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Laguna de Bay Basin
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Pilot Ecosystem Account for Laguna de Bay Basin

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Wealth Accounting and the
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WAVES – Global Partnership for Wealth Accounting and the Valuation of Ecosystem Services

Wealth Accounting and the Valuation of Ecosystem Services (WAVES) is a global partnership led by the World Bank that aims to promote sustainable development by mainstreaming natural capital in development planning and national economic accounting systems, based on the System of Environmental-Economic Accounting (SEEA). The WAVES global partnership (www.wavespartnership.org) brings together a broad coalition of governments, UN agencies, non-government organizations and academics for this purpose. WAVES core implementing countries include developing countries Botswana, Colombia, Costa Rica, Guatemala, Indonesia, Madagascar, the Philippines and Rwanda, all working to establish natural capital accounts. WAVES also partners with UN agencies—UNEP, UNDP, and the UN Statistical Commission—that are helping to implement natural capital accounting. WAVES is funded by a multi-donor trust fund and is overseen by a steering committee. WAVES donors include Denmark, the European Commission, France, Germany, Japan, The Netherlands, Norway, Switzerland, and the United Kingdom.

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Note on the Report

This final report presents the collective findings of the Technical Working Group for Laguna de Bay ecosystem accounting, a pilot undertaking conducted between January 1, 2014 and December 10, 2015 in the lake region.

The Laguna de Bay ecosystem account explores potential pathways to developing specific accounts based on a comprehensive framework called the System of Environmental-Economic Accounting-Experimental Ecosystem Accounting (SEEA-EEA), which shows the interactions between the economy and ecosystems, consistent with the System of National Accounts. Although experimental in nature, the account is replicable across time and geographical scales (e.g., national). It is also useful in policy making.

Through this groundbreaking endeavor, substantial capacity has been built locally to produce ecosystem accounts and update them on a regular basis, thus helping ensure effective policy making and sustainable management of natural resources.

Case Study Area

The pilot ecosystem account covers the physical watershed of the Laguna Lake. The name commonly used for this area in the Philippines is the Laguna de Bay (LdB) basin, which is used throughout this report. 'Laguna Lake' refers to the lake itself.

EXECUTIVE SUMMARY

As the largest inland water body in the Philippines and the third largest in Southeast Asia, the Laguna de Bay has been confronted with growing pressures on its ecosystems. Over the past decades, population expansion, urbanization, industrialization, deforestation, and land conversion have led to degradation of the lake water and its watershed. These are some of the key challenges facing the Laguna Lake Development Authority (LLDA) and other relevant government agencies tasked to manage and protect the lake and its resources.

The dire situation affecting the lake today assumes greater significance when one considers that this large freshwater body is a multiple-use natural resource. It supports the fisheries sector and provides livelihood for more than 24,000 fisherfolk including fishermen and people working in the fishing industry; supplies domestic water through water concessionaires; provides irrigation water for approximately 103,000 hectares (ha) of agricultural land; and supports hydropower production. The lake is also used for recreation and industrial cooling and serves as a waste sink for household wastes and industrial and solid, liquid, toxic, and hazardous wastes.

The Philippines is taking steps to address these and other ecosystem trends in the Laguna de Bay basin and elsewhere in the country. A vital step in this direction is the national government's revitalized efforts to mainstream natural capital accounting (NCA), an evidence-based tool that takes stock of the state of a country's natural resources, into policy making.

An integral part of NCA is ecosystem accounting, which links natural capital analysis with economic data, thereby clarifying the contributions of the ecosystem to economic activities. Ecosystem accounts are useful for monitoring trends in natural capital and enforcing resource management policies.

Today, the Philippines is one of the core implementing countries of a World Bank-led global partnership called Wealth Accounting and the Valuation of Ecosystem Services (WAVES). This initiative aims to promote sustainable development by mainstreaming natural capital in development planning and national economic accounting systems.

As part of the WAVES project, the Laguna de Bay basin was selected as one of two pilot test sites in the Philippines to develop ecosystem accounts (the other being Southern Palawan). The ecosystem account was developed using an adopted standardized system called the System of Environmental Economic Accounting (SEEA) – Experimental Ecosystem Accounting (EEA) framework, which ensures consistency with regularly produced economic statistics at the national and international level.

The ecosystem account covers the Laguna de Bay watershed and the Laguna de Bay region, the administrative jurisdiction of the LLDA,[1] and comprises the following specific accounts:

- a **land account** containing land cover and changes
- a **water account** providing information on water quantity aspects
- an **ecosystem condition account** indicating various terrestrial and water quality indicators, changes in lake bathymetry, and sediment loading

[1] Covering the whole provinces of Rizal and Laguna; the towns of Carmona, Silang, and General Mariano Alvarez, and Tagaytay City in Cavite; the towns of Tanauan, Sto. Tomas, and Malvar in Batangas; the town of Lucban in Quezon; Pateros town; and the cities of Muntinlupa, Taguig, Pasig, Marikina, Quezon, Caloocan, Pasay, and Manila in Metro Manila

- an **ecosystem services supply and use account** indicating the flow of ecosystem services, in particular fishery production, water supply, flood retention, and soil erosion regulation.

This technical report explores the specific challenges confronting natural resource management in the Laguna de Bay basin, and presents the key findings of the ecosystem account developed between January 2014 to December 2015

Key Findings

There has been a significant change in land cover due to rapid and unplanned urban sprawl.

Major land cover changes in the basin were observed for the period 2003-2010. First, built-up areas increased by 116% with rapid urbanization and industrialization affecting particularly the northwest, western, and southern parts of the lake. The population density thus increased rapidly in the municipalities immediately adjacent to the lake from 29% between 2003 and 2010, that is, from 6.7 million to 8.6 million people.

The spread and location of these residential subdivisions are characterized by unplanned urban sprawl, involving conversion of agricultural lands to residential uses, and the construction of new settlements close to the lake shore, the zone that is vulnerable to flooding. This poses a number of major challenges to addressing issues revolving around infrastructure development, sewage and waste, flood control, and fisheries production in the lake.

Second, closed forest areas decreased by 35%, significantly increasing soil erosion and, in turn, sedimentation of the lake. The remaining forests are found, in particular, in the Mt. Makiling Forest Reserve and Sierra Madre mountain ranges. But even the forest zone in these areas has not been spared from illegal settlements.

Degradation in the watershed is leading to siltation of the lake and increased flood risk for Metro Manila.

One of the major problems affecting the Laguna de Bay basin is rapid deforestation in the watershed, which is leading to soil erosion of mountain slopes, riverbanks, agricultural lands, and siltation of the lake. In fact, the accounts show that an estimated 2 million tons of suspended sediment entered the lake in 2010. This sedimentation is significantly affecting the water storage capacity of the lake by making the periphery of the lake shallower.

Combined with rapid population growth along the lake's shore, this backfilling of the lake has significantly increased the flood risk for Metro Manila in the last decade. Assuming the 2009 level of flooding were repeated in 2015, floods could have affected some 166,000 houses (as against around 146,000 houses in 2009) and damage costs would have amounted to 7 billion pesos (US $150.12 million) as against 6 billion pesos (US $128.78 million) in 2009.

To reduce flood risks, it will be critical to rehabilitate the lake's shorelines by restoring mangrove cover, which has been virtually lost over the last 15 years. Moreover, management of the slopes and uplands of the Laguna de Bay basin will be essential in maintaining the long-term viability of the lake as a water storage reservoir. The accounts can help identify priority areas for rehabilitation, such as the Pagsanjan River basin and the Marikina River basin, which make up half of the sediment loading in Laguna de Bay.

Domestic waste is a major contributor of pollution to the lake.

One of the critical issues confronting the lake is the discharge of pollutants from domestic, industrial, and agricultural/forest sources into the lake. This pilot account analyzed only the biochemical oxygen demand (BOD) as an indicator of organic pollution loading in the lake. This means inorganic pollutants, which were not examined, will need to be considered in succeeding versions of the account.

The ecosystem account shows that 81% of the BOD load comes from domestic wastes, while the rest of the load comes from industry (9%), agriculture (5%), forest (2%), and solid wastes (3%). This finding indicates that treating household discharges holds much potential for improving the water quality of the Laguna de Bay.

The BOD loading also affects the water quality in the lake, which has deteriorated significantly in the western portion of the lake, where the built-up area substantially increased in the period between 2003 and 2010, and remained at the same levels thereafter. In fact, the water quality of these rivers in terms of BOD concentrations was found to be worse than the Class D classification provided by the DENR Administrative Order No. 34; which is the water quality appropriate only for agricultural, irrigation, and livestock use, as well as for industrial cooling and navigation.

Fisheries production is an important source of livelihood but is threatened by pollution.

The accounts show that around 14,000 fishermen depend on the lake for their livelihood through both capture fisheries and aquaculture in the form of fishpens and fishcages. The Laguna de Bay generates an annual gross revenue of 6.6 billion pesos (US$141.66 million)[2]. The ecosystem contribution to this economic activity is estimated at around 2.8 billion pesos (U$60 million) yearly.

Although the lake can still sustain fisheries, it is threatened by pollution. Currently, the water quality in the lake still meets the minimum legal requirements for water used for fishing. However, progressive increases in population density around the lake show the need for continuous vigilance through regular monitoring and reporting of water quality.

Mainstreaming

Understanding these and other changes in Laguna de Bay's ecosystems highlights the extreme importance of mainstreaming the ecosystem accounting framework into decision making. The ecosystem accounts can serve as a benchmark to identify key policy needs and impacts as well as areas where specific policy interventions should be carried out as a matter of priority. Integrating data on the different dimensions of ecosystems (e.g., water quantity and quality, fish production, etc.) as well as disciplines (hydrology, ecology, soil sciences, economics) offers a comprehensive overview of ecosystem and its interactions with the economy in contrast to fragmented datasets and analyses.

However, the full value of the ecosystem accounts will only be realized when they are produced on a regular basis. A regular production of the ecosystem accounts will allow for the monitoring of trends in ecosystem condition, asset, and service flows. Moreover, the Government of the Philippines expects that the methodologies and framework developed for this pilot can be

[2] At P46.59:$1. Based on the Bangko Sentral ng Pilipinas Reference Exchange Rate Bulletin as of September 7, 2016.

applied in other parts of the country that also demand indicators, tools, and methodologies to inform development planning and policy analysis in support of the goals of sustaining the use of natural resources, economic growth, and alleviating poverty.

They can also be used to monitor changes in the ecosystem. An important dimension of the value of these accounts lies in showing trends in ecosystem condition, asset, and service flows over time, requiring regular updating of the accounts.

Given the capacities built and the lessons learned in the process of developing these accounts for the Laguna de Bay basin, the cost of updating them in the future should be much lower compared to establishing them. Potentially, given the rate of ecosystem changes in the Laguna de Bay basin, updates should take place at least once every two or three years. This should mark an important step forward as the Philippines pursues natural capital accounting in earnest.

Selected key indicators derived from the accounts are presented in the table below.

Summary of Account Indicators for Policy Makers

	2001	2003	2010	2011	2012	2013	2014
Land account							
Annual cropland (1000 ha)		91	52				
Plantations (1000 ha)		58	44				
Closed forest cover (1000 ha)		4	3				
Open forest cover (1000 ha)		22	21				
Mangrove forest		94	1				
Protected areas (1000 ha)			51				
Of which preserved as open or closed forest (1000 ha)			19				
Of which degraded to shrublands or grasslands			27				
Of which encroached by cropland or buildings (1000 ha)			5				
Water Account							
Outflow through Pasig River (trillion l/year)	5.3	4.8	5.1	8.5	11.2		
Modelled water use of Laguna Lake by all sectors billion l/year)	205						
Ecosystem Condition Account							
Households connected to sewage system (%)		7%	6%	7%	6%	8%	8%
BOD discharged by households in the Laguna de Bay (LdB) region (1000 tons/year)		56	65	66	68	69	70
BOD loading from households emitted into Laguna Lake following treatment (1000 tons/year)							65
Total BOD loading in the LdB region excluding sewage effluent (1000 tons/year)		70	79	78	79	78	80

	2001	2003	2010	2011	2012	2013	2014
Total BOD loading in the LdB region including sewage effluent (1000 tons/ year)							81
Water quality in the lake compared to legal requirements (% sample stations with water quality level 'A or B')/1		100%	80%	100%			
Sediment inflow in the lake (ton of sediment)			2,011				
Ecosystem Service Supply and Use Account							
Fish production from capture fisheries and aquaculture:							
Gross revenue fisheries in Laguna Lake							6,447
Gross revenue capture fisheries (million pesos)							3,846
Gross revenues aquaculture (pens + cages) (million pesos)							2,601
Ecosystem contribution[2] to fisheries in Laguna Lake (million pesos)							2,712
Ecosystem contribution to capture fisheries (million pesos)							1,878
Ecosystem contribution to aquaculture (fishpens + fishcages) (million pesos)							834
Number of capture fishermen employed			13,139				
Number of households in the 13.8m water level (x 1000)	116	124	151	155	159	162	166
Sediment control by vegetation (ton of sediment)[3]			4,874				

[1] *Water quality is compared to the national legal requirements for water used for irrigation or aquaculture. Other uses have different requirements. Levels A and B indicate water of sufficient quality to support irrigation and fisheries.*

[2] *This is expressed in terms of resource rent. The resource rent reflects the contribution of the ecosystem to economic production, following the framework of the System for Environmental Economic Accounting – Experimental Ecosystem Accounts.*

[3] *This metric is calculated by modelling how much sediment loads in the lake would increase in the absence of vegetation. This represents the avoided sedimentation due to soil protection by vegetation.*

[4] *No data was available for specific accounts for certain years.*

Acronyms

BFAR	Bureau of Fisheries and Aquatic Resources
BOD	Biochemical Oxygen Demand
BSWM	Bureau of Soils and Water Management
CALABARZON	Cavite, Laguna, Batangas, Rizal, Quezon
CRC	Cooperative Research Centre
DAR	Department of Agriculture
DBM	Department of Budget and Management
DENR	Department of Environment and Natural Resources
DOF	Department of Finance
DPWH-EFCOS	Department of Public Works and Highways - Effective Flood Control Operation System
DSS	Decision Support System
DTI	Department of Trade and Industry
ENRAP	Environment and Natural Resources Accounting Project
ERDB	Ecosystems Research and Development Bureau
ESA	European Space Agency
HLURB	Housing and Land Use Regulatory Board
JICA	Japan International Cooperation Agency
KBA	Key Biodiversity Areas
LDB	Laguna de Bay Basin
LLDA	Laguna Lake Development Authority
LMU	Land Management Unit
LWUA	Local Water Utilities Authority
MMDA	Metro Manila Development Authority
MFR	Makiling Forest Reserve
NAMRIA	National Mapping and Resource Information Authority
NASA	National Aeronautics and Space Administration
NCR	National Capital Region
NEDA	National Economic and Development Authority
NHRC	National Hydrology Research Center
NSO	National Statistics Office
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
Phil WAVES	Philippines Wealth Accounting and the Valuation of Ecosystem Services
PRRC	Pasig River Rehabilitation Commission
PSA	Philippine Statistics Authority

PWSC	Philippines WAVES Steering Committee
RUSLE	Revised Universal Soil Loss Equation
SDLBE	Sustainable Development of the Laguna de Bay Environment
SedNet	Sediment River Network Model
SEEA	System of Environmental-Economic Accounting
SRTM DEM	Shuttle Radar Topography Mission - Digital Elevation Model
TWG	Technical Working Group
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WLM	Waste Load Model
ZOMAP LLDA	Zoning and Management Plan of the LLDA

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1.| Introduction

Background

As the largest inland water body in the Philippines and the third largest in Southeast Asia, the Laguna de Bay has been confronted with growing pressures on its ecosystems. Over the past decades, population expansion, urbanization, industrialization, deforestation, and land conversion have led to degradation of the lake water and its watershed. These are some of the key challenges facing the Laguna Lake Development Authority (LLDA) and other relevant government agencies tasked to manage and protect the lake and its resources.

The dire situation affecting the lake today assumes greater significance when one considers that this large freshwater body is a multiple-use natural resource. It supports the fisheries sector and provides livelihood for some 14,000 fishermen; supplies domestic water through water concessionaires; provides irrigation water for approximately 103,000 hectares of agricultural land; and supports hydropower production. The lake is also used for recreation and industrial cooling and serves as a waste sink.

The Philippine government is cognizant of this situation and has begun to take steps toward ensuring that natural capital is systematically integrated into both macroeconomic indicators and natural resource management in the country. An essential part of this undertaking is the selection of the Laguna de Bay (alongside Southern Palawan) as one of two pilot test sites for an international undertaking that seeks to implement and institutionalize natural capital accounting.

The Philippines was selected as one of the core implementing countries of the World Bank-led Wealth Accounting and the Valuation of Ecosystem Services (WAVES) Global Partnership, which aims to promote sustainable development by mainstreaming natural capital in development planning and national economic accounting systems. The National Economic and Development Authority serves as the national coordinating agency for the project, with support from the Philippines WAVES Steering Committee[3].

The rollout of WAVES in the Philippines builds on the country's efforts in natural capital accounting in the 1990s and early 2000s, which led to the formation of considerable capacity and technical skills that still exist today.

At present the Philippines WAVES project covers water, mineral, mangroves, land, and ecosystem accounts. The first four will be implemented at the national scale, and the ecosystem accounts at the scale of a test site. The choice of Laguna de Bay Basin and Southern Palawan as pilot test sites for ecosystem accounting in the Philippines highlights the significant challenges policy makers face in natural resource management in these areas.

As the foregoing issues affecting the two test sites are also widespread in other parts of the Philippines, the lessons learned from the pilot accounts will also help to establish ecosystem accounts elsewhere in the country. By applying the resulting methodologies and framework in other parts of the country, ecosystem account can inform development planning and policy analysis in support of the goals of sustainable use of natural resources, economic growth, and poverty alleviation.

Methodology

One of the objectives of WAVES is to pilot and test different methodologies for compiling ecosystem accounts based on a framework

[3] The members of the national Phil-WAVES Steering Committee are the Department of Budget and Management (vice chair), Department of Finance, Philippine Statistics Authority, Department of Environment and Natural Resources, Climate Change Commission , Department of Agriculture, Office of the Presidential Advisor on Environmental Protection/Laguna Lake Development Authority, and Union of Local Authorities of the Philippines.

called the System of Environmental-Economic Accounting (SEEA)-Experimental Ecosystem Accounting (EEA).

The SEEA contains internationally agreed standards (including concepts, definitions, and accounting rules and tables) for producing globally comparable data on the environment and its linkage with the economy. The EEA, on the other hand, is one of three subsystems that provides further details on specific topics relating to ecosystems and seeks to build bridges between the accounting community and the community of experts in select subject areas, including ecosystems.

WAVES aims to test how the SEEA-EEA framework can provide science-based evidence and information to help assess the economic, environmental, and social trade-offs between different natural resource use options and their implications for sustainable development.

Using the SEEA framework offers several advantages. It facilitates linking an analysis of natural capital with economic data, thereby clarifying the contribution of ecosystems to economic activities in physical and monetary terms.

The use of the framework, if regularly undertaken, also helps to enable monitoring of trends in natural capital, and ensures efficiency of resource management policies in contrast to other types of assessment that are typically one-off studies.

Regular production of the ecosystem accounts contributes to capacity building and greater cost efficiency. As an adopted and standardized system, the SEEA accounting approach ensures data comparability both nationally and internationally and promotes recurring production of consistent data, thus enabling monitoring and comparison over time.

There are a number of methodologies and approaches to assessing projects and policies, including Cost-Benefit Analysis (CBA), Strategic Environmental Assessment, and Environmental Impact Assessment, among others. Some of these measure strictly environmental issues, while others such as the CBA include an economic component and valuation of environmental factors.

There is a difference between these environmental-economic methods and analyses using the accounting framework. National capital accounts are designed to be readily used together with national accounts data. Valuation methods are based on exchange values and reflect the contribution of ecosystems to economic production and consumption, not to welfare. In this regard, ecosystem accounting aims to produce datasets on a regular basis in order to show trends in ecosystems and their uses.

Still a developing field, ecosystem accounting is distinct from the physical environmental accounts included in the SEEA-Central Framework, an internationally adopted statistical standard. In some cases, it calls for quite advanced modelling exercises and is often undertaken at a sub-national level.

As methodologies and access to data are rapidly developing, applying this system at a regional or national scale becomes increasingly viable. The accounts presented in this report illustrate this development.

Institutional setting

The Laguna Lake Development Authority is the central authority for the management of the Laguna de Bay. It is the only chartered lake basin organization in the Philippines with a comprehensive and integrated management and regulatory mandate/authority. Its mandate includes regulating lake development, which requires preparation of lake development plans, and regulation of water use and discharges to the lake by various sectors.

As part of its regulatory function, the LLDA issues surface water permits to, or revokes those of, different users, collects fees for the use of lake resources, and approves development plans within its jurisdiction, which include entire or portions of five provinces and Metro Manila, 17 cities, and 44 municipalities that the lake covers.

Still part of its mandate are the preparation and implementation of infrastructure projects such as river works, dikes and flood control structures, and reclamations.

The LLDA is also tasked to readjust, resettle, or relocate settlements, develop water supply from ground or lake water, and engage in fish production and aquaculture projects. In this regard, the Authority engages with national policy and decision-making agencies such as the National Economic and Development Authority, Department of Finance, Department of Budget and Management, Department of Trade and Industry (DTI), Department of Tourism, Board of Investments (under DTI), Presidential Task Force on Water Resources Development and Management, Bureau of Fisheries and Aquatic Resources (BFAR) under the Department of Agriculture, Pasig River Rehabilitation Commission, Metro Manila Development Authority, and the Mt. Makiling Reserve Area and Laguna de Bay Commission.

The LLDA must also engage with the National Water Resources Board, the Local Water Utilities Administration, the Department of Environment and Natural Resources (DENR), and the Housing and Land Use Regulatory Board for its water and settlements regulatory functions.

Decisions and actions of the LLDA take the form of resolutions by the board, which is composed of 10 members, with the DENR secretary as chairperson, and the LLDA's general manager as vice-chairperson.

In the performance of its functions, the LLDA involves academic and research institutions as well as non-government organizations. It coordinates with over 30 environmental and natural resource, as well as water-related, agencies, alongside 66 local government units within the watershed, each with its own policy and planning, regulation and infrastructure development, and environment- and fisheries-related functions.

The LLDA, in collaboration with the DENR, has taken the lead in developing the ecosystem account for Laguna de Bay, as described in this report. Staff from several of its technical units, covering such disciplines as hydrology, GIS, fisheries and general ecology have been responsible for the analyses undertaken for this pilot study, supported by several capacity-building initiatives, including three workshops conducted jointly by international and national consultants (on ecosystem accounting) and two others given by national consultants (on GIS and modelling).

In addition to the LLDA, the Philippine Statistics Authority (PSA) and the government's central mapping agency, National Mapping and Resource Information Authority (NAMRIA), have played a major role in supporting the development of the account. PSA provided advice on data collection and reviewed the draft report. NAMRIA gave inputs, such as images and processed maps, toward the development of the other accounts.

Finally, additional support was obtained from the European Space Agency (ESA), through the GECOMON project, through which additional remote-sensing analysis was conducted by GeoVille, an international company specializing in this field.

In the Laguna de Bay area, GeoVille conducted several analyses of land and forest cover areas. The results of the NAMRIA, PSA, and the ESA support are presented in this report.

Ecosystem Management Issues in Laguna Lake

The western and northwestern parts of the Laguna de Bay area lie within Metro Manila — a megacity with a 14 million-strong population and home to much of the country's population and economic activity.

The southern side of the Laguna Lake is densely populated owing to a significant rise in population density, and expansion of economic activities in the past decades, putting more pressure on natural resources.

The drivers of environmental change confronting Laguna de Bay include population growth, land and resource use intensification, and climate change, which could lead to more intense and more frequent typhoons.

Increased demand for water resources is evident, for instance, in rising demands for water extraction and fisheries licenses. Owing to a large demand for water in Metro Manila, more efforts are needed to prevent water deficit in the future amid rising population growth.

The LLDA's main target is to maintain water quality in the lake during dry and wet seasons. Rising levels of nutrient pollution and pollution from industrial, agricultural and domestic sources, as well as sedimentation are critical issues affecting the lake.

In terms of terrestrial resource uses, the LLDA is confronted with unregulated conversion of forest lands, expansion of urban areas, encroachment of informal settlers on shore lands of the lake, rapid clearing of forests, and the conversion of prime agricultural lands to residential areas. Driving these terrestrial pressures are rapid population growth and in-migration to the region, brought about by the lure of economic opportunity that otherwise is lacking in other regions of the country.

Other land policy drivers are issues of shore land reclamation, particularly those involving local government units and private entities, which are inconsistent with the national policy of controlling reclamation of foreshore areas; and titling of reclaimed areas. The land use plans of LGUs are often not in harmony with the Laguna de Bay master development plan.

The accounts yield the scientific basis for better land and water management in the Laguna de Bay basin by providing an up-to-date and comprehensive information system on the natural resources present in the area, and the trends in the use and availability of these resources.

"The drivers of environmental change confronting Laguna de Bay include population growth, land and resource use intensification, and climate change"

As discussed earlier, the LLDA and other government agencies are faced with a range of challenges in natural resource management. The accounts thus focus on some of the most critical aspects of these challenges, based on the LLDA mandate: water use, quality, hydrology and flood risk; terrestrial land cover change; erosion and sedimentation; and fisheries.

In addition to water use, another key issue affecting the lake area is flooding, since it is prone to heavy rainfall, especially during typhoons. Another contributory factor is the increasing population density in low-lying areas of the watershed, or close to the shore of the lake. This has led to continuous infrastructure development, including upgrading of roads and public works.

A specific issue currently being discussed is the potential construction of a flood protection structure alongside land reclamation in the southwest corner of the lake. Specific information needs, which could potentially be addressed using an ecosystem account, include those relating to flood-risk areas, the costs of flood damage, and flood mitigation interventions, specifically in priority areas.

The rapid population increase in the Laguna de Bay region affects the cover of different ecosystems in the area. Its impacts are expected to be revealed by the accounts. Erosion and sedimentation are linked to land cover change and affect the hydrology and the flood control service of the lake by changing the lake's bathymetry.

In fisheries, the policy drivers are conflicts between open access fishery and aquaculture, and the regulation of stocking densities in aquaculture; strategies to deal effectively with invasive species; and incentives for improving aquaculture practices. These are resource management issues that have an economic dimension.

While fisheries are an important economic activity in the Laguna Lake area (as explained in this pilot ecosystem account), floods pose major economic and development risks to Metro Manila, while the availability of drinking water is critical for both households and industries.

This pilot phase tests the degree to which an ecosystem accounting approach is capable of meeting the relevant information demands, and shows the linkages across the different aspects of and processes in the Laguna de Bay Basin.

The TWG hopes to perform policy analyses on the foregoing issues, using the accounts it has developed and presented in this report. This goal is expected to be achieved through the formulation of specific policy briefs and policy scenario analysis that could respond to several of the major policy issues surrounding the Laguna de Bay area. Such issues include dealing with flood risks as well as water pollution and erosion in the basin, which are affecting the communities.

2.| Methodology

SEEA-Experimental Ecosystem Accounting framework

The System of Environmental-Economic Accounts (SEEA) — Experimental Ecosystem Accounting (UN et al., 2014) approach (subsequently called 'ecosystem accounting' in this report) involves determining the following: 1) the extent and condition of ecosystems; 2) the ecosystem's capacity to generate ecosystem services as a function of its extent and condition; 3) flows of ecosystem services; and 4) the linkages between ecosystems and economic activity (UN et al., 2014; Edens and Hein, 2013; World Bank, 2014).

Fundamental to ecosystem accounting is the spatial approach taken, as well as — in line with the SEEA framework and the System of National Accounts (SNA) — the distinction between the flows of ecosystem services and stocks of ecosystem assets.

In ecosystem accounting, ecosystem condition, capacity, and services flows are analyzed using a spatially explicit approach. That is, with the use of maps and tables (UN et al., 2014), which allows integration of scarce data on multiple ecosystem services at aggregation levels (e.g., province or country) relevant to accounting. The spatial approach also supports additional applications such as land use planning.

For instance, ecosystem accounts can indicate which parts of the landscape should be better protected to sustain the supply of regulating services such as water regulation, which are critical to the supply of other ecosystem services including crop production. Information on ecosystem condition, capacity, and ecosystem service flow is measured in basic spatial units, and may be aggregated for ecosystem types or administrative units (UN et al., 2014).

The ecosystem accounting approach differs from the complementary SEEA-Central Framework (SEEA-CF). The former aims to analyze ecosystem assets and ecosystem services in a manner that conforms to national accounting.

