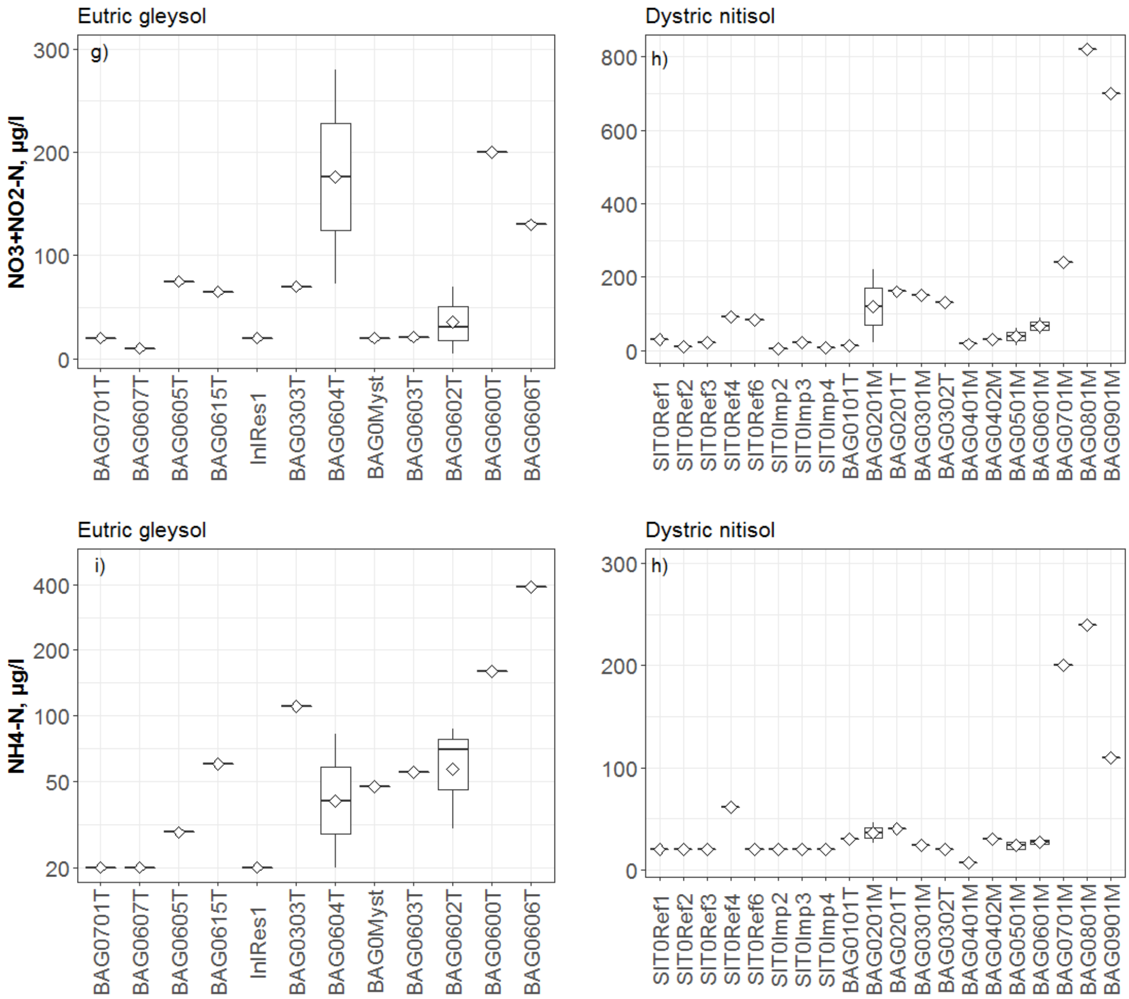


Figure 4.8. continued

Figure 4.9. The Bago River receives inputs from fecal pollution from the city center (left), and from bank settlements (right; just upstream BAG0601M). See also section 3.1.3 for more details on this pressure.

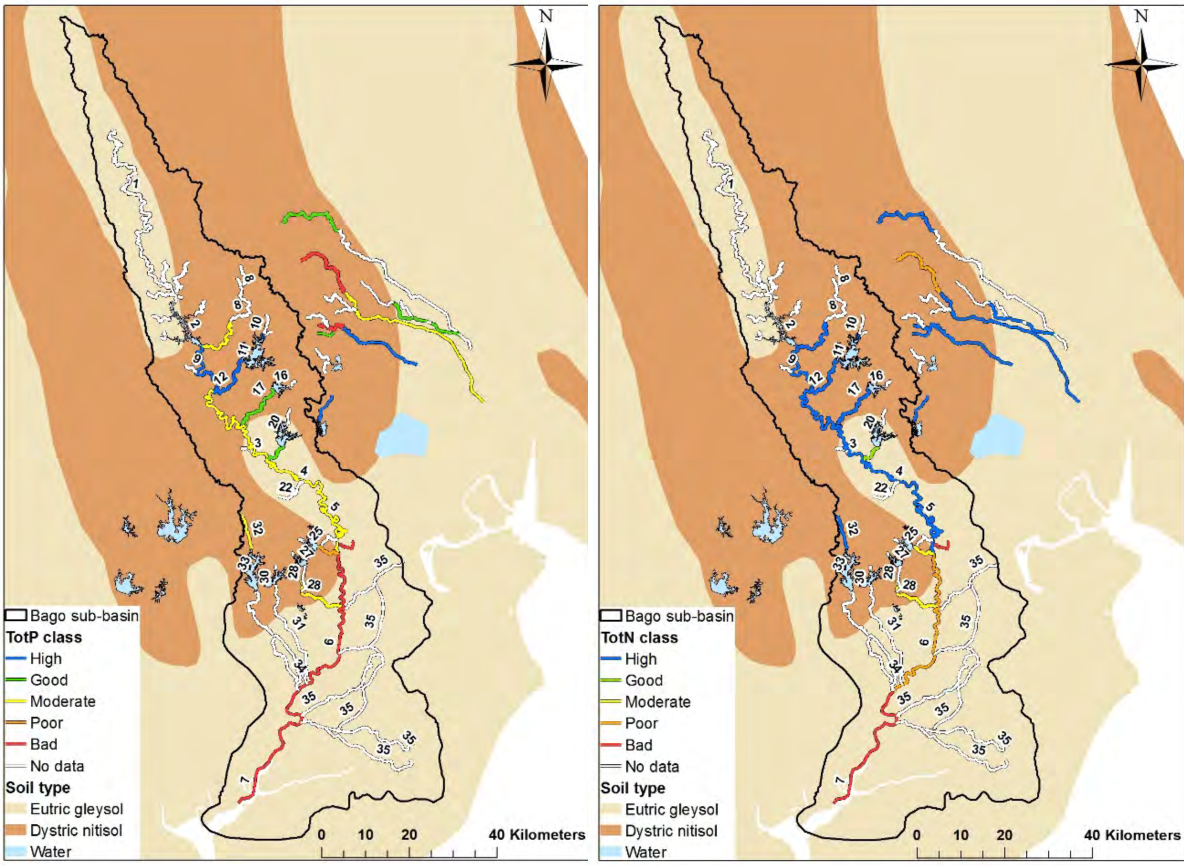


Figure 4.10. A very preliminary classification of total phosphorus (TotP; left panel) and total nitrogen (TotN; right panel) from streams in the Bago Sub-basin and lower parts of the Sittaung River basin. Classification is based on Norwegian status class boundaries and may need revision (see table 4.2. for details). The classifications were based on a very limited number of samples (1-3 samples).

Benthic macroinvertebrates as ecological indicators

Benthic macroinvertebrates are robust indicators of ecological quality and are in particular sensitive to oxygen depletion of water and effects of eutrophication. In areas with no or insignificant human activities, we observed high diversities of macroinvertebrates and several taxa with expected high oxygen requirements (Figure 4.11). In urban streams, with high input of sewage, communities were species poor and dominated by taxa with low oxygen requirements (Figure 4.12). The observed response fits well with predicted responses to organic pollution from other parts of the world (Figure 4.13). The results suggest that it will be possible to create an ecological status evaluation system for Myanmar streams based on benthic macroinvertebrates as the biological quality element although not all samples have been processed. At present, more work is needed to see whether the creation of a five-class system is possible (like shown in Figure 4.1). A qualitative evaluation of the macroinvertebrates data so far, support that the upper parts on the Bago River Sub-basin is insignificantly impacted by human degradation (acceptable status) whereas the urban parts near Bago City are highly impacted (not acceptable; Figure 4.14). More work is needed to make a quantitative evaluation system and to test for the application of more than two status classes.

Figure 4.11. Macroinvertebrate community composition in streams with no or low organic pollution. Macroinvertebrates were collected from BAG0101T, BAG0201T and BAG0201M (Figure 4.2; Appendix table D).

Figure 4.12. Macroinvertebrate community composition in streams with high organic pollution. Macroinvertebrates are collected from BAG0606T and BAG0602T (Figure 4.2; Appendix table D)

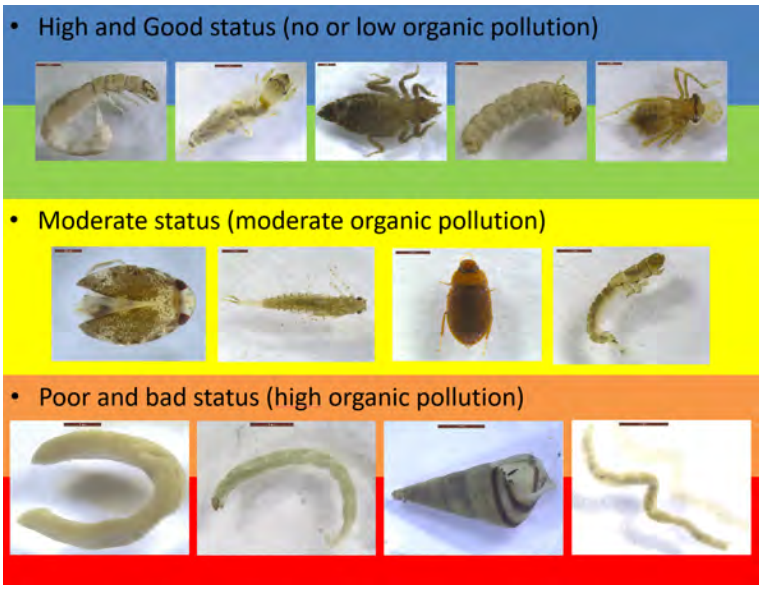


Figure 4.13. Expected shifts in community composition in response to organic pollution in streams in the Bago Sub-basin. The figure is adapted based on results from the Bago Sub-basin (see Figure 4.11-4.12). Similar responses have been documented worldwide.

