Republic of the Philippines

NWRB Permit Management Process

A Context-Aware Groundwater Permitting System – Proof of Concept

April 22, 2016

GWA02

EAST ASIA AND PACIFIC
A Context-Aware Groundwater Permitting System –
Proof of Concept

Final Report

March 2016
ACKNOWLEDGMENTS

This is the final report for the National Water Resources Board (NWRB) Permit Management System, the technical assistance of the World Bank Water and Sanitation Program to NWRB. The objective of this technical assistance was to develop a prototype for the water permit management system and complete a pilot implementation for this system applied to a group of approximately 100 applicants defined by NWRB. The pilot was intended to improve the permit management process by making it easier for applicants to file and complete their water permit application process, making data from permittees easily accessible and useful for decision-making purposes, and to make billing and collection of fees and charges more efficient.

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Acknowledgment is also given to the cooperation of the NWRB management and staff who provided information needed in developing the system, led by Executive Director Dr. Sevillo David, Jr.
# ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
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<tr>
<td>AEM</td>
<td>analytic element method</td>
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<tr>
<td>CWP</td>
<td>conditional water permit</td>
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<tr>
<td>DPWH</td>
<td>Department of Public Works and Highways</td>
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<td>DW</td>
<td>deep well</td>
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<td>IBM</td>
<td>IBM Research Africa</td>
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<td>IT</td>
<td>information technology</td>
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<td>IWRM</td>
<td>integrated water resources management</td>
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<tr>
<td>KPI</td>
<td>key performance indicators</td>
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<td>MCM</td>
<td>million cubic meters</td>
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<td>NWRB</td>
<td>National Water Resources Board</td>
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<td>PPP</td>
<td>public-private partnership</td>
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<td>SP</td>
<td>spring</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>WP</td>
<td>water permit</td>
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<td>WPA</td>
<td>water permit application</td>
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</tbody>
</table>
A Context-Aware Groundwater Permitting System – Proof of Concept

CONTENTS

EXECUTIVE SUMMARY .............................................................................................................................. 1

I. INTRODUCTION ..................................................................................................................................... 5
   A. PROBLEM CONTEXT/ORIGINS ............................................................................................................. 5
   B. GROUNDWATER MANAGEMENT AND ISSUES ............................................................................ 7
   C. PAST INITIATIVES ON DATA SHARING AND UPDATING ............................................................. 11
   D. REQUEST OF GOVERNMENT OF THE PHILIPPINES .............................................................. 11

II. TECHNICAL ASSISTANCE OBJECTIVES .......................................................................................... 12

III. IMPLEMENTATION ............................................................................................................................. 13
    A. SCOPING ......................................................................................................................................... 14
    B. RESEARCH AGREEMENT AND PARTNERSHIP ............................................................................ 14
    C. INTELLECTUAL PROPERTY .......................................................................................................... 14
    D. FINANCIAL MODEL ....................................................................................................................... 14
    E. STUDY METHODOLOGY AND PROOF OF CONCEPT DEVELOPMENT ........................................ 15
    F. SYSTEM CONFIGURATION ............................................................................................................ 25
    G. SUPPORT FOR MIGRATION AND ACTION BY NWRB .......................................................... 26

IV. CONCLUSION ..................................................................................................................................... 27

V. KEY RECOMMENDATIONS .................................................................................................................. 28

VI. LIST OF ANNEXES ............................................................................................................................. 30

ANNEX 1 – REQUEST OF THE GOVERNMENT OF THE PHILIPPINES ....................................................... 30
ANNEX 2 – REVIEW OF THE PHILIPPINE WATER RIGHTS SYSTEM ....................................................... 30
ANNEX 3 – DETAILED WATER PERMIT APPLICATION PROCESS ............................................................ 30
ANNEX 4 – WATER PERMITS REVENUES AND EXPENDITURES ............................................................ 30
ANNEX 5 – FEES AND CHARGES ........................................................................................................... 30
ANNEX 6 – PERMITTING SYSTEM USER GUIDE .................................................................................... 30
ANNEX 7 – APPLICATION OF THE AEM MODEL TO THE SANTA ROSA WATERSHED .................... 31
ANNEX 8 – PERMITTING JOURNEY MAP ............................................................................................... 31