The SEEA-CF has a different and complementary focus, including, but not limited to, emissions to the environment, expenditure for environmental protection, as well as accounting for water, carbon, minerals, land and timber. It is not spatially explicit, since it does not use maps to the same degree as the SEEA-EEA. Moreover, the linkages between ecosystem condition and ecosystem services are not specified. Hence, the ecosystem accounting provides a more comprehensive way of looking at ecosystem services.

Some benefits related to these services are included in the national accounts, such as tourism, timber production, and crop production. However, the ecosystem account specifically aims to show the contribution of the ecosystem to these benefits such as by providing opportunities for ecotourism.

The ecosystem accounts include several core as well as four thematic accounts (see the UN Technical Guidance for Ecosystem Accounting). In addition, there are designs for integrated ecosystem-economy accounts, the specification of which is still ongoing. These accounts will help link the flows of ecosystem services and stocks of ecosystem capital to the national accounts. Together, the ecosystem accounts provide a comprehensive and consistent picture of ecosystems, the services they provide, how these services are used in society, and the potential capacity of the ecosystem to sustain services supply in the future.

Out of the full suite of ecosystem accounts, the most policy-relevant ones for Laguna de Bay were selected, such as the land and water account, the ecosystem condition account, and the ecosystem services supply and use account.

The selection was based on consultations with the main policy makers responsible for the Laguna de Bay area during several meetings at the onset of the Phil WAVES project. The selected accounts are described in the succeeding sections of this report, begnning in Chapter 3.

Due to time constraints, a monetary asset account, which presents the net present value (NPV) of the expected flow of ecosystem services, has not been produced. In principle, the asset account could be prepared for the fisheries service to indicate the NPV of the expected flow of ecosystem services expressed as resource rent (see Annex 9).

Biodiversity and carbon accounts were likewise not covered in the case study area, since focus was made on the accounts that were most relevant to the LLDA in terms of policy. Besides, this agency does not have the mandate to manage carbon or biodiversity in Laguna de Bay.

Table 2.1. Ecosystem Accounts and Their Testing in Laguna de Bay

Account	Description	Application in Laguna de Bay
Land account	Contains information on land cover, land use, and land titles	Prepared for Laguna de Bay for the period 2003 and 2010
Water account	Contains information on stocks of water and changes therein, as well as water quality	Prepared for Laguna Lake, covering the period 2003-2012
Ecosystem condition account	Measures the physical condition of ecosystems and trends in condition	Created for the Laguna de Bay watershed including the lake itself and its surrounding area
Ecosystem services supply and use account	Measures flows of ecosystem services, per land cover/ ecosystem unit, and how ecosystem services are used by beneficiaries	Developed for two ecosystem services provided by the lake, namely, fisheries and water retention. For the terrestrial part, the erosion control service was mapped. The link to users is indicated in a generic manner and therefore is not specified per sector. Ecosystem use has been described, but not included, in the account.

Laguna de Bay Basin

The Laguna de Bay (LdB) basin and Laguna de Bay region are two different reference areas. The basin is the physical watershed, defined by the boundaries of where water flows into the Laguna Lake. It includes sub-watersheds that contribute to inflow of water into the lake. The ecosystem accounting reporting unit for this ecosystem account is the basin.

LdB region refers to the administrative region, based on administrative boundaries of cities and municipalities where the basin is located. The administrative region is substantially larger than the watershed. The lake region has a total area of 3,880 square kilometers (km^2) while the basin covers 2,920 km^2. The LLDA is mandated to govern land and water use across the entire administrative region.

LdB is located 13°55' to 14°50' N latitudes and 120°50' to 121°45' E longitudes in Luzon island, just southeast of Metro Manila, the country's center of urban and industrial development (see Fig. 2.1).

The basin occupies around 1% of the total land area of the Philippines. It encompasses the whole provinces of Rizal and Laguna; the towns of Tanauan, Sto. Tomas, and Malvar in Batangas; the towns of Silang, General Mariano Alvarez, and Carmona, and Tagaytay City in Cavite; Lucban town in Quezon province; and the cities of Marikina, Pasig, Taguig, Muntinlupa, Pasay, Caloocan, Quezon, Manila, and the town of Pateros in Metro Manila.

The LdB region boundaries include 61 municipalities and cities within five provinces and Metro Manila. Of these, 29 are lakeshore towns, covering 188 barangays (the smallest political unit in the country), and 32 are non-lakeshore towns. These areas have an estimated total population of 14 million (National Statistics Office, 2010) or about 14% of the country's total population (World Bank, 2011).

This configuration makes the region a critical source of food (including fish from capture and aquaculture fisheries) and water. The basin hosts several industries, including garment/ textile factories, cement factories, quarrying/ mining activities, and semi-conductor/ electronics industries. Poultry and piggery establishments, which fall under agro-industrial activities, are significant industries catering to a high demand for meat products from the nearby metropolises. Such facilities are centered in the northern towns of Rodriguez, San Mateo, Angono, and Baras in Rizal province and in the southern towns of Sta. Cruz, Pila, and Victoria in Laguna province.

Both the Laguna Lake and smaller lakes in the basin are important sources of livelihood for the fishery sector and serve several purposes: irrigation, transportation, energy generation, and other industrial uses (Laguna de Bay Masterplan, 1996).

All the municipalities and cities comprising the LdB region are within the jurisdiction of the LLDA.

Hydrology and water use

The Laguna Lake is the largest inland body of water in the Philippines and the third largest freshwater lake in Southeast Asia. Around 100

Figure 2.1. The Laguna de Bay region, including provinces (shown in selected colors) and municipal boundaries

rivers and streams drain into the lake. Twenty-two of these are significant rivers[4] contributing to the total amount of water in the lake.

Only one outlet, the Pasig River through the Napindan Channel, drains lake waters into Manila Bay. The outflow of the lake is controlled by the Napindan Hydraulic Control Structure, which was built in 1982 to control the backflow of saline water from, and the amount of pollution entering, the Pasig River.

In addition to the Laguna Lake, there are other, smaller, lakes in the region, in particular the Seven Crater Lakes (Sampaloc, Calibato, Bunot, Palakpakin, Pandin, Yambo, and Mohicap), which have a total surface area of 305 ha, and Tadlak lake in Los Baños, which covers 25 ha.

Runoff from the sub-basins brings in freshwater to the lake. Half of the inflows come from rivers found on the eastern side of the lake. The biggest volume of inflow comes from the Pagsanjan River, making up 18%-20% of the total.

When the lake level is lower than Manila Bay and when there is sufficient tidal fluctuation, the entry of saltwater through the Pasig River raises the salinity of the lake, resulting in brackish water. Freshwater runoff and saltwater backflows maintain the salt balance of the lake (Tongson et al., 2012).

Livelihood and management

The Laguna Lake is a source of livelihood for around 14,000 fishermen engaged in capture fisheries and two types of aquaculture (see Section 6). The lake is also a source of domestic water through the Maynilad Water Treatment Plant. Other than supplying water for domestic uses, the lake also provides irrigation water for approximately 103,000 ha of agricultural areas.

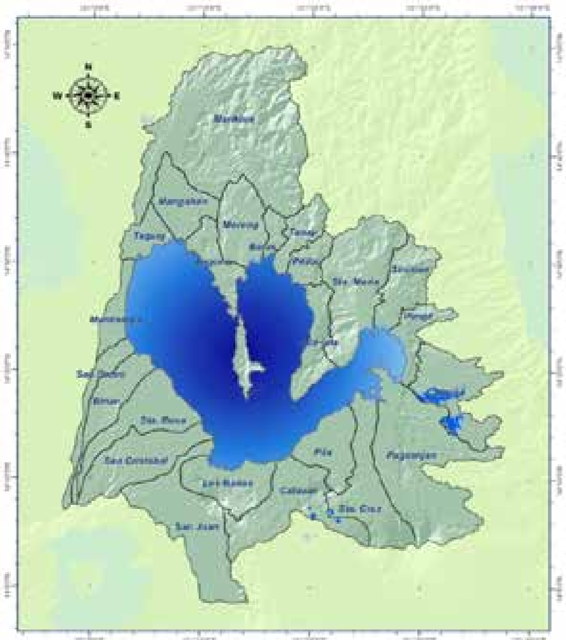


Figure 2.2. Laguna de Bay Basin and its main sub-watersheds

It also generates 700 megawatts of hydroelectric power[5].

With these features and uses, the lake is a reservoir for floodwater, and a source of drinking water, irrigation water, nutrients for fishery, and industrial cooling water. It is also used as a waste sink and for recreation.

Over the past decades, conflicts of interest, competing uses and unsustainable land and water uses have led to the rapid degradation of the lake and its watersheds. Population expansion, urbanization, industrialization, deforestation, and land conversion have led to massive changes in the Laguna de Bay catchment and the lake itself, threatening water quality and ecology.

The root causes of the lake's degradation may include intensified economic activities, open access to natural resources, lack of economic resource pricing policies as well as a common policy for management and development of

[4] *These tributary rivers are the following: Marikina , Muntinlupa, San Pedro, Binan, Santa Rosa, San Cristobal, San Juan, Los Baños, Bay, Pila, Santa Cruz, Pagsanjan, Pangil, Siniloan, Santa Maria, Jalajala, Pililia, Baras, Tanay, Morong, Angono, SapangBaho.*

[5] *Specifically, water is pumped out of the lake during periods of low electricity demand and excess electricity supply in Metro Manila into a storage reservoir located at an altitude several hundred meters above the water level at the Laguna Lake. During periods of high electricity demand, the water flows back to the lake through a set of turbines, and electricity is generated using hydropower.*

the lake and its watershed. This kind of situation has had a number of impacts on the livelihood provided by the lake. For instance, an assessment by Lasco and Espaldon (2005) showed that the lake was suffering from deteriorating water quality, which was potentially affecting fisheries production in the lake. The condition of the lake and its various competing uses are the subject of this ecosystem account.

"The root causes of the lake's degradation may include intensified economic activities, open access to natural resources, lack of economic resource pricing policies, as well as a common policy for management and development of the lake and its watershed"

3.| Land Account

Introduction

Land accounts include land cover and/or land classification. Together they support the LLDA strategic environmental policy by providing information on the status of and trends in the land cover and land use in the watershed that are influencing both the quantity and quality of water flowing into the Laguna Lake.

Understanding land cover changes is also vital to addressing the need to monitor how land assets contribute to the generation of economic benefits to the people living in the Laguna de Bay area.

Land cover in Laguna de Bay includes built-up, agricultural, forest, and barren lands. The barren land category includes grasslands and shrublands. Observation shows that most of these barren lands have been cleared by landowners for future conversion to residential and industrial uses. The forest cover that makes up about one-tenth of the study area falls below the recommended forest-non-forest national standard ratio of 40:60 based on the slopes of the watershed.

"The forest cover that makes up about one-tenth of the (Laguna de Bay) area falls below the recommended forest-non-forest national standard ratio of 40:60 based on the slopes of the watershed."

The expanding built-up area shows a decline in agriculture and forest areas that are the first to give way to expanding urbanization emanating from Metro Manila (LLDA Masterplan, 2011).

Methodology

The basic methodology for compiling land accounts includes the following steps:

- Data scoping and selection of parameters and aggregation level of information to be included in the account (e.g., land classification system, land cover units, land use, among others, based on budget and data availability)
- Data collection (including ground truthing of data), preprocessing (e.g., preparing remote-sensing images for classification through atmospheric correction and linking these to the relevant coordinate system), and processing
- Development of maps (following standard conventions on legend)
- Preparing of tables of land cover units
- Calculating land cover change over time
- Assessment of accuracy and validation activities

Understanding land cover changes is also vital to addressing the need to monitor how land assets contribute to the generation of economic benefits to the people living in the Laguna de Bay area.

The map data on land cover came from NAMRIA, supplemented with information from ESA on forest cover, which was used in the erosion and sediment modelling. These data were presented and validated by the TWG members to make sure they were up to date and valid. Processing of these map data took into account recalculation of the area, reclassifying classes where appropriate, and overlaying with watershed and political boundaries and with the jurisdictional boundary of the Laguna de Bay basin.

Land cover was analyzed using 2003 and 2010 maps provided by NAMRIA. The 2003 land cover map was generated from 30-m resolution images while the 2010 land cover map was processed from a 10-m resolution remote-sensing image. Both maps used almost the same classifications based on the Food and Agriculture Organization's (FAO) standard classification system, which includes closed forest, open forest, annual crop, perennial crop, built-up areas, inland water, grassland, shrubs, wooded grassland, open/barren, and mangrove forest).

However, the 2003 classification has 'fallow' land while the 2010 one added 'marshland/ swamp'. Future work must examine how resampling the 2010 map to 30 m can be done to determine the differences in accuracy between using 10 m and 30 m resolutions.

The difference in resolution affects the land cover change analysis. The 2003 land cover map, which has a coarser resolution, does not capture smaller details, particularly inland waters. In contrast, the 2010 map has a finer resolution.

Thus, based on the 2010 land cover map, it can be assumed that land cover — specifically the land cover types such as inland water, built-up areas, and fishponds that vary across relatively fine scales — is more accurately mapped in 2010 compared to 2003. The TWG will resample the 2010 map to 30 m resolution and check the differences in accuracy between 10 m and 30 m resolutions. (Preparation of the 2014 map is in progress.)

Since the Laguna de Bay region is not synonymous to the lake's watershed (as pointed out earlier), it is necessary to differentiate between the two. The land cover data (2003 and 2010) from NAMRIA were based on the two LLDA jurisdictions: administrative and hydrological/geographical boundaries.

Initially, to cover the entire LLDA jurisdiction, the land cover data from NAMRIA were processed or clipped according to the municipal boundary to correlate land cover and land use in the region within the municipal context. Understanding the land cover data on a political unit aims to help local officials better understand their roles as watershed managers.

In terms of political boundaries, the LLDA used the 2000 data from the National Statistics Office since the GIS unit incorporating these data was established in the same year through the Sustainable Development of the Laguna de Bay Environment project. The boundary covered the Laguna de Bay region comprising all cities and municipalities, as mandated in Republic Act 4850, which created the LLDA.

Modifications of the political jurisdiction were undertaken in 2010, when the agency acquired the barangay boundary shapefiles of Region 4A (CALABARZON, comprising Cavite, Laguna, Batangas, Rizal and Quezon provinces) and the National Capital Region from the Bureau of Agricultural Research. Subsequently, the municipal boundary was delineated to support the developmental and regulatory mandates of the agency.

The watershed boundaries in Laguna de Bay Basin were delineated by NAMRIA using version 2.1 of the 3-arc second Shuttle Radar Topography Mission (SRTM3) Digital Elevation Model (DEM) data collected in February 2000 by the National Aeronautics and Space Administration.

This is currently the highest-quality, highest-resolution, global-coverage (60°N-56°S) DEM available. At the equator, the resolution is approximately 90 m. (For a general description of the data, please see http://www2.jpl.nasa.gov/srtm/cbanddataproducts. html.)

The coverage area includes the 24 major sub-basins of the Laguna de Bay Basin, namely: Marikina, Manggahan, Tanay, Morong, Baras, Angono, Pillila, Jala-jala, Sta. Maria, Siniloan, Pangil, Caliraya, Pagsanjan, Sta. Cruz, Pila, Victoria, Calauan, Los Baños, San Cristobal, San Juan, Santa Rosa, Binan, San Pedro, and Muntinlupa.

The data were processed using the ArcGIS 10 software to come up with the delineation of different land cover classifications on political boundaries. From the original 21 land cover classifications of NAMRIA, following the FAO standard classification, only 14 classifications remain and are delineated within the municipal boundary of the region. The land cover matrix and physical accounts were prepared with the corresponding tables using pivot table in MS Excel. Land cover maps of 2003 and 2010 were also prepared.

Findings

Land cover by watershed

Land cover in 2003

In 2003, industrial and urban/built-up areas covered 7.9% of the basin or about 30,469 ha (see Figure 3.1. and Table 3.2.). Built-up areas were mostly found at the western portions of the Laguna Lake and the six sub-basins, with the highest concentration of urban sprawl located in Manggahan, Marikina, Muntinlupa, Sta. Rosa, Binan, and Taguig sub-basins.

A large portion of the land cover, approximately 91,245 ha or 23.5%, was covered by annual crops, while 57,704 ha consisted of perennial crops, including rice, coconut, and fruit. These also covered piggery/poultry/livestock raising, and other agricultural activities. The agricultural areas were concentrated in the southern area of the region, particularly in the towns of Laguna province and some portions of Rizal province.

Rice farming and crop production were observed in areas bordering the level lands of Laguna de Bay, such as the towns of Pakil, Pangil, Siniloan, Famy, and Sta. Cruz in Laguna. Sugarcane was the most important crop in the municipalities of Calamba, Cabuyao, and Sta. Rosa in Laguna; Sto. Tomas and Tanauan in Batangas province; and Carmona in Cavite.

Fishponds and duck farms/balut (fertilized duck egg) production could be observed in the marshlands of the coastal areas. The mountainous northeastern, eastern, and southern areas, many of which used to be forestlands, were devoted to coconut, banana, and fruit production.

Forest cover represented by closed forest (1.1% or 4,350 ha) and open forests (5.5% or 21,504 ha) constitutes the remaining forest ecosystems. The closed forest areas, including primary and secondary forests, were mainly located in the northeastern and eastern parts of the region, with a few patches in the southwestern section.

The primary forest held stands of trees such as lauan *(Dipterocarpus spp.)*, apitong *(Dipterocarpus grandiflorus)*, manggachapui *(Hopea acuminata)*, and yakal *(Shorea astylosa)*, while the secondary forests are usually planted to reforestation tree species such as mahogany *(Swietenia macrophylla)*, gmelina *(Gmelina arborea)*, falcata *(Paraserianthes falcataria)*, and ipil-ipil *(Leucaena leucocephala)*, or have been naturally occupied with bamboo and palm trees, among others.

The shrubland area covered 65,049 ha or 16.8% while the open/barren site comprised 1,160 ha or 0.3% of the total watershed area of the Laguna de Bay basin. The grasslands and bushlands were located close to the forested areas in the northern, eastern, and southern sections of the region.

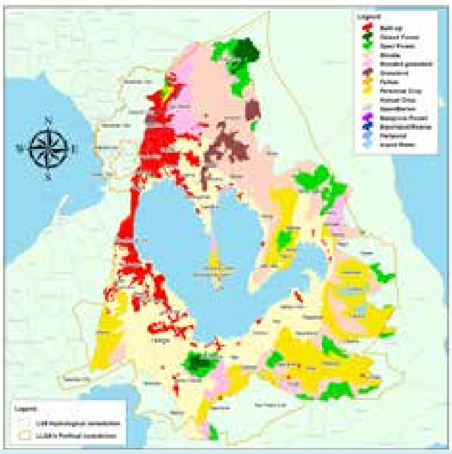


Figure 3.1.Land Cover by Watershed, 2003

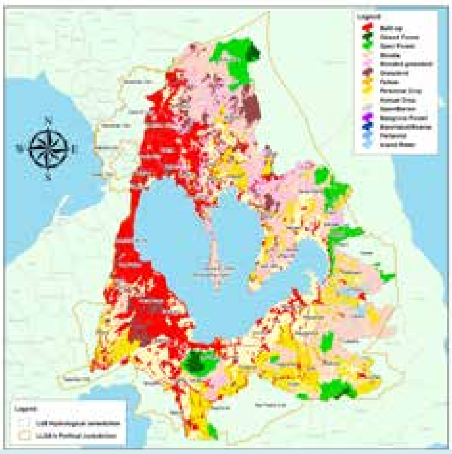


Figure 3.2 .Land Cover by Watershed, 2010

Except for the bare lands, the grasslands were utilized for grazing. Many of the grazing areas, however, were below the 18% slope, which by law should be relegated only to urban and agricultural uses. Grazing was only allowed on 18% to 50% slopes, along with mining and production forestry or silviculture. Slopes above 50% should, by law, be used strictly for protection forest (Table 3.1.). These land use limits are more accurately delineated at the sub-watershed level. Hence the need to also plan the whole region at the level of each of the 24 sub-watersheds comprising it.

The grassland areas in the region were dominated by cogon *(Imperata cylindrica)* and talahib *(Saccharum spontaneum)* whose immature shoots were used as animal feeds. In other cases, more palatable pasture grasses such as Kudzu *(Pueraria lobata)*, Para Grass *(Urochloa mutica)*, and Guinea Grass *(Megathyrsus maximus)* were purposely planted to produce more healthy livestock.

Table 3.1. Land Cover Composition by Slope Category

Land Cover 2010	Unclass-ified	0 to 3	3 to 8	8 to 18	18 to 30	30 to 50	50 and above	Grand Total
	Area in hectares							
Annual Crop	117	23,651	10,265	13,426	1,774	1,466	1,593	52,291
Built-up	345	23,517	13,892	20,126	5,784	1,520	504	65,687
Closed Forest		1,555		10		315	952	2,831
Fishpond		51		25				76
Grassland	1	938	1,177	4,904	794	3,987	4,682	16,482
Inland Water		91,111	731	1,049	816	312	906	94,924
Mangrove Forest		1						1
Marshland/ Swamp		2	2					4
Open Forest	2	2,271	291	1,630	673	4,511	11,389	20,768
Open/ Barren	1	105	84	327	26	69	93	707
Perennial Crop	98	3,873	7,516	18,703	4,047	4,668	4,830	43,734
Shrubs	478	3,122	2,621	13,330	12,178	12,276	19,647	63,652
Wooded grassland	76	1,445	1,410	8,842	506	5,692	8,881	26,853
Grand Total	1,118	151,641	37,990	82,371	26,598	34,816	53,476	388,011

The water bodies covered about 23.1% or 89,517 ha, which included the Laguna Lake itself and other inland waters such as the seven crater lakes, Tadlak lake, Caliraya reservoirs, and other marshy areas or wetlands within the region. Observed differences in water areas marked on the

2003 and 2010 maps may be attributed to the different time periods of the remote-sensing images on which the maps were based, and to the different resolution of the images (as discussed above).

Land cover in 2010

The land cover classification of 2010 captures spatial units more accurately, especially small portions of land cover, due to its 10 m image resolution backed up by ground validation.

Based on the 2010 land cover map of the Laguna de Bay Basin, forest cover represented only 6.1% of the basin, including closed forest (2,831 ha or 0.7%) and open forest (5.4% or 20,768 ha). (See Figure 3.2 and Table 3.2.)

Among the 24 sub-basins of the Laguna de Bay Basin, the highest cover (closed and open) in 2010 was still found in Marikina with 7,307 ha, followed by Pagsanjan with 2,966 ha, and Los Baños sub-basin with 2,946 ha. Built-up areas comprising 16.9% or 65,687 ha had the highest cover while the mangrove forest had the lowest with only 1 ha.

Marikina, being the largest sub-basin of the Laguna de Bay basin, also occupied the largest built-up areas with 9,530 ha, followed by Manggahan (7,264 ha), Santa Rosa (7,042 ha), San Cristobal (5,896 ha), and San Juan (4,710 ha) sub-basins. Considerable built-up areas could also be found in the cities and towns of Santa Rosa, San Juan, and San Cristobal sub-basins, where large number of industries, residential areas, and other commercial establishments were emerging.

Agricultural lands including areas planted to annual and perennial crops such as rice, corn, and certain root crops were mostly found in agricultural sub-basins such as San Juan, Pagsanjan, Calauan, Pila, and Sta. Cruz. In terms of annual crops, the San Juan sub-basin was the largest with 8,858 ha, followed by Pagsanjan with 5,698 ha, and Pila with 4,724 ha. Perennial crops were largely situated in Pagsanjan (6,670 ha), Calauan (6,689 ha), and Sta. Cruz (5,648 ha) sub-basins.

Large areas of shrubs were also evident in the sub-basins of Marikina (17,916 ha), Pagsanjan (12,901 ha), and Sta. Maria (6,759 ha). Wooded grasslands and grassland areas were largely situated in Marikina sub-basins with 7,145 ha of wooded grasslands and 7,192 ha of grasslands. These were followed by Sta. Maria sub-basin with 5,049 ha of wooded grasslands and 775 ha of grasslands. Interestingly, Sta. Rosa sub-basin had 1,403 ha of grassland areas but without wooded grasslands. San Cristobal sub-basin contributed to the total grassland areas with 1,955 ha of grasslands and 199 ha of wooded grasslands.

"Open forest areas declined by 3% and closed forests by 35% during the 2003-2010 period. This may be attributed to rampant forest degradation and persisting shifting cultivation in the upland areas ..."

Land cover change in 2003 and 2010

Based on a comparison of 2003 and 2010 land cover (Table 3.2), built-up areas more than doubled during this period, representing an average annual growth of more than 11%. This reflects a rapid development and change of land use in the region, as lands were converted, mostly by private owners, for industrial/ commercial and residential purposes. Grassland (8,190 ha) and wooded grassland (8,225 ha) areas also increased.

On the other hand, open forest areas declined by 3% and closed forests by 35% during the 2003-2010 period. This may be attributed to rampant forest degradation and persisting shifting cultivation in the upland areas of the Laguna de Bay Basin.

Forests in the region were subjected to deforestation in the past decades. Between the mid-1940s and mid-1990s, forest cover decreased from about 53% to 8%. The deforestation rate in the region was at its peak in the 1970s because of rampant logging. Expanding urban areas, poverty, and unregulated trading of forest products also contributed to the degradation of the Laguna Lake watershed and the region.

There was also a marked decrease in agricultural areas in the 2003-2010 period, averaging about 35% in the Laguna de Bay Basin. In particular, annual crop production declined by about 42.7% or 38,954 ha, and perennial crop 24.2% or 13,970 ha. The last patches of mangrove forest virtually disappeared in the lake basin in this period — from 94 ha in 2003 to 1 ha in 2010. The last remaining mangroves can be found in the intersection of the Laguna Lake and Pasig River.

Overall, land cover change in the period 2003-2010 had been very rapid. Analyses are ongoing for the year 2014 to see if this trend still holds.

Table 3.2. Comparison of Land Cover in 2003 and 2010 by Watershed (area in hectares)

Land Cover	Land Cover 2003		Land Cover 2010		Change in Land Cover		
	Hectares	Share of Land Cover	Hectares	Share of Land Cover	Change in Hectares	% Change Land Cover	% Change in Share of Land Cover
Annual Crop	91,245	23.5%	52,291	13.5%	-38,954	-42.7%	-10.0%
Perennial Crop	57,704	14.9%	43,734	11.3%	-13,970	-24.2%	-3.7%
Built-up	30,469	7.9%	65,687	16.9%	35,218	115.6%	9.2%
Open/ Barren / fallow	1,160	0.3%	707	0.2%	-453	-39.1%	-0.1%
Shrubs	65,049	16.8%	63,652	16.4%	-1,397	-2.1%	-0.4%
Grassland	8,292	2.1%	16,482	4.2%	8,190	98.8%	2.1%
Wooded grassland	18,628	4.8%	26,853	6.9%	8,225	44.2%	2.1%
Marshland/ Swamp	-		4	0.0%			0.0%
Open Forest	21,504	5.5%	20,768	5.4%	-736	-3.4%	-0.1%
Closed Forest	4,350	1.1%	2,831	0.7%	-1,519	-34.9%	-0.4%
Mangrove Forest	94	0.0%	1	0.0%	-93	-98.9%	0.0%
Inland Water	89,517	23.1%	95,000	24.5%	5,407	6.0%	1.4%
Total	**388,012**		**388,012**				

Land classification in Laguna de Bay

This section seeks to include the administrative aspects of land management in the land account, and therefore presents the land classification system in the area. Land classification is shown in Table 3.3. Given that these administrative data correspond only to the administrative region of Laguna de Bay, the map shown in Figure 3.3 and Table 3.3 are limited in scope to the Laguna de Bay region.

Based on the processed data, alienable and disposable (A&D) lands occupy 60% of the entire Laguna de Bay region, or 292,857 ha. As defined by government, these lands belong to the public domain but have been the subject of the present system of classification and declared as not needed for forest purposes.

Forest land only occupies 6% (30,598 ha) of the total land area, while protected lands such as national parks cover about 50,770 ha, or 10%. Unclassified areas are about 30,106 ha in size, mostly concentrated in Silang, Tagaytay, Paete, Pangil, and Kalayaan municipalities.

Under the classification 'forest land', the land cover types that occupy the largest areas are shrubs (11,969 ha) and open forest (8,920 ha). A significant area is devoted to wooded grasslands (3,946 ha) and perennial crops (1,869 ha). Built-up areas are highly concentrated in A&D lands but also occupy a certain percentage of land in forestland with 179 ha, and 794 ha of protected sites. Built-up areas, perennial, and annual crop plantations are the three largest areas within the A&D classification with 83,275 ha, 58,451 ha, and 49,946 ha, respectively.