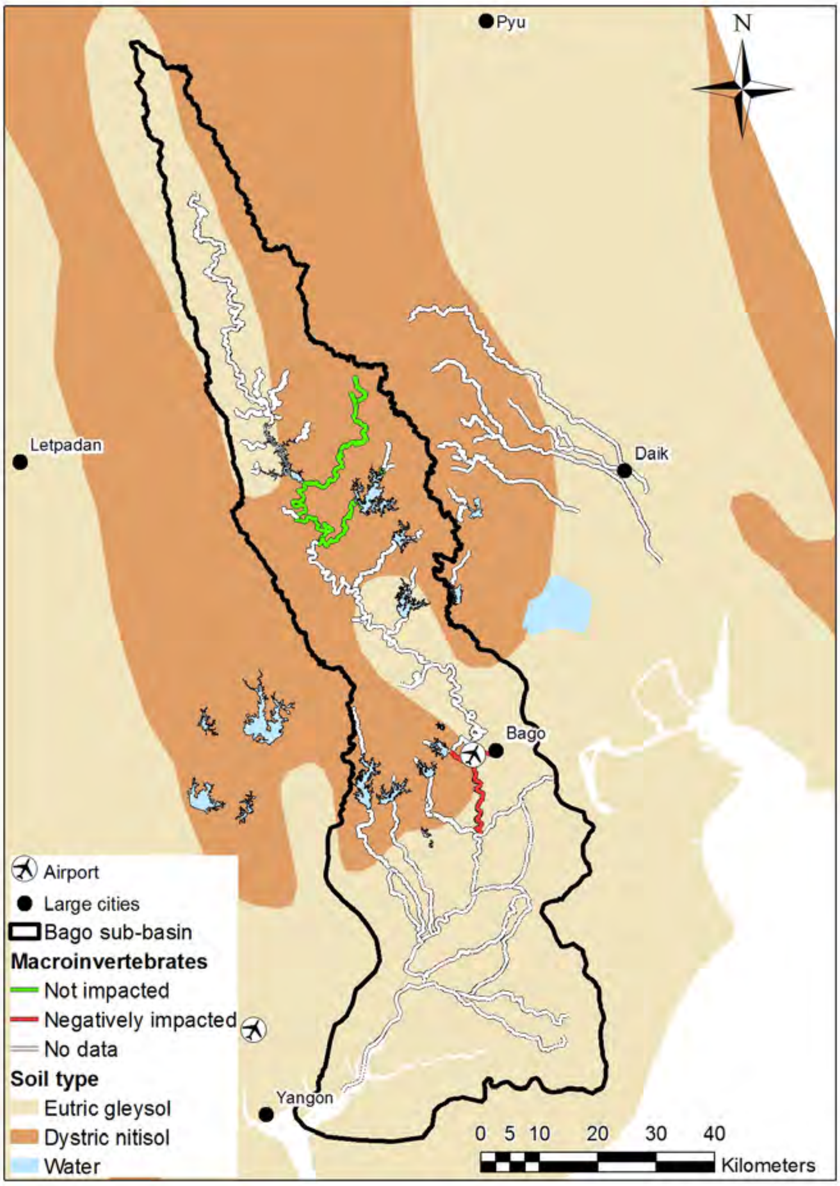


Figure 4.14. Preliminary evaluations of macroinvertebrates communities in the Bago and Sittaung Sub-basins.

4.3.1 Hydromorphological data

Hydromorphology was assessed using a modified version of MQI, a method originally developed in Italy but now introduced in several European countries (Rinaldi 2013; Appendix table E; Figure 4.15). Hydromorphological features are visually assessed in the field and combined to score which can be translated into quality classes. The version applied here was simplified to test its use in Myanmar and results cannot be compared directly with results obtained with the original MQI method. However, the modified MQI used in Bago River can give a good indication of the degree hydromorphological degradation in the Sub-basin as well as an impression of its potential use in future.

The results showed that hydromorphology across the Sub-basin ranged from pristine rivers with no evidence of modifications, to very degraded river reaches (Figure 4.16). Overall, most river reaches assessed showed relatively little hydromorphological degradation. The main pressures of rivers in terms of hydromorphology are the presence of dams upstream, embankments and extensive loss of riparian vegetation. The least degraded rivers are found in the upper part of the Sub-basin. In and around Bago City, most river reaches have been physically modified to some degree and the most impacted rivers are found here. However, even in populated areas, river reaches can be found that are still in an acceptable condition in terms of hydromorphology. If MQI class boundaries developed in Europe are used on the Bago River dataset, 76 % of the reaches assessed were either in high (n=13) or good (n=9) status class. Only 7 reaches had moderate (n=3) or lower (poor (3); bad (1) hydromorphological status class. Naturally, these results should be interpreted with caution as both the method, and class boundaries, were not developed to fit Myanmar conditions. Nevertheless, the findings suggest that the impact of hydromorphological degradation in many river reaches is at level where it will have a limited negative effect on ecological status. In about 25 % of the river reaches however, hydromorphology is likely to have a negative effect and mitigation measures, such as physical restoration, could be considered in the future.

Figure 4.15. The assessment of hydromorphological status is done by qualitative evaluations.

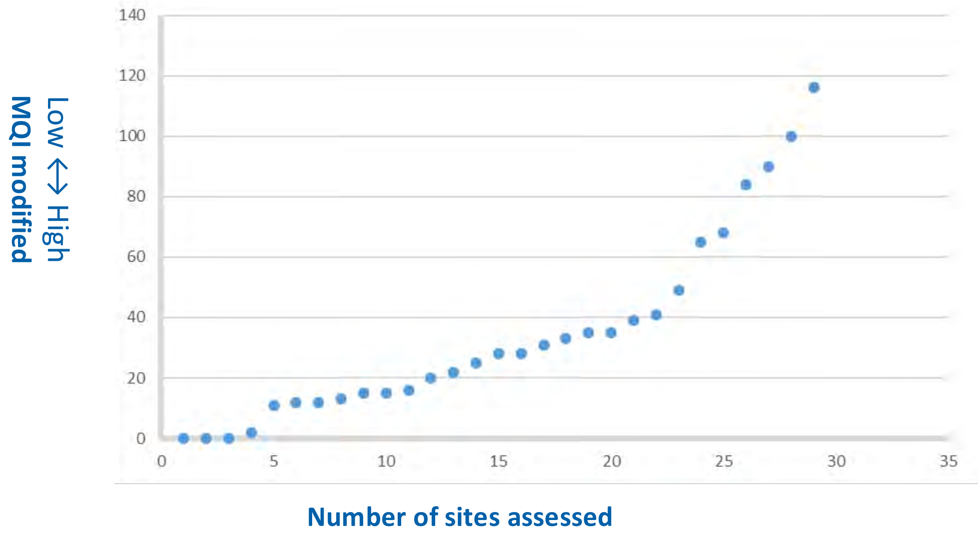


Figure 4.16. MQI (modified) scores assessing hydromorphological degradation at 29 river reaches in the Bago Sub-basin (in ascending order i.e. increasing degree of hydromorphological degradation). MQI (modified) range from 0 (pristine) to 150 (extremely impacted). Class boundaries the original MQI system are: (1) high, 0.85 ≤ MQI ≤ 1; (2) good, 0.7 ≤ 0.85; (3) moderate, 0.5 ≤ 0.7; (4) poor, 0.3 ≤ 0.5; (5) bad, 0 ≤ 0.3. Applying these boundaries to the data in the figure, and assuming a maximum score of 150 also is valid for Myanmar, give the following number of reaches in each status class: High (13); Good (9); Moderate (3); Poor (3) and Bad (1). The results are preliminary and may need revision.

4.3.2 Identifying water bodies at risk

The first classification of ecological status in the river basin should be based on available data and expert judgement. There is not yet sufficient data to define class boundaries for macroinvertebrates, physico-chemical elements, specific pollutants and hydromorphology, and therefore the first classification will be somewhat conceptual and explorative. The aim of the preliminary classification is to group water bodies into one of the three categories not "**at risk**", "**possibly at risk**" or "**not at risk**". **At risk** means that there is significant alteration in the ecological quality, while **possibly at risk** means moderate alterations or that there is not sufficient information to decide, and **not at risk** means no or slight alteration. The preliminary classification therefore helps to identify problem areas where monitoring should be focused. Based on available data and knowledge, we believe areas in forested areas with no or few human settlements to be not at risk, whereas areas downstream the Bago City are clearly impacted and at risk. For several areas, there is uncertainties about the conditions, and these are therefore categorized as possibly at risk (Figure 4.17).

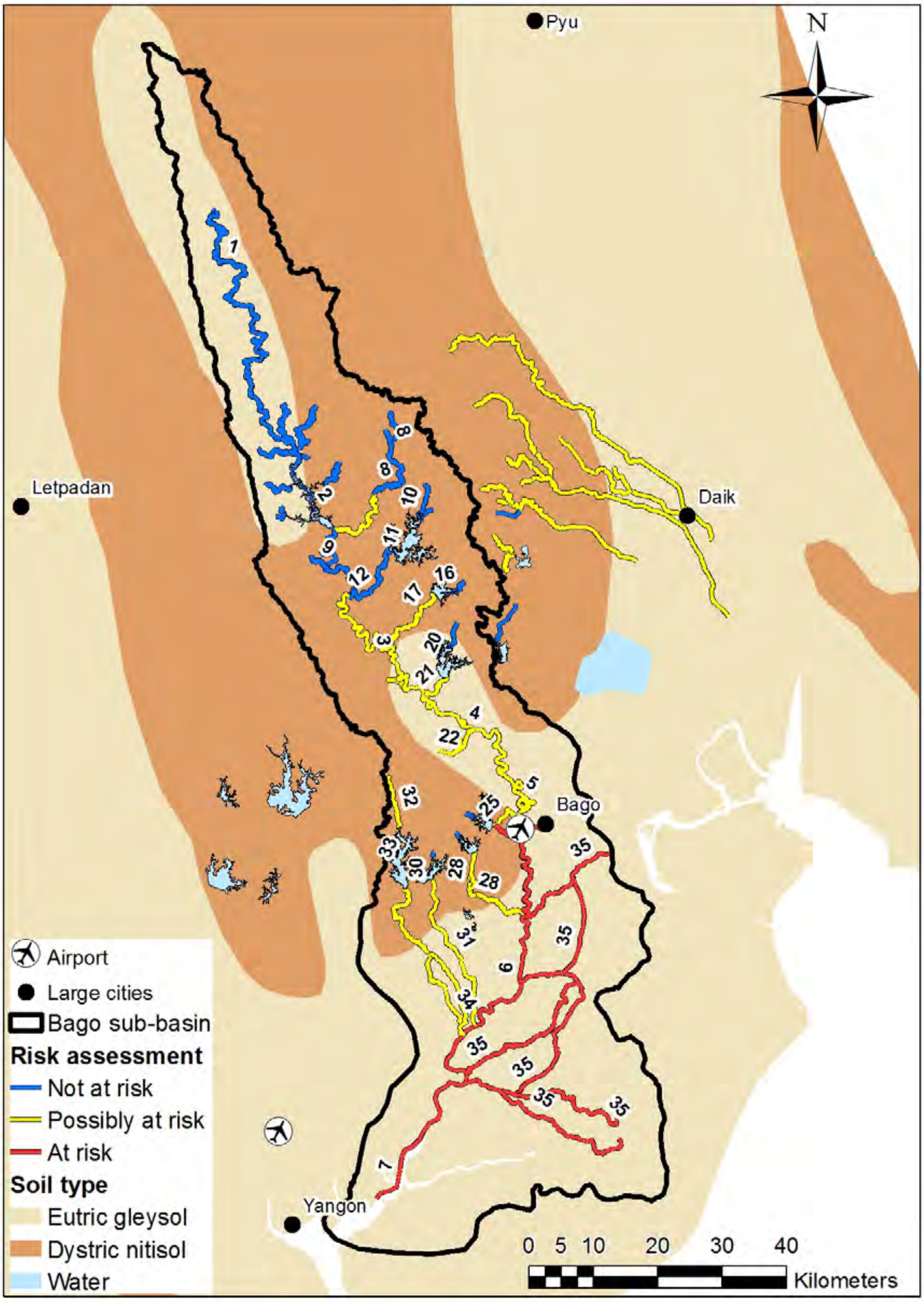


Figure 4.17. Risk assessment of waterbodies not to achieve acceptable status (good status). Water bodies are grouped into one of the three categories not "**at risk**", "**possibly at risk**" or "**not at risk**". Assessments were very preliminary and based on single or < 3 anayses for water chemistry, macroinvertebrates and hydromorphology data, as well as expert judgements. Available data varied among water bodies as the sampling program and processing are not finalized in this moment in time.

5 Suggested monitoring program for Bago River and its tributaries

The monitoring program suggested in the following will comprise of all defined water bodies in the sub-basin and each water body needs to be monitored with a sampling frequency that depends on type of pressures, ecological status and downstream recipients such as lakes or coastal areas. The initial division into 35 water bodies in the Bago River and its tributaries was based on several criteria given in section 4.2.1. However, prior to establishing a monitoring program, the number of water bodies will need to be revised when all samples have been processed and the ecological status of each water body has been established i.e. seasonal data on water chemistry are obtained and all macroinvertebrate samples have been processed. Neighboring water bodies with the same status class might be merged to create less monitoring sites. In particular, water bodies in either high or good ecological status in areas with a low risk of impact could be grouped. In contrast, water bodies at risk, or possible at risk (see section 4.3.2. and Fig. 25), i.e. not obtaining good ecological status or where significant pressures are identified, should be kept as they are or maybe even be subdivided if there are several separate points of impact.