List of Maps

Map 1. Philippines Water Resources Management Areas ........................................................................... 8

List of Figures

Figure 1. NWRB Permits Summary ........................................................................................................... 11
Figure 2. Overview of the Digital Aquifer Connected Ecosystem Solution for Groundwater ..................... 13
Figure 3. NWRB Revenue Projections – 2015 to 2020 ............................................................................ 15
Figure 4. Flowchart of NWRB’s “As-Is” Permitting Process .................................................................. 17
Figure 5. Simplified View of NWRB’s “To-Be” Permitting Process ....................................................... 19
Figure 6. Overview of Requirements for NWRB’s New Permitting System ........................................... 19
List of Tables

Table 1. Overview of Critical Water Resources Regions .......................................................... 9
Table 2. Subject Matter Expert (SME) Goals and Tools for Permitting .................................. 18
Table 3. Data Requirements .................................................................................................... 20
EXECUTIVE SUMMARY

1. In the Philippines, it is estimated that available water is three times the annual use but there are serious seasonal and geographic shortages, not ameliorated by the high cost of developing storage¹. Based on comprehensive planning studies², nine cities were flagged as having a high likelihood of future water shortages. As of 2014, a total of 21,460 permits were issued, more than 50 percent of which are for groundwater allocations.

2. The National Water Resources Board (NWRB) serves as a water resource regulatory body with functions in policy and water resources regulation. However, given its small staff, limited financial resources and limited regional presence, NWRB has not been able to completely fulfill its mandate, and has concentrated mainly on the approval (but little enforcement) of water rights.

3. This report documents the development of a cloud-hosted, context-aware decision-making system for water management. The purpose of the system is to automate tasks (both routine and complex) and to improve the quality of the information and interpretations available to decision makers and permitting staff, ultimately enhancing the capacity for stewardship of water resources in the Philippines. The new context-aware system, a so-called “connected water management system”, signals a first step toward changing this status quo.

Output

4. From June to December 2015, the NWRB Permit Management System proof of concept was developed as an integrated permitting framework that automates and links administrative processes with an aquifer model that is able to update the effects on the aquifer of potential additional wells using data from existing permittees and sensors.

5. The proof of concept consists of two parts:

a. A cloud-hosted permit management system that automates the receipt, processing, evaluation and monitoring of water extraction permits; and

b. A prototype of a context driven decision-making model. Different from traditional physical models of an aquifer, the project aspires to develop the initial proof of a


‘context-aware’ system that uses machine learning algorithms to help understand aquifer characteristics based on the existing behavior and responses of the physical system (aquifer) to new events (such as the addition of new wells or continuous drawdowns from existing wells). This Proof of Concept successfully tested the algorithm in Santa Rosa, Laguna.

6. The proof of concept does not include a permit management system for surface water and NWRB’s permitting system does not cover water quality evaluations, which are dealt with by other government institutions.

7. The new system allows NWRB to upload actual data from permit applications, drill test reports and monitoring that were previously not integrated, and which functionality, in turn, provides basis for “automating” the analysis required to determine if a new well should be approved. The analytic element method (AEM) is the underlying modelling methodology used by the system. Using this system, distance to nearest well neighbors and the maximum decrease in water levels of nearby wells are continually assessed and presented as evidence for the NWRB staff to make the final judgment on approving a permit. The same system automates permit screening and tracking processes, increasing the accuracy of water allocation accounting and reducing the time required to execute administrative processes. The system has been built to allow modular development so that in the future, it is possible for the system to support streamlined monitoring and enforcement, incorporate other data sources in the analysis such as weather data to provide updated insights on the ground water levels, advise on how water fees should be structured to balance conservation and economic development goals.

Key Findings

8. Automating the different stages of evaluation and hosting it in the cloud allows different regulator’s staff to engage in the process in a more efficient and streamlined way and makes the system portable (i.e. not anchored in a server that is physically sited in one place). These simple enhancements increase the productivity of a very limited number of regulator’s staff.