Table 3.3. Land Cover by Land Classification (2010), Laguna de Bay Region

Land Cover 2010	A&D	Forestland	National Park	Lake	Unclassified	TOTAL
Annual Crop	49,946	324	1,855	81	5,161	57,367
Perennial Crop	58,451	1,869	2,203	5	4,527	67,055
Built-up	83,275	179	794	170	4,521	88,939
Open/Barren	572	90	16	0	24	702
Shrubs	47,290	11,969	13,479	27	5,132	77,897
Wooded grassland	23,877	3,946	7,756	2	1,768	37,348
Mangrove Forest	1	-	-		-	1
Marshland/ Swamp	4	-	-		-	4
Open Forest	9,243	8,920	14,326		8,215	40,704
Closed Forest	116	874	4,274		-	5,263
Fishpond	76	-	-		-	76
Grassland	13,197	763	5,662	1	245	19,868
Inland Water	6,808	1,665	407	86,776	512	96,168
Grand Total	**292,857**	**30,598**	**50,770**	**87,061**	**30,106**	**491,392**

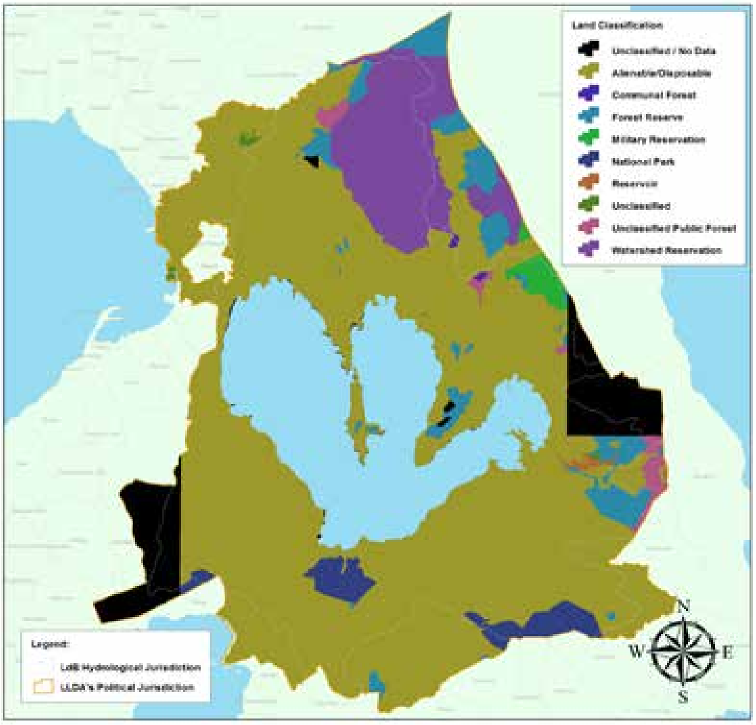


Figure 3.3. Land classification of Laguna de Bay region 2010

Evaluation

The land account clearly illustrates the major land cover change in the basin in the period 2003-2010. There was rapid urbanization and industrialization in the lake region, in particular in the Greater Metro Manila area, and in the northwest, western, and southern portions of the lake. The spread and location of residential subdivisions were marked by unplanned urban sprawl. This involves, among others, the conversion of agricultural lands to residential uses, and the construction of new settlements close to the lake shore, or in the zone that is vulnerable to flooding (as analyzed in Chapter 6).

The forest cover underwent a rapid decline in the same period. All mangrove forests (except a 1-ha patch) had disappeared, while closed forest has declined by 35%. The remaining forests were found largely in the Makiling Forest Reserve and Sierra Madre mountain ranges. But even these areas had not been spared from illegal settlements. The remaining forest areas should be preserved as they maintain the ecological balance of the lacustrine region.

There are still many parts of the region that should be reforested by law (Presidential Decree 705). They feature slopes of more than 18% and above 1,000 m meter elevations, and are primarily found in the Sierra Madre Mountain foothills in Rodriquez, San Mateo, Antipolo, Tanay, Pagsanjan, and Sta. Cruz. The flooding catastrophes that came in the wake of Typhoons Ketsana (local codename: Ondoy) and Parma (local codename: Pepeng) in 2009 were wake-up calls to immediately reforest the denuded foothills of the region, especially those of the northern Marikina and southern Sta. Cruz-Pagsanjan sub-watersheds.

The 42.4 km^2 Makiling Forest Reserve (MFR) in Los Baños, for instance, is a step in this direction. Located south of the Laguna Lake, it has been preserved as a wildlife sanctuary, pool for genetic diversity, and training laboratory for the advancement of scientific knowledge on natural resources. As a natural resource the MFR also provides irrigation, industrial and domestic water as well as electric power — through the Makiling-Banahaw Geothermal Power Plant — to the surrounding communities.

An underlying assumption of this report is that an understanding of the implications of changes in land cover and land use is a fundamental part of planning for sustainable development and ecosystems of Laguna de Bay Basin.

The report shows how the development of land accounts can contribute to knowledge and understanding in this important area. For instance, the accounts can yield information on recent efforts at land conversion that may not be aligned with development plans or planning laws, thus ensuring better enforcement of such regulations. Of considerable importance to policy is information on forest land conversion.

For example, a question that is relevant to policy makers is if legally classified forest lands with longstanding claimants should be converted to A&D lands. Another important policy question is whether existing but otherwise illegal land use should be legalized or reverted to forests. These and other policy issues require regular updates of the land account.

The land cover maps are used in ecosystem accounting in a number of ways. First, they provide useful information that supports policy making, as described above. Second, they provide a basis for calculating the supply of ecosystem services (see Remme et al., 2015). Regulating services, for example, require the modelling of ecological processes that generally depend on land cover, among others. This is illustrated in this account through the calculation of sedimentation control by vegetation. One of the most important input datasets for measuring this service focuses on land cover.

Further development of land accounts should continue to obtain basic information on the availability and usability of land resource and thus provide planners and users with adequate basis for facilitating the orderly development and wise use of this vital resource. It is therefore recommended that land accounts be regularly updated and incorporated in the watershed-based or regional planning process. This requires sustained collaboration with NAMRIA to obtain datasets that allow comparisons of land cover and land use at the micro-watershed to regional scales.

Data quality

In terms of methodology, the TWG notes that resolution and accuracy are vital, and that the 10 m resolution (alongside ground truthing) is highly preferable to 30 m resolution images. It has also become clear that perennial crops are not separated totally from the forest categories, leading to potential inaccuracies in the classifications of the open forest, bush/shrubland, and perennial crop categories.

The obvious difference in lake levels between 2003 and 2010 should be standardized to avoid artificial lake level differences across the years. This can be done, for instance, by selecting a specific high water level for the map and correcting the land cover map accordingly. Consistent land cover classification and spatial resolution of land cover data in the future will maximize data comparability over time, resulting in more accurate accounts that are easier to compile.

Highlights of Land Account

- The land account covers built-up, agricultural, forest, and barren land.
- The land account clearly illustrates the major land cover change that took place in the Laguna de Bay Basin during the period 2003-2010.
    - Closed forest decreased by 35%, while built-up areas increased by 116%.
    - The forest cover that makes up one-tenth of the study area falls below the recommended forest-non-forest national standard ratio of 40:60 percent.
    - The expanding built-up area shows a decline in agricultural and forest areas since these are the first to give way to growing urbanization emanating from Metro Manila.
    - Annual crop production declined by about 43% or 38,953 hectares and perennial crop by 24% or 13,970 hectares. The last patches of mangrove forest virtually disappeared in the lake basin between 2003 and 2010.
- These massive changes in the Laguna de Bay basin and the lake itself are threatening the lake's water quality and ecology.

4.| Water Account

Introduction

The water account records the physical stocks and water flows in the Laguna Lake. (Water quality aspects are discussed under Ecosystem Condition Account, in Chapter 5). The Laguna de Bay Basin faces a number of water management issues, which are linked to the rising population density in the area and increasing demand for water resources. Among fisherman, for instance, there is pressure to increase possibilities for aquaculture amid intensive capture fisheries.

The benefits derived from the lake cannot be emphasized enough. Water is used for irrigation and drinking, and as a sink for pollution emissions. It is also valuable for electricity generation. During periods of peak demand, hydroelectricity is generated by letting water flow from the basin to the lake. But during off-peak hours, water is pumped out of the lake to a storage basin at higher altitude.

Laguna Lake serves as an important retention storage that mitigates flood risks around the lake shores and the southern part of Metro Manila.

"Laguna Lake serves as an important retention storage that mitigates flood risks around the lake shores and the Southern part of Metro Manila."

The interaction between the landscape and climate plays a critical role in the movement of water in the hydrologic system of Laguna de Bay basin. This interaction is best described through the water cycle and linkages among the water components. Most precipitation is stored in the Laguna Lake before flowing through the Pasig channel to Manila Bay.

During the dry season, the water level in the lake falls to an average minimum elevation of 10.5 m leading to the intrusion of seawater from Manila Bay during high tides via the Pasig River. The lake water level that is reached in the rainy season varies from year to year, and averages around 12.5m.

Objectives and methodology

Analysis of the water account seeks mainly to assess the water resources in the Laguna De Bay Basin for the years 2000 until 2012. Critical to the study is the availability of existing data and information from various agencies tasked to collect and record pertinent parameters in the field and conduct computer simulations. The scope of the study is the entire Laguna de Bay Basin. Units of analysis are the amounts of water expressed in million liters per year.

Water balance modelling

The Laguna Lake water balance was produced with the use of hydrology and hydrodynamics model of the LLDA Decision Support System (DSS). The DSS is a flexible tool consisting of an interconnected set of modelling tools which are refined by calibration using actual data. The LLDA DSS provides balanced decision making based on a comprehensive assessment including several modules.

Hydrology module

The module provides information on the water quantity flowing to the lake at the level of the sub-basin. Computations of water distribution among the hydrologic components of the Laguna de Bay Basin are simulated by transforming rainfall input into channel inflows and its corresponding catchment water balance. The occurrence, circulation, and distribution of water are analyzed through this module.

Hydrodynamics module

The module facilitates understanding of the water balance of Laguna de Bay in relation to the different forcing functions such as changes in meteorology, bathymetry, catchment discharges, gate operations, among others. It also yields predictions on water circulation, flooding events, water level variations, flow velocity, saltwater intrusion, thermal pollution caused by industrial discharge extent of accidental spills, among others.

The output of the model will serve as an input for sediment transport, water quality, and ecological modelling, and may also be used to determine future changes in the lake water, especially with respect to the projected infrastructure development.

Hymos 4

Hymos is an information system for water resources management. It can store, process, and present hydrological and environmental data and can be used for water resources investigations and administration. The annual mean water balance, from 2000 to 2012, for the whole Laguna de Bay Basin was calculated with Hymos using the following equation:

$$\frac{dV}{dt} = Q_{streams} + Q_{precipitation} - Q_{users} - Q_{evaporation} \pm Q_{Pasig\ Exchange} \pm Q_{Mangahan} \pm Q_{excess/deficit}$$

in which:

V	= lake volume
dV/dt	= rate of change of lake volume
$Q_{streams}$	= calculated discharge from 23 sub-basins
$Q_{precipitation}$	= calculated average precipitation in the lake
Q_{users}	= combination of power generation, industrial cooling, domestic water supply and irrigation
$Q_{evaporation}$	= calculated potential evaporation
$Q_{Pasig\ Exchange}$	= Pasig River discharge
$Q_{Mangahan}$	= discharge from the Mangahan Floodway (Marikina Sub-Basin discharge)
$Q_{excess/deficit}$	= groundwater flux and the uncertainties in all other balance terms

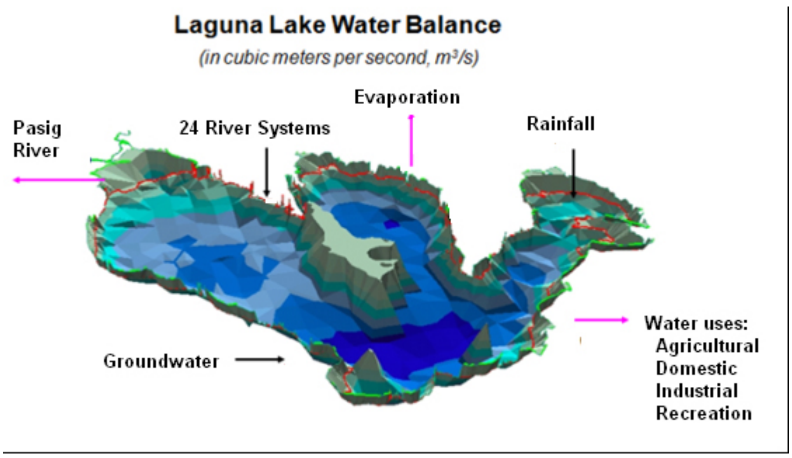


Figure 4.1.Schematization of the Laguna Lake water balance

Based on available information (i.e., the river inflow, precipitation, evaporation, water use, groundwater influx and exchange with the Pasig River), the lake water balance can be described as shown in Figure 4.1.

Calculation of the Laguna Lake water balance was based on 2000-2012 data. Hence this report focuses on process flows during this period, with the following as the sources of data for the software used:

- Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) for rainfall and mean temperature
- List of LLDA surface water permit recipients
- Sacramento Hydrologic Modelling of Sustainable Development of Laguna de Bay Environment in 2000 using processed hydro-meteorological data as input
- Department of Public Works and Highways - Efficient Flood Control Operating System/ Japan International Cooperation Agency (JICA) data on hydraulic structure operation
- Digitized map from the National Hydraulic Research Center
- Ecosystems Research and Development Bureau, LLDA, and Environmental and Natural Resources Accounting Project (ENRAP) (2000)
- SOGREAH Study (1991)

Delft3D model

The Pasig River water exchange was derived through the Delft3D model — a useful hydrologic tool applied to tide-driven flows, fresh water discharges in bays, and river flow simulations. These scenarios are similar to the interaction between Manila Bay and Laguna de Bay basin, which are linked together by the Pasig River. Thus, the hydrodynamic condition of these two water bodies is interpreted in terms of the volume of water passing through the Pasig River. The results of the Hymos 4 model are utilized as raw data fed inro the Delft3d model.

Assumptions and data gaps

Water input/inflows

Hydro meteorological stations in the area were used in the analysis. However, data for some stations in the basin were unavailable. There were 23 rainfall stations established by the LLDA, PAGASA, and Effective Flood Control Operation System within the Laguna de Bay region.

Only four stations in the basin had complete annual data, namely, Science Garden, Ninoy Aquino International Airport, Ambulong and Tayabas stations of PAGASA. The Hymos 4 model interpolated the data based on the neighboring stations, thus facilitating the calculation of missing daily precipitations in all stations. At least two stations had mean temperature data — Science Garden in Quezon City and the National Agrometeorological Station at the University of the Philippines in Los Baños, Laguna.

Lake water uses/outflows

Not all the water users in the lake were factored into the pilot ecosystem account. Those that were covered in the account were based on the LLDA list of recipients of surface water permits, which were issued beginning in 2009 , when the National Water Resources Board transferred to the LLDA the power to grant and allocate rights over public water within the Laguna de Bay region.

Note that only extractive water use was considered in the account. An important non-extractive use of the lake water involves hydropower generation. The water is pumped out of the lake into a reservoir located in the hills above the lake during off-peak hours of the Luzon electricity grid. During this period the water can be pumped back into the lake using a number of turbines to generate electricity.

Results

Water balance

The results are divided into three major parameters, namely, inflows, outflows, and changes in lake storage. As a hydrologic system, the Laguna de Bay Basin has interacting components where water moves from one source to another.

Inflows are the addition of water to the hydrologic system, where it interacts with the components of the basin. Outflows are the release or discharge of water out of the hydrologic component of the basin or release from the entire basin itself.

Inflow sources of water were simulated using the Hymos 4 model and based on previous studies. These sources were microwatershed discharges, direct lake rainfall, groundwater interaction, and contribution from the Manggahan Floodway. These collectively contribute to the lake water supply. However, in the case of the floodway, the simulation covered only the years when it was open. As it was closed in 2000 and 2012, it did not contribute to inflows in those years.

Microwatershed discharges are the total surface runoff from the different river systems of the Laguna de Bay basin. These consist of combined runoff that has been converted from precipitation in the microwatershed, and water discharged by users from different facilities.

Since the surface area of the lake is estimated to be 900 km^2, the amount of water, or direct rainfall, it catches is significant for analysis. (Direct rainfall is the amount of precipitation that falls into the lake.)

Another contributory source simulated by the Hymos software is the interaction of groundwater and the lake. The gradual movement of groundwater toward the lake represents water inflow into the lake.

According to the Hymos 4 and Delft3D models, removal of water from the hydrologic system, or its outflow from the lake to beyond the boundary of Laguna de Bay Basin is attributed to evaporation, river exchange, and usage. Lake evaporation is a natural phenomenon whose main driver is temperature. The Hymos 4 model processed the annual amount of evaporated water from the lake.

Meanwhile, the sole outlet of Laguna Lake is the Pasig River, which channels outgoing water from the lake into Manila Bay, the amount of which is simulated by the Delft3D model. Utilization of water for human activities facilitates outflow of water. This is taken into account using information based on the surface water permits issued by the LLDA as part of the general water balance of Laguna de Bay basin.

Storage is defined as the amount of water retained in a specific component of the hydrologic system. In the case of the Laguna Lake, the Hymos 4 and Delft3D models simulated the total inflow and outflow of water and took note of the difference, which shows the change in the quantity of water stored in the lake per annum from 2000 to 2012. (Table 4.1 presents the results of the simulation by the Hymos model, indicating the total value of water inflows and outflows expressed in megaliters during the period.)

Table 4.1. Hymos Simulation Results of Water Inflows, Outflows, and Changes in storage in the Laguna De Bay (in million liters, 2000-2012)

Laguna Lake Water Balance, in million liter per year													
Simulation Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
A. Inflows:													
Microwatershed Discharges	5,291,740	3,144,139	3,386,966	2,970,691	3,929,385	4,919,931	3,292,358	4,651,560	3,169,368	5,423,561	4,021,470	6,287,016	7,976,715
Direct Lake Rainfall	1,668,254	1475884	1,561,032	1,545,264	1,198,368	1,545,264	1,652,486	1,797,552	1,901,620	2,555,992	1,972,261	2,650,916	3,196,488
Groundwater Interaction	498,268	498,268	498,268	498,268	498,268	498,268	498,268	498,268	498,268	498,268	498,268	498,268	498,268
Mangahan Floodway Contribution	-	-	-	-	-	-	-	-	-	-	-	-	-
Total inflow	7,458,262	5,118,291	5,446,266	5,014,223	5,626,021	6,963,463	5,443,112	6,947,380	5,569,256	8,477,821	6,491,999	9,436,200	11,671,471
B. Outflows:													
Direct Lake Evaporation	864,086	895,622	927,158	961,848	920,851	873,547	883,008	879,854	901,929	1,187,330	990,230	826,873	861,878
Pasig River Exchange	7,552,872		5,698,555	4,834,468	4,683,096	5,304,355	4,720,939	5,389,502	4,802,932	7,347,572	5,067,519	8,503,413	11,211,04
Total Lake Water Usage	204,984	204,984	204,984	204,984	204,984	204,984	204,984	204,984	204,984	204,984	204,984	204,984	204,984
Total outflow	8,621,942		6,830,697	6,001,300	5,808,931	6,382,886	5,808,931	6,474,340	5,909,845	8,739,886	6,262,733	9,535,270	12,277,902
Lake Change in Storage	-1,163,678	-1,267,747	-1,384,430	-987,077	-182,909	580,578	-365,818	473,040	-340,589	-262,064	229,267	-99,070	-606,437,

The amount of abstraction is based on the permit issued by the LLDA for the utilization of the lake water while evaporation and outlet discharges are based on observations and hydrologic modelling, respectively. Based on the simulation, the stock of lake water increased in 2005, 2007, and 2010. For the rest of the years analyzed, more water was lost (outflows) due to abstraction, evaporation, and outlet discharges than what was replenished (inflows).

However, in the long run, the stock of water in the lake may remain relatively constant, since at low water levels, the lake will be replenished over time by rain water and at high water levels the outflow to Manila Bay will increase.

Efforts were made to capture data on Laguna de Bay basin's water balance corresponding to more recent years. But water balance calculations for 2013 and 2014, for instance, were not possible due to data limitation.

Limited rainfall data for those years showed extremely high rainfall values compared to historical data. To conduct simulation for 2013 and 2014 would cause public misinformation about the hydrology of the lake. Hence there is a need to update and collect more recent data and re-run the model for 2013 onwards.

Water asset account

Based on inputs to, and data generated by, the Hymos 4 and Delft3d models, as well as data on industry returns of water to the Laguna de Bay region (as monitored by the LLDA Environmental User Fee System, which covers many industries and households existing in the area), a SEEA water asset account was prepared for the pilot site for the year 2000.

The Phil WAVES technical working group found several data gaps and challenges that needed addressing to produce water balances for the lake.

The TWG found several data gaps and challenges confronting water balance in the lake. Soil water was assumed to remain constant throughout the year, resulting in all rainfall to the watershed eventually flowing into rivers and, finally, the lake. Likewise, rivers were assumed to retain no water and that all flows to rivers combined with outflows to the lake.

Moreover, there was no data available on the lake's recharge from the groundwater except in the Environmental Assessment of Laguna de Bay. Finally, a 1991 study by French consulting company SOGREAH, which indicated a 15.8 m^3/sec groundwater flow into the lake, was also used as basis for subsequent years.

The LLDA environmental user fee does not apply to businesses operating in Makati, Mandaluyong, and San Juan cities, which lie within the Laguna de Bay watershed, and therefore the returns on investment in these cities are not taken into account. However, the share of flows from these areas will be determined in future undertakings. Additionally, as no spatial analysis of the fees collected is undertaken by the LLDA, some units subject to these fees (and therefore are included in the model) are known to discharge water outside of the watershed.

As with the water balance presentation of data, there are no opening or closing stocks for the water assets in the area. The tables describe the annual flow of water across different assets (groundwater, soil water, rivers and lakes) and present a net change for each asset corresponding to each period. The hydrologic data are therefore prepared in such a way as to conform to the SEEA supply and use tables. As such they can eventually be integrated into the national accounts of the Philippines.

Table 4.2 presents a SEEA water asset account for 2002. See Annex 1 for accounts relating to the years 2001, 2010 and 2012.

Table 4.2. SEEA Water Asset Account for the Laguna de Bay Basin, 2000 (million liters)[1]

2000	Surface water		Groundwater EA.132	Soil water EA.133
	EA.1312 Lakes	EA.1313 Rivers		
1. Opening Stocks	n.a.	-	-	-
Increases in stocks	7,458,262	5,338,649	498,268	5,291,740
2. Returns		46,909		
3. Precipitation	1,668,254			5,291,740
4. Inflows	5,784,008	5,291,740	498,268	-
Decreases in stocks	8,621,942	5,291,740	498,268	5,291,740
5. Abstraction	205			
6. Evaporation/ Actual evapotranspiration	864,086			
7. Outflows	7,552,872	5,291,740	498,268	5,291,740
7.a. to downstream territories				
7.b. to the sea	7,552,872			
7.c. to other resources in the territory		5,291,740	498,268	
Other changes in volume				
Net changes	(1,163,678.40)	46,909	0	0
Closing Stocks	n.a.			

[1]: Note that water accounts for 2001, 2010, and 2012 are provided in Annex 1.

Evaluation

Technical and policy implications

The LLDA continues to exercise water rights over public waters within the Laguna de Bay region. To further ensure the availability of surface waters for various users and minimize conflicts through systematic water allocation, the LLDA issued Board Resolutions 2007-338 and 2008-362 to implement the surface water permitting system for the region.

However, there should be a firm basis for the amount of water that a company can abstract from a specified location of the lake over a certain period during the year. This will avoid over abstraction during the dry season when the water recharge from precipitation is low. Also, identified critical water areas can be protected from over abstraction of users. A concern in this regard is the inadequacy of information on water uses. In the modelling it was assumed that water use is constant over time although this seems unlikely considering the strong increase in population density.

Hence there is a need to further strengthen water resources management and development through an integrated and holistic approach to achieving harmony between water use and allocation. The following activities can help support policy development on sustainable water resources management:

- Intensify monitoring of rainfall, water flows, and especially water users within the Laguna de Bay region including those operating without the necessary permits from the LLDA;
- Develop and validate a concordance between the LLDA activity descriptions and the Philippine Standard Industrial Classification to allow better integration of physical and monetary data;
- Conduct sub-annual (dry season – wet season) water balance assessments of the sub-basins and lake;
- Identify constraints in water availability (in terms of time, space, and water quality) and prioritize preferential use of water. This requires a finer, sub-annual temporal resolution compared to the approach of the accounts, since water shortages typically occur during certain periods of months and in specific sections of the lake.

Highlights of Water Account

- The water account records the physical stocks and flows of water in the Laguna de Bay during the years 2000-2012. Several data gaps and challenges have been found confronting water balance in Laguna de Bay. Likewise, there was no data on the lake's recharge from groundwater.
- The stock of lake water varies considerably given an increase in 2005, 2007, and 2010, with the other years showing a water loss.
- Laguna de Bay requires stronger water resources management and development through an integrated and holistic approach that will ensure harmony between water use and allocation. Specifically, an optimum level of lake water should be maintained and a policy for water allocation should be crafted.

5.| Ecosystem Condition Account

Introduction

The ecosystem account requires the use of a range of different condition indicators. These are grouped into three categories: 1) geomorphological, 2) environmental state indicators; 3) ecosystem condition indicators[6], in line with the recent discussions on the new Technical Guidance for Ecosystem Accounting released in December 2015 by the UN Statistics Division. The geomorphological indicators express the physical parameters that define that landscape, which are exogenous to the system, and that typically do not significantly change at time scales of relevance to the accounts (say, several decades).

Examples are slope and basic soil type, as well as climatic variables such as rainfall and temperatures. As these indicators are constant and/or exogenous (i.e., they do not change from one year to the next as a function of changes in the ecosystem), there is usually no need to report them on a regular basis to policy makers. They are therefore part of the underlying data in the accounts but not usually of the indicators reported on the basis of the accounts to policy makers or the public at large.

The environmental state indicators reflect environmental conditions that are relevant to the account such as when they are used to analyze regulation services. For instance, air pollutant concentrations (expressed as particulate matter concentrations) are important to understand the air filtration service provided by vegetation. Air filtration is a function, among others, of the concentration of pollutants — the higher the concentration, the more pollutants are captured by vegetation. These indicators may change from year to year, and potentially across accounting periods (e.g., air pollution concentrations can vary on a daily basis). They are in themselves often also policy relevant and therefore must be included in the accounts where appropriate.

Finally, the ecosystem condition indicators reflect the state of the ecosystem including its components, processes, and functioning (and, potentially, aspects such as resilience).

This section describes the condition indicators for the terrestrial part of the Laguna de Bay Basin, and the aquatic side, i.e., the lake itself. Given the scope of the pilot account, there are no terrestrial environmental state indicators reflected in the account although air pollution levels, for instance, may be relevant to the LdB area. However, expanding the account to include other indicators would be possible in the succeeding phases of account development. In the aquatic part of the condition account, BOD loading is included as an environmental state indicator, and water quality as an ecosystem condition indicator.

However, there is as yet no specific information on how a condition account is to be prepared in the context of ecosystem accounting. In addition to providing policy-relevant information, the current account is intended to test potential indicators for the condition account as a basis for discussion. In the future, the condition indicators presented in this report require a multi-year data analysis. By showing trends across the years the information will become more relevant to policy making. At present, this is not possible owing to time and resource constraints.

Terrestrial condition

Objective, scope, and methodology

The terrestrial condition account aims to capture a number of key variables that reflect ecosystem components and functioning in the Laguna de Bay Basin. These variables include soil loss, hazards, key biodiversity areas, and forest cover. Together with those of the land cover account, terrestrial condition variables are important for understanding the services provided by the uplands and for modelling

[6] Note that the specific terminology is still being discussed and may change.

erosion and the sedimentation control services of the upland ecosystems.

Moreover, they provide insights into key existing ecosystem degradation processes and their potential consequences for people, in addition to changes in the ecosystem services supply. In particular, soil loss is an indicator of changes in land cover and deforestation. Understanding the terrestrial condition is important since land degradation leads to increases in soil loss, which in turn generates the sediment ending up in the Laguna Lake.

Hazards, which are a threat to biodiversity, include vulnerability to landslides and flooding based on elevation. Key biodiversity areas are therefore important for ecosystem management. In the absence of a biodiversity account developed as part of this pilot phase, it is nonetheless included in the condition account. Changes in forest cover indicate degradation, and are therefore significant because forests provide a number of important ecosystem services, of which only sedimentation control is included in this pilot account.