The sampling frequency will influence the ability to detect change and hence the time it will take to see the effects of abatement measures. The frequency will also depend on the quality element used. Water chemistry and discharge shows large seasonal variation and should be sampled on several occasions (at least seasonal and preferable a minimum of 4 times to account for variability) during a year. In contrast, macroinvertebrates only need to be sampled once a year in the dry season when sampling/assessment is feasible, and hydromorphology should only be re-assessed after 6 years. Water bodies having good or high ecological status should be sampled less frequently than waterbodies at risk. These sites are expected to show only natural variation in water chemistry, hydromorphology and macroinvertebrates and hence vary little over time. The minimum sampling frequency should be every six years, where water chemistry is measured 4 times during the year (3 months intervals as to cover wet and dry seasons) and hydromorphology and macroinvertebrates are sampled once in the same year (table 5.1.). In water bodies at risk, or possible at risk, sampling should be undertaken more frequently e.g. on a yearly basis. Water chemistry and discharge sampling frequency should be four times per year as a minimum but monthly sampling is recommended. Macroinvertebrate should be sampled in dry season once a year while hydromorphology should be assessed every six years.

In addition to the suggested surveillance monitoring program it is advised that investigative monitoring is undertaken if necessary applying the same methods and quality elements. Investigative monitoring is relevant if pressures increase in certain areas of the sub-basin and there is a need to check the possible impact on ecological status. Examples could be new urban developments, large scale deforestation, industry developments etc. Specific sampling sites for impact assessment should also be set up in connection with the establishment of point sources (sewage outlets; industrial waste effluents etc.) using an upstream control and downstream impact design.

5.1 Preliminary suggestion regarding a monitoring program

From the initial assessment of characterization, ecological status and use of the quality elements in the Bago Sub-basin it appears that the upper parts of the system could be sampled every six years.

Water chemistry should focus on nutrients and BOD if the method is available with regard to the latter. There is little evidence that heavy metals are a risk in this area. Around Bago city and downstream it appears from the initial analysis that many water bodies are impacted and do not satisfy good ecological status. Here it would be appropriate to sample quality elements on a yearly basis in addition to a site in Bago River (e.g. Bago501M) upstream of the urban area as a reference. Water chemistry could include heavy metals at the upstream and downstream monitoring stations. Furthermore, *E*. *coli* should be sampled as the river has multiple human uses in the area with a high risk of infection. It is important to note that these recommendations are for a future surveillance monitoring and based on preliminary analyses, as there is not sufficient data gathered yet in the project on ecological status, nutrients and variation between seasons. Furthermore, as the analytical capacity increases and the mapping of pressures are more complete, the need to include more toxic compounds, or priority substances, might become evident.

Table 5.1. Recommended frequency for the different elements in future surveillance monitoring in the Bago Sub-basin

Quality elements	**Frequency Waterbodies at risk/possibly at risk**	**Frequency Waterbodies not at risk**
Biology		
Macroinvertebrates	Once a year (dry season)	Every six years (dry season)
Discharge measurements* Morphological surveys	Monthly to quarterly Every 3 years (dry season)	Quarterly every six years Every six years (dry season)
Physico-chemical elements	Monthly to quarterly	Quarterly every six years

**Discharge measurements are particularly important where streams and rivers enters lakes or coastal area as it enables estimation of nutrient loads to these recipients, which can cause eutrophication.*

6 Recommendations and remarks

1. Population density in a river basin is an important parameter for evaluating water needs and the human impact on water quality and quantity. Information on socio-economic groups and the types of economic activities that are found in the basin is important for a risk assessment of water bodies regarding identified environmental aims.
2. Rarely however, are socio-economic data available within the boundaries of basins; there is a need in most cases to estimate information on the basin level, based on information available from administrative units.
3. As part of characterizing water bodies in the basin, it is recommended to provide a register of protected areas – identified as areas requiring special protection under existing national or regional legislation or regarding specific water use criteria, or for the conservation of habitats or species that directly depend on those waters.
4. A major incident of non-point source pollution into rivers and streams is related to the monsoon season, as heavy precipitation acts as surface wash-off for various pollutants.
5. Our preliminary results indicate that it could be possible to create an ecological status evaluation system based on the biological quality element benthic macroinvertebrates in Myanmar streams. However, more data is needed from stream reaches along gradients of anthropogenic degradation, from non-impacted to very perturb, to see whether the creation of a five-class system is possible. Such data can also be used to suggest class boundaries for physico-chemical supportive elements, such as nutrients and biological oxygen demand, as well as chemical substances like heavy metals. We therefore support that the chemical and ecological monitoring continues. However, we support that more emphasis is put on organic pollution, nutrients and bacteria because this seems so be the main pressures and stressors acting on streams in this region.
6. Based the data presented is this report, water bodies were classified as “at risk”, “possibly at risk” and “not at risk” of having good status. There were uncertainties about the risk assessment in several areas because little information was available. However, the areas near and downstream the Bago City are with no doubt “at risk”.

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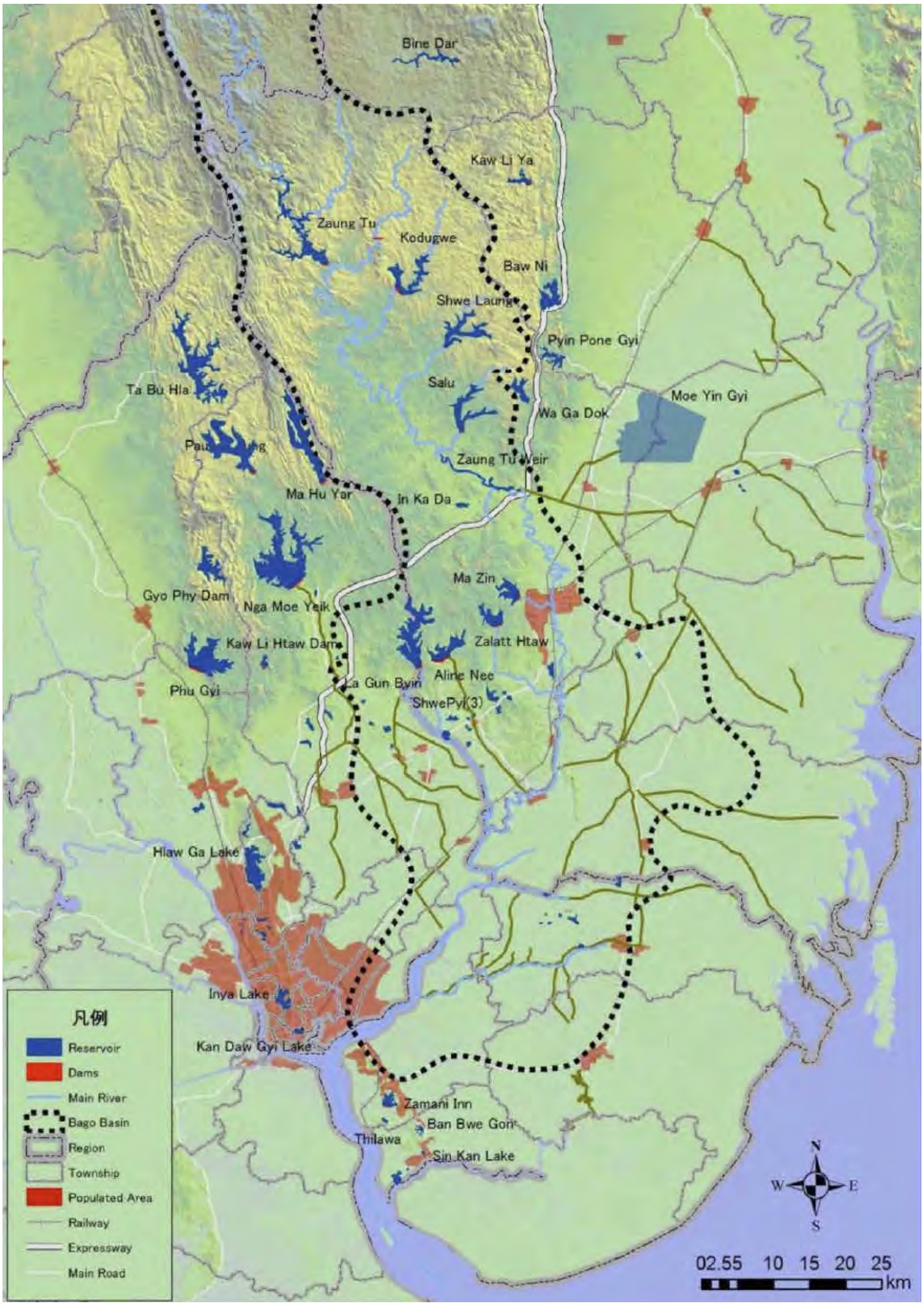
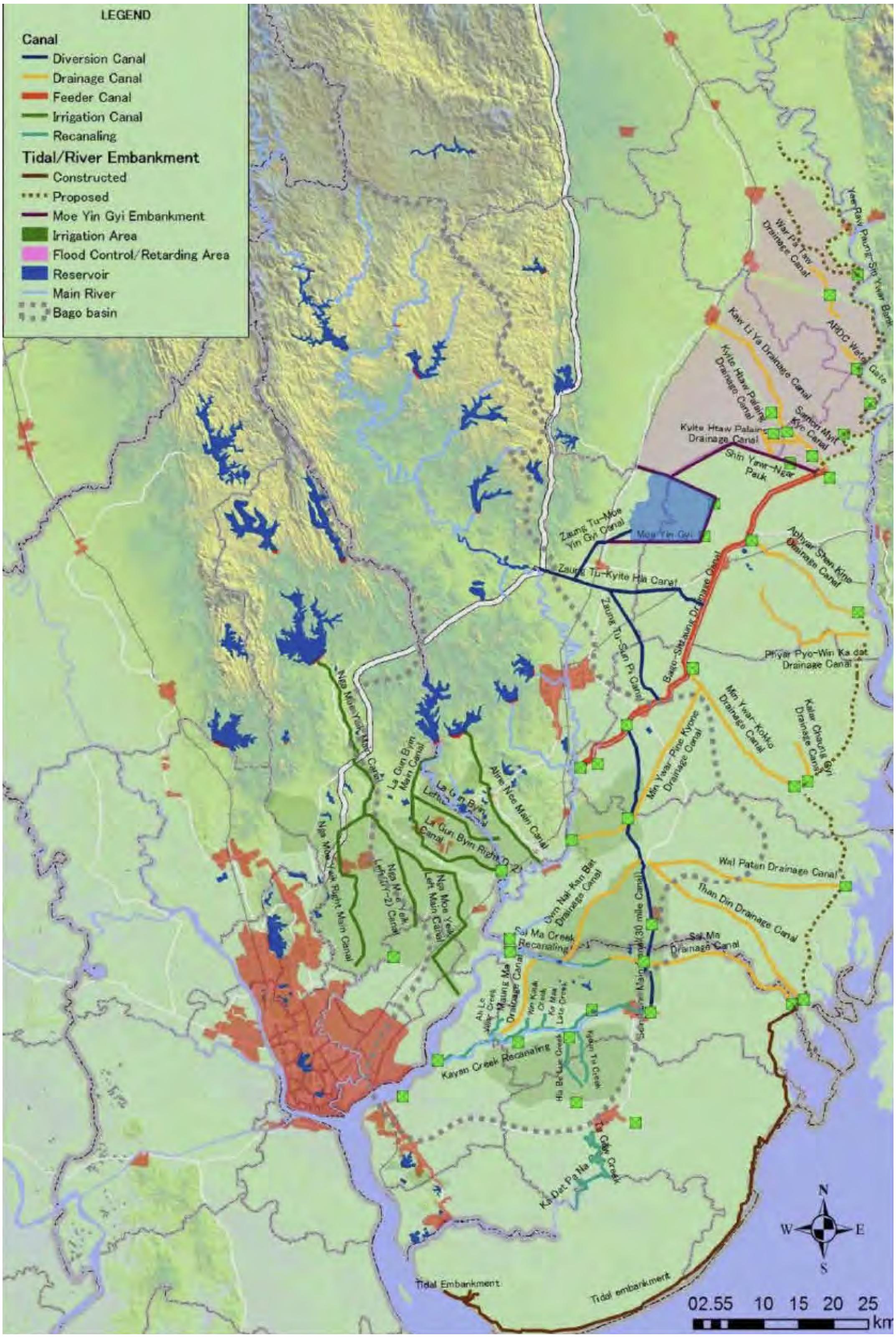
Appendix A. **Location of reservoirs**

Source: JICA, 2014 (copied with permission from JICA).



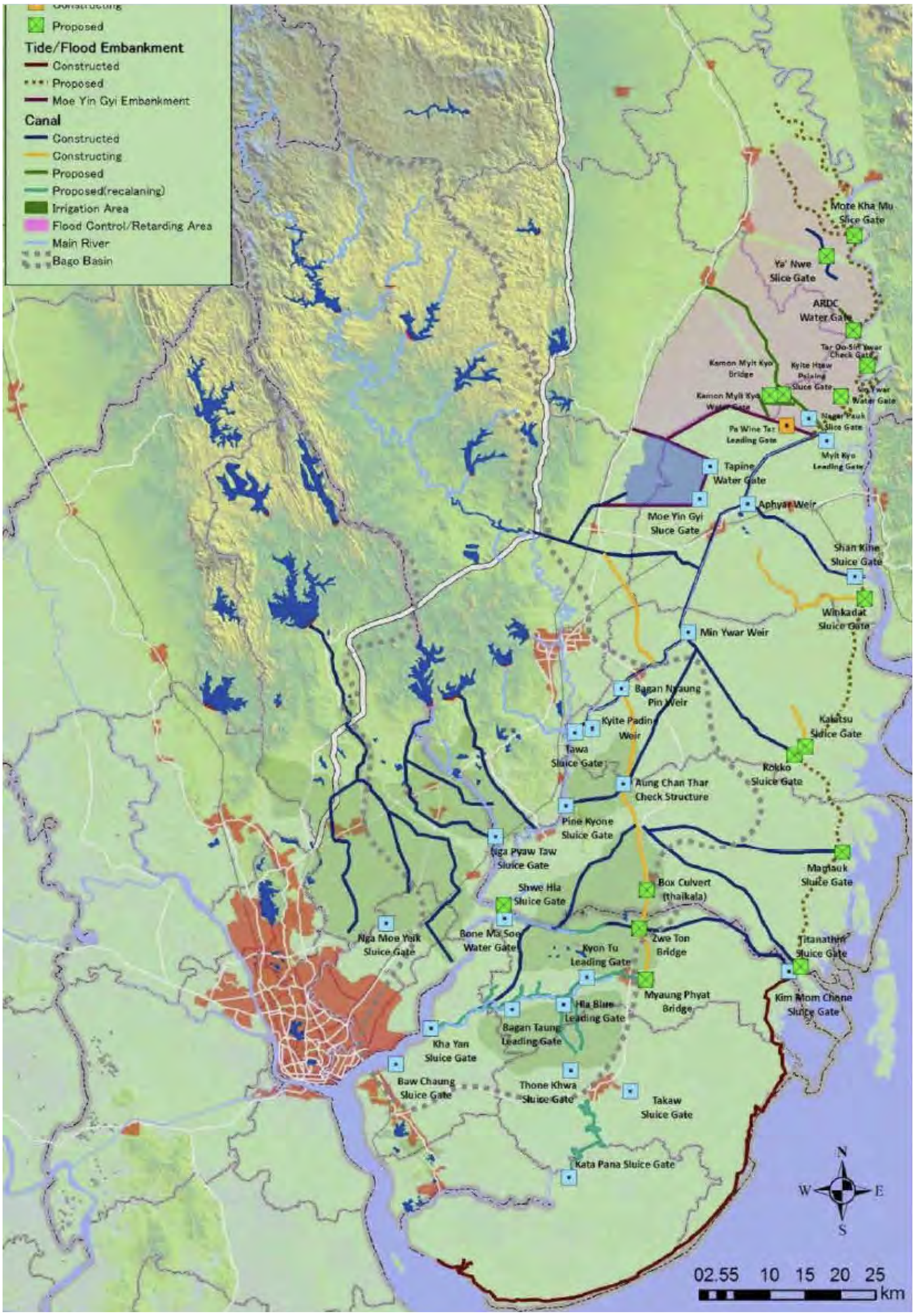
Appendix B. Location of drainage canals

Source: JICA, 2014 (copied with permission from JICA).



Appendix C. **Location maps of water gates**

Source: JICA, 2014 (copied with permission from JICA).



Appendix D. **Sample station coordinates**

Catchment	Station	Longitude	Latitude
Bago	BAG0101T	96.21139	17.75437
Bago	BAG0201M	96.23661	17.67427
Bago	BAG0202T	96.23871	17.65681
Bago	BAG0301M	96.28061	17.58665
Bago	BAG0302T	96.28410	17.59296
Bago	BAG0303T	96.35365	17.52629
Bago	BAG0401M	96.35486	17.50067
Bago	BAG0402M	96.44641	17.46536
Bago	BAG0501M	96.48022	17.38383
Bago	BAG0600T	96.480135	17.327763
Bago	BAG0601M	96.48826	17.29674
Bago	BAG0602T	96.47294	17.33214
Bago	BAG0603T	96.44821	17.33764
Bago	BAG0604T	96.439516	17.342018
Bago	BAG0605T	96.45272	17.22751
Bago	BAG0606T	96.49297	17.33986
Bago	BAG0607T	96.40734	17.26978
Bago	BAG0615T	96.44638	17.23698
Bago	BAG0701M	96.49464	17.21640
Bago	BAG0701T	96.29305	17.37319
Bago	Bag0801M	96.44964	17.09413
Bago	BAG0801T	96.41359	17.06809
Bago	BAG0802T	96.39671	17.05223
Bago	BAG0803T	96.41004	16.99465
Bago	BAG0804T	96.41517	16.98140
Bago	BAG0901M	96.28258	16.81452
Bago	BAG0Myst	96.445131	17.340200
Sittaung	InlRes1	96.44358	17.60961
Sittaung	SIT0Imp2	96.61851	17.72264
Sittaung	SIT0Imp3	96.66282	17.78757
Sittaung	SIT0Imp4	96.67139	17.80014
Sittaung	SIT0Ref1	96.49021	17.78941
Sittaung	SIT0Ref2-3	96.47173	17.78477
Sittaung	SIT0Ref4	96.49225	17.86902
Sittaung	SIT0Ref6	96.48161	17.98970

Appendix E. **Hydromorphology evaluation sheet**

Indicators of hydromorphological status – field assessment

Bago River and tributaries

Date of assessment _______________2016

Name of location ____

Map references____

Estimated length of reach assessed_________________m

Estimated width:_________________m

Estimated depth_________________ m

Water clarity ____low ______moderate ____ high : ____________________________________

F1		
A	absence of alteration in the continuity of sediment and wood 0	
B	slight alteration (obstacles to the flux but with no interception) 3	
C	significant alteration (complete interception of sediment and wood) 5	
F2		
A	presence of a continuous (>66% of the reach) and wide modern floodplain (>*nW*, where *n* = 1 or 2 for wandering – braided or for single thread - anabranching channels, respectively, and *W* = channel width) 0	
B1	presence of a discontinuous (10 ÷ 66%) but wide modern floodplain or > 66% but narrow 3	
B2	presence of a discontinuous (10 ÷ 66%) and narrow modern floodplain 2	
C	absence of a modern floodplain or negligible presence (≤10% of any width) 5	
F3		
A	full connectivity between hillslopes and river corridor (>90%) 0	
B	connectivity for a significant portion of the reach (33 ÷ 90%) 3	
C	connectivity for a small portion of the reach (≤33%) 5	
F4		
A	bank erosion occurs for >10% and is distributed along >33% of the reach 0	
B	bank erosion occurs for ≤10%, or for ≤10% but concentrated along ≤33% of the reach, or significant presence (>25%) of eroding banks by mass failures 2	
C	complete absence (≤2%) of retreating banks, or widespread presence (>50%) of unstable banks by mass failures 3	
F5		
A	presence of a potentially erodible corridor (*EC*) for a length > 66% of the reach and wide (>*nW*, where *n* = 1 or 2 for wandering – braided or for single thread - anabranching channels, respectively, and *W* = channel width) 0	

B	presence of a narrow (≤*nW*) potentially *EC* for >66%, or wide but for 33 ÷ 66% of the reach 2	
C	presence of a potentially *EC* of any width but for ≤33% of the reach 3	
F6		
A	bed forms consistent with the mean valley slope 0	
B	bed forms not consistent with the mean valley slope 3	
C	complete alteration of bed forms for the presence of an artificial bed 5	
F7		
A	absence (<5%) of alteration of the natural heterogeneity of geomorphic units and channel width 0	
B	alteration for a limited portion of the reach (≤33%) 3	
C	consistent alteration for a significant portion of the reach (>33%) 5	
F8		
A	presence of floodplain landforms (oxbow lakes, secondary channels, etc.) 0	
B	presence of traces of floodplain landforms (abandoned during the last decades) but with possible reactivation 2	
C	complete absence of floodplain landforms 3	
F9		
A	absence (≤5%) of alteration of the cross-section natural heterogeneity 0	
B	presence of alteration for a limited portion of the reach (≤33%) 3	
C	presence of alteration for a significant portion of the reach (>33%) 5	
F10		
A	natural heterogeneity of bed sediments and no significant clogging 0	
B	evident armouring (*PC–U* only) or clogging in various portions of the site 2	
C1	evident and widespread (>90%) armouring (*PC–U* only) or clogging, or occasional substrate outcrops (*PC–U* only) 5	
C2	widespread substrate outcrops (>33% of the reach) (*PC–U* only) or widespread substrate alteration by bed revetments (>33% of the reach) 6	
F11		
A	significant presence of large wood along the whole reach 0	
B	negligible presence of large wood for ≤50% of the reach 2	
C	negligible presence of large wood for >50% of the reach 3	
F12		
A	A - wide connected functional vegetation (*PC-U:* >*nW*, where *n* = 1 or 2 for wandering – braided or for single thread - anabranching channels, respectively, and *W* = channel width; *C:* >90% of hillslopes, 50 m from each bank) 0	
B	B - intermediate width of connected functional vegetation (*PC-U:* 0.5 *W* ÷ *nW*; *C*: 33 ÷ 90% of hillslopes, 50 m from each bank) 2	
C	C - narrow connected functional vegetation (*PC-U*: ≤0.5 *W*; *C*: ≤33% of hillslopes, 50 m from each bank) 3	
F13		
A	linear extension of riparian vegetation >90% of maximum available length and significant presence of aquatic vegetation 0	
B	riparian vegetation 33 ÷ 90%, or riparian >90% but negligible aquatic vegetation, or riparian ≤33% but significant presence of aquatic vegetation 3	
C	riparian vegetation ≤33%, or <90% but negligible presence of aquatic vegetation 5	