Note that land cover, including vegetation, is discussed in the land account (Chapter 3). Elevation, precipitation, evapotranspiration, and slope are all geomorphological condition indicators. Elevation and slope will not change within the time frames of the account, while precipitation and evaporation are not significantly affected by the ecosystem condition. Therefore, these indicators are presented in Annex 2.

Figure 5.1.Soil loss (t/ha/yr) using RUSLE equation.

The data for the condition account were collected from international and local sources, as specified for each succeeding dataset. The European Space Agency supported the Gecomon project implemented by GeoVille, and mapped forest cover for Laguna de Bay, which can be used to enhance the erosion modelling of the SedNet model.

Results

Soil loss

Soil loss under current land cover conditions was derived using the Revised Universal Soil Loss Equation (RUSLE), and is expressed in tons/hectare/year. It is the primary input in modelling sedimentation for the watershed. High erosion is observed in the hilly and mountainous parts of the Laguna de Bay region, as shown in Figure 5.1.

One of the major problems affecting Laguna de Bay is the accelerated soil erosion in the watershed, which is acknowledged to be the main contributor to siltation in the lake. An estimated 4 million tons of suspended sediment enter the lake annually, leading to an average net accretion of 0.50 cm per year (SDLBE-Nauta, 2002). The Pagsanjan River basin and, secondly, the Marikina River basin are perceived to be the major contributors of sediment loadings in Laguna de Bay.

Hazards

The Laguna de Bay region is prone to various hazards, the most common of which is flooding of the shorelands during rainy season and typhoon events. Another is earthquake. The west valley fault, which traverses Bulacan to Laguna (eastern part of LdB) is considered as a dangerous fault line. There is a possibility that within the period 2000-2058, the west valley fault will unleash havoc on the cities of Metro Manila (PhiVolcs, 2013). The upland parts of the

LdB region are also susceptible to landslide, primarily due to topography relative to high rainfall and the absence of vast forest cover.

Key biodiversity areas (KBA)

These are areas with very high biodiversity, endemism, and species richness, and therefore need conservation and protection. The Philippines' first KBA definition process, completed in 2006, identified 128 KBAs for 209 globally threatened and 419 endemic species of freshwater fish, amphibians, reptiles, birds and mammals, as well as for 62 species of congregatory birds (Conservation International, 2006). Based on the IUCN Red List, threatened ecosystem classification are as follows: critically endangered (CR), endangered (EN), vulnerable (VU), restricted-range (RR), and congregatory.

Forest cover

Forest (crown) cover is important for understanding soil erodibility and can be used as an input in erosion models. It is also an indicator of the amount of biomass. In forested areas, it shows the condition of the forest. Degraded forests, for instance, have lower forest cover.

Aquatic Condition Account: Bathymetry

Introduction and methodology

Figure 5.3. Key biodiversity areas

Analysis of bathymetry sought to assess lake volume change over time, and establish how sedimentation, if at all, has affected the water storage volume of the lake. Primary data was collected in the lake using a multi-beam echo sounder (multi-beam) over a span of two years. In 1997, around 350 points of water depth were measured. In 2014 over 500 points were analyzed. Interpolation between points to model the total depth of the basin was done using ArcGIS (Spline with barriers) and the Delft3d model (for comparison of results).

Results

Various model runs were conducted using different interpolation techniques to establish

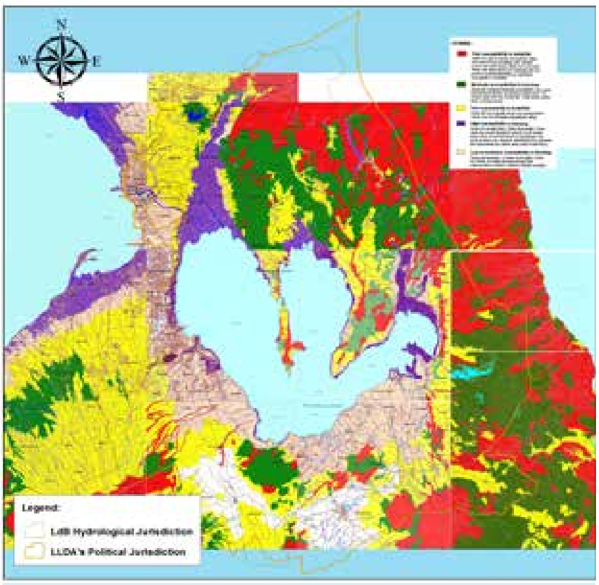


Figure 5.2. Geo-hazard prone areas (MGB-DENR)

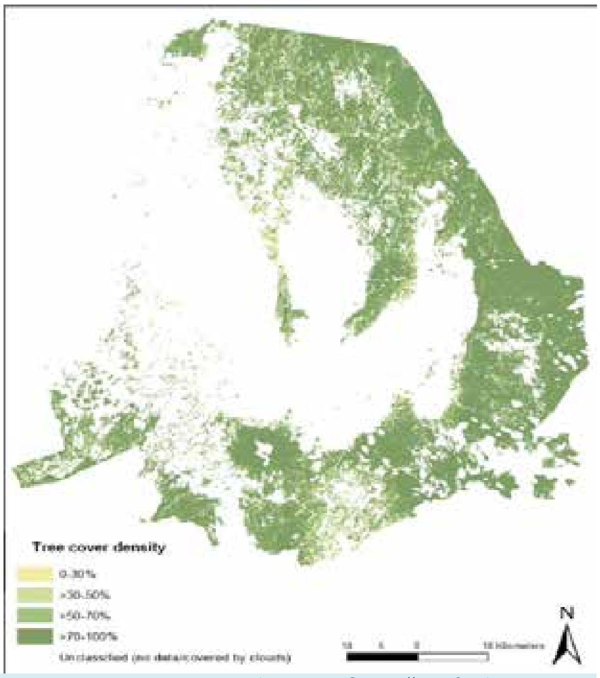


Figure 5.4. Forest cover (Source: GeoVille, 2015)

the overall lake depth based on the sample points. These consistently show a small reduction in the lake volume in the period 1997-2014 (<5%).

The main patterns of change show that the deeper parts of the lake became somewhat deeper (1 to 2 cm) over time, particularly in the western and central parts of the lake (see Figures 5.5. and 5.6.). However, the periphery of the lake were found shallower, especially in areas close to where rivers drain into the lake.

There was a noticeable decrease in the 0.5 m lake surface area, which could be attributed to sedimentation and land reclamation, which often follows sedimentation in areas where there has been a significant build-up of sediments.

It appears, however, that the overall volume of water contained in the lake and drained into the Pasig channel did not change markedly during the 1997-2014 period. Yet the lake volume of between 10.5 and 12.5 m decreased due to the backfilling as sediments were deposited near its river outlets.

The likely impact of the shallowing of the periphery and decreasing water volume retention was increasing flood frequency in the flood plains of the lake if the capacity of the Pasig River, the only outlet of the lake, was reduced. The TWG is presently reviewing the estimates to refine the results. The bathymetry measurements have to be taken more frequently than those generated in 1997 and 2014 if these are to be linked to the water and flood accounts.

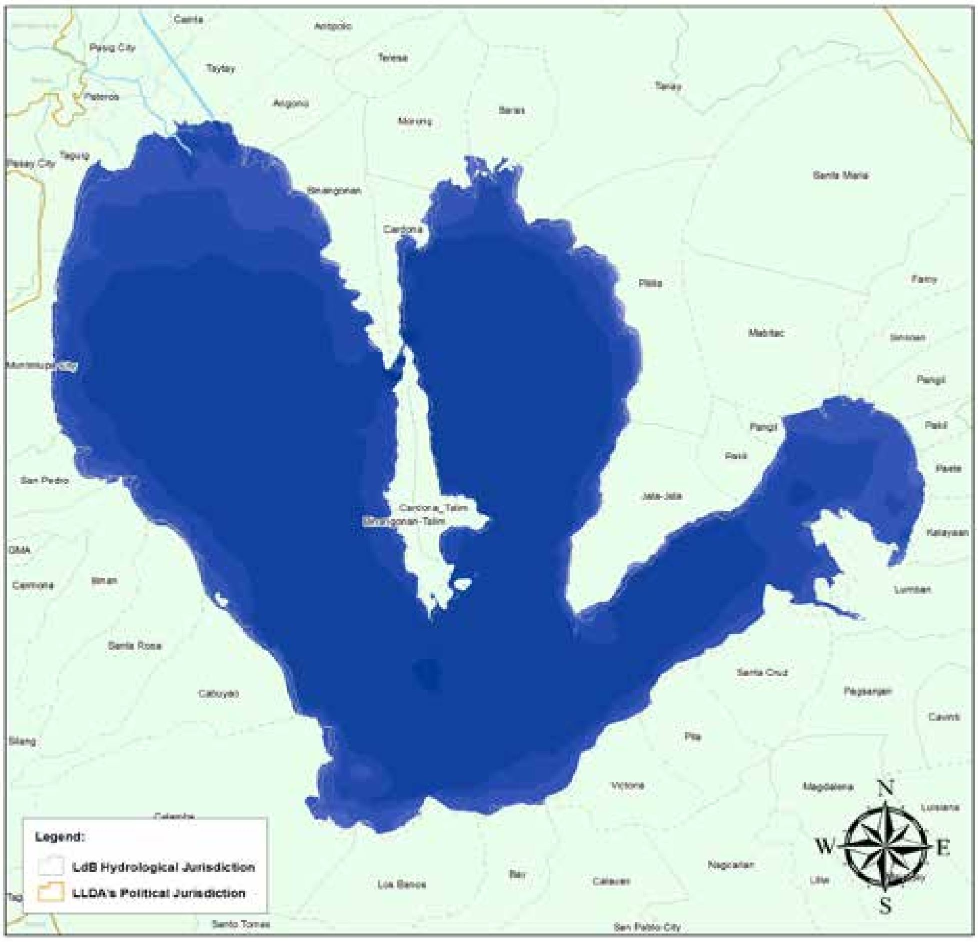


Figure 5.5. Lake depth in 1997 (in meters)

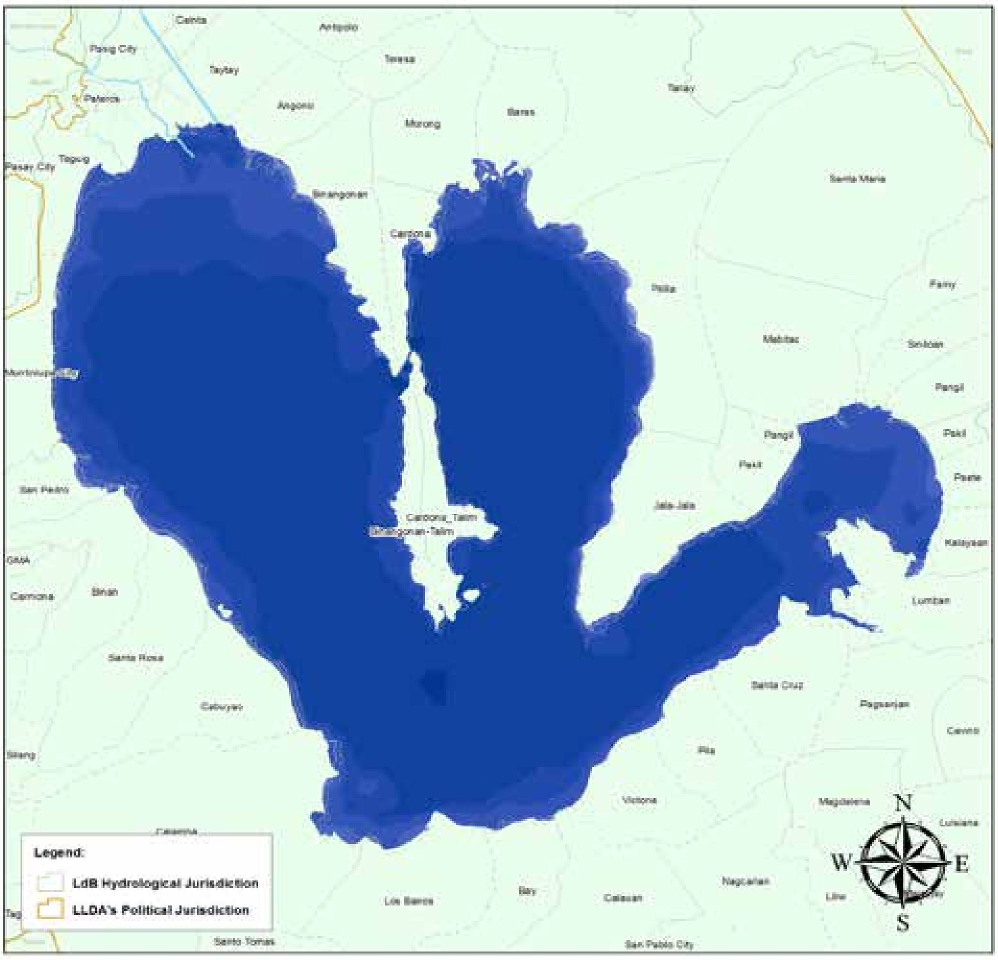


Figure 5.6 Lake depth in 2014 (in meters)

Aquatic Condition Account: Water Pollution Loading in the Lake

Background

Pollution is caused by industrial, agricultural, and residential effluents and wastes, which are drained to or deposited in the water system. In the Philippines, several laws have been enacted to address environmental problems. One of these is the Philippine Clean Water Act of 2004, which aims to protect the country's water bodies from pollution from land-based sources such as industries and commercial establishments, agricultural and community/ household activities. It provides for a comprehensive and integrated strategy to prevent or minimize pollution through a multi-sectoral and participatory approach involving all the stakeholders.

In the Laguna de Bay region, the LLDA implemented the Environmental User Fee System (EUFS), otherwise known as Wastewater Charge System, starting in 1997. The system is a market-based instrument that encourages companies to invest in and operate pollution prevention and/or abatement systems within their establishments.

Applying the 'polluter pays' principle, the EUFS ensures direct accountability for damage inflicted on the integrity of Laguna de Bay region, thereby encouraging individuals and businesses to factor into their decision-making process the environmental impacts of their day-to-day activities.

Under the EUFS, the wastewater discharge of an industry or establishment must conform to the effluent standards prescribed in the DENR Administrative Order No. 35, series of 1990, such as those for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand

(COD), Total Suspended Solids (TSS), Oil and Grease (O/G), color, pH, total coliform, and heavy metals. In case of non-compliance with any of these standards, a notice of violation will be issued by the LLDA and a penalty of 10,000 pesos (US$214.64) per day shall be imposed. Likewise, failure to meet the standards for BOD or TSS will mean a higher environmental user fee rate shall be charged to the erring establishment. Continuous violation can even lead to the issuance of a cease and desist order directing the discontinuance, temporary suspension, or cessation of the establishment generating wastes.

Objectives

The water condition account (pollution loading) seeks to estimate the BOD loadings generated from different sources of water pollution in the Laguna de Bay region and to link the result with the water quality of the river systems within its watershed. The pollution loadings covering the period 2003-2014 were analyzed based on the BOD in the entire Laguna Lake during the period under review. BOD was used in the calculations since organic pollution was identified as one of the principal problems of the lake in one of the studies conducted before the implementation of the EUFS in 1997. BOD is a good compound indicator for organic pollution. As comprehensive data on other pollutants is currently lacking, corresponding accounts of other pollutants will be included in future reports.

Methodology and Results

Calculations of BOD loadings of industry, domestic, agriculture, solid wastes, etc. were based on actual data. However, such data were also expanded and adjusted based on either actual figures and/or various scenarios involving each source of pollution for a particular year. Formulas and templates for the estimation of BOD loadings from domestic effluents, solid wastes, agricultural, and forest runoff were based on the "Estimation of Annual BOD Loading in the Laguna Lake" study conducted by LLDA, as described in the succeeding section.

Industrial effluents

These refer to wastewater generated by industrial activity. BOD generation from industrial effluents was computed as the product of BOD concentration in effluent and the effluent discharge rate.

More than 12,000 small-, medium-, and large-scale industries within the region are being regulated by the LLDA to ensure their compliance with the agency's rules and regulations. Of these, about 5,000 are under the EUFS and are actual or potential dischargers of wastewater into the bodies of water. Only 3,731 of them are registered with the LLDA (with issued or pending applications for a discharge permit).

Table 5.1. Total Industrial BOD Loading (in tons per year)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
7,753	7,187	7,157	7,506	8,333	6,546	7,041	8,136	7,267	6,522	6,805	7,207

The actual BOD loading per outfall/discharge point of industries was computed based on the following formula:

BOD loading =	BOD concentration x Q x D x 0.001
Where:	
BOD loading =	pollution (BOD) loading in kilograms
BOD concn =	average concentration of BOD in the effluent or wastewater discharged, mg/l or g/m^3
Q =	average daily volumetric flow rate of the final effluent of wastewater discharged, m^3/day
D =	number of discharge days per year, days/yr
0.001 =	conversion factor, ml to m^3 and mg to kg

Note: For industries with more than one outfall, a summation of BOD loading per outfall was obtained.

Table 5.2. Assumed Population in the LdB Region (x1000)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
12,338	12,676	13,026	13,389	13,862	14,256	14,665	14,572	14,848	15,135	15,432	15,740

BOD concentrations were based on the Results of Laboratory Analysis (ROLA) of wastewater samples collected by the LLDA from industrial effluents, and from the Quarterly Self-Monitoring Reports (SMRs) submitted by the industries. The volumetric rate of discharge was based on the on-site measurements of LLDA inspectors and/or from the SMRs and application forms for a discharge permit.

All monitored wet industries (registered and unregistered) were considered in the computation of industry BOD loading. For registered wet industries, computations were based on the above formula. Since EUFS implementation was gradual, the number of industries covered by the system was increasing. For the account, it was assumed that the said industries had been existing since 2003 although they were only included in the system after that year except for newly constructed/installed facilities/establishments, which had filed new discharge permit applications.

For unregistered wet industries whose loadings were not calculated using the EUFS formula due to the absence of pertinent data, the following procedures were undertaken.

1. The industries were classified according to business activities. For similarity and homogeneity, 62 categories were adopted.

2. Calculation of the average BOD loading per industry per category based on computed BOD loading of registered wet industries. To determine the loading of the unregistered wet industries, the calculated average BOD loading of industries belonging to the same category was used.

For a summary of the BOD loadings from industrial effluents, industries were re-classified into four major categories: 1) agriculture, 2) accommodation, food services, and related industries (e.g., hotel, motel, commercial establishments, etc.), 3) manufacturing and others, and 4) sewage treatment. The total industrial BOD loading is presented in Table 5.1.

Domestic effluents

Domestic effluents are discharges from human settlements or residential areas. They consist of grey water (from bathing and kitchen use) and toilet discharges. BOD loadings from domestic effluents were calculated using the mass of BOD generated per person multiplied by the number of persons involved. The population data for 2000, 2007, and 2010 from the National Statistics Office and the annual growth rate were used in the estimation of the annual population, as shown in Table 5.2.

BOD1 = P (F1 + F2) [365 days/year /1000000 g/MT]

where:

BOD1 =	Generated from domestic activities
P =	population
F1 =	BOD generation rate from grey water = 15 g/person/day
F2 =	BOD generation rate from toilets = 35 g/person/day

Septic tanks were assumed to remove 50% of BOD (LLDA waste load model report, 2004) while the local drains were believed to remove 20% of BOD from both grey water and toilet discharges (Capalungan with LLDA study team, 2009). It was further assumed that about 90% of the population maintains septic tanks (PSA data as of May 2000). The BOD generated now becomes BOD loading into sub-basins, computed using the following formulas:

BOD2 = P [F1 (1-D1/100) + F2 (1-(D2/100)(S/100))(1-D1/100)] [365 days/year / 1000000 g/MT]

where:

BOD2=	BOD discharged to sub-basin
D1 =	BOD loss in local drains = 20%
D2 =	BOD loss in septic tanks
S =	percent of population with septic tanks = 90%

As domestic effluent travels along the watercourses of the sub-basin, further BOD loss was assumed. Factors associated with BOD loss are BOD decay rate constant, distance of source from the bay water, and mean speed of stream water. The fraction of BOD remaining was computed as exp(-Kx/u). The equation is written as follows:

BOD3 = BOD2 * exp(-Kx/u)

where:

BOD3 =	BOD loading in Laguna Lake
K =	decay rate constant by waste type
K =	K2 **θ** (T-20) ; K2= 0.7/day; **θ** = 1.047; T= 27 oC
K = ***x =*** ***x =*** ***x/u =***	0.97 the average of the nearest and farthest stream distance of the municipality from the shoreline. mean stream flowrate within distance x. the mean travel time (in days) of effluent from discharge point to distance x.

Generically, BOD loss, % = (1 - exp(-Kx/u)) x 100. On the average the BOD loss was computed at 48%.

The total BOD generated by households is shown in Table 5.3.

Table 5.3. Total BOD generated by households (in tons per year)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
56,205	57,660	59,159	60,708	62,720	64,394	65,930	65,408	66,510	67,652	68,828	70,044

Data shows the number of households connected to one of the sewage treatment plants (STPs) operated by Manila Waters Company, Inc. (MWCI), Maynilad Water Services, Inc. (MWSI), and other water concessionaires. However, there were no data on the number of persons connected to the STPs. Thus, the volumetric flow rate data from the STPs of establishments under the EUFS and the assumption of 200 l/capita/day (UNEP, 2014) as the amount of domestic effluent generated per person per day was used to estimate the number of persons connected to the STPs (see Table 5.4).

Table 5.4. BOD Loading from Households into the Lake (in tons per year)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Volumetric flow rate of STPs	173,436	188,507	190,477	188,672	202,069	201,778	164,969	175,290	198,038	188,211	254,442	246,952
Number of persons served by STPs	867,180	942,533	952,387	943,360	1,010,344	1,008,888	824,847	876,451	990,190	941,053	1,272,210	1,234,762
% of population served by STPs	7.03	7.44	7.31	7.05	7.29	7.08	5.62	6.01	6.67	6.22	8.24	7.84
BOD loadings reduced due to treatment in STPs	3,951	4,287	4,325	4,277	4,572	4,557	3,708	3,934	4,436	4,206	5,674	5,495
Remaining BOD loadings from domestic effluents	52,254	53,373	54,833	56,430	58,149	59,837	62,222	61,474	62,075	63,445	63,153	64,549

Agricultural and forest wastes

Agricultural waste is referred to as the runoff from rice farming and plantations. Wastes from livestock were assumed included in the EUFS calculation. BOD generation from agriculture was computed as the product of the agricultural land and unit BOD generated per area of the agricultural land, given as follows:

***BOD1* = A F1 [1 MT/1000 kg]**

where:

***BOD1* =**	BOD generated, MT
***A* =**	area of the agricultural land, ha
***F1* =**	BOD generation factor = 0.75 kg/ha/year for rice farming and 0.25 kg/ha/year for other crops (based on the LLDA Waste Load Model)

BOD loading in Laguna Lake for agricultural lands is calculated as follows:

***BOD2* = BOD1 [exp(-Kx/u)]**

where:

BOD2 =	BOD loading in Laguna Lake
K =	decay rate constant at 27 oC = 0.166/day
x =	the average distance of the agricultural land from the shoreline = 1,000m
u =	mean stream flow rate within distance x = 0.1 m/s
x/u =	mean travel time (in days) of effluent from discharge point to distance x.

BOD loss, % = **(1 - exp(-Kx/u)) x 100**

BOD generation from forest land was computed as the product of the forest land and unit BOD generated per area per year of the forestland, as follows:

***BOD1* = A F1 [1 MT/1000 kg]**

where:

BOD1 =	BOD generated, MT
A =	area of the forested land, ha
F1 =	50 kg/ha/year for forest land (based on the LLDA Waste Load Model)

BOD loading in Laguna Lake from forest land is calculated in the same way as for agricultural land, as follows:

***BOD2* = BOD1 [exp(-Kx/u)]**

where:

BOD2 =	BOD loading in Laguna Lake
K =	decay rate constant at 27 oC = 0.166/day
x =	the average distance of the agricultural land from the shoreline = 1,000m
u =	mean stream flow rate within distance x = 0.1 m/s
x/u =	mean travel time (in days) of effluent from discharge point to distance x.
BOD loss, % =	(1 - exp(-Kx/u)) x 100

Data on agricultural and forest lands was obtained through the GHG inventory conducted for LLDA by Daruma Technologies, a consulting firm, by comparing the 1993 and 2003 satellite image maps. In the absence of yearly updates, a linear interpolation was done for the years between 2003 and 2010, the result of which was extrapolated to 2014. The results for agricultural land and forest land are shown in Table 5.5.

Table 5.5. BOD Loading from Agricultural and Forest Lands (in tons per year)

Land Use	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Agriculture												
Rice farming	2,796	2,796	2,796	2,796	2,796	2,796	2,796	2,796	2,796	2,796	2,796	2,796
Other crops	3,541	3,338	3,135	2,932	2,729	2,526	2,323	2,120	1,917	1,714	1,511	1,308
Subtotal	6,337	6,134	5931	5728	5,525	5,322	5,119	4,916	4,713	4,510	4,307	4,104
Forest land	1,901	1,881	1,860	1,840	1,819	1,799	1,778	1,758	1,738	1,717	1,697	1,676
Total	8,238	8,015	7,791	7,568	7,344	7,121	6,897	6,674	6,451	6,227	6,004	5,780

"The BOD (biochemical oxygen demand) loadings from domestic effluents and solid wastes are growing due to increased population."

Solid wastes

These pertain to municipal solid waste, assumed to be generated from households and industries. The BOD generation was computed using the following formula:

BOD1 = **P F1 F2 F3 [365 days/year x 1 MT/1000 kg]**

where:

BOD1 =	BOD generated, MT
A =	municipal population
F1 =	solid waste generation rate = 0.5 kg/person/day in urban areas or 0.3 kg/person-day in rural areas (World Bank, 2004)
F2 =	fraction of kitchen waste in solid waste = 45% (World Bank, 2004; MMDA, 2003)
F3 =	biodegradable to BOD conversion factor from field tests = 0.00285 BOD/wet waste (based on Visvanatha et al., 2002; Chiemchaisri et al., 2002)

The BOD from solid waste was also assumed to decay as it travels along the sub-basin channel. Thus the following formula was adopted:

BOD2 = **BOD1 x (1-F4/100)**

where:

BOD2 =	BOD loading in Laguna Lake
F4 =	BOD decay rate during travel time to Laguna Lake = 48% (derived from the decay rate of domestic waste)

The computation above applies to solid wastes from household or residential areas. The quantity of solid waste from other sources (collectively referred to as "industries") was estimated based on the findings of the MMDA (2003) and Bravo (2006). Based on the Marikina City solid waste collection, 3/4 of the solid wastes come from households and the rest were assumed to have come from the industries (Bravo, 2006). By comparison, the studies in 1997 of MMDA and JICA revealed that 74% of the total wastes originated from Metro Manila households. From these findings, the estimated BOD at source and loading from households were multiplied by 1/3 to arrive at estimates for the "industries" or other "establishments."

Table 5.6. BOD Loading from Solid Waste (in tons/year)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Domestic	1,423	1,462	1,502	1,544	1,598	1,644	1,691	1,679	1,711	1,743	1,777	1,812
Industry	474	487	501	515	533	548	564	560	570	581	592	604
TOTAL	1,897	1,949	2,003	2,058	2,131	2,191	2,254	2,239	2,281	2,324	2,369	2,416

Aggregated results

The aggregate annual BOD loadings from 2003-2014 from all sources, in absolute and percentage values, are presented in Table 5.7.

The BOD loadings from domestic effluents and solid wastes are growing due to increased population. On the other hand, the drop in the measured BOD loading from agriculture and forest was due to the decrease in areas based on land use.

For industrial effluents, there are fluctuations in BOD loading due to the increasing number of industries covered by the LLDA EUFS. The results also include the BOD loading from sewage treatment plants. The efficiency of the plants in the LdB area is not known, but the maximum efficiency of secondary treatment (as applied in the LdB area) is around 80 to 85% BOD removal depending on the design of the facility. It is therefore assumed that the sewage treatment plants remove 75% of the BOD of the effluent that they receive. As the sewage plants drain directly into the lake, there is little BOD removal from the effluent of the sewage treatment plants themselves. Based on these assumptions, the BOD loading from sewage facilities is included in Table 5.7. For 2014, this is reworked into an accounting table based on the International Standard Industrial Classification of All Economic Activities (see Table 5.8.).