Channel alterations	
A1 A no significant alteration (≤10%) of channel-forming discharges and *Q* with return interval >10 years 0 B significant alteration (>10%) of *Q* with return interval > 10 years 3 C significant alteration (>10%) of channel-forming discharges 6	
A2 A absence or negligible presence of structures of interception of sediment fluxes 0 B1 presence of dams for drainage area 5 ÷ 33%, and/or weirs or check dams with total interception of bedload and drainage areas 33 ÷ 66%, and/or weirs or check dams with partial interception of bedload and drainage areas >33% (*plain/hills areas*) or >66% (*mountain areas*) 3 B2 presence of dams for drainage area 33 ÷ 66%, and/or weirs or check dams with total interception of bedload and drainage areas >66% 6 C1 presence of dams for drainage area >66% 9 C2 presence of a dam at the upstream boundary of the reach 12	
A3 A no significant alteration (≤10%) of channel-forming discharges and *Q* with return interval > 10 years 0 B significant alteration (>10%) of *Q* with return interval > 10 years 3 C significant alteration (>10%) of channel-forming discharges 6	
A4 A A - absence of structures of sediment flux interception (dams, check dams, weirs) 0 B B – *channels with S≤1%:* consolidation check dams and/or abstraction weirs ≤1 every 1000 m; *steep channels (S>1%):* consolidation check dams ≤1 every 200 m and/or open check dams 4 C C - *channels with S≤1%:* consolidation check dams and/or abstraction weirs >1 every 1000 m; *steep channels (S>1%):* consolidation check dams >1 every 200 m and/or retention check dams or presence of a dam or artificial reservoir at the downstream boundary (*any bed slope*) 6 *In case of density of interception structures, including bed sills and ramps (A9), is >1 every d1, add* 6 *In case of density of interception structures, including bed sills and ramps (A9), is >1 every d2, add* 12 *d1=150 m and d2=100 m in steep channels, d1=750 m and d2=500 m in channels with S≤1%*	
A5 A absence of crossing structures (bridges, fords culverts) 0 B presence of some crossing structure (≤1 every 1000 m on average in the reach) 2 C presence of numerous crossing structures (>1 every 1000 m on average in the reach) 3	
A6 A absence or localized presence of bank protections (≤5% total length of the banks) 0 B presence of protections for ≤ 33% total length of the banks (sum of both banks) 3	

C	presence of protections for > 33% total length of the banks (sum of both banks) 6 *In case of high density of bank protections (>50%) add* 6 *In case of extremely high density of bank protections (>80%) add* 12	
A7		
A	levees absent or distant, or presence of levees close or in contact ≤ 10% total length of the banks0	
B	medium presence of levees close and/or in contact (in contact ≤ 50% bank length) 3	
C	high presence of levees close and/or in contact (in contact > 50% bank length) 6 *In the case of high density of bank-edge levees (>66%) add* 6 *In the case of extremely high density of bank-edge levees (>80%) add* 12	
A8		
A	absence of artificial changes of river course in the past (meanders cut-off, channel diversions, etc.) 0	
B	presence of changes for ≤ 10% of the reach length 2	
C	presence of changes for > 10% of the reach length 3	
A9		
A	absence of structures (bed sills/ramps) and absent or localized (≤ 5%) Revetments 0	
B	limited presence of structures (≤ 1 every *n*, where *n* = 200 m for *mountain areas*, *n* = 1000 m for *plain/hills areas*) and or revetments (≤ 15% impermeable and/or ≤ 25% permeable) 3	
C1	presence of many structures (> 1 every *n*) and/or significant bed revetments (≤ 33% impermeable and/or ≤ 50% permeable) 6	
C2	presence of impermeable bed revetments > 33% and/or permeable revetments > 50% 8 *In the case of high density of bed revetment (impermeable>50% or permeable>80%) add* 6 *In the case of extremely high density of bed revetment (impermeable>80%) add* 12	
A10 *PC–U*:		
A	absence of recent (last 20 years) and past (over the last 100 years) significant sediment removal activities 0	
B1	sediment removal activity in the past but absent during last 20 years 3	
B2	recent sediment removal activity (last 20 years) but absent in the past 4	
C	sediment removal activity either in the past and during last 20 years 6	
A10 *C:*		
A	absence of significant sediment removal activities during the last 20 years 0	
B	localized sediment removal activities during the last 20 years 3	
C	widespread sediment removal activities during the last 20 years 6	
A11		
A	absence of removal of woody material at least during the last 20 years 0	
B	partial removal of woody material during the last 20 years 2	
C	total removal of woody material during the last 20 years 5	
A12		
A	no cutting interventions on riparian vegetation (last 20 years) and aquatic vegetation (last 5 years) 0	

B	selective cuts and/or clear cuts over ≤ 50% of the reach (last 20 years) and partial or no cutting of aquatic vegetation (last 5 years), or no cutting of riparian but partial or total cutting of aquatic vegetation 2	
C	clear cuts over > 50% of the reach (last 20 years), or selective cuts and/or clear cuts of riparian vegetation ≤50% of the reach but total cutting of aquatic vegetation (last 5 years) 5	
Channel adjustments – cannot be directly assessed but must be based on local information		
CA1		
A	absence of changes in channel pattern from 1930s – 1960s 0	
B	change to a similar channel pattern from 1930s – 1960s (*PC–U*) or change of channel pattern from 1930s – 1960s (*C*) 3	
C	change to a different channel pattern from 1930s – 1960s (only *PC–U*) 6	
CA2		
A	absent or limited changes (≤15%) from 1930s – 1960s 0	
B	moderate changes (15 ÷ 35%) from 1930s – 1960s (*PC–U*) or changes >15% from 1930s – 1960s (*C*) 3	
C	intense changes (>35%) from 1930s – 1960s (only *PC–U*) 6	
CA3		
A	negligible bed-level changes (≤ 0.5 m) 0	
B	limited or moderate bed-level changes (0.5 ÷ 3 m) 4	
C1	intense bed-level changes (> 3 m) 8	
C2	very intense bed-level changes (> 6 m) 12	

Appendix F. Land use and land cover data of Bago District

TS_Name	RF_Name	Water	Closed Forest	Open Forest	Other Wooded Land	Other	Total (Acres)
Kyauktaga							
1,5	Aingdonkun R.F	583	35698	109186	22157	7906	175531
4	Kawliya R.F	2	2073	8222	838	38	11173
8	Monbon R.F	134	2242	8171	2320	413	13280
10	Baing Dar R.F	5661	21049	59000	10693	2296	98699
7	Yenwe R.F	7326*	49191	87165	7106	2652	153440
13	Yenwe Ext: RF	11428*	8079	13553	3442	692	25766
14	Daingtaya R.F	48	1	215	1942	468	2674
15	Upper Kanyinmyaung R.F	30	6	46	2538	926	3546
16	Tonkan West R.F	46	0	278	1585	1376	3285
17	Tonkan East R.F	46	2	3	832	5081	5964
	total RF Area	25305	118342	285839	53454	21847	493358
	Unclassify Area	2798	1941	2759	32926	154348	206200
	TS Total Area	28102	120283	288598	86380	176195	699558
Remark: * Yenwe RF & Yenwe Ext RF Water Area - 18754 Acres (Yenwe Dam)							
Bago							
3	Intagaw R.F	792	12	8759	6836	2292	18692
6	Moyingyi Reservoir	9633	0	3	1400	2506	13542
9	Talaingma R.F	1	13	9722	3046	363	13145
11	Shwe Laung Ko Du Gwe R.F	82	6946	33140	13280	661	54109
12	SALU R.F	1053	2159	39716	17526	3171	63624
18	Pyinma R.F	4	356	10999	1556	294	13209
19	North Zamayi R.F	6	1718	2615	37	52	4428
20	Letpan aungmyaR.F	196	1135	13600	1715	466	17112
21	South Zamayi R.F	5164	40577	133166	13479	4328	196714
24	Kantawgyi watership PPF	84	47	575	516	87,68	1310
	total RF Area	17016	52964	252294	59392	14220	395885
	Unclassify Area	11898	114	46716	105130	158105	321963
	TS Total Area	28913	53078	299009	164522	172325	717848
Daik_U							
2	Lower Kanyinmyaung R.F	9	0	99	7619	7664	15391
4	Kawliya R.F	3636	6908	38711	21775	2868	73898
12	SALU R.F	421		1243	3719	504	5888
	total RF Area	4066	6909	40054	33113	11035	95177
	Unclassify Area	3315	475	2892	48976	167263	222921
	TS Total Area	7381	7384	42945	82089	178299	318098

TS_Name	RF_Name	Water	Closed Forest	Open Forest	Other Wooded Land	Other	Total (Acres)
Shwegyin							
22	Kyun Taung R.F	1	8	200	413	16	638
23	Shwekyin P.P.F	30	125808	116248	30271	10843	283200
	total RF Area	31	125815	116449	30684	10859	283838
	Unclassify Area	4292	59231	80697	133266	43760	321246
	TS Total Area	4323	185046	197146	163950	54619	605084
Waw							
6	Moyingyi Reservoir	3425	0	2	3159	5473	12058
	total RF Area	3425	0	2	3159	5473	12058
	Unclassify Area	8204	81	167	11717	208859	229028
	TS Total Area	11629	81	169	14876	214332	241086
Nyaunglebin							
	total RF Area	0	0	0	0	0	0
	Unclassify Area	2828	2	755	41405	136027	181018
	TS Total Area	2828	2	755	41405	136027	181018
Kawa							
	total RF Area	0	0	0	0	0	0
	Unclassify Area	8879	1	210	10150	395274	414515
	TS Total Area	8879	1	210	10150	395274	414515
Thanatpin							
	total RF Area	0	0	0	0	0	0
	Unclassify Area	20842	463	435	18095	206559	246394
	TS Total Area	20842	463	435	18095	206559	246394
Total Township Area		**112898**	**366339**	**829268**	**581467**	**1533629**	**3423600**

Appendix G. **Myanmar National Water Framework Directive (English version, 2015)**

DWIR

Proposed Myanmar Water Framework Directive

Introduction

Sustainable Water Resources Development Standing Committee (SWRDSC) was established by the Presidential order on 29 Nov 2012. It is chaired by the Vice President Two U Nyan Tun and has 18 members in total at the start. Later on few selected internationally and locally outstanding, water experts in their respective fields of expertise were invited to the join SWRDSC. Since then SWRDSC has consulted the wider audience of Myanmar professionals, international and local experts, fellow citizens, civil society organizations and government officials as well as global water leaders occasionally and informally. All of them expressed their concerns and stressed the need for a single piece of water framework legislation to resolve current and potential water problems, which includes water shortage, water-related disasters and water pollution in Myanmar. In response to this, SWRDSC presented a concept proposal for a Water Framework Directive with the following key purposes:

- to ensure water security, water-related disaster risks reduction, good water governance, sustainable development and acceleration of the promotion of Green Economy and Green Growth through Integrated Water Resources Management practices;
- consequently expanding the scope of SWRDSC from 'water resources development for Special Economic Zones focus' to 'protection, management and economic use of all waters, i.e. surface waters and groundwater' in Myanmar
- achieving the status of clean and sufficient water for all purposes by a set deadline
- water management based on proper spatial unit called basin-wide approach
- combined approach of green practices and quality standards
- getting the pro-poor prices to respect the human rights as well as economically viable prices for commercial uses
- getting right perspective and priorities in relation to water-energy-food nexus and Climate Change
- getting the citizen involved more closely and hands-on projects to achieve dire need for Peace and Prosperity
- formulating a continuum of water legislation in Myanmar to ensure the direct and indirect revenues from water resources

The below concept explains what elements should be stated in the Directive and need to begin the process as soon as possible.

The Water Framework Directive

The proposed **"Water Framework Directive"** of the Republic of the Union of Myanmar (Zero Draft) aims to establish **"a framework for all walks of life in field of water policy"**, which commits all local governments (States and Divisional Governments) to achieve good qualitative and quantitative status of all Water Bodies within Myanmar (including marine waters up to one nautical mile from shore) by 2015. It is a framework in the sense that it prescribes steps to reach the common goals rather than adopting the pretext by top down approach.

Goals

Three main goals of this proposed Water Framework Directive are:-

1. getting Myanmar rivers healthier, waters cleaner and more beneficial for all purposes;
2. getting the citizens involved in a peaceful way; and
3. getting Green Economy momentum quickly and achieve Green Growth shortly.

Objectives of the Directive

There are seven objectives as listed below.

Objective (1): Good status for all ground water and surface water

The Directive aims for 'good status, i.e. clean and sufficiently stored' for all ground water and surface water (rivers, lakes, transitional waters, and coastal waters) in Myanmar.

Objective (2): National Water Budget

The Water Framework Directive stipulates that National Water Budget must be estimated under the current hydrological and meteorological conditions taking into consideration of the Climate Change impacts already visible. The groundwater must achieve "good quantitative status" and "good chemical status" (i.e. not polluted) by 2020. Classification of groundwater bodies, "good" or "poor" according to the current status, should be examined.