Table 5.7. Annual BOD Loadings from All Sources (in tons per year)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Domestic	52,254	53,373	54,833	56,430	58,149	59,837	62,222	61,474	62,075	63,445	63,153	64,549
Industrial	7,753	7,187	7,157	7,506	8,333	6,546	7,041	8,136	7,267	6,522	6,805	7,207
Agricultural	6,337	6,134	5,931	5,728	5,525	5,322	5,119	4,916	4,713	4,510	4,307	4,104
Forest	1,901	1,881	1,860	1,840	1819	1799	1778	1758	1738	1717	1,697	1,676
Solid Waste	1,897	1,949	2,003	2,058	2,131	2,191	2,254	2,239	2,281	2,324	2,369	2,416
TOTAL	70,142	70,524	71,784	73,562	75,957	75,695	78,414	78,523	78,074	78,518	78,331	79,952

Table 5.8. Water Emission Account for BOD Loadings in Laguna de Bay Region in 2014 (tons per year), including sewage effluent

2014	Industries/establishments (Philippine Standard Industrial Classification Classes)				Households	Agricultural Lands	Forest Lands	Solid Wastes	TOTAL
	Agriculture Industry	Manufacturing & Others	Sewage Treatment	Accommodation, Food services, etc.					
1. Gross emissions (BOD, metric ton)									
1a. Direct emissions to water	55	1,536	3,910	1,706	64,549	4,104	1,676	2,416	79,952
1a.1 Without treatment					70,044				
1a.2 After onsite treatment	55	1,536		1,706	64,549				
1a.i to inland water resources									
1a. Ii to the sea									
1b. To Sewerage									
2. Reallocation of emissions									

2014	Industries/establishments (Philippine Standard Industrial Classification Classes)				House-holds	Agri-cultural Lands	Forest Lands	Solid Wastes	TOTAL
	Agri-culture Industry	Manu-facturing & Others	Sewage Treat-ment	Accom-modation, Food services, etc.					
3. Net emissions (1a +2)	55	1,536	3,910	1,706	64,549	4,104	1,676	2,416	79,952

Evaluation and conclusion

The estimation of BOD loadings from the different sources of pollution was intended for the whole of Laguna de Bay region, which covers the 61 cities and municipalities within the administrative jurisdiction of the LLDA. However, not all of these areas discharge water into the Laguna de Bay basin. For example, since only portions of Manila, Pasay City, Quezon City, and Tagaytay City are located within the basin, their water discharges drain into Manila Bay and Taal Lake. Therefore, the estimate presented in Tables 5.7 and 5.8 may exceed the actual BOD loading in the Laguna Lake.

The calculations assume that a major part of the BOD is removed before the household effluents drain into the lake (based on previous BOD modelling for the lake). For instance, whereas households generate a total of 287,000 tons of BOD per year (prior to treatment), only 70,000 tons are assumed to be released into the Laguna Lake.

The efficiency of septic tanks and oxidation in the streams and rivers may therefore be overestimated pending further analysis. In addition, the sewage treatment is now assumed to be on top of the reduction in BOD loading through the use of septic tanks and oxidation in rivers. This could lead to inaccuracy since the households connected to the sewage system will probably no longer use their septic tanks. This in turn could result in an underestimation of BOD loading in the lake, which will be examined when the accounts are further developed in the future.

The TWG verified the BOD loadings by calculating those of the various rivers draining into the Laguna Lake, based on water quality samples and stream flows (see Aquatic Condition Account: Water Quality in Chapter 5). There were only two-year data for the BOD loadings in the river systems, because complete stream flow measurements just started in 2012. These data showed that 2012 BOD loading in the systems (90,000 tons) was greatly affected by the stream flow measurements that year due to extreme events (typhoons and southwest monsoon, otherwise called habagat in Filipino).

In 2013, the BOD loading estimated based on observed BOD values in the rivers just before they drained into the Laguna Lake was pegged at 80,000 tons. Hence, there was generally a very good alignment between the estimate based on the calculation of produced BOD (as shown in Tables 5.7 and 5.8) and the measured data.

Nevertheless, there is a need to enhance the BOD loading calculations in the future, especially since the absence of GPS coordinates for the exact locations of industries is a major limitation.

"Effluents from households are the main source of pollution in the lake."

As such it is not possible to assess if the industries are based in the Laguna de Bay basin or in the other watersheds of the LdB region. Thus it is recommended that GPS coordinates be included in the industrial register.

For the next step, a pilot study shall be conducted in one of the sub-basins within the Laguna de Bay basin, where spatial locations of industries shall be determined. BOD loading for the selected sub-basin shall be calculated, the results of which will be compared with the results with the BOD loading in the river systems of the sub-basin.

Overall, the account shows that BOD loading into the lake increased over time despite an intensified sewage treatment in the last decade. Notwithstanding the uncertainties explained above, the main source of pollution in the lake has turned out to be household effluents. In this regard, a crucial step toward improving water quality in the lake is connecting more households (as well as industries) to a sewage treatment system.

Highlights of Ecosystem Condition Account

Terrestrial condition

- Terrestrial conditions such as soil loss, hazards, key biodiversity areas, and forest cover were analyzed to understand and assess the services provided by the uplands and yield insights into key ecosystem degradation processes and their impact.
- Accelerated soil erosion is one of the major problems affecting Laguna de Bay and is said to be the main contributor to siltation in the lake.
- The Laguna de Bay region is prone to various hazards, including flooding of the shorelands during the rainy season, typhoons and earthquake. The upland parts are also susceptible to landslide, primarily due to topography relative to high rainfall and the absence of vast forest cover.

Aquatic Condition Account: Water Quality

Objective and scope

Since the early 1970s the LLDA has been regularly conducting water quality monitoring of the Laguna de Bay and its tributaries. These routine monitoring activities have been made part of the LLDA program, especially when assessing the status of the lake under different circumstances.

This study aims to classify the lake's water quality and its tributary rivers across the years using the BOD on the different stations. It also seeks to show how much the quality of water had changed in 2003, 2010, and 2013, and how much the river discharge had affected the water quality of the lake, giving a better understanding of the lake's assimilative capacity.

Only 2013 data will be used to compare the actual BOD loading with the BOD loading generated by the waste load model based on the actual BOD loading data for industries, domestic waste, and solid waste, because 2003 and 2010 data did not cover stream flow measurement of which was established in 2012.

Methodology and data

Data come from a range of water quality measurement stations, located both inside the lake and in the tributary rivers (see Figure 5.7). Up until 2010 there were only 15 river stations. Two years later 19 river stations were added.

BOD was measured and the streamflow was recorded for the river sampling stations. These data were processed to determine the actual BOD loading. Also, the Water Mondriaan model was used to determine the water quality classification of the rivers and lake based on DENR Administrative Order No.34, series of 1990.

The Waste Load Model (WLM) used in data processing measures the amount of BOD load produced by human activities (i.e., domestic, agricultural, and industrial) and the amount of substances that end up in the lake after passing through treatment facilities, sewer systems, or natural processes in surface waters. It provides information on the waste loads on surface water within each sub-basin and allows for future waste load scenario generation. Furthermore, it specifies where and what kind of waste loads are produced in the catchment, the kind and amount of treatment (capacity, efficiency, and location) they undergo, and the final waste loads on surface water entering the lake.

To calculate the discharge rate of the river, the distance, section width, depth, and average velocity are measured. Then using the formula below, the discharge rate is calculated thus:

(D = depth, V = Velocity and W = Width)

Area (m^2) = sec. width x depth; Flow (m^3/s) = (D1+ D2) x (V1 + V2) x W ***Equation 1***

To calculate the actual BOD load of the river using the formula below (BOD = BOD in mg/L, DF = Discharge Flow Rate in L/sec, F= 0.0315), where F is a conversion factor from mg/sec to MT/yr.

Actual BOD loading MT/yr = BOD x Discharge Flow Rate x F ***Equation 2***

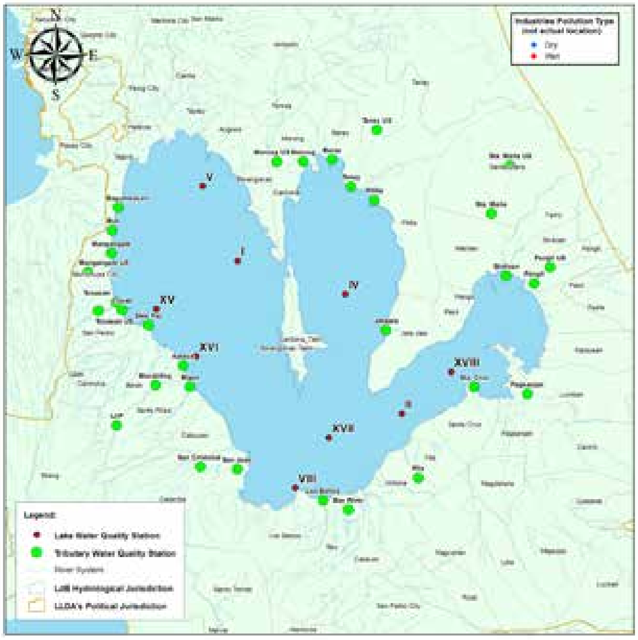


Figure 5.7. Laguna de Bay and tributary river water quality monitoring stations

Results

Water quality

Tables 5.9. and 5.10. show the water quality at the various sampling stations, and changes in water quality over time. Classification is according to the DENR water quality criteria /water usage and classification for fresh water:

- Class A — Public water supply (still requires treatment to meet national standards for drinking water)
- Class B — Recreational water class I (for contact recreation as bathing and swimming)
- Class C — Fishery water for the propagation and growth of fish (also non-contact recreation and industrial use class I)
- Class D — For agriculture, irrigation, livestock watering and industrial water supply
- Class BD — water unsuitable for any purpose

Table 5.9. Concentration and Classification of Laguna de Bay's Water Quality (W.Q.) According to DENR Water Quality Criteria for Biochemical Oxygen Demand

Sampling Station	2003		2010		2013	
	Ave Conc. (Ppm)	DENR W.Q. Classification	Ave Conc. (Ppm)	DENR W.Q. Classification	Ave Conc. (Ppm)	DENR W.Q. Classification
Station I	2	A/B	6	C	2	A/B
Station II	2	A/B	5	A/B	2	A/B
Station IV	2	A/B	4	A/B	2	A/B
Station V	3	A/B	5	A/B	3	A/B

Sampling Station	2003		2010		2013	
	Ave Conc. (Ppm)	DENR W.Q. Classification	Ave Conc. (Ppm)	DENR W.Q. Classification	Ave Conc. (Ppm)	DENR W.Q. Classification
Stn VIII	2	A/B	5	A/B	2	A/B
Stn XV - San Pedro	*	*	*	*	2	A/B
Stn XVI -Sta. Rosa	*	*	*	*	2	A/B
Stn XVII - Sanctuary	*	*	*	*	2	A/B
Stn XVIII - Pagsanjan	*	*	*	*	2	A/B

*Note: * stands for "no data" (lake stations were added in 2012)*

Table 5.10. Concentration and Classification of Tributary Rivers' Water Quality (W.Q.) According to DENR Water Quality Criteria for Biochemical Oxygen Demand

Sampling Stations	2003		2010		2013	
	Ave Conc. mg/L	DENR W.Q. Criteria	Ave Conc. mg/L	DENR W.Q. Criteria	Ave Conc. mg/L	DENR W.Q. Criteria
Marikina	9	C	25	BD	21	BD
Bagumbayan	*	*	238	BD	53	BD
Buli Creek	*	*	161	BD	115	BD
Mangangate Downstream	43	BD	42	BD	26	BD
Mangangate Upstream	*	*	*	*	12	D
Tunasan Downstream	55	BD	159	BD	170	BD
Tunasan Upstream	*	*	*	*	16	BD
San Pedro River	28	BD	18	BD	19	BD
Biñan	*	*	*	*	21	BD
Sta. Rosa Downstream	*	*	*	*	18	BD
Sta. Rosa Midstream	*	*	*	*	13	D
Sta. Rosa Upstream	*	*	*	*	6	C
Cabuyao	6	C	14	D	25	BD

Sampling Stations	2003		2010		2013	
	Ave Conc. mg/L	DENR W.Q. Criteria	Ave Conc. mg/L	DENR W.Q. Criteria	Ave Conc. mg/L	DENR W.Q. Criteria
San Cristobal River	11	D	78	BD	35	BD
San Juan River	4	C	5	A/B	6	C
Los Baños	*	*	*	*	4	A/B
Bay River	2	A/B	4	A/B	6	C
Pila	*	*	*	*	5	A/B
Sta. Cruz River	3	A/B	3	A/B	4	A/B
Pagsanjan River / Lumban	1	AA	3	A/B	3	A/B
Pangil Downstream	2	A/B	5	A/B	3	A/B
Pangil Upstream (Pangil Resort)	*	*	*	*	2	A/B
Siniloan	6	C	7	C	4	A/B
Sta. Maria Downstream	*	*	*	*	2	A/B
Sta. Maria Upstream (Dam-Site)	*	*	*	*	2	A/B
Jala-jala	*	*	*	*	3	A/B
Pililla	*	*	*	*	6	C
Tanay Downstream	6	C	4	A/B	4	A/B
Tanay Upstream (Daranak falls)	*	*	*	*	2	A/B
Baras	*	*	*	*	6	C
Morong Downstream	9	C	13	D	14	D
Morong Upstream (Bombongan)	*	*	*	*	21	BD
Taytay (Manggahan Floodway)	*	*	14	D	16	BD
Cainta, Sapang Baho	31	BD	17	BD	26	BD

*Note: *No data (river stations were added 2012)*

Streamflow measurement

Table 5.11. shows the discharge flows of the various river stations. Such data are also an important input to the sediment modelling.

Table 5.11. Discharge Flow Rate and Actual BOD Loading of the River Stations for 2013

Sampling Station	BOD mg/L	Discharge rate L/sec	BOD mg/sec	BOD kg/year	BOD MT/Yr
Marikina	21	6,441	135,256	4,265,425	4,265
Bagumbayan	53	597	31,618	997,114	997
Buli Creek	115	114	13,059	411,825	412
Mangangate Downstream	26	478	12,435	392,164	392
Mangangate Upstream	12	410	4,920	155,157	155
Tunasan Downstream	170	166	28,220	889,946	890
Tunasan Upstream	16	561	8,971	282,923	283
San Pedro River	19	473	8,981	283,214	283
Biñan	21	5,060	106,260	3,351,015	3,351
Sta. Rosa Downstream	18	1,920	34556	1,089,742	1,090
Sta. Rosa Midstream	13	4,400	57,200	1,803,859	1,804
Sta. Rosa Upstream	6	298	1,787	56,339	56
Cabuyao	25	900	22,500	709,560	710
San Cristobal River	35	1,524	53,340	1,682,130	1,682
San Juan River	6	3,056	18,338	578,291	578
Los Baños	4	3,083	12,331	388,877	389
Bay River	6	1371	8,227	259,447	259
Pila	5	365	1,827	57,606	58
Sta. Cruz River	4	8,434	33,736	1,063,898	1,064
Pagsanjan River / Lumban	3	23,336	70,007	2,207,741	2,208
Pangil Downstream	3	773	2,318	73,108	73
Pangil Upstream (Pangil Resort)	2	1,313	2,625	82,782	83
Siniloan	4	1,474	5,895	185,900	186
Sta. Maria Downstream	2	1,767	3,534	111,455	111
Sta. Maria Upstream (Dam-Site)	2	3,661	7,322	230,907	231
Jala-jala	3	37	112	3,532	4
Pililla	6	1,261	7,564	238,526	239
Tanay Downstream	4	8,043	32,173	1,014,601	1,015
Tanay Upstream (Daranak falls)	2	1,074	2,148	67,748	68
Baras	6	1,640	9,841	310,352	310
Morong Downstream	14	3,784	52,976	1,670,651	1,671
Morong Upstream (Bombongan)	21	3,845	80,748	2,546,469	2,546
Taytay (Manggahan Floodway)	16	99,812	1,596,992	50,362,740	50,363
Cainta, Sapang Baho	26	1,031	26,806	845,354	845
				Total BOD Loading	**78,670**

Evaluation

Water quality has not deteriorated significantly in the period under study in spite of the increase in BOD loading, as shown earlier. Only Station 1 in Table 5.9. changed its water quality from Class A/B in 2003 to a lower Class C in 2010. This may be attributed to the dynamics of the lake, with relatively rapid flow of water combined with, plus additional breakdown of nutrients in the lake itself.

An increase in BOD concentration was observed, however, in some river stations such as Marikina, Cabuyao, Morong Downstream, San Cristobal, and Tunasan Downstream. The stations showing the strongest decline in water quality correspond to the areas with the largest increase in population density over the same period (see the Land Account in Chapter 3).

The actual BOD loading of 78,670 metric tons in 2013 for the lake corresponds well to the pollution loading calculated in the discussion under Aquatic Condition Account: Water Pollution Loading in the Lake). A major restriction is that only one type of indicator was analyzed, i.e., BOD, reflecting organic pollution. Inorganic pollutants (e.g., heavy metals from industry, pesticides from agriculture) was not analyzed. It is therefore recommended that the accounts be expanded to include a few particularly relevant indicators of inorganic pollution in the lake.

Highlights of Ecosystem Condition Account Aquatic condition

- The two key aquatic condition indicators are bathymetry and water quality. Bathymetry has been analyzed in order to assess lake volume changes over time, and to establish how sedimentation, if at all, has affected the water storage volume of the lake. The water condition account (pollution loading) seeks to estimate the BOD loadings generated from different sources of water pollution in the LdB region and to link the result with the water quality of the river systems in the watershed.
- The deeper parts of the lake have become even deeper (1 to 2 cm) over time while the periphery has been found to be more shallow, especially in areas close to where rivers drain into the lake.
- The likely impact of shallowing of the periphery and decreasing water volume retention is increasing flood frequency in flood plains of the lake if the capacity of the Pasig River, the only outlet of the lake, is reduced.
- The LLDA conducts regular monitoring of the lake and its tributary rivers. Data monitoring indicates that the rivers on the western portion of the lake have deteriorated due to the significant increase in built-up areas between 2003 and 2010. Built-up areas increased by 116% during that period.
- BOD loading into the lake has increased over time despite an increase in sewage treatment over the last decade. The stations showing the strongest decline in water quality correspond to the areas with the largest increase in population density over the same period. About 80% of the BOD loadings in the lake come from domestic waste.
- There is immense potential in improving the water quality of the Laguna de Bay by increasing the rate of treatment of domestic sewage.

6.| Ecosystem Service Account

Fisheries

Laguna de Bay is a multiple-use resource, but its dominant use is fisheries, i.e., capture fisheries and aquaculture through fishpens and fishcages. Thus, the lake is classified as a Class C water body. This means its water quality needs to be suitable for fishery based on the DENR Administrative Order 34.

Fisheries revolve around several fish species

Milkfish (*Chanos chanos*) was introduced in Laguna de Bay in the early '70s based on the assessment done by Delmendo and Gedney (1974). They found that the native species fed mostly on benthic organisms, thus underutilizing the phytoplankton of the lake. Aquaculture of milkfish was introduced with the aim of improving the livelihood of local fishermen. The culture period was initially four months with twice-a-year fish stocking.

Owing to encouraging results, businessmen within and outside the Laguna de Bay region were attracted to the aquaculture business in the lake. Since this method was capital-intensive, the businessmen became the majority players in the aquaculture business. Aquaculture expanded in the 1980s when tilapia culture was successfully introduced in the lake.

"Businessmen became the majority players in the aquaculture business, (which) expanded in the 1980s when tilapia culture was successfully introduced in the lake."

But conflicts started to arise between the open water fishermen and aquaculture operators due to limited access among the former to their traditional fishing grounds. This further escalated when aquaculture structures occupied almost a third of the lake surface area. Fishermen often complained of decreasing catch that affected their livelihood. There were also water quality issues such as decreasing natural food supply and alleged pollution from aquaculture activities, which are believed to have adverse effects on fish growth. From a stocking period of twice a year (that assured them of two fish harvests per year), it now takes more than a year to harvest fish.

To ensure the equitable distribution of the lake's fishery resources, the LLDA implemented a Zoning and Management Plan (ZOMAP), which delineated areas for fishpens, fishcages, and open water fishing. A 5,000-ha sanctuary was designated off the tip of Talim Island, which is the confluence of the West Bay, Central Bay, and East Bay (Figure 6.1.).

Since 1983 when it was introduced, the ZOMAP has undergone revisions due to socio-economic and environmental issues, especially on the allowable area for aquaculture. From an initial allocation of 21,000 ha in 1983, it was reduced to 15,000 ha, taking into account the primary productivity of the lake. A total of 67% or 10,000 ha were allocated for fishpens and 33% or 5,000 for fishcages. In 2014, the fishpen area occupied around 10,415 ha while the area devoted to fishcages was estimated at 3,356 ha based on LLDA data.

Figure 6.1. Layout of the fishpen and fishcage belts based on the 1999 ZOMAP.

The LLDA issued rules and regulations on the implementation of the ZOMAP. Limits were set on the maximum area for fishpen operation, i.e., 50 ha for a corporation, 10 ha for a cooperative, and 5 ha for an individual owner. For a fishcage, the maximum area allocated is 1 ha.

Based on the annual permit issued by the LLDA, fishpen owners are required to pay 6,000 pesos (US$128.28) per hectare, and fishcage owners 4,200 pesos (US$90) per hectare. Fishcages are still in the process of being transferred to the fishcage belt.

Fishpen fees collected by the LLDA are shared with the lakeshore local government units based on the following scheme: 1) 15% if there are no fishpens off their shore, and 2) 15%, plus an additional 20% if there are fishpens off their shore. The LLDA specifies that their share should be used to finance environmental projects.

Capture fisheries employ some 14,000 fishermen, who catch a wide variety of fish on either a full- or part-time basis. The presence of invasive alien species in the lake, of which the most notable are janitor fish (*Pterygoplichtys disjunctivus*) and knife fish (*Chitala ornata*), is believed to have adversely affected fish production. Several personal communications and testimonials from fishermen and aquaculture operators support this claim, which is being investigated by the LLDA and BFAR.

Objectives

The fisheries account seeks to provide a comprehensive assessment of the use of the Laguna Lake for fisheries, including capture fisheries, and aquaculture with fishpens and fishcages, in both physical and monetary terms. Until the development of the account, no such comprehensive assessment had been carried out for the lake. The assessment is conducted for 2014 and covers the entire Laguna Lake, subdivided into the West Bay, Central Bay, and East Bay. The information gathered is meant to inform policy making, which is crucial in addressing issues pertaining to the dominant use of the lake for fisheries and in rationalizing the fishpen and fishcage fees (or resource user fees).

Methodology

General approach

Data on fish production — type of fish species harvested, expressed in metric ton (MT)/year, from aquaculture and capture fishery and their corresponding market value (pesos/year) from 2003 to 2014 — were based on the published online data from the Bureau of Agricultural Statistics (BAS) and the Philippine Statistics Authority.

However, BAS gets its data only from fish landing areas in four municipalities per province. These data cover only the provinces of Rizal and Laguna, thus excluding the parts of the lake in Metro Manila, particularly the waters off Muntinlupa and Taguig, which are considered as prime areas for aquaculture. Due to their proximity to the Napindan Channel, these municipalities are the first to enjoy the benefits of saltwater intrusion whenever the Pasig River flows back to the lake in summer months. (Salt water intrusion is beneficial to milkfish, which have a relatively high market value).

In Rizal, the landing site in Binangonan was not included in the data gathering although there are many aquaculture structures in this part of the lake. Another limitation is that most of the required data for environmental accounting purposes were not available on the websites of PSA, BAS, and the Bureau of Fisheries and Aquatic Resources, or were never collected and recorded by these government agencies including the LLDA. This brings to the fore the need to collect additional physical and monetary data on fisheries production.

To address these concerns, the LLDA decided to conduct a field survey as part of the ecosystem account to cover the entire lake including the relevant parts of Metro Manila. It also opted to gather various data that would be used in the computation of the production and the resource rent from fishpens, fishcages, and capture fisheries.

Two kinds of survey questionnaires were

prepared for this pilot — one for aquaculture operators and one for fishermen — both of which were in the native language (Filipino) and English. The English questionnaire was submitted to the Australian Bureau of Statistics for comments and recommendations. Additional inputs and corrections were incorporated in the two versions, after which they were submitted to the PSA, in order to secure a survey clearance. The permit was issued to the LLDA after compliance with the PSA requirements. Note that a slightly simplified approach to calculating the resource rent was used in view of a lack of data on some of the monetary aspects (e.g., subsidies and on costs of capital including depreciation). Annex 9 presents the formal steps required to analyze the resource rent.

The enumerators are composed of LLDA staff from the Environmental Regulation Department, Resource Management and Development Department, and the LLDA-Phil WAVES Technical Working Group. Meetings were held to orient everyone on the survey questionnaires and the protocol to be observed in the conduct of the surveys. Field surveys were conducted on weekdays from March 4 to April 7, 2015. The intent of the survey was explained to the aquaculture operators, with the assurance that the information they would give would be used only for the ecosystem account.

The enumerators (or survey takers) were deployed to different areas around the lake. Pre-testing of the survey questionnaires was done to determine the length of interview time and the ease with which the respondent could answer the survey questions and provide all the information. As the preferred technique, the survey entailed the enumerator writing the answer to the questionnaire instead of the respondent, and this took an average of 30 minutes per respondent.

Sampling design

The number of respondents was set at 30 each from among the registered fishpen operators and fishcage operators in the LLDA's record. For open water fishermen, one respondent per lakeshore town and city was interviewed. The stratified proportional sampling method or random sampling was employed for the aquaculture operators.

The 30 respondents among the fishpen operators were further subdivided into 10 each for those with fishpen areas ranging from 1 to 10 ha, 11 to 25 ha, and more than 25 ha. For those using fishcages, there were two respondents in zones with more fishcages. The respondents were pre-identified but not all of them were interviewed due to their unavailability at the time of survey, prompting the need for their replacements. Of the target 30 fishermen from different zones of the lake, 31 were interviewed.

Data processing

All of the accomplished survey questionnaires were compiled and the collected physical and monetary data were encoded in Excel format for analysis. Two workshops conducted by the TWG and the national consultant were held to process the data in order to obtain the specific information needed in to determine value of the ecosystem service expressed as resource rent, or the contribution of the ecosystem to economic production. No resource rents were computed for survey respondents who did not disclose their total gross revenues.

The general formula used to obtain the resource rent from the operation of a fishpen and a fishcage, and from open water fishing is described on page 52. Note that the LLDA is not aware of any subsidies on fisheries. Fees paid by aquaculture operators for the license to operate fishpens or fishcages are deducted (cf UN et al., 2014) from the gross sales in the calculation of the resource rent. No taxes are imposed on fish catch.

RR = GS-CFC-UCFC-LC-II

where:

RR = Resource Rent

GS = Gross Sales (Price x Catch)

CFC = Consumption of Fixed Capital

UCFC = User Cost of Fixed Capital (assumed to be 10% of Total Fixed Capital)

LC = Labor Cost

II = Intermediate Input

Figure 6.2. Delineation of the lake area in six zones

The resource rent for the three types of fishing activities was determined for the West Bay, Central Bay, and East Bay. The delineation of the three bays and the computation of the area of each bay were based on the LLDA's map showing the different zones in the lake (Figure 6.2 and Table 6.1). Among a small proportion of fishermen, the resource rent was found to be negative. It was assumed that this may be due to an overstatement of their actual expenses or an underreporting of profits. Negative resource rents among survey respondents were regarded as zero in the computation of the average resource rent for each bay.

Table 6.1. Lake Zone and Area

Part of the lake	Zone	Area (ha)	% of the Total Lake Area
West Bay	A	10,870	
	B	19,048	
	E	8,360	
	FBS	11,396	
Subtotal		49,674	55
Central Bay	D	17,034	
	FCS	6,912	
Subtotal		23,946	26
East Bay	C	17,100	19
TOTAL		**90720**	**100%**

Note: Zone F surrounds Talim Island, which is divided into two municipalities, namely, Cardona and Binangonan in the province of Rizal. It is the only populated island in the lake and is divided into two zones — Zone F for Binangonan side (FBS) and Zone F for Cardona side (FCS)

Results

Capture fisheries

The most commonly used fishing gear by the capture (or 'open water') fishermen in the Laguna Lake are the gill net and fish corral. The average fish catch in the 78,627 ha allocated to open water fisheries is 7,663 kilograms per fisherman per year. West Bay yielded the highest fish catch, followed by the East Bay and the Central Bay. The total number of fishermen engaged, either full-time or part-time, in open water fisheries is estimated at 13,139. Table 6.2 presents details on fisheries in the Laguna Lake, based on the LLDA data.