Objective (3): The ecological and chemical status

The ecological and chemical status of surface waters should be assessed according to the following criteria:

- Biological quality (fish, benthic invertebrates, aquatic flora);
- Hydro-morphological quality such as status of river banks, river bank structures, river training works, river continuity or substrate of the river bed;
- Physical-chemical quality such as temperature, oxygenation and nutrient conditions;
- Chemical quality that refers to environmental quality standards for river basin specific pollutants. These standards specify maximum concentrations for specific water pollutants. If even one such concentration is exceeded, the water body will not be classed as having a "good ecological status".

Objective (4): Cooperation between the Union Government and the States and Divisional Governments

The proposed Directive requires local governments (States and Divisional Governments) "to encourage the active involvement of interested parties" in the implementation of the Directive. This is generally acknowledged the requirement of frequent consultative and coordinating meetings yielded by capacity building workshops across the country. It also emphasizes the need to have clear mandate sharing between the Union and Local Governments.

Objective (5): Spatial management of river basins

One important aspect of the Water Framework Directive is the introduction of River Basin Management approach. These basin areas have to be designated, not according to administrative or political boundaries, but rather according to the river basin (the spatial catchment area of the river) as a natural geographical and hydrological unit. As our main rivers cross many administrative boundaries, i.e. States and Divisional Administrative Boundaries, the Local Governments have to cooperate and work together for the management of the river basin (so-called national basins) such as Ayeyarwady, Sttaung, Chindwin , etc.

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and international basin such as Thanlwin River. All major basins in Myanmar need River Basin Development Plans, which provide a clear indication of the way the objectives set for those river basins, are to be reached within the required timescale. They should be updated every ten years.

Objective (6): Transgressions
The River Water Transfer projects are very popular due to water scarcity around the world and heavily criticized as being contrary to the principles of Sustainable Water Resources Management of River Basin. Therefore this topic should be addressed in a proper manner. Thus it needs a section in the proposed Water Framework Directive.

Objective (7) Restructuring Process
Citizens of Myanmar expressed their concerns over water scarcity, safety and water pollution issues through media and various workshops as well as direct communication to the President's office. This is one of the main reasons to draft this Water Framework Directive. New Water Policies will be formulated and proposed along the line after holding a number of public consultations at the regional and community levels. In achieving three goals and seven objectives, the changing role of the Government and that of citizens and civil society groups will be crucial. This is why a new Myanmar Water Policy has to get citizens more involved in order to achieve Peace and Prosperity. That means a serious restructuring process is necessary!

Key issues to be addressed in the Directive

1. Water Pollution
2. Environmental Flow
3. Water Allocation
4. Water Pricing
5. Mandate Sharing between authorities
6. Effective use of Integrated Water Resources Management
7. Water use Efficiency for economic development towards Green Economy and Green Growth
8. Phase by phase tackling of "water legislation" – water law, policies and procedures, regulations and Acts, etc.
9. Efficient communication mechanism by the SWRDSC to up and down channels; the Union Government, States and Divisional Governments, Ministries, Line Agencies and Citizens of Myanmar – setting up an open process
10. Coordination of objectives to achieve a good status for all waters by a set deadline
11. Coordination of measures
12. The river basin management plans
13. Public Private Participation (PPP) for secure investments
14. Water-related Data Bank (i.e., not only limited to hydrological, meteorological, geotechnical, environmental and climate change data but also including economy, market, trade, product, innovative technologies, societal, cultural, research and investment opportunities as well as financial aid data)
15. Water-related disaster risk reduction and early warning systems
16. Water for peoples, water for food, water for energy and water for industries
17. Water projects for social inclusion and good governance
18. Water, sanitation and hygiene programmes
19. Water and Peace
20. Streamlining legislation to abolish the outdated ones and to enact the suitable ones with present time. This is extremely important for the revenue creation.

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21. Getting the appropriate prices for the business and for the peoples
22. More topics can be added . . . .

Conclusion

In reality, it is a political process!

Let us share the momentum from the President led national reform process.

We can begin by:-

- Water protection in each and every state and division and also tackling significant problems at the Union level. For example Food Security and Energy Security issues, water for Industries and Special Economic Zones SEZs);
- To keep our waters clean, we need water legislation. What we meant by 'water legislation' is a complete set of legal instruments that includes water law, regulations, Acts, standards and procedures, and water policies enforced by law enforcement bodies, neighbor watch system, citizen's active participation and properly budgeted by both internal and external financing mechanisms as a continuum of water legislation. Parliament has approved the motion on drafting of the water law since Sept 2011, however, it is just the very beginning;
- scientific community and other experts need to join forces with water professionals in capacity building; and
- We should take up the challenge of water protection as one of the most important tasks in achieving Green Economy and Green Growth.

Appendix H. **Myanmar National Water Framework Directive, Myanmar language**

အမျိုးသားအဆင့် ရေအရင်းအမြစ် ကော်မတီမှ ပြုစုတင်သွင်းသော
မြန်မာနိုင်ငံလုံးဆိုင်ရာ အမျိုးသားအဆင့် ရေဥပဒေလမ်းညွှန်မှုဘောင်
၂၀၁၅ ခုနှစ်၊ မေလ

Myanmar National Water Framework Directive (MNWFD)
by the National Water Resources Committee (NWRC)
May, 2015

နိဒါန်း

ပြည်ထောင်စု သမ္မတ မြန်မာနိုင်ငံတော်၏ အမျိုးသားအဆင့် ရေဥပဒေလမ်းညွှန်မှုဘောင်သည် မြန်မာနိုင်ငံသူ နိုင်ငံသားများအားလုံးအတွက် အဆင့်အတန်း မခွဲခြားသော ရေမူဝါဒ ဆိုင်ရာ နယ်ပယ် အတွင်းမှ မူဘောင်တစ်ခု ဖြစ်လာပြီး တိုင်းဒေသကြီးနှင့် ပြည်နယ် အစိုးရများအနေဖြင့် မိမိတို့ အုပ်ချုပ်မှု ပိုင်နက်အတွင်းရှိ ရေအရင်း အမြစ်များ၏ ပိုင်ဆိုင်မှု ရေပမာဏနှင့် ရေအရည်အသွေးတို့ကို ကောင်းမွန်သော အဆင့်အတန်းတွင် ထိန်းသိမ်းထားနိုင်စေရန်အတွက် အထောက်အကူပြု ကိရိယာ တစ်ခုအဖြစ် အသုံးချနိုင်ရန် ရည်ရွယ်ပါသည်။ ဤမူဘောင်သည် အထက်မှအောက်သို့ ကိစ္စရပ်များကို ညွှန်ကြားစေခိုင်းသော နည်းမဟုတ်ပဲ လုပ်ဆောင်ရန် လိုအပ်သော လုပ်ငန်းဆောင်တာများကို တစ်ဆင့်စီ ရှင်းလင်း တင်ပြသွားခြင်းအားဖြင့် တာဝန်ရှိသူများအားလုံး၏ ကိုယ်စားပြု တူညီသော ပန်းတိုင်တစ်ခုကို မြင်လာပြီး အသီးသီး ကိုယ်တိုင်ကိုယ်ကျ မိမိတို့ဘာသာ တာဝန်ခံယူ၍ အကောင် အထည်ဖော်သော နည်းလမ်းဖြစ်ပါသည်။ အောက်ဖော်ပြပါ အတွေးအမြင်အယူအဆများသည် မြန်မာနိုင်ငံလုံးဆိုင်ရာ အမျိုးသားအဆင့် ရေဥပဒေ လမ်းညွှန်မှုဘောင် Myanmar National Water Framework Directive (MNWFD) တွင်ပါဝင်သည့် အချက်များကိုဖေါ်ညွှန်းပြီး လုပ်ငန်းစဉ်များကို အမြန်ဆုံး အကောင်အထည်ဖော် ဆောင်ရွက်ရန်လိုအပ်ကြောင်း တိုက်တွန်း၊ ရှင်းလင်း၊ တင်ပြထား ပါသည်။

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ရည်မှန်းချက်ပန်းတိုင်

ဤမူဘောင်တွင် ရည်မှန်းချက်ပန်းတိုင် သုံးခုရှိပါသည်။

- ❖ ရေကိုဘက်စုံအသုံးချရာတွင် မြန်မာ့ရေအရင်းအမြစ်များ ဖြစ်ကြသော၊ မြစ်၊ ချောင်း၊ အင်း၊ အိုင် နှင့် မြေအောက်ရေကြောများ ဖွံ့ဖြိုးရှင်သန် အရှည်တည်တံ့ရန်၊ သန့်ရှင်းစင်ကြယ်သော ရေရရှိနိုင်ရန်နှင့် ရေကိုအကျိုးရှိစွာ အသုံးချနိုင်စေရန်

- ❖ နိုင်ငံသူ၊ နိုင်ငံသားများအားလုံး တက်တက်ကြွကြွနှင့် ငြိမ်းချမ်းစွာ၊ ပူးပေါင်းပါဝင်ဆောင်ရွက်နိုင်ရန်

- ❖ အစိမ်းရောင် စီးပွားရေးစနစ်ကို လျှင်မြန်စွာ အရှိန်အဟုန် မြှင့်တင်ပေးပြီး၊ အစိမ်းရောင်ဖွံ့ဖြိုးတိုးတက်ရေးကို အချိန်တိုတိုအတွင်း အထမြောက်စေရန်

<u>**အဓိကရည်ရွယ်ချက်များ**</u>

- ❖ နိုင်ငံတော်အတွင်း ရေဖူလုံစေရေး၊ ရေနှင့်နီးနွယ်သော သဘာဝဘေးအန္တရာယ်များ လျှော့ချရေး၊ **ကောင်းမွန်သော ရေစီမံခန့်ခွဲခြင်း** (Good Water Governance) နှင့် **ရေရှည်တည်တံ့သောဖွံ့ဖြိုးတိုးတက်မှု** (Sustainable Development) တို့ ဖြစ်ပေါ်လာရန် အတွက်အာမခံချက်ပေးနိုင်ရန်နှင့် **အစိမ်းရောင်စီးပွားရေးနှင့် အစိမ်းရောင်ဖွံ့ဖြိုးတိုးတက်ရေး** (Green Economy and Green Growth) ကို အရှိန်အဟုန် မြှင့်တင်နိုင်ရန်တို့အတွက် ၊ **ရေအရင်းအမြစ် ဘက်စုံစီမံခန့်ခွဲခြင်း** (Integrated Water Resources Management) နည်းစနစ်ကို အသုံးပြုရန်၊
- ❖ အမျိုးသားအဆင့် ရေအရင်းအမြစ် ကော်မတီ National Water Resources Committee (NWRC) အနေဖြင့် အထူးစီးပွားရေးဇုံများအတွက် ရေပေးဝေနိုင်ရေး အပါအဝင် မြန်မာ့ မြေပေါ်မြေအောက် ရေသယံဇာတများကို ရေရှည် အရည်အသွေး ကောင်းမွန်စွာဖြင့် လုံလုံလောက်လောက်အသုံးချနိုင်အောင် ထိန်းသိမ်း ကာကွယ်ခြင်း၊ စီမံခန့်ခွဲခြင်းနှင့် အလေအလွင့်နည်းပါး၍ ကျိုးအမြတ်ရှိစွာ သုံးစွဲခြင်း စသည့် လုပ်ငန်းများကို ပိုမိုကျယ်ပြန့်စွာ ဦးဆောင်လမ်းညွှန် ဆောင်ရွက်နိုင်ရန်၊