Table 6.2. Annual Average Fish Catch by Open Water Fishermen in Laguna de Bay in 2014

Location	Open water area (hectare)	No. of fishermen (2010 data)	Average catch (all species) per fisherman (kg/year)
West Bay	43,983	6,839	10,607
Central Bay	20,574	3,364	3,766
East Bay	14,069	2,936	7,309
Laguna Lake	78,627	13,139	7,663

For the 2014 ecosystem account, the resource rent obtained by open water fishermen was calculated. Table 6.3 shows the annual average resource rent per fisherman in the three bays of Laguna Lake, which is estimated at 143,774 pesos (US$3,085) per year or 650 pesos (US$14) per day of the 221 average total fishing days per year.

The resource rent was derived by deducting the cost input of the fishermen from the gross revenue or sale. The gross revenue includes sales from tilapia, milkfish (bangus), therapon (ayungin), catfish (kanduli), mamali, bighead carp (mamali or karpa), manila catfish (hito), mud fish (dalag), biya, arroyo, palos, shrimp (hipon), dulong, gurami, knife fish, and janitor fish. No subsidies or taxes apply to open water fishermen.

The highest resource rent for open water fishermen is in the West Bay, where the density of these fisherfolk is higher compared to the other parts of the lake. Table 6.4 shows the total resource rent generated in the lake. For lack of more recent data, it is assumed that the number of fishermen per part of the lake in 2014 equals the number of fishermen in 2010.

For the computation of the resource rent, it is assumed, based on the responses to the survey, that fishermen undertake one fishing trip per day. The labor cost was computed using the average minimum wage set by the Department of Labor and Employment, and the National Wages and Productivity Commission, and the regional daily minimum wage rates for non-agriculture and agriculture.

Table 6.3. Average Resource Rent Capture Fishery (per fisherman per year) in Laguna Lake in 2014

BAY	Gross revenue (pesos)	Labor cost (pesos)	Intermediate input (pesos)	Consumption of fixed capital (pesos)	User cost of fixed capital (pesos)	Resource rent (pesos)
West	357,915	87,020	63,530	14,930	1,493	190,942
Central	209,623	76,076	36,646	8,040	804	88,057
East	236,094	76,901	53,477	7,249	725	97,742
Average for the whole lake	292,726	81,957	54,400	11,449	1,144	143,774

*The average for each column was calculated by multiplying the data in each row by the total number of fishers (Central = 3,364; East = 2,936; West = 6,839). The resulting products were then summed up and then divided by the total number of fishers in Laguna de Bay (Total fishers = 13,139). For illustration purposes: Average Gross Revenue/ Fishers for Laguna Lake: (209,623*3,364+236,094*2,936+357,915*6,839)/13,139=292,726. The process for computing the Laguna Lake average for each column is the same.*

Table 6.4. Total Annual Resource Rent from Capture Fisheries in the Open Water of Laguna Lake in 2014

BAY	Gross revenue (pesos)	Labor cost (pesos)	Intermediate input (pesos)	Consumption of fixed capital (pesos)	User cost of fixed capital (pesos)	Resource rent (pesos)
West	2,448	595	434	102	10	1,306
Central	705	256	123	27	3	296
East	693	226	157	21	2	287
Laguna Lake	3,846	1,077	715	150	15	1,889

Fishcages

The total harvest in fishcages, both in kilograms and in gross sales value, per bay, is indicated in Table 6.5. The table clearly shows that milkfish is the most valuable fish species cultivated in the lake (as in the case of fishpens), and that the species is only grown in West Bay, which has higher salinity. Tilapia is popularly grown in the East Bay.

Table 6.5. Average Harvest in Fishcages Per Fish Species Per Hectare Per Year by Bay (2014)

Location	Milkfish		Tilapia		Big-head carp		Knifefish	
	Kg/ha	Pesos/ha	Kg/ha	Pesos/ha	Kg/ha	Pesos/ha	Kg/ha	Pesos/ha
West Bay	18,015	396,156	4,300	167,250	7,625	156,812	154	3,000
Central Bay	0	0	1,560	66,087	7,250	160,000	0	0
East Bay	0	0	6,500	325,000	4,000	68,000	0	0

As fishcages are often operated by smallholders, it is also important to understand the income that is generated by these structures and the ecosystem's contribution to it (see Table 6.6). For instance, even though milkfish is the highest-value species in terms of gross revenue per hectare, the costs of producing it are relatively high. Table 6.6 shows that intermediate inputs in West Bay, which are dominated by milkfish production, are relatively high.

The resource rent for fishcages is higher in East Bay, where tilapia is widely grown. The weighted average resource rent per hectare, as shown in Table 6.6, is based on the following distribution of fishcages across the Laguna Lake: West Bay with 2,380 ha; Central Bay 874 ha; and East Bay 102 ha, totalling 3,356 ha (based on 2014 data from LLDA).

The average size of a fishcage in the sample (n=17, distributed over the three parts of the Bay) was 0.86 ha. As shown in Table 6.6, the overall average resource rent in fishcages in the entire lake is around 95,000 pesos (US$2,039) per hectare per year. Total gross revenue for fishcages equals 568,983*3,356 = 1,909 million pesos (US$40.98 million).

Table 6.6. Average Resource Rent in Fishcages Per Hectare Per Year

BAY	Gross revenue (pesos)	Labor cost (pesos)	Intermediate input (pesos)	Consumption of fixed capital (pesos)	User cost of fixed capital (pesos)	Resource rent (pesos)
West	641,930	81,080	289,610	123,487	60,435	87,317
Central	379,391	167,243	39,269	38,624	29,786	104,469
East	491,424	36,997	32,855	125,906	86,703	208,964
Laguna Lake	568,983	102,180	216,611	101,460	53,251	95,481

Fishpens

The fishpen industry flourishes in particular in the West Bay Area of Laguna de Bay, where high-value milkfish is cultivated in the prevailing brackish water conditions. Salt water intrusion decreases the turbidity of the lake due to flocculation. The flocs, being heavy, sink to the bottom of the lake, thereby increasing the clarity of the water. This enhances sunlight penetration and increases the photosynthetic action of phytoplankton, thereby improving the primary productivity of the lake and the amount of natural food for fish.

However, not all fish species such as Bighead Carp are tolerant of brackish water conditions. Such conditions are caused by the proximity of West Bay to Napindan Channel, where saline waters enter the lake during backflow of the Pasig River. Fishpens in Laguna Lake occupy 4,500 ha in West Bay; 2,935 ha in Central Bay; and 2980 in East Bay, totalling 10,415 ha (based on data from the LLDA).

Table 6.7. shows the resource rent generated by fishpens in the lake, plus the weighted average for the Laguna Lake. The total gross revenue for fishpens equals 66,351*10,415 = 691 million pesos (US$ 14.83 million).

Table 6.7. Resource Rent from Fishpens (pesos per hectare per year)

BAY	Gross revenue	Total Compensation of Employees	Total Intermediate Consumption	Consumption of Fixed Capital	Total User Cost of FC	Resource rent
West	102,417	27,890	3,299	1,560	809	68,860
Central	63,357	388	2,274	419	227	60.049
East	14,837	1,531	3,253	735	430	8,889
Laguna Lake	66,351	12,598	2,997	1,002	537	49,218

Aggregated results

Based on the calculations presented above, the total resource rent generated by the three types of fisheries in Laguna Lake is computed (see Table 6.8.). The table shows that the total resource rent generated by the fisheries service of the lake is around 3 billion pesos (US$64.3 million) per year. A rough comparison of the productivity scales of the systems shows that open water capture fisheries generates around 24 thousand pesos (US$515.13) per hectare per year, fishcage fisheries around 95 thousand pesos (US$2,039) per hectare per year, and fishpens around 50 thousand pesos (US$1,073) per hectare per year.

Clearly, this does not mean that the most profitable way of managing the fisheries potential of Laguna Lake is through the conversion of open water fishing to aquaculture, since it is not known how the ecosystem responds to increases in aquaculture cages and pens. For example, increasing the density of aquaculture cages and pens could potentially reduce per hectare harvests due to reduced food availability for aquaculture fish, or due to increases in fish diseases.

Table 6.8. Resource Rent Generated by Fisheries in Laguna Lake, by Type of Fisheries

2015	Hectares	Fishermen	Average resource rent per person (capture only) (1000 pesos per fisherman per year)	Average resource rent per hectare (1000 pesos per hectare per year)	Total resource rent for Laguna Lake (in million pesos per year)
Capture fisheries	78,627	13,139	143	23.9	1,878
Fishcages	3,356			95.5	320
Fishpens	10,451			49.2	514
Total	**92,434**				**2,712**

Evaluation and recommendations

Data quality

The account provides detailed insights into the ecosystem services 'support for fisheries' generated by the lake. This account has been the first attempt at quantifying the resource rent generated by this service for the Laguna Lake. However, the resulting estimates pose some uncertainties.

First, the sample size was relatively small. For instance, only 17 fishcage operators that generate a positive resource rent were included in the analysis. They cultivate a total of 15 ha of fishcages, or 0.1% of the cultivated acreage.

Second, there is a need to examine why relatively many respondents (e.g., around 13 out of a sample of 30 fishcage operators) recorded negative resource rents. It may well be that the respondents who indicated positive resource rents may have underreported their profits.

Third, there is a need to analyze the standard deviation in the responses of the fishermen in order to determine the potential accuracy of the account. For future surveys, the number of respondents should be increased.

Clearly, this does not mean that the most profitable way of managing the fisheries potential of Laguna Lake is through the conversion of open water fishing to aquaculture, since it is not known how the ecosystem responds to increases in aquaculture cages and pens.

In spite of these uncertainties, however, the account shows that fishpens and fishcages generate a higher resource rent compared to capture fisheries, with fishcages yielding a considerably higher resource rent than fishpens.

Fishcages, in general, are operated by small-holders and fishpens by larger operators. Capture fisheries generate the highest total resource rent and employ around 14,000 people. The accounts also show that there are significant differences in terms of revenue across the different areas of Laguna de Bay. The western part is said to be the most profitable for both capture fisheries and the two types of aquaculture. This is due to the regular intrusion of salt water, creating a brackish water environment that is suitable for the highest-value species — milkfish.

Based on the foregoing, the TWG offers the following recommendations:

1. Repeat the fisheries survey in a few years' time to determine how fish production, if at all,

changes over time;

2. To achieve the above in a cost-efficient manner, the LLDA, PSA, and BFAR should establish a partnership in the collection of information on the fisheries in Laguna de Bay.

3. The LLDA, PSA, and BFAR should jointly prepare a standard procedure for the collection of data, as well as for the regular publication of the fisheries accounts (which should also include the resource rent).

4. The PSA should include Metro Manila, particularly Taguig and Muntinlupa cities, in its annual fish production survey.

5. The survey questionnaires used the ecosystem account reviewed by all parties in light of the lessons learned during the survey for the project, e.g., uniform unit of measurement, definite answer, etc. for the ecosystem account should be further enhanced.

6. The LLDA needs to create a special unit that would collect and manage data for fisheries accounts and accordingly coordinate with BFAR and PSA on this respect. The members of the LLDA-Phil WAVES TWG must come from different divisions and have the ability to cascade the knowhow gained to the staff of the unit that will be created.

Soil erosion control

Objective

The Laguna Lake basin serves as a multipurpose resource for fisheries, navigation, flood water reservoir, power generation, recreation, irrigation, industrial cooling, waste sink, and potable water. Yet several of these services have been affected by the siltation of the lake, which has been identified as one of the pressures that has been brought to bear on the lake.

As erosion increases, the severity of siltation also increases. This may result in reductions in lake depth that could affect navigation, decreased potable water quality, and increased risks of flooding.

The LLDA thus identified flood retention as one of the key ecosystem services that needs to be included in ecosystem accounting. In line with this, the objective of this component is to model and map the sedimentation load coming from the 24 sub-basins contributing to the Laguna Lake basin's siltation under normal and simulated conditions. The modelling and mapping of sediment load was conducted for the 24 sub-basins feeding into the lake, using the 2010 input data (since 2014 input date on land cover were not yet available).

Methodology

The modelling and mapping of sediment loads for the first seven sub-watersheds was conducted using the Sediment River Network Model (SedNet). Sednet is a GIS-based water quality modelling software package originally developed by CSIRO Land and Water as part of the Australian National Land and Water Resources Audit (Wilkinson et al., 2004).

SedNet identifies major erosion processes and constructs sediment budgets on a regional scale to identify patterns in the material fluxes under normal and simulated conditions. The resulting budget accounts for the major sources, storage, and fluxes of sediment material. The SedNet software and its online documentation are available via the toolkit website of the Cooperative Research Centre (CRC) for Catchment Hydrology (http://www.toolkit.net.au). The data used in the SedNet modelling of the Laguna Lake are shown in Table 6.9.

The SedNet model uses a simple annual mean conceptualization of transport and deposition processes in streams (Hartcher et al., 2005). Spatial patterns of sediment sources, stream loads, and areas of deposition within the system can be produced. The contribution from each watershed to the river mouth can be traced back through the system, allowing downstream impacts to be put into a regional perspective (Kinsey-Henderson et al., 2003).

Table 6.9. List of Input Data for SedNet

SedNet Data Requirement	Metadata	
	Source	Formula and Method used
Base data, Stream define		
DEM	SRTM 90 meter resolution DTM-IFSAR 5 meter resolution	Filling sinks
Flood Plain		
Physical and Climatic, Spatial inputs		
Rainfall Erosivity (R)	world climate data	Empirical equation
Soil Erodibility (K)	BSWM	Empirical equation
Slope Length-Steepness (LS)	SRTM 90 meter resolution	Empirical equation
Land Use (C)	DTM-IFSAR 5 meter resolution	Empirical equation
Gully Density	land cover 2010	Conservative estimate
Mean Annual Rainfall	sub-basins, rivers	Hydrologic modeling
Potential Evapotranspiration-Rainfall Ratio (PET)	2010 mean annual rainfall	Hydrologic modeling
Riparian Vegetation	land cover 2010	Map overlay
Flow data		
Streamflow data	PAGASA weather stations	Hydrologic modeling
Gauge locations	Gauge points	

SedNet is composed of several modules. Central to the structure and operation of the SedNet model is a stream network defined from a digital elevation model. The network is composed of links that extend between each stream junction. For each link in the network, separate budgets for sediment (i.e., bedload and suspended load) and nutrients (i.e., phosphorus and nitrogen) are computed. The budgets are each a mass balance of inputs and outputs.

The spatial data module calculates the inputs and outputs that come from grids. For example, hillslope sediment supply comes from a grid of hillslope erosion. The Flow module computes the measures of flow required for calculating the terms in the budget. For example, bank flow is used to calculate bank erosion and overbank flow floodplain deposition.

The input datasets are divided into three categories — the base data, the physical and climatic data, and the flow data (see Table 6.9). Figure 6.3 provides the hillslope factors that are needed to model erosion. The preparation of input data (including the combination of measurements of river discharge, conceptual representation of material transport, soil types, land use and vegetation cover, terrain and climate) was done using ArcMap in ArcGIS.

SedNet's scenario analysis capabilities were used to analyze the ecosystem service 'sediment retention,' i.e., avoided erosion. To analyze the amount of avoided sediments, all semi-natural and natural ecosystems, like closed and open forest, shrublands, grasslands, and wooded grasslands were converted into bare lands in the model.

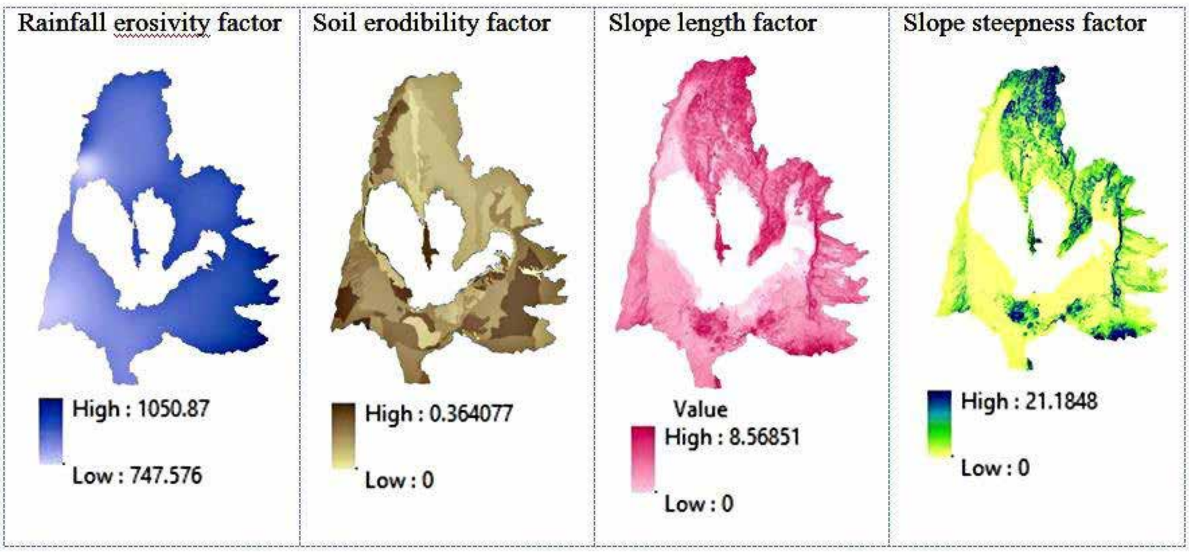


Figure 6.3. The erosion modelling factor for SedNet modelling

The resulting amount of erosion and sedimentation was assumed to equal the avoided erosion and sedimentation, respectively, as a consequence of the presence of the vegetation. The effects on sediment loads and exports were analyzed by re-running the model for this simulated scenario. Results of the normal condition were then deducted from the results of the simulated conditions to determine the avoided erosion service.

Post-processing of maps for each sub-watershed was conducted using ArcGIS. Only 21 sub-watersheds were run using SedNet. The small watersheds of Angono, Caliraya, and Taguig were not included in the analysis due to difficulty in getting good results in terms of stream definition. This non-inclusion, however, will not have a significant impact on the overall results, given that these streams contribute little only a very minor part (<5%) to the overall sediment loading.

Results

The total area of the 24 sub-watersheds analyzed is 2,741 km^2. Under normal conditions, the total sediment generated based on the 2010 land cover is 2,011 kilotons of sediment per year. Sta. Maria, Los Baños, Sta. Cruz, Pagsanjan, and Marikina have the highest contributing sub-watersheds (see Table 6.10.). Under simulated conditions sedimentation rate increased to 6,885 kilotons of sediment per year. Simulated conditions entail all natural and semi-natural ecosystems including close and open forests, shrublands, grasslands, and wooded grasslands being converted to bare lands. Figure 6.4. presents 21 sub-watersheds and their suspended sediment yields.

The ecosystem service of closed forest, open forest, shrubs, grasslands, and wooded grasslands in terms of avoided erosion was then calculated to be 4,874 kilotons of sediment per year. This was calculated by deducting the results of the normal conditions and simulated conditions.

Table 6.10. Contribution of Sediments by Twenty Sub-basins Under Present and Simulated Conditions

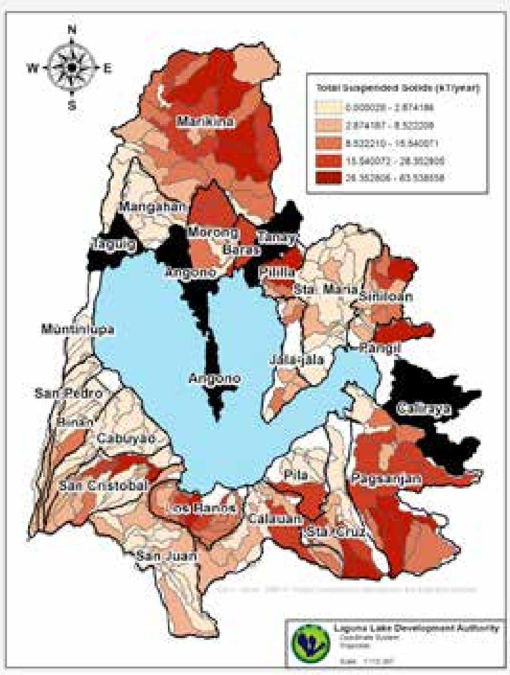
Subwatershed	Area (km^2)	Sediment generated under 2010 land cover (KT/Y)	Sediment that would be generated under bare land cover	Ecosystem service (avoided erosion)
Units	square kilometer	kilotons per year	kilotons per year	kilotons per year
Muntinlupa	44	2	3	1
Mangahan	88	13	27	14
Sta Rosa	120	16	50	34
Binan	91	17	146	129
Jala-Jala	86	29	46	17
San Juan	73	44	86	42
San Cristobal	204	46	259	213
San Pedro	140	48	79	31
Pangil	47	50	148	98
Pililia	56	51	61	10
Calauan	41	58	256	198
Tanay	163	73	167	94
Morong/Baras	54	82	137	55
Siniloan	122	99	112	13
Pila	93	119	256	137
Sta Maria	205	139	524	385
Los Baños	103	141	252	111
Sta Cruz	149	157	785	628
Pagsanjan	319	296	1154	858
Marikina	543	531	2337	1,806
TOTAL	**2,741**	**2,011**	**6,885**	**4,874**

Key: /1 assuming that all closed forest, open forest, shrubs, grasslands, and wooded grasslands would be converted to bare land

Evaluation

The highest sediment-yielding sub-watersheds under current land cover conditions are Marikina, Pagsanjan, and Sta. Cruz. Based on the evaluation of the land account analysis (see Chapter 3), these areas included several highly denuded areas, the majority of which are within 18% and higher in slope. These watersheds are dominated by shrublands, grasslands, wooded grasslands, and perennial and annual crops.

Sediments produced by each of the sub-watersheds cause silt deposition along the shorelines of the lake, especially along the northwest and southeast parts of the bay. The location of the five major watersheds with the highest sedimentation rates coincides with the shorelines that have



Note: No computations were made for the black areas due to lack of data

Figure 6.4. Total suspended solids (kilotons per year) generated by 21 sub-watersheds of Laguna de Bay

displayed sediment deposition similar to the findings of the bathymetry model. Silt deposition along the lake shoreline causes natural land reclamation, leading to further encroachment of human settlers along the lake shoreline. This in turn decreases the water retention of the lake, causing a higher risk of flooding (See the next section.)

Despite the current state of the ecosystem in the Laguna Lake region, the semi-natural and natural ecosystems are still capable of preventing 4,874 kilotons of sediment per year from being deposited along the shorelines of the basin. Still, efforts should be made to protect these natural and semi-natural ecosystems to prevent further degradation that would hasten the siltation along the shoreline as well as shallowing of the lake.

Data quality

Constraints to data gathering were as follows:

- Land cover was only available for 2003 and 2010. Hence no calculations for 2014 could be presented. The year 2003 was excluded from this account due to time limitations.
- Current climatic data (in particular rainfall data) was limited.
- Streamflow data was limited.

In view of the foregoing, the results of this account should be interpreted with some caution. Still, the relative erosion rates generated in the different parts of the basin are well represented. Hence, the map shows priority areas for soil and water conservation measures.

Flood control

Objective and scope

Flooding of houses and infrastructure within the Laguna de Bay region is an important economic issue. In most years, only minor floods have affected parts of the basin. But in case of major typhoons, the area is subject to heavy flooding, leading to losses of life as well as houses and infrastructure. The last time this happened, in 2009, during Typhoon Ketsana, the lake water level rose to 13.8 m above sea level, while the damages in the Laguna de Bay region amounted to around 6 billion pesos (US$128.78 million) (LLDA, 2014).

The Laguna Lake is a crucial element in the hydrological system of the watershed. It acts as a retention basin, where water generated in the upper parts of the watershed is collected before it is discharged through the relatively small Pasig River to Manila Bay. Through the retention of water in the lake, the flood risk is mitigated. This is interpreted as the flood retention service of the lake, which has been analyzed, in physical and monetary terms, in this section.

Methodology

The flood retention service is defined as the capacity of the lake to store water that would otherwise lead to flooding of houses and infrastructure. In the Laguna de Bay watershed, flood risk is posed by rain water collected in the lake through runoff from the 24 sub-watersheds draining into the lake, in particular during high rainfall events such as typhoons.

The capacity to store water refers to the amount of water that can be held in the zone between 1) the beginning of the rainy season (July) and 2) the level at which the houses along the lake initially get flooded. In between these two levels water can be stored without causing economic losses due to flooding. Note that the flood retention capacity is not based on the overall volume of water stored in the lake. The water level below the average onset of the rainy season level is usually filled throughout the year and therefore not available as retention basin.

Based on the above, the retention service is defined as the zone between 11.5 m and 12.5 m (see Figure 6.6). Over time, people live closer to the lake. However, at present, there are very few houses, if any, in the lake area that are built below the 12.5 m level, which has been prone to flooding in the past years.

The flood retention service is affected by the inflow of sediments in the lake. Although the overall depth of the lake did not change substantially in the period 1997-2014, as earlier explained, sedimentation nonetheless affected the flood retention service because sediments were deposited through backfilling of the shores of the lake. Aerial photos show extensive sandbanks, where sediments were deposited close to the shore including in the 11.5 to 12.5 m zone.[7]

The flood retention service of the lake was analyzed in a number of subsequent steps.

1. The population density and number of houses in each 1m zone above the 12.5m water level (12.5-13.5, 13.5-14.5, 14.5-15.5m) was analyzed. Population data were available for the years 2000 and 2010 (see Annex 5), which have been interpolated. The average annual growth rate in this period was extrapolated to the period 2011-2014.

2. The average number of people per household was assumed to be 4.6 (PSA 2014; data for 2010). The number of houses per flood zone is calculated by dividing the number of people living around the Laguna Lake basin by 4.6. The average price of a basic house in the flood zone is assumed to be 500,000 pesos (US$10,731), based on LLDA estimate.

PSA's estimated house prices are averages over a larger area. Since the lake area includes parts of the urban zone of Metro Manilla, as well as the well-developed area south of the Laguna Lake with relatively expensive houses, PSA's estimates were assumed to be unrepresentative of the prices of houses built in the zones most prone to flooding. These houses are often illegally built simple constructions. Consequently, the costs of flooding need to be interpreted with caution. Note that the model is calibrated based on the prevailing costs during the 2009 flooding. Based on this calibration, the costs of damages to infrastructure were assumed to be equal to around 25% of the damages to houses.

Further research is needed to analyze both the costs of damages to houses in the flood zone and those of the affected infrastructure. Given the uncertainty

[7] *Water levels cited in this report are based on the LLDA reference system, where 11.5m corresponds to 1.5m above mean sea level.*

attached to this monetary value, the value is not included in the summary account for policy makers.

3. The amount of damage caused by flooding depends on inundation depth, flood duration, the construction type and materials used (wood, concrete, bricks, etc.), and the flood control measures in place. Based on past floods, inundation depth and damage costs have been correlated (Figure 6.7) (Arias et al. 2014). This analysis only considers damages to houses. Damage to infrastructure, crops, and other properties, on average, made up 25% of damage to houses during past flood events (LLDA, 2014). Therefore damage ratios were multiplied by a factor of 1.25.

4. A simple spreadsheet model was prepared in order to relate annual flood level to damage costs. The equations of the model are shown in Annex 6. The outcomes of the model are illustrated in Table 6.11, which presents the model calculations of the damage costs of a 13.8 m flood (the 2009 flood level). Note that the model also allows predicting flood damages as a consequence of flood levels in the future (by extrapolating population growth rates). When new census data become available, population data can be updated in the model.