- သတ်မှတ်ထားသော အချိန်ကာလအတွင်း၊ ဖြစ်နိုင်ချေရှိသော **ရေအရင်းအမြစ် ဘက်စုံစီမံခန့်ခွဲခြင်း** နည်းနာများအတိုင်း၊ သန့်ရှင်းသောရေကို ပြည်သူပြည်သားတိုင်း မျှတစွာ အချိုးကျ ရရှိစေရန်နှင့် တိုင်းဒေသကြီးနှင့် ပြည်နယ်များအကြား ရေနှင့် ပတ်သက်သော ပူးပေါင်းဆောင်ရွက်မှုများတိုးပွားလာပြီး မြန်မာနိုင်ငံသူနိုင်ငံသားများ အချင်းချင်းနားလည်မှုနှင့် ခင်မင်ရင်းနှီးမှုများ တိုးပွားလာစေရန်၊
- ရေကိုဘက်စုံစီမံခန့်ခွဲရာတွင် သင့်တင့်လျောက်ပတ်သော အကျယ်အဝန်းယူနစ်များ အပေါ်အခြေခံ၍ လုပ်ဆောင်ရန်၊ ဥပမာ- မြစ်ဝှမ်းအခြေပြု ရေစီမံခန့်ခွဲရေးစနစ် (basin-wide approach) ကို အသုံးပြုရန် လိုအပ်ပါသည်။
- ရေနှင့်ဆိုင်သော စီးပွားရေးနှင့်ဖွံ့ဖြိုးရေးလုပ်ငန်းများကို အစိမ်းရောင်စီးပွားရေးအသွင်ဖြင့် ဖော်ဆောင်လုပ်ကိုင်ခြင်းနှင့် သောက်သုံးရေ၊ မြစ်ရေ၊ ကန်ရေ၊ မြေအောက်ရေ၊ စိုက်ပျိုးရေနှင့် စွန့်ပစ်ရေအပါအဝင်၊ ရေနှင့်ဆိုင်သော စံချိန်စံညွှန်း သတ်မှတ်ချက်များအား လေးစားလိုက်နာတတ်သော အလေ့အကျင့်ကောင်းများကို တပါတည်းပေါင်းစပ် လေ့ကျင့် ပေးသွားရန်၊
- ဆင်းရဲသားများအကျိုးကို ရှေးရှုသော၊ လူ့အခွင့်အရေးကို လေးစားလိုက်နာသော၊ သင့်တော်သော ရေဈေးနှုန်းများကို သတ်မှတ်ဖော်ဆောင်ပေးရမည် ဖြစ်သကဲ့သို့၊ စီးပွားရေးဆိုင်ရာ ရေအသုံးချမှုများအတွက်ကိုမူ နိုင်ငံတော်နှင့် စီးပွားရေးလုပ်ငန်းရှင်တို့နှစ်ဦးနှစ်ဘက် စီးပွားရေးတွက်ခြေကိုက်စေမည့် သီးခြားနှုန်းထားများဖြင့် တွက်ချက်၍၊ ရေအရင်းအမြစ်များရရှိနိုင်မှုနှင့် ပြန်လည်ဖြည့်ဆည်းနိုင်မှု အနေအထားအလိုက်၊ နေရာအလိုက်၊ သင့်တော်သလောက်သာ ထုတ်ယူသုံးစွဲခွင့် စည်းမျဉ်း၊ စည်းကမ်းများ ပြဋ္ဌာန်းပေးရန်၊
- ရာသီဥတုပြောင်းလဲခြင်း Climate Change) နှင့် ရေ၊ စွမ်းအင်နှင့် အစားအစာ ဖူလုံမှု၊ ဤသုံးခု တို့အကြား အချင်းချင်း အပြန်အလှန် ဆက်စပ်ပတ်သက်မှု (water-energy-food nexus) များအပေါ် မှန်ကန်သောအမြင်နှင့် ခံယူချက်များ ထားရှိလာစေရန်၊
- နိုင်ငံတော်ငြိမ်းချမ်းရေးနှင့် စီးပွားရေးဖွံ့ဖြိုးတိုးတက်၊ ကြွယ်ဝလာစေရေးတို့အတွက် နိုင်ငံသူ၊ နိုင်ငံသားများအနေဖြင့် အစိမ်းရောင်ဖွံ့ဖြိုး တိုးတက်ရေး စီမံကိန်းများတွင် ပိုမိုတက်ကြွစွာ ပူးပေါင်းပါဝင်လာမှုရရှိနိုင်စေရန်နှင့် ဂေဟာစံနစ်ကြီး အရှည်တည်တံ့ပြီး ကောင်းမွန်စွာလည်ပတ်နိုင်ရေးအတွက် စီးပွားရေးလုပ်ငန်းရှင်များအနေဖြင့် ဥပဒေ

စည်းမျဉ်း၊ စည်းကမ်းများကို လိုက်နာယုံမျှသာမက၊ ရေနှင့် ပတ်ဝန်းကျင်ထိန်းသိမ်း စောင့်ရှောက်ရေး လုပ်ငန်းများတွင် လိုက်လှဲစွာ ပူးပေါင်းပါဝင်ဆောင်ရွက်ရန်၊

- ❖ မြန်မာနိုင်ငံတွင် မှီတင်းနေထိုင်ကြသော ပြည်သူများအားလုံးအတွက် ရေအရင်းအမြစ်များ၊ ရေလုပ်ငန်းနှင့် ရေဆိုင်ရာဝန်ဆောင်မှုလုပ်ငန်းများမှ တိုက်ရိုက်သော်လည်းကောင်း သွယ်ဝိုက်၍သော်လည်းကောင်း၊ အခွန်အခ၊ ဝန်ဆောင်ခနှင့် ရေအရင်းအမြစ် သုံးစွဲမှုတို့မှ ဝင်ငွေအစုစုတို့ကို ရရှိစေရန် တို့ဖြစ်ကြပါသည်။

<u>ပြဋ္ဌာန်းချက် (၇) ရပ်</u>

ပြဋ္ဌာန်းချက် (၁) မြန်မာနိုင်ငံရှိ မြေပေါ်ရေနှင့် မြေအောက်ရေများသည် စဉ်ဆက်မပြတ် **<u>ကောင်းမွန်သော အခြေအနေ</u>**တစ်ရပ်တွင် ရှိရမည်ဆိုသည့် အခြေအနေသစ်တစ်ရပ်ကို ဖော်ဆောင်ရန် လမ်းညွှန်ပါသည်။

ဤ ရေဥပဒေလမ်းညွှန်မှုဘောင်ပါ **ကောင်းမွန်သော အခြေအနေ** ဆိုသည်မှာ ရေ အရည်အသွေး ကောင်းမွန်သော၊ သန့်ရှင်းသော၊ လုံလောက်သော ပမာဏတစ်ခုထိ စုဆောင်းထားသော မြေအောက်ရေနှင့် မြေပေါ်ရေ တို့ကို ဆိုလိုပါသည်။ မြေပေါ်ရေတို့တွင် မြန်မာနိုင်ငံ တစ်ဝှမ်းလုံးရှိ မြစ်၊ ချောင်း၊ အင်း၊ အိုင်၊ ကန်များ၊ ကမ်းရိုးတန်းများနှင့် ရေတိမ်ဒေသများ အားလုံး ပါဝင်ပါသည်။

ပြဋ္ဌာန်းချက် (၂) ဤရေဥပဒေလမ်းညွှန်မှုဘောင်တွင် အဆိုပြုသည့် ပထမဆုံးလုပ်ဆောင်ရမည့် အချက်မှာ မြန်မာနိုင်ငံတစ်ခုလုံးအနေဖြင့် စုစုပေါင်း ရေရရှိနိုင်မှုပမာဏ (နိုင်ငံတော်၏ ရေဘတ်ဂျက်) ကို အချိန်ကာလအလိုက်တွက်ချက်ပြီး စဉ်ဆက်မပြတ် သုံးသပ်နေရန်လိုပါသည်။

ဤသို့တွက်ချက်ရာတွင်လက်ရှိမိုးလေဝသနှင့်ဇလဗေဒအချက်အလက်များအပြင်သိသာထင်ရှားသော ရာသီဥတုပြောင်းလဲခြင်း၊ ကမ္ဘာကြီးပူနွေးလာခြင်းတို့၏ သက်ရောက်မှုများကြောင့် ဖြစ်နိုင်ခြေ ပြောင်းလဲနိုင်မှုနှင့် သဘာဝရေဘေးအန္တရာယ် ကြုံတင်ကာကွယ်ရန် ပြင်ဆင်နိုင်မှုများကိုပါ ထည့်သွင်းစဉ်းစားရပါမည်။ မြေအောက်ရေထုတ်ယူရာတွင်လည်း နှစ်ရှည်စီမံကိန်းချမှတ်၍ အချိန်တစ်ခုတွင် အရည်အသွေးကောင်းသော ပမာဏတစ်ခုကို စုဆောင်းပြီး ဖြစ်နေရန်လိုအပ်ပါသည်။ မြေပေါ်၊ မြေအောက်ရေ ထုထည်အစုစုတို့၏ အနေအထားနှင့်အရည်အသွေးကို တိုင်းတာစစ်ဆေး၊ ဆန်းစစ်

လေ့လာပြီး အကောင်းအဆိုးအလိုက် အဆင့်များခွဲခြားသတ်မှတ်သင့် ပါသည်။ ထို့နောက်တွင် ပြုပြင်ထိန်းသိမ်း ဆောင်ရွက်ရန် အစီအစဉ်များကို အဆောတလျင် ချမှတ်လုပ်ဆောင်ရမည်။

[ရှင်းလင်းတင်ပြချက်။ နိုင်ငံတစ်ခု၏ ရေ ဘတ်ဂျက်သည် ငွေ ဘတ်ဂျက်ထက် ပို၍ အရေးလည်းကြီး၊ အရေးလည်းပါ ပါသည်။ ငွေမရှိလျှင်ချေးလို့ရပါသည်။ ရေမရှိလျှင် ချေးဘို့တောင် မလွယ်ပါ။ ထို့ကြောင့် အရေးကြီးပါသည်။ ရေ လုပ္ပွဲများမှ စစ်ပွဲတွေ ဖြစ်လေ့ ရှိပြီး၊ ရေကို အကြောင်းပြု၍လည်း ငြိမ်းချမ်းရေး ဖေါ်ဆောင်နိုင်ရန် ယုံကြည်မှုတည် ဆောက်ရာတွင် အဓိက ကြားခံနယ် အဖြစ် အသုံးပြုလေ့ရှိပါသည်။ ထို့ကြောင့် အရေးပါ ခြင်းဖြစ်သည်။]

ပြဋ္ဌာန်းချက် (၃) ဂေဟာစနစ်ဆိုင်ရာ အခြေအနေနှင့် မြစ်၊ ချောင်း၊ အင်းအိုင်နှင့် မြေအောက်ရေ ထဲတွင် ဓာတုပစ္စည်းများ ပျော်ဝင်လာမှု အခြေအနေကို စဉ်ဆက်မပြတ် စောင့်ကြည့် လေ့လာ ကြပ်မတ် ရမည်။

နိုင်ငံတော်၏ မြေပေါ်၊ မြေအောက် ရေတို့နှင့်ဆိုင်သော ဂေဟာစနစ်၏အခြေအနေနှင့် ရေထဲတွင် ဓာတုပစ္စည်းများ ပျော်ဝင်လာမှု အခြေအနေတို့ကို လေ့လာစမ်းစစ်ရာတွင် အောက်ပါအချက်များကို မှတည်၍ အကဲဖြတ်သင့်ကြောင်း ဤရေဥပဒေလမ်းညွှန်မှုဘောင်မှ အကြံပြုပါသည်။

၁. ရေ ၏ ဇီဝဆိုင်ရာ အထောက်အပံ့ပေးနိုင်မှု အရည်အသွေး (ငါးများ၊ ကျောရိုးမဲ့သတ္တဝါများ၊ ရေနေ အပင်များ ရှင်သန်မှုအခြေအနေ)

၂. မြစ်၏ ကျန်းမာရေး အရည်အသွေး၊ မြစ်ကြမ်းပြင်နှင့် မြစ်ပြင် အနေအထား၊ မြစ်ကမ်းပါးများ၊ ကမ်းထိမ်း တမံများ၊ မြစ်ကြောင်း၏ တစ်ဆက်တစ်စပ်တည်းဖြစ်တည်မှု၊ ရေကြောင်း ပြတ်တောက်မှု အစရှိသည်။

၃. ရေ၏ ရူပ-ဓါတု အရည်အသွေးများ (အပူချိန်၊ အောက်ဆီဂျင်ပျော်ဝင်မှုနှင့် ရေနေအပင်နှင့် သတ္တဝါ များအတွက် အာဟာရပါဝင်မှု)

၄ ပတ်ဝန်းကျင် အရည်အသွေး စံနှုန်းများအရ မြစ်ဝှမ်းကိုညစ်ညမ်းစေသော သီးသန့် ဓာတု ဓာတ်ပျော်ဝင်မှု ရာခိုင်နှုန်း ပမာဏနှင့် အရည်အသွေးကို တိုင်းတာရန်လိုအပ်ပါသည်။

[မြစ်ရေထဲတွင် အများဆုံးခွင့်ပြုနိုင်သော စွန့်ပစ်ရေနှင့် အညစ်အကြေးပမာဏ စံချိန်၊ စံညွှန်းကို အတိအကျ ကန့်သတ်ထားနိုင်ပါသည်။ ထိုသတ်မှတ်စံချိန်၊စံညွှန်းထက် ပိုမများစေရပါ။ ဂေဟာစနစ်တစ်ခုတွင် ဓာတုဓာတ်များပျော်ဝင်မှုသည် အများဆုံး ခွင့်ပြုနိုင်သော ပမာဏထက် ပိုနေပါက ကောင်းသော ဂေစနစ်ဟု မယူဆနိုင်ပါ။]

ပြဿနာချက် (၄) ပြည်ထောင်စုအစိုးရအဖွဲ့နှင့် တိုင်းဒေသကြီး/ ပြည်နယ် အစိုးရအဖွဲ့များအကြား ပူးပေါင်းဆောင်ရွက်ခြင်းကို ထိရောက်မှုရှိစေရန်၊ တိကျသော လုပ်ပိုင်ခွင့်များကို ရေးဆွဲသတ်မှတ်ရမည်။

တိုင်းဒေသကြီးနှင့် ပြည်နယ်အစိုးရများအနေဖြင့် ဤရေဥပဒေလမ်းညွှန်မူဘောင်ကို အကောင်အထည်ဖော်ရာတွင် မိမိတို့သက်ဆိုင်ရာ ဒေသအတွင်းရှိ စိတ်ပါဝင်စားသည့် ဒေသအသင်းအဖွဲ့များအနေဖြင့် ရေဆိုင်ရာလုပ်ငန်းများတွင် တက်ကြွစွာပါဝင်ဆောင်ရွက်နိုင်ရေးကို အားပေးရန်လိုအပ်ပါသည်။ နိုင်ငံတဝှမ်းလုံးရှိ ပြည်သူလူထု၏ စွမ်းဆောင်ရည် မြင့်မားတိုးတက်လာစေရန် အလုပ်ရုံဆွေးနွေးပွဲများ၊ လူထုအကြံပြု အစည်းအဝေးများ၊ ညှိနှိုင်းဆောင်ရွက်ခြင်း အစည်းအဝေးများကို မကြာခဏကျင်းပပြုလုပ်ရန် လိုအပ်ပါသည်။ ထို့ကြောင့် ပြည်ထောင်စုအစိုးရအဖွဲ့နှင့် တိုင်းဒေသကြီးနှင့် ပြည်နယ် အစိုးရများကြားတွင် တိကျသော လုပ်ပိုင်ခွင့်ရရှိရန် လိုအပ်နေကြောင်း အလေးပေးဖော်ပြထားပါသည်။

ပြဿနာချက် (၅) ရေဘက်စုံစီမံခန့်ခွဲခြင်းကို အကောင်အထည်ဖော်ရာတွင် မြစ်ဝှမ်းဒေသကို အခြေခံယူနစ်အဖြစ် သတ်မှတ်၍လုပ်ဆောင်ရမည်။ မြစ်ဝှမ်းဒေသဆိုင်ရာ စီမံကိန်းရေးဆွဲခြင်းနှင့် စီမံအုပ်ချုပ်ခြင်း လုပ်ငန်းသည် ရေဥပဒေလမ်းညွှန်မူဘောင် အတွက်အရေးပါသောလုပ်ငန်း တစ်ခုဖြစ်သည်။

ရေကို ဘက်စုံ စီမံခန့်ခွဲရာတွင် ဒေသအုပ်ချုပ်ရေး (သို့မဟုတ်) စီရင်စုများဖြင့် မသတ်မှတ်နိုင်ပါ။ မြစ်ကြောင်းဒေသရှိ သဘာဝပထဝီဝင်အနေအထားနှင့် ရေသယံဇာတဆိုင်ရာ ကိန်းဂဏန်းများဖြင့်သာ တွက်ချက်ရပါသည်။ မြန်မာနိုင်ငံတွင် အဓိက မြစ်ကြီးများသည် နိုင်ငံ၏ အစိတ်အပိုင်း အနှံ့အပြားသို့ ဖြန့်ကျက် စီးဆင်းနေပါသည်။ သက်ဆိုင်ရာ အစိုးရအဖွဲ့များသည် နိုင်ငံအတွင်းရှိ မြစ်ဝှမ်းဒေသများ (ဧရာဝတီမြစ်၊ ချင်းတွင်းမြစ်၊ စစ်တောင်းမြစ် စသည်) သာမက အပြည်ပြည်ဆိုင်ရာ မြစ်ဝှမ်းဒေသ (သံလွင်မြစ်) ကိုပါ စီမံခန့်ခွဲရန် လုပ်ငန်းများကို အတူညှိနှိုင်း လုပ်ဆောင်ရပါမည်။ မြန်မာနိုင်ငံရှိ အရေးပါသော မြစ်ဝှမ်းဒေသများအတွက် မြစ်ဝှမ်းဒေသများဆိုင်ရာ ဖွံ့ဖြိုးမှုစီမံချက်များ လိုအပ်ပါသည်။ ထိုစီမံချက်များတွင် ရည်ရွယ်ချက်အဆင့်များကို အစဉ်လိုက် တိကျစွာ ဖော်ပြထားရမည်ဖြစ်ပြီး လုပ်ငန်းအဆင့်ဆင့်ပြီးစီးဆောင်ရွက်ရန် လိုအပ်သော အချိန်ကာလများကိုပါ ရေးဆွဲရပါမည်။ ၎င်းစီမံချက်များကိုလည်း ဆယ်နှစ်တစ်ကြိမ် (သို့) လိုအပ်သလို ပြန်လည် သုံးသပ်သင့်ပါသည်။

ပြဋ္ဌာန်းချက်(၆) ဇလဗေဒနှင့် သဘာဝ၏သတ်မှတ်ချက်ဘောင်များကို ကျော်လွန်လိုပါက သုတေသနပြုလုပ်ပြီးမှ လုပ်ဆောင်သင့်ပါသည်။

မြစ်တစ်ခုမှ တစ်ခုသို့ ရေလမ်းကြောင်းပြောင်း ရယူခြင်းစီမံကိန်းများသည် ယခုအခါ ခေတ်စားနေပါသည်။ အကြောင်းရင်းမှာ ကမ္ဘာအနှံ့အပြားတွင် ရေရရှိမှု နည်းပါးလာပြီး ရေရှားပါးလာခြင်းနှင့် မြစ်ဝှမ်းဒေသဆိုင်ရာ စဉ်ဆက်မပြတ် ရေသယံဇာတ စီမံအုပ်ချုပ်မှု စည်းမျဉ်းများကို ဆန့်ကျင်သောကြောင့် ဖြစ်သည်။ ဤကဲ့သို့ အခြေအနေမျိုးကို သင့်တင့်လျောက်ပတ်စွာ သတိဖြင့်ကိုင်တွယ်ဖြေရှင်းသင့်ပါသည်။ ဤကိစ္စအတွက် အသေးစိတ်လေ့လာသော သုတေသနဌာနတစ်ခု ဖွဲ့စည်းပေးရန် လိုအပ်ပါသည်။

<u>ပြဋ္ဌာန်းချက် (၇)</u> ပိုမို တိကျခိုင်ခံ့သော လုပ်ငန်းစဉ်များနှင့် ယင်းတို့ကို အကောင်အထည်ဖော်ဆောင်မည့် ဌာနများ၊ အဖွဲ့အစည်းများ၊ ရေအာဏာပိုင်များအား စံနစ်တကျ ပြန်လည်တည်ဆောက်ဖွဲ့စည်းရန် လိုအပ်ပါသည်။ ပြန်လည် ဖွဲ့စည်းတည်ဆောက်ခြင်းတွင် အစိုးရ၏ ပြုပြင်ပြောင်းလဲခြင်း၊ နိုင်ငံသားများ လူမှုအဖွဲ့အစည်းများ၏ ပူးပေါင်းပါဝင်ခြင်း အခန်းကဏ္ဍသည်လည်း အဓိကနေရာမှ ပါဝင်သည်။

*[မြန်မာနိုင်ငံသားများသည် ရေရှားပါးမှု၊ ရေအရင်းအမြစ်များကို ရေရှည်သုံးစွဲနိုင်ရန်၊ ရေဖူလုံမှုရေရရှိစေရန် စသည့်အချက်များနှင့် ရေထုညစ်ညမ်းမှုများအကြောင်းတို့နှင့် ပတ်သက်၍ ၎င်းတို့၏ သဘောထားများကို အလုပ်ရုံဆွေးနွေးပွဲများတွင်လည်းကောင်း၊ ရုပ်မြင်သံကြားမှလည်းကောင်း၊ နိုင်ငံတော် သမ္မတရုံးသို့ တိုက်ရိုက်ဆက်သွယ်ခြင်းအားဖြင့်လည်းကောင်း ဖော်ပြခဲ့ပါသည်။ ထိုအချက်သည် **ရေဥပဒေ လမ်းညွှန်မှုဘောင်**နှင့် **ရေဥပဒေ ရေးဆွဲခြင်း**ကို အဓိကဖြစ်စေသော အခြင်းအရာ ဖြစ်လာပါသည်။ အစုအဖွဲ့ အဆင့်ဆင့်လိုက် **ရေဥပဒေ ရေးဆွဲရေး** လူထုအကြံပြုဆွေးနွေးပွဲများစွာ လုပ်ခဲ့ပြီး အဆိုကိုတင်သွင်းကာ **အမျိုးသားအဆင့် ရေဥပဒေ လမ်းညွှန်မှုဘောင်**ကို သက်ဆိုင်ရာမှ ပြဋ္ဌာန်းမည် ဖြစ်ပါသည်။ ရည်မှန်းချက် မဏ္ဍိုင် ၃-ရပ်နှင့် ပြဋ္ဌာန်းချက် ၇-ချက် ကို ဖော်ဆောင်ရာတွင် အစိုးရ၏ ပြုပြင်ပြောင်းလဲခြင်း၊ နိုင်ငံသားများ၊ လူမှုအဖွဲ့အစည်းများ၏ ပူးပေါင်းပါဝင်ခြင်း အခန်းကဏ္ဍသည်လည်း အဓိကမှ ပါဝင်ပါသည်။ **မြန်မာ့ အမျိုးသားအဆင့် ရေဥပဒေလမ်းညွှန်မှုဘောင်**သည် မြန်မာနိုင်ငံသားများ အားလုံး တက်ကြွစွာ ပါဝင်ဆောင်ရွက်ခြင်းဖြင့် ငြိမ်းချမ်းမှု၊ ကြွယ်ဝချမ်းသာမှုတို့ကို ပိုမိုရရှိစေမှာ ဖြစ်ပါသည်။ ထို့ကြောင့် ပိုမိုတိကျ ခိုင်ခံ့သော လုပ်ငန်းစဉ်များနှင့် **ယင်းတို့ကို** အကောင်အထည် ဖော်ဆောင်မည့် ဌာန၊ အဖွဲ့အစည်း၊ **ရေအာဏာပိုင်များအား** စံနစ်တကျ ပြန်လည်တည်ဆောက် ဖွဲ့စည်းရန် လိုအပ်ပါသည်။]*

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