Table 6.11. Damage Costs of 13.8 m Flood in Laguna de Bay Area, 1997-2015

Year	Damage costs (billion pesos)
1997	4.1
1998	4.2
1999	4.4
2000	4.5
2001	4.7
2002	4.9
2003	5.0
2004	5.2
2005	5.3
2006	5.5
2007	5.6
2008	5.8
2009	5.9
2010	6.1
2011	6.2
2012	6.4
2013	6.6
2014	6.7
2015	6.9

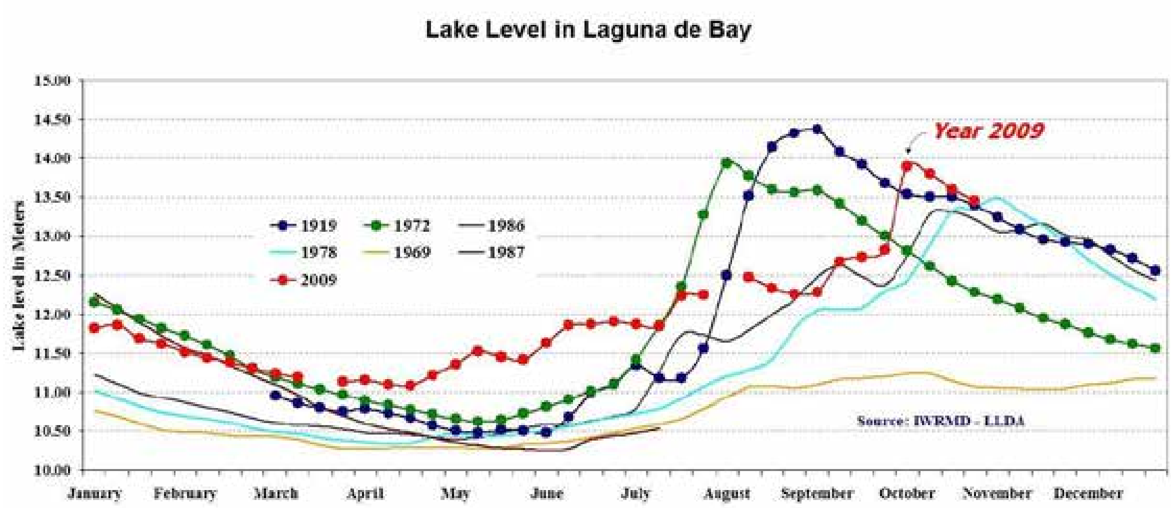


Figure 6.5. Water levels in the lake in selected years with floods (source: LLDA)

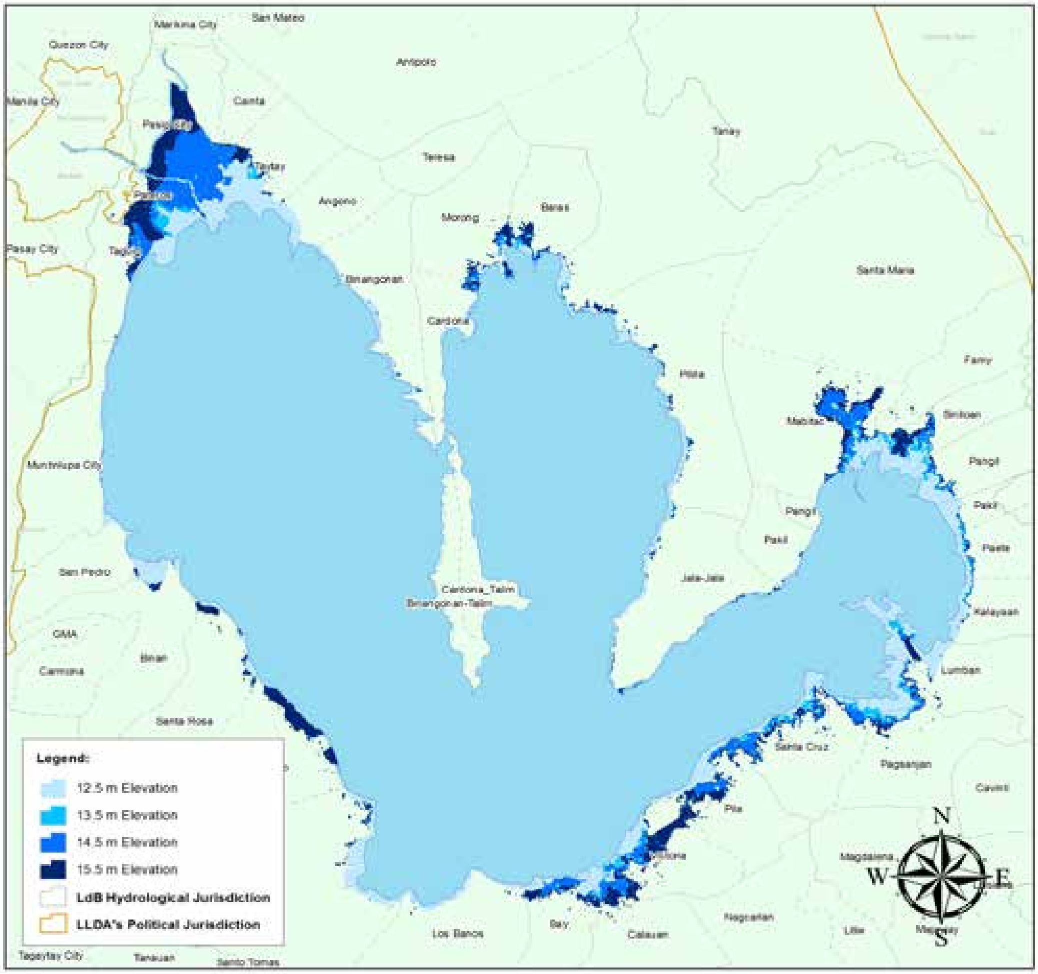


Figure 6.6. Lake showing flood retention service vis-a-vis flood plain areas (2014)

The value of the ecosystem service 'water retention' can be approximated by comparing flood levels with and without the water storage volume of the lake. In line with the assumptions above, at 12.5 m it is assumed that there are no significant flood damages in the Laguna de Bay area. If there were no water storage between 11.5 and 12.5 m, then the annual water level could be expected to reach 13.42 m in the rainy season. Due to the bathymetry of the lake shore, the flood level would rise with 0.92 m instead of 1m[8].

Hence comparing flood damage costs at 12.5 m and 13.42 m levels yields the monetary value of the water retention service of the lake, based on the avoided damage costs from floods. At 12.5m the damage costs are assumed to be zero, and at 13.42 m the damage costs are modelled to be 4.2 billion pesos (US$90.15 million) (in 2015). Hence the value of water retention (i.e., flood control) can be estimated to represent 4.2 billion pesos (US$90.15 million) per year. However, this value is strongly dependent on the assumptions made. On one hand, it is a conservative estimate, since the water storage also reduces the flood levels during years with extremely high water levels, as in the case of the 2009 typhoon. On the other hand, it may also be an overestimate, since in reality people may move out of the 12.5 m to 13.42 m flood zone in case the present water storage in the lake is not possible. It may be worth noting that many of the affected

[8] *Based on this formula: (water volume at 12.5m – water volume at 11.5m)/(water volume at 13.5 – water volume at 12.5m) = (4.1-3.1)/(5.2-4.1). These are rounded values in million m^3.*

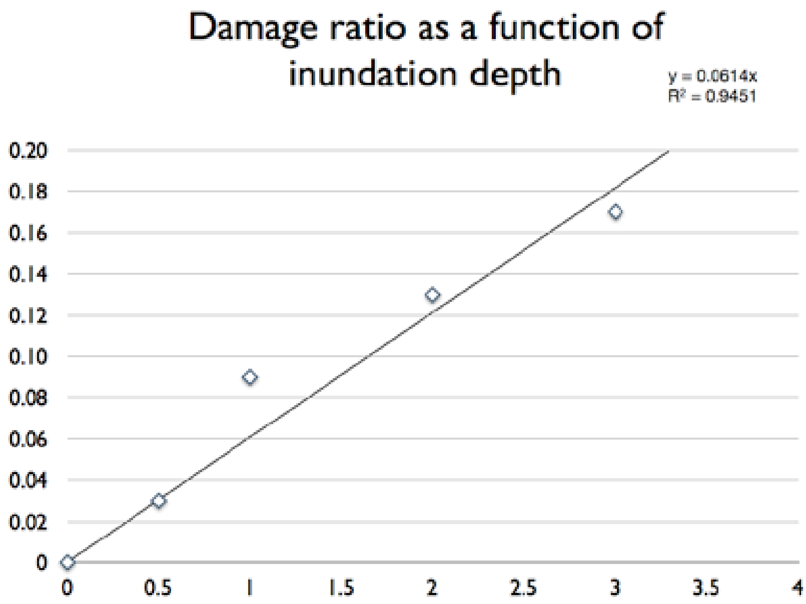


Figure 6.7. Damage ratio as a function of inundation depth (based on Arias et al, 2014)

people have few places to go or few alternatives to build a dwelling, and therefore are forced to settle in the flood-prone zones of the lake.

Hence, the value of 4.2 billion pesos (US$90.14 million) per year should be interpreted with much caution. It is an approximation of the value of this service only, and given the lack of experience among the TWG with valuing flood control, further discussion is needed before this, or alternative value estimates, can be considered sufficiently robust for monetary ecosystem accounting. Recognizing that further discussion is needed on how the flood control service can best be valued, the TWG opted not to include this indicator in the summary account for policy makers.

Policy evaluation and next steps

The analyses provide a number of insights that are relevant for policy making. First, they show that the flood risks in the lake zone have substantially increased since the last major typhoon in 2009, because of an increasing population in the lake shore. The model used indicates that if the same flood level of 13.8 m occurred today, the flood damages would be valued at 6.9 billion pesos (US$148.10 million).

These calculations do not, of course, include the potential loss of lives. Typhoon Ketsana in 2009 spawned not only economic damages estimated at 6 billion pesos (US$128.78 million) but also the loss of 104 lives in the national capital region.

Depending on the emergency response strategies designed and implemented in the Laguna de Bay area in the aftermath of Typhoon Ketsana, flood impacts are growing with increased population density. Climate change may exacerbate these problems in the future due to potential increases in extreme events and rising sea levels, making drainage of water from the lake to Manila Bay even harder.

The model developed for the account forecasts a specific number of houses that would be flooded in each municipality around the lake based on a given flood level. Such modelling could help inform the development of emergency response plans.

Based on the impacts of flooding, a flood risk map was produced to show a potential additional policy application of the ecosystem accounting approach (Annex 7). The map clearly shows the areas with high population density and therefore people are at risk of flooding, and those where the potential economic losses from floods are highest. It also highlights the need for more stringent measures relating to emergency response including evacuation plans.

The modelling approach could also be useful for analyzing the potential effects of the proposed water levee (dyke) in the southwestern part of the lake. Since this structure will reduce the size of the overall flood plain of the river, it is likely to lead to increased flooding in other parts of the lake. The magnitude of the flooding in other parts has not been predicted in this account but could easily be determined once the design of the levee is available.

Highlights of Ecosystem Service Account

- The Laguna de Bay is a multi-use resource primarily used for fishing. Other ecosystem services include flood control and soil erosion control.
    - The fisheries study conducted in 2014 showed that the lake can still sustain fisheries production, providing livelihoods for 14,000 fishermen, but it is threatened by pollution. From a stocking period of twice a year, it now takes more than a year to harvest fish. The western portion of the lake is the most profitable for capture fisheries and aquaculture. However, this is also the part of the lake that is the most polluted.
    - The siltation of the lake has been identified as one of the pressures being experienced by the lake and affecting the lake's flood control service. As erosion increases, the severity of siltation also increases. The reduced water retention of the lake increases flood risk during high rainfall or rainy season.
    - Around 2 kilotons of total suspended sediment was discharged into the lake in 2010. However, the basin is still capable of preventing around 5 kilotons of sediment per year from being deposited into Laguna de Bay.
- The rise and growth of capital-intensive aquaculture business in and around the lake has led to the entry of more businessmen, which has resulted in conflicts between open water fishermen and aquaculture operators amid limited access to the former's traditional fishing grounds.
- The ecosystem accounts show that the flood risks in the lake zone have substantially increased in the last decade, mainly because of an increasing population in the lake shore. Climate change and the potential frequency and increase in extreme events may increase these problems in the future.

7.| Findings relevant to ecosystem accounting

Policy implications and recommendations

The ecosystem accounts show areas where specific policy interventions should be carried out as a matter of priority.

The ecosystem accounting approach offers a practical and comprehensive tool to monitor changes in ecosystem condition and ecosystem use. It can be used to identify key policy issues such as by pointing out ecosystem types or ecosystem services that are under particular threat. In addition, it can be used as a benchmark to assess policy impacts, for example by assessing if policies have led to changes in trends in specific areas of policy intervention. By integrating data at different dimensions (e.g., water quantity, water quality, fish production, etc.), ecosystem accounting provides a more comprehensive overview of ecosystem state and uses compared with fragmented datasets.

There are several potential policy uses for the accounts making up ecosystem accounting.

Policy interventions should be based on rapid declines in specific environmental components

For instance, the accounts show large urban sprawl, including in highly flood-prone areas and forest zones, and a lack of connectivity of households to sewage systems. Both issues merit priority action by policy makers to avoid progressively increasing environmental risks in the future.

Policy interventions should be prioritized for most affected areas

For example, the accounts indicate which zones are responsible for the generation of sediment into the lake, and should therefore be prioritized for protection of remaining forest cover.

The accounts in this study can provide a benchmark for assessing the effectiveness of policy interventions

In two ways: through a comprehensive and long-term monitoring system, and through the spatial information set that facilitates identification of trends in areas that may be affected in a different way by policy interventions (e.g., closed forests inside and outside protected area boundaries).

The specific policy uses of the accounts were discussed in a major stakeholder workshop in October 2015. Feedback from the stakeholders indicated that integrated information is highly useful for supporting policy making and implementation in the region. One critical issue that was raised, however, is that many of the decisions on land management affecting the lake (including the establishment of houses, and land conversion) were made by local governments. This highlights the need for sharing information on the accounts with the LGUs concerned. This could take the form not only of one-off workshops but also of sustained efforts at information sharing. Specific policy relevant findings are briefly described below:

1. ***The population density has increased very rapidly in the Laguna de Bay basin in the last decades.*** For instance, the population in the municipalities immediately adjacent to the lake increased 29% between 2003 and 2010, that is, from 6.7 million to 8.6 million people (Annex 5). This poses a number of major challenges to efforts to address issues revolving around infrastructure development, sewage and waste, flood control, and fisheries production in the lake.

2. ***The Laguna Lake plays a major role in preventing flooding in Metro Manila.*** It acts as water storage reservoir, thus necessitating explicit recognition of this service and appropriate management including ensuring the outflow capacity of

Pasig River. In the absence of reliable water storage facility, flood risks would be considerably higher for the approximately 9 million people living in flood risk zones. Hence, the capacity of the lake to retain water during cyclone events must be maintained such as through efforts to forestall increased urbanization of the flood prone zones and reduce sediment loading in the lake through watershed protection measures.

3. A growing concern is that people are settling and building houses closer than ever to the lake shore. Amid typhoons, these individuals face immediate risks to their lives and properties. For instance, if the 2009 flood level were repeated in 2015, floods would have affected 166,000 houses (instead of 146,000 in 2009) and damage costs would have amounted to 7 billion pesos (US$150.12 million) as against 6 billion pesos (US$128.78 million) in 2009.

Since a significant number of people are living across the flood risk zones (see Annex 5), and that this number is still rising, there is an urgent need to ensure that no further settlement in the two most risk prone zones (<2 meters above the lake level) takes place.

4. To reduce flood risks, rehabilitation of the lake's shorelines is also urgent. Lost mangrove cover should be restored where possible, especially since virtually all mangrove has been lost in the lake in last 15 years. These ecosystems could contribute to flood control, serve as nursery area supporting capture fisheries in the lake, and act as sediment trap, thereby reducing siltation in the lake.

5. Management of the slopes and uplands of the Laguna de Bay basin is essential in maintaining the long-term viability of the lake as water storage reservoir. Sedimentation is leading to a backfilling of sediments, which reduces the water storage capacity of the lake. (Significant amounts of sediment are deposited in the zone that contributes to flood control and with flood retention capacity of 11.5 m to 12.5 m above sea level.) Maintaining forest cover is essential to reducing sedimentation. The ecosystem account, as discussed in Chapter 6, shows the areas that contribute most to sedimentation and therefore should be accorded priority for rehabilitation.

6. An issue that has not been covered by the account is that forest vegetation also acts as buffer, storing water during high rainfall and gradually releasing this water over time. Hence the forests also provide a flood control service. The next phase of the account should examine this service.

7. Fishing is a major economic activity in the Laguna Lake region. The accounts show that the western side of the lake is the most productive, because it has a higher salt content, which is required for milkfish production. The accounts specify the number of people deriving their livelihoods from the lake, their fishing catch volume, and the resource rent obtained across different production systems in the lake. The resource rent generated could serve as a basis for setting fair fees for fishpen and fishcage operators. The fees should be considerably lower than the resource rent to allow for rewards for entrepreneurial risks.

8. Water quality is a constant issue in the lake. The account focused on BOD, the levels of which are merely acceptable during much of the year for the use of the lake for fisheries. Inorganic pollution loads (such as from pesticide runoff or emissions of inorganic pollutants like heavy metals by households and industries in the lake area) were not considered but will need to be analyzed. Given the growing population density around the lake, the local authorities need to increasingly connect households (the main source of BOD loading) to the sewage system.

9. Since the population in the lake area keeps increasing, continuous efforts are needed to improve the management of sewage and waste. The accounts show that households are the largest source of BOD (especially that of untreated sewage), followed by industry. Thus further efforts must be taken to ensure that an increasing proportion of people are connected to the sewage system. Without such efforts, lake water quality could decline over time.

10. There is a need to carefully consider the effects of the proposed land reclamation project on the southwestern side of the lake on flood risks in the other parts of the lake. Depending on the area size to be reclaimed, there is a risk that land reclamation will reduce the water storage service of the lake. This in turn could lead to heightened flood risks to people occupying the other parts of the lake (particularly the northwestern side, which covers the urban zones of Metro Manila) during typhoons.

Analyzing the potential flood risks of this planned reclamation is therefore recommended. Potentially significant risks should be considered in the design of the project. In this regard, the models developed for the ecosystem account could be useful.

11. Management of the natural resources of the Laguna Lake is increasingly challenging due to strong increases in population and economic activity. Yet, maintaining the natural resource base of the area (including, but not limited to, water, fish, flood control, cropland, forests) is essential to ensuring the well-being of the people and the growth of economic activities.

A pro-active approach is required to understand how the Laguna Lake's resources are changing over time, how demand for these resources is growing, how the ongoing degradation of the resources is affecting people, and how trade-offs in natural resource management can be best handled based on comprehensive information on the costs and benefits of various environmental management options. Hence, it is recommended that the accounts be produced as well in the future, with regular updates, say, every two or three years. As the accounts discussed in this report have been developed by the LLDA, this recommended undertaking should be feasible.

12. Continuous data collection and improvement must be included in the accounts. For instance, there is a need to verify and update the assumed costs of residential dwellings constructed in the flood zone and the flood damages to these infrastructure, the efficiency and connectivity of households to septic tanks, and the inflow of inorganic pollutants in the lake. Assessing the 2014 land cover is also vital. It is recommended that the LLDA develop a strategy and priority listing for improving data quality in the accounts.

Ecosystem accounting process

The pilot ecosystem account completed by the TWG with support from national and international experts demonstrates the following.

1. Ecosystem accounting fills a significant information gap in ecosystem management. Particularly important is its ability to consolidate information from different disciplines (e.g., hydrology, ecology, soil sciences, economics) and cover different ecosystems (e.g., uplands, lowlands and coastal ecosystems).

2. The pilot demonstrates that information required for analyzing many ecosystems is available in various line agencies. In fact, data availability proved much better than anticipated. However, these data are scattered across agencies, making it time-consuming to access them. The pilot also shows the need to apply high-quality standards for data collection and recording. This means there should be clear logbooks for data collection and well-defined procedures to facilitate retracing the steps taken to collect and analyze both primary

and secondary data.

Overall, the ecosystem accounts produced over a period of around 24 months have turned out to be comprehensive, covering a range of condition, asset and service indicators, some of which are presented in both physical and monetary terms in this report. They also include several 'complex' ecosystem services such as flood control. Needless to say, it is a pilot undertaking and at best could serve as basis for further learning and development. It is by no means intended to represent a definitive outline of an ecosystem account.

3. Compiling the accounts entailed enormous time and effort, as well as the participation of a number of staff from the LLDA, not to mention substantial support from national and international experts alike.

A key bottleneck for developing the accounts was that the TWG members had other responsibilities outside of the Phil WAVES project, making their work on the ecosystem accounts an even bigger challenge. Nevertheless, an expansive analysis using a broad dataset was conducted by, and led to considerable capacity building in, the TWG. Around 20 members of the group took part in a total of four training sessions on ecosystem accounting, plus numerous other training activities on the development of the accounts (e.g., land account, modelling, valuation).

Because of the hands-on character of the training, and the opportunity accorded to the TWG to conduct most of the analysis themselves, the group may well be considered now fully trained in the ecosystem accounting approach.

4. An important part of the value of the accounts lies in showing trends in ecosystem condition, asset, and service flows. This means that the accounts should be regularly updated — a task that relies on available resources, both in terms of time the TWG members can devote to the task at hand and the budget for field work and data collection. Given the lessons learned, however, in the course of this pilot undertaking, the costs of updating the accounts in the future should be much lower than the costs of initially establishing them.

5. The pilot study shows the need for a proper and well-designed system to store and share information including GIS maps. At present, these data are commonly stored on the laptops of the experts that conducted the analysis, which makes it difficult to implement the ecosystem accounting method over the long term, especially once the staff concerned move to other organizations. Hence the TWG should identify two storage options (one in each implementing agency) apart from their personal laptops, and ensure that there is a proper and detailed filing system indicating among others how the data were collected and need to be interpreted.

6. There is a need to consider jointly with the Philippines Statistics Authority the lessons that can be drawn from the case study of national environmental and environmental-economic statistics. Eventually, it would be useful to have an integrated system where some key variables are analyzed at the national level while other environmental-economic statistics, which are more context-specific, are assessed at the local (e.g., provincial) scale. Efforts must be made to ensure that data quality standards are uniformly high for both groups of data, and that there is scope for an increasingly important contribution from the PSA in terms of ensuring data quality. Further analyses are needed to identify which statistics should be collected at specific scales.

7. The institutionalization of NCA is critical. It is important that NCA units are established in government agencies to create and update a comprehensive set of ecosystem accounts at the national and subnational levels. These accounts must be replicated in other parts of the country. There is also a need to continuously develop government expertise for creating ecosystem accounts.

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Annex 1a Additional water accounts (2001)

2001	EA. 131 Surface water			EA. 132 Groundwater	EA. 133 Soil water	Total
	EA. 1311 Artificial reservoirs	EA. 1312 Lakes	EA. 1313 Rivers			
1. Opening Stocks	**-**	**-**	**-**	**-**	**-**	**-**
Increases in Stocks		5,118,292	8,473,628	-	3,144,139	11,617,767
2. Returns			44,055			44,055
3. Precipitation		1,475,884			3,144,139	3,144,139
4. Inflows		3,642,408	8,429,572			8,429,572
4.a. from upstream territories	-					-
4.b. from other resources in the territory	-	3,642,408	8,429,572			8,429,572
Decreases in Stocks		6,386,040	8,429,572	498,268	3,144,139	12,071,980
5. Abstraction		204,984				
6. Evaporation/ Actual evapotranspiration		895,622				
7. Outflows		5,285,433	8,429,572	498,268	3,144,139	12,071,980
7.a. to downstream territories			5,285,433			5,285,433
7.b. to the sea						
7.c. to other resources in the territory		5,285,433	3,144,139	498,268	3,144,139	6,786,547
8. Other changes in volume						
Net Changes		(1,276,747)	44,055	(498,268)		(454,212)
9. Closing Stocks						

Annex 1b Additional water accounts (2010)

2010	EA. 131 Surface water			EA. 132 Groundwater	EA. 133 Soil water	Total
	EA. 1311 Artificial reservoirs	EA. 1312 Lakes	EA. 1313 Rivers			
1. Opening Stocks	**-**	**-**	**-**	**-**	**-**	**-**
Increases in Stocks		6,492,000	10,222,954	-	4,021,470	14,244,425
2. Returns			1,133,964			1,133,964
3. Precipitation		1,972,261			4,021,470	4,021,470
4. Inflows		4,519,739	9,088,990			9,088,990
4.a. from upstream territories	-					-
4.b. from other resources in the territory	-	4,519,739	9,088,990			9,088,990
Decreases in Stocks		6,262,734	9,088,990	498,268.80	4,021,470	13,608,730
5. Abstraction		204,984				
6. Evaporation/ Actual evapotranspiration		990,230				
7. Outflows		5,067,519	9,088,990	498.268.80	4,021,470	13,608,730
7.a. to downstream territories			5,067,519			5,067,519
7.b. to the sea						
7.c. to other resources in the territory		5,067,519	4,021,470	498.268.80	4,021,470	8,541,210
8. Other changes in volume						
Net Changes		229,266	1,133,964	(498,268.80)		635,695
9. Closing Stocks						

Annex 1c Additional water accounts (2012)

2012	EA. 131 Surface water			EA. 132 Groundwater	EA. 133 Soil water	Total
	EA. 1311 Artificial reservoirs	EA. 1312 Lakes	EA. 1313 Rivers			
1. Opening Stocks	-	-	-	-	-	-
Increases in Stocks		11,671,473	20,368,173	-	7,976,715	28,344,889
2. Returns			1,180,410			1,180,410
3. Precipitation		3,196,488			7,976,715	7,976,715
4. Inflows		8,474,984	19,187,763			19,187,763
4.a. from upstream territories	-					-
4.b. from other resources in the territory	-	8,474,984	19,187,763			19,187,763
Decreases in Stocks		12,277,910	19,187,763	498,268.80	7,976,715	27,662,748
5. Abstraction		204,984				
6. Evaporation/ Actual evapotranspiration		861,878				
7. Outflows		11,211,048	19,187,763	498,268.80	7,976,715	27,662,748
7.a. to downstream territories			11,211,048			11,211,048
7.b. to the sea						
7.c. to other resources in the territory		11,211,048	7,976,715	498,268	7,976,715	16,451,700
8. Other changes in volume						
Net Changes		(606,437)	1,180,410	(498,268)		682,141
9. Closing Stocks						

Annex 2 Geomorphological condition indicators

Climate and Rainfall. Daily rainfall readings from weather stations of PAGASA and other local sources within LdB were averaged annually and interpolated. Rainfall data were primarily used as input to sedimentation modelling. High rainfall is observed in some parts of LdB especially at the Sierra Madre mountain ranges.

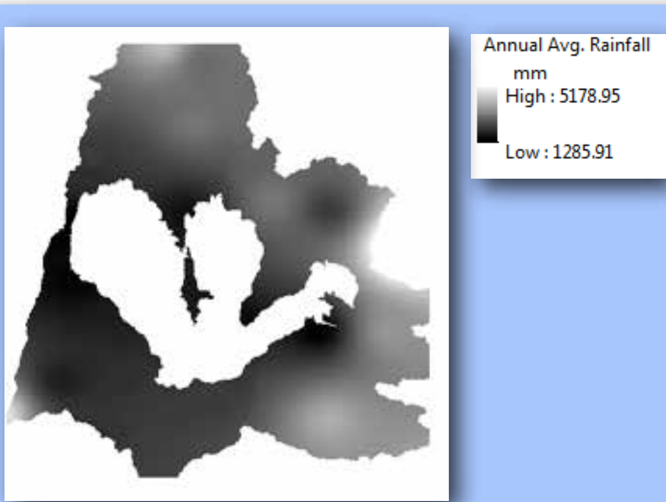

Figure A2.1 Annual average rainfall in LdB and Climate Type

Soil Texture. Soil texture defines the relative proportions of sand, silt, and clay. Texture contributes to the erodibility property of soils which were used as input for modelling sedimentation. Data came from the Land Management Unit (LMU) of the Bureau of Soils and Water Management (BSWM) with classifications from official soil reports of actual soil tests. The LdB region is composed of a variety of soil classification as shown in Figure A2.2.

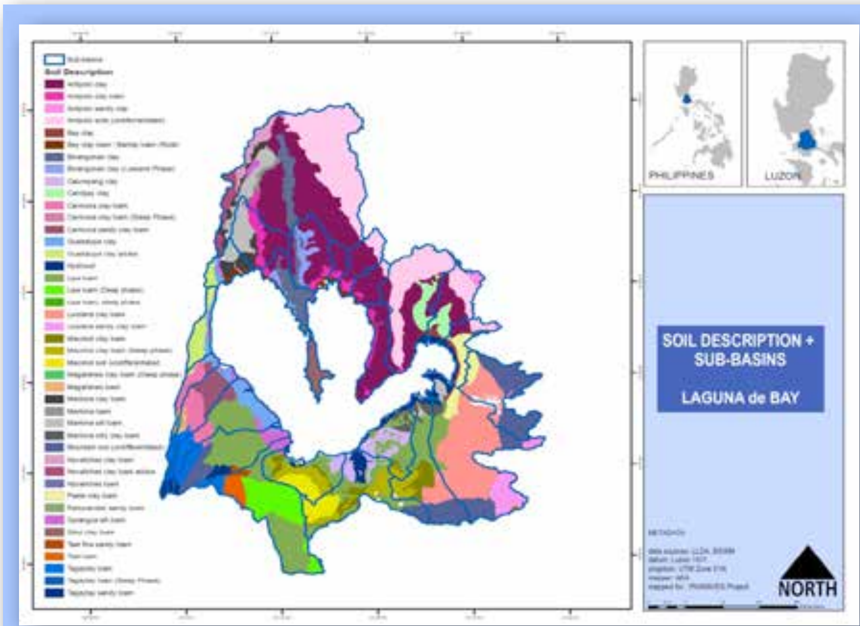

Figure A2.2 Soil classification within LdB region

Annex 2 Geomorphological condition indicators (cont'd)

Slope. Spatial data came from NAMRIA-DENR with classification of slope in percent rise. Slope defines land classification is aligned with (PD 705, s.1975). Among others, this classification shows that there shall be no 'Alienable and Disposable' land (essentially land that can be converted to cropland) on slopes steeper than 18% slope. Moreover, according to this regulation, at least 50% of the forest cover on slopes shall be considered as protection forests. Slope data were used in modelling soil loss/erosion of the watershed using Revised Universal Soil Loss Equation (RUSLE).

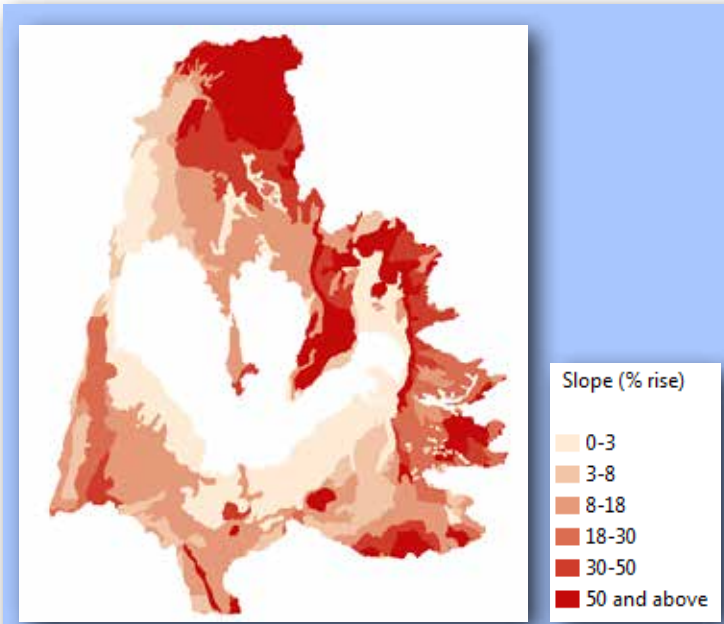

Figure A2.3 Slope classification in LdB (DENR)

Annex 3 Additional data for fisheries

Table A3.1. Open water fishermen: Number of survey respondents per municipality per zone

ZONE	Municipality	Number of Respondents
A	Muntinlupa	2
	Taguig	1
B	San Pedro	1
	Binan	1
	Santa Rosa	1
	Cabuyao	1
	Calamba	1
	Los Banos	1
	Bay	1
C	Pila	1
	Victoria	1
	Santa Cruz	1
	Lumban	1
	Kalayaan	1
	Paete	1
	Pakil	1
	Pangil	1
	Mabitac	1
D	Morong	1
	Baras	1
	Tanay	1
	Pililia	1
	Jala-jala	1
E	Angono	1
	Cardona (Main)	1
	Binangonan (main)	2
F	Cardona (Talim Island)	1
	Binangonan (Talim Island)	1
TOTAL:		30

Table A3.2 Fishpen Operators: Number of survey respondents per municipality per zone.

Zone	Municipality	Number of Respondents		
		1-10 hectares	11-25 hectares	>25 hectares
A	Muntinlupa	2	2	1
	Taguig	2	1	1
B	Binan	1	2	
	Calamba			1
	San Pedro	2	1	
C	Jala-jala			1
D	Pililia			1
	Tanay			1
E	Binangonan (Main)	1		1
	Cardona (Main)	1	2	1
F	Cardona (Talim)		1	1
	Binangonan (Talim)	1	1	1
TOTAL:		10	10	10

Annex 3 Additional data for fisheries

Table A3.3. Fishcage Operators: Number of survey respondents per municipality per zone

ZONE	Municipality	Number of Respondents
A	Muntinlupa	2
	Taguig	2
B	Binan	2
	Calamba	2
	San Pedro	2
	Santa Rosa	1
	Los Banos	1
C	Pila	1
	Santa Cruz	1
	Paete	1
	Pangil	1
	Pakil	1
	Kalayaan	1
	Bagunbong, Jala-jala	2
D	Jala-jala	1
	Pililia	1
	Tanay	1
E	Cardona (Main)	1
	Binangonan (main)	2
F	Cardona (Talim Island)	2
	Binangonan (Talim Island)	2
TOTAL:		30

Table A3.4. Average fish catches (in kg/ha) in open water fisheries per lake zone (2014)

Lake Zone	Location	Average harvest in kg per hectare
A	Muntinlupa and Taguig in Metro Manila (West Bay Areas)	9,041
B	San Pedro, Binan, Sta. Rosa, Cabuyao, Calamba, Los Banos, and Bay in the province of Laguna (West Bay to South Bay Areas)	27,825
C	Pila, Victoria, Sta.Cruz, Lumban, Kalayaan, Paete, Pakil, Pangil and Mabitac in the province of Laguna (East Bay Areas)	18,400
D	Morong, Baras, Tanay, Pililia and Jala-jala in Province of Rizal (Central Bay Area)	6,981
E	Angono, Cardona (main), and Binangonan (main) in the province of Rizal (West Bay to Central Bay areas)	4,766
F	Cardona and Binangonan (Talim Island)	10,750

Annex 3 Additional data for fisheries

Table A3.5. Enumerators of the LLDA WAVES Fishery Survey

Fisheries Account

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Resource Person for the Fisheries Account

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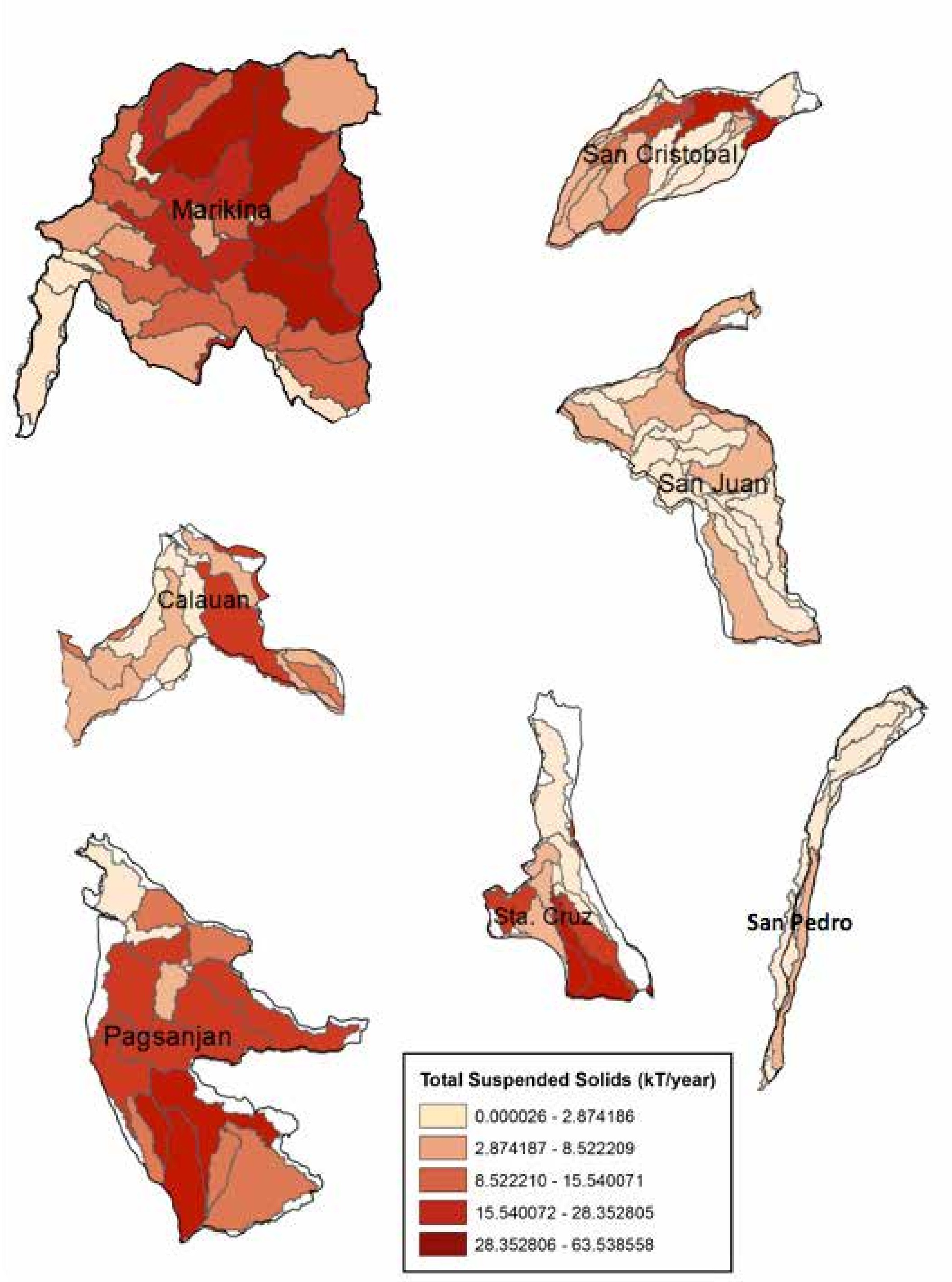
Annex 4 Sediment retention per sub-watershed



Annex 5 Population at flood risk in the Laguna Lake shore zone, per municipality

Lakeshore Municipality	PROVINCE	2000 Population	2010 Population	population increase	Municipal Area (ha)	Affected Area (ha) per Elevation				% of Affected Area (ha) per Elevation				Affected Population per Elevation 2000				Affected number of Households per Elevation (2000)				Affected Population per Elevation (2010)				Affected number of Households per Elevation (2010)			
						12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5 m	12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5m
Bay	LAGUNA	43,762	55,698	27%	4,052	158	171	296	419	0.04	0.042	0.073	0.103	1,704	1,849	3,201	4,528	370	402	696	984	2,169	2,353	4,075	5,762	471	512	886	1,253
Cabuyao	LAGUNA	201,186	248,436	23%	4,666	63	70	86	400	0.01	0.015	0.018	0.086	2,731	3,020	3,697	17,258	594	656	804	3,752	3,372	3,729	4,565	21,311	733	811	992	4,633
Calauan	LAGUNA	43,284	74,890	73%	7,709	97	119	231	355	0.01	0.015	0.030	0.046	547	667	1,300	1,994	119	145	283	434	946	1,154	2,249	3,451	206	251	489	750
City Of Biñan	LAGUNA	201,186	283,396	41%	4,805	416	417	421	449	0.09	0.087	0.088	0.094	17,408	17,478	17,617	18,819	3,784	3,800	3,830	4,091	24,521	24,620	24,816	26,509	5,331	5,352	5,395	5,763
City Of Calamba	LAGUNA	281,146	389,377	38%	13,105	461	462	481	527	0.04	0.035	0.037	0.040	9,882	9,911	10,326	11,311	2,148	2,155	2,245	2,459	13,686	13,727	14,301	15,666	2,975	2,984	3,109	3,406
City Of Santa Rosa	LAGUNA	185,633	284,670	53%	4,811	105	105	110	188	0.02	0.022	0.023	0.039	4,054	4,065	4,258	7,269	881	884	926	1,580	6,217	6,234	6,529	11,147	1,352	1,355	1,419	2,423
Famy	LAGUNA	10,419	15,021	44%	3,153	130	157	168	196	0.04	0.050	0.053	0.062	428	519	555	648	93	113	121	141	617	748	800	934	134	163	174	203
Kalayaan	LAGUNA	19,580	20,944	7%	4,593	265	272	281	290	0.06	0.059	0.061	0.063	1,128	1,160	1,196	1,236	245	252	260	269	1,207	1,240	1,279	1,322	262	270	278	287
Los Baños	LAGUNA	82,027	101,884	24%	5,004	197	199	200	209	0.04	0.040	0.040	0.042	3,237	3,257	3,285	3,427	704	708	714	745	4,020	4,045	4,080	4,257	874	879	887	925
Lumban	LAGUNA	21,996	29,470	34%	9,213	1,823	1,910	1,986	2,084	0.20	0.207	0.216	0.226	4,353	4,559	4,741	4,975	946	991	1,031	1,082	5,831	6,108	6,352	6,666	1,268	1,328	1,381	1,449
Mabitac	LAGUNA	13,309	18,618	40%	5,938	550	651	1,022	1,274	0.09	0.110	0.172	0.215	1,232	1,458	2,291	2,856	268	317	498	621	1,723	2,040	3,205	3,995	375	444	697	869
Paete	LAGUNA	21,809	23,523	8%	2,051	137	155	175	190	0.07	0.076	0.085	0.093	1,459	1,653	1,858	2,020	317	359	404	439	1,574	1,782	2,005	2,179	342	387	436	474
Pagsanjan	LAGUNA	32,622	39,313	21%	4,076	57	98	146	202	0.01	0.024	0.036	0.050	459	786	1,172	1,620	100	171	255	352	553	947	1,412	1,952	120	206	307	424
Pakil	LAGUNA	18,021	20,822	16%	2,264	479	506	533	559	0.21	0.224	0.235	0.247	3,814	4,030	4,241	4,446	829	876	922	967	4,407	4,657	4,901	5,137	958	1,012	1,065	1,117
Pangil	LAGUNA	20,698	23,201	12%	3,226	777	861	932	987	0.24	0.267	0.289	0.306	4,986	5,521	5,979	6,329	1,084	1,200	1,300	1,376	5,589	6,189	6,702	7,095	1,215	1,345	1,457	1,542
Pila	LAGUNA	37,427	46,534	24%	2,839	270	293	462	647	0.09	0.103	0.163	0.228	3,555	3,858	6,086	8,526	773	839	1,323	1,854	4,420	4,797	7,567	10,601	961	1,043	1,645	2,305
San Pedro	LAGUNA	231,403	294,310	27%	2,016	41	41	41	42	0.02	0.021	0.021	0.021	4,752	4,752	4,752	4,808	1,033	1,033	1,033	1,045	6,044	6,044	6,044	6,116	1,314	1,314	1,314	1,329
Santa Cruz	LAGUNA	92,694	110,943	20%	3,684	568	706	939	1,125	0.15	0.192	0.255	0.305	14,283	17,761	23,633	28,293	3,105	3,861	5,138	6,151	17,094	21,258	28,285	33,864	3,716	4,621	6,149	7,362
Santa Maria	LAGUNA	24,574	26,839	9%	13,229				0	-	-	-	0.000	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Siniloan	LAGUNA	29,902	35,363	18%	2,024	345	413	494	620	0.17	0.204	0.244	0.306	5,103	6,098	7,297	9,164	1,109	1,326	1,586	1,992	6,035	7,211	8,629	10,837	1,312	1,568	1,876	2,356
Victoria	LAGUNA	29,765	34,604	16%	2,816	355	428	566	897	0.13	0.152	0.201	0.319	3,754	4,522	5,986	9,483	816	983	1,301	2,061	4,364	5,258	6,959	11,024	949	1,143	1,513	2,397
City Of Makati	NCR	471,379	529,039	12%	311	1	1	3	14	0.00	0.005	0.008	0.045	1,620	2,247	3,845	21,433	352	488	836	4,659	1,818	2,521	4,316	24,055	395	548	938	5,229
City Of Muntinlupa	NCR	379,310	459,941	21%	3,804	126	126	128	134	0.03	0.033	0.034	0.035	12,547	12,560	12,718	13,326	2,728	2,730	2,765	2,897	15,214	15,230	15,421	16,159	3,307	3,311	3,352	3,513
City Of Pasig	NCR	505,058	669,773	33%	3,183	97	137	959	1,511	0.03	0.043	0.301	0.475	15,426	21,755	152,159	239,721	3,353	4,729	33,078	52,113	20,457	28,849	201,783	317,901	4,447	6,272	43,866	69,109
Pateros	NCR	57,407	64,147	12%	184		0	8	68	-	0.001	0.044	0.372	0	85	2,509	21,346	0	19	545	4,640	0	95	2,803	23,852	0	21	609	5,185
Quezon City	NCR	2,173,831	2,761,720	27%	3,261	7	8	9	11	0.00	0.002	0.003	0.003	4,462	5,403	6,242	7,497	970	1,175	1,357	1,630	5,668	6,864	7,930	9,525	1,232	1,492	1,724	2,071
Taguig City	NCR	467,375	644,473	38%	2,827	635	759	1,142	1,427	0.22	0.268	0.404	0.505	104,907	125,436	188,786	235,957	22,806	27,269	41,040	51,295	144,659	172,967	260,321	325,366	31,448	37,602	56,591	70,732
Angono	RIZAL	74,668	102,407	37%	2,138	198	198	198	199	0.09	0.093	0.093	0.093	6,931	6,931	6,931	6,950	1,507	1,507	1,507	1,511	9,506	9,506	9,506	9,532	2,066	2,066	2,066	2,072
Baras	RIZAL	24,514	32,609	33%	2,601	154	198	248	336	0.06	0.076	0.095	0.129	1,456	1,867	2,334	3,166	317	406	507	688	1,937	2,483	3,104	4,211	421	540	675	915
Binangonan	RIZAL	187,691	249,872	33%	4,782	1,636	1,638	1,644	1,655	0.34	0.343	0.344	0.346	64,235	64,288	64,512	64,960	13,964	13,976	14,024	14,122	85,516	85,586	85,884	86,481	18,590	18,606	18,671	18,800

Annex 5 Population at flood risk in the Laguna Lake shore zone, per municipality

Lakeshore Municipality	PROVINCE	2000 Population	2010 Population	population increase	Municipal Area (ha)	Affected Area (ha) per Elevation				% of Affected Area (ha) per Elevation				Affected Population per Elevation 2000				Affected number of Households per Elevation (2000)				Affected Population per Elevation (2010)				Affected number of Households per Elevation (2010)			
						12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5 m	12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5m	12.5m	13.5m	14.5m	15.5m
Cainta	RIZAL	242,511	311,845	29%	1,260	0	6	60	69	0.00	0.005	0.047	0.055	26	1,100	11,510	13,324	6	239	2,502	2,897	34	1,415	14,800	17,133	7	308	3,217	3,725
Cardona	RIZAL	39,003	47,414	22%	2,914	1,412	1,419	1,436	1,453	0.48	0.487	0.493	0.499	18,905	18,993	19,221	19,451	4,110	4,129	4,178	4,229	22,981	23,089	23,366	23,646	4,996	5,019	5,080	5,140
Jala-Jala	RIZAL	23,280	30,074	29%	4,756	320	336	367	417	0.07	0.071	0.077	0.088	1,565	1,644	1,797	2,043	340	357	391	444	2,022	2,123	2,321	2,639	440	462	505	574
Morong	RIZAL	42,489	52,194	23%	3,836	345	381	444	567	0.09	0.099	0.116	0.148	3,827	4,227	4,918	6,290	832	919	1,069	1,367	4,701	5,192	6,041	7,727	1,022	1,129	1,313	1,680
Pililla	RIZAL	45,275	59,527	31%	6,624	505	512	539	596	0.08	0.077	0.081	0.090	3,454	3,503	3,689	4,077	751	761	802	886	4,541	4,605	4,851	5,361	987	1,001	1,055	1,165
Tanay	RIZAL	78,223	98,879	26%	11,594	235	247	261	292	0.02	0.021	0.023	0.025	1,591	1,668	1,767	1,973	346	363	384	429	2,011	2,109	2,233	2,494	437	458	485	542
Taytay	RIZAL	198,183	288,956	46%	3,003	894	933	1,164	1,255	0.30	0.311	0.388	0.418	59,042	61,597	76,829	82,811	12,835	13,391	16,702	18,002	86,085	89,810	112,018	120,741	18,714	19,524	24,352	26,248
		6,652,640	**8,580,726**	29%									TOTAL	**388,860**	**430,226**	**673,237**	**893,338**	84,535	93,527	146,356	194,204	**521,538**	**576,586**	**901,455**	**1,186,648**	113,37	125,345	195,968	257,967

Annex 6 Spreadsheet model used to analyze flood costs

Step 1. Calculating the number of houses flooded

		Houses flooded per flood zone			
Year	Flood Level	13.5-14.5m flood zone	14.5-15.5m flood zone	15.5-16.5m flood zone	13.5-14.5m flood zone
1997	Insert flood level	=MAX(0,MIN(1,(flood level-12.5))*#houses)	=MAX(0,MIN(1,(flood level-13.5))*#houses)	=MAX(0,MIN(1,(flood level-14.5))*#houses)	=MAX(0,MIN(1,(flood level-15.5))*#houses)
...	"	"	"	"	"
2014	Insert flood level	"	"	"	"

The number ofhouses is calculated per year and per flood zone (see Table 6.5. in the main report.

Step 2. Calculating damage costs

	Damage costs per flood zone				Damage costs houses all flood zones	Total Damage costs
Year	12.5-13.5m flood zone	13.5-14.5m flood zone	14.5-15.5m flood zone	15.5-16.5m flood zone		
1997	=MAX(0,0.0614*(inundation depth * #houses flooded* house price)	=MAX(0,0.0614*(inundation depth * #houses flooded* house price)	=MAX(0,0.0614*(inundation depth * #houses flooded* house price)	=MAX(0,0.0614*(inundation depth * #houses flooded* house price)	=sum(all damage costs)	=damage costs houses * 1.2
...		"	"	"	"	"
2014		"	"	"	"	"

Annex 7 Flood risk maps

A flood risk map was derived using the number of households within the flood plain areas up to 14.5m lake level or 4.5 meter above sea-level (MASL), which correspond to the worst flood event recorded in history (in 1919). In other words, flood risks were visualized spatially by calculating the effects of a 14.5 m flood for the shore of Laguna Lake. Demographic data in the various sections of the flood plain are according to Annex 5 (PSA data). The number of households affected was plotted per municipality and dot density was used to come up with the number of flood-affected households per hectare (HH/ha). This output was used in combination with flood damage cost parameters from the model specified in Annexes 4 and 6 to generate the potential flood damage cost map in pesos per hectare or pesos/ha.

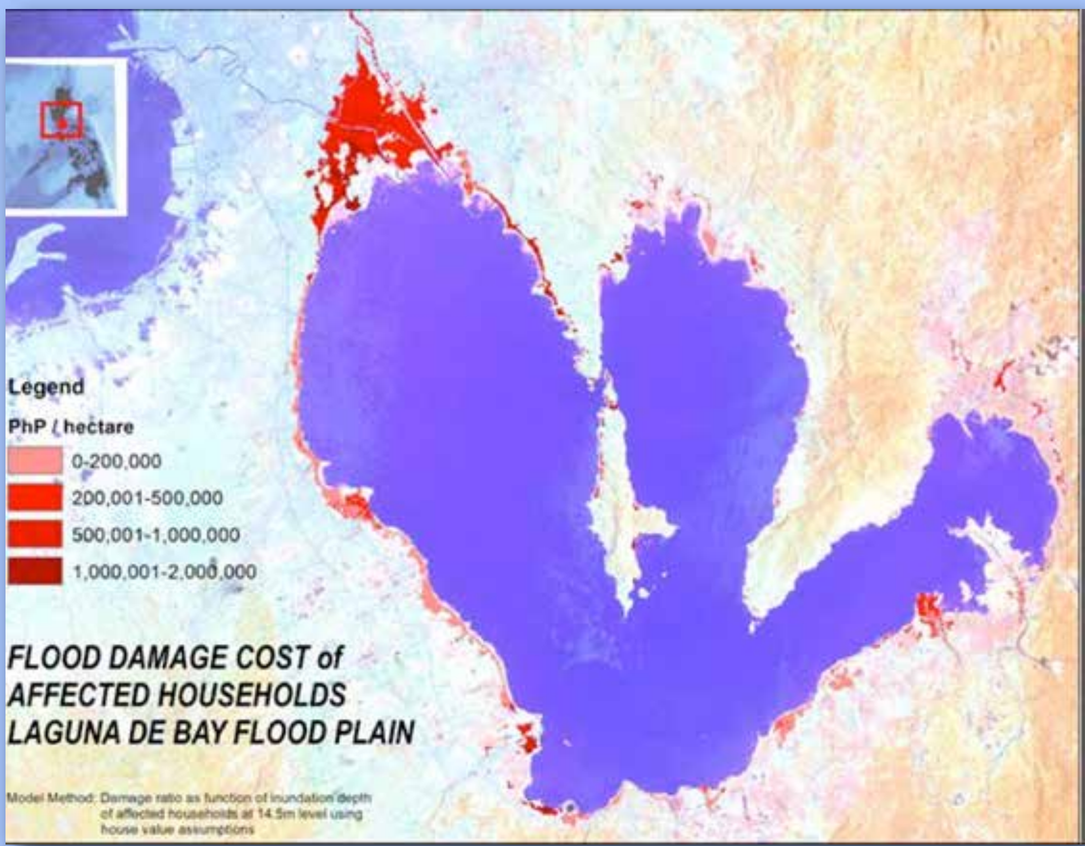


Figure A7.1. Flood risk expressed as potential damage costs (in pesos per ha)

Annex 8 Data quality assurance for Ecosystem Accounting

In principle, the data quality standards for Ecosystem Accounting are comparable to those of the National Accounts. However, it needs to be kept in mind that ecosystem accounting is still in an experimental phase, and that trial and error is needed to pinpoint the best approaches for the biophysical and monetary analysis of ecosystems and the services they supply.

In the WAVES Philippines Ecosystem Accounting pilot, the authors have have made every effort to select the most accurate modelling and valuation approach for each account on the basis of the available data. However, data shortages were a significant concern, for instance in relation to effluent loading by different sectors including the emissions of other pollutants than BOD. In view of data deficiencies, some datasets have been collected by the TWG, for instance with regards to fisheries.

Further work on enhancing the accuracy of the datasets would be needed if ecosystem accounting would be continued in the future. In addition, more work is needed to pinpoint the accuracy of the used data, and the sensitivity of the ecosystem services models for the underlying assumptions. Due to time constraints this was not possible in this first phase of the accounting project.

Based on the Eurostat Data Quality Framework[2], some guidance is provided below for handling data in the compilation of ecosystem accounts, specified for five key considerations in assessing data quality.

Relevance
The selection of ecosystem services and assets needs to be guided by user needs, usually in aide of informing specific policy questions, and with an eye to integration with wider information frameworks. Users include local, regional, and national government, NGOs, academia and the general public.

Accuracy and reliability
Where possible, remote sensing datasets need to be field validated using sampling points, and the validation approach, number of sample points and measurement errors need to be published. Questionnaire surveys (for fishing, agricultural production) need to be assessed for sampling or non-sampling error, and standard deviations in the results should be published.

Timeliness and punctuality
The presented accounts need to be compiled with the most up-to-date information available and released within the timeframe requested.

Coherence and comparability
Where possible, data in the accounts needs to be (and has been) compiled using the System of Environmental-Economic Accounting Experimental Ecosystem Accounting framework and the associated Technical Recommendations for SEEA-EEA. This framework ensures the concepts and measures are comparable between the accounts and other standardised macro-economic datasets such as the System of National Accounts.

Accessibility and clarity
All data to be compiled in the ecosystem accounts needs to be accessible and clear for the users. Interactions with users on a regular basis is important in order to update users on recent developments and to provide insights in how the accounts can be best made available to existing and potential users. Note that these pilot accounts are released in accordance with the World Bank policy on access to information, available at http://documents.worldbank.org/curated/en/2010/07/12368161/world-bank-policy-access-information

[9] *See:* http://ec.europa.eu/eurostat/quality

Annex 9 Calculation of the Resource Rent

(From the SEEA Central Framework)

Relationships between different flows and income components
Output (sales of extracted environmental assets at basic prices, includes all subsidies on products, excludes taxes on products)
Less Operating costs
Intermediate consumption (input costs of goods and services at purchasers; prices, including taxes on products)
Compensation of employees (input costs for labor)
Other taxes on production plus other subsidies on production
Equals Gross operating surplus -- SNA basis*
Less Specific subsidies on extraction
Plus Specific taxes on extraction
Equals Gross operating surplus -- for the derivation of resource rent
Less Use costs of prduced assets
Consumption of fixed capital (depreciation) + return to produced assets
Equals Resource Rent
Depletion + net return to environmental assets**
* Strictly speaking, this accounting identity also includes gross mixed income (the surplus earned by unincorporated enterprises) and should be adjusted for net taxes and subsidies on production. These details do not affect the logic of the plantation provided. ** In principle, the net return to environmental assets derived here also incorporates a return to other non-produced assets (e.g. marketing assets and brands), as these assets also play a role in generating the operating surplus. These returns are ignored in the formulation presented here.

Wealth Accounting and the Valuation of Ecosystem Services

Wealth Accounting and the Valuation of Ecosystem Services (WAVES) is a global partnership led by the World Bank that aims to promote sustainable development by ensuring that natural resources are mainstreamed in development planning and national economic accounts.

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