9. Data that exists in NWRB (through reports submitted by permit holders) can more readily be analyzed and used for water governance. For example, the proof of concept assessed permit allocation versus usage over 10 years in the Laguna basin region (pilot area). The study found that nearly 50% of roughly 40 audited accounts show consumption above allocations. Those using more water than their allocation were industrial users such as those engaged in manufacturing or commercial services and who voluntarily report their usage on a timely basis. A beverage company, in particular, was found to be extracting 10x over its permit allocation. It is likely that such users are not aware of their excess or consider that the consequence for such behavior is low compared to the benefit and therefore, can pay the penalties if charged.
10. The system can pay for itself. A financial model was developed to capture NWRB’s revenue sources and expenditures related to water permits. Annual water charges comprise 83% of revenues, while application or filing fees and penalties comprise 8% each. This is based on the actual 60% collection efficiency. Meanwhile expenditures related to the proposed water permit system comprise 6% to 7% of revenues. The potential financial return from implementing the system could be significant. With a more efficient water permit management system, revenues can be expected to further improve as a result of the following benefits:

   a. More water permits granted or refused due to more efficient and faster processing period
   b. Potential to incorporate automatic billing of annual water charges on the anniversary date
   c. Ability to more effectively monitor over extraction and potential to incorporate automatic billing of penalties for water abstraction above the allocated volume.

11. The results from the Analytical Element Method (AEM) used as the basis of the modelling algorithm is robust compared to traditional, data- and computation-intensive grid-based modelling.

12. Enabling modularity in the design of a software system (using Application Protocol Interface) provides flexibility and future enhancements such as allowing other users to interface with and derive value from the system. Examples include: a. Provision of electronic notification to other government agencies involved in the regulatory process in lieu of notification by postal service, b. Submission of application online directly by applicants, and c. Integration with the billing and accounting system.

**Conclusion**

13. The proof of concept offers the following functionality: (i) continuous monitoring and forecasting of resource levels, (ii) process automation and workflow management, (iii) data aggregation and visualization, and (iv) decision support. The system developed presents a framework that demonstrates how intelligence can be embedded into the water management process. Inputs accessed more regularly from the environment such as continuously sensed water levels, water abstractions and user complaints about water supply abnormalities will be required to fully realize this intelligence.

**Key Recommendations**

14. The following are recommended:

15. **NWRB to focus on key actions that have a high efficiency pay-off.** Specific actions identified by the Project were: a. Current public notification policies do not allow e-notification to other government institutions and the public. Integrating e-notifications in the process could
shave at least 30 days off the application time. b. Acceptance of application package online is constrained by the requirement to submit legally notarized original documents. A policy allowing preliminary acceptance of scanned documents with original documents to be sent would save time and costs for permit applicants and encourage registration of use. c. Providing information to the public on areas where permits are no longer being issued.

16. **AEM model will need further verification and calibration and the NWRB hydrogeologists will need to have sufficient training to use and update the model.** The proof of concept tested the AEM in one pilot area. However, a number of assumptions had to be made and data on river flows were not available. The model requires a set of parameters to be entered and so to apply the model in other regions these parameters will be needed: aquifer depth, transmissivity and lake elevation. NWRB staff occasionally come across these information from different sources such as permit applicants and other donor-support projects. A trained user of the AEM model will be able to update the system and continue to test and verify its results. Selection of AEM has been based on the current situation at NWRB to provide an aquifer model that would work on relatively small data sets, uncomplicated hydrogeological features but provide reasonable result reliability. For the medium and long term projections, AEM may be coupled with the grid based models to provide better definition of boundary conditions and water budgets in addition to projections due to changes in climate, land use and population growth.

17. **Further develop the system to automate the collection of monitoring data, identifying and assessing fines for chronic over use.** This would reduce the manpower required to execute the monitoring and enforcement function. One of the options discussed with NWRB, for which they are open, is the outsourcing of the permit application and investigation process through a public-private partnership (PPP) similar to the Land Transport Office outsourcing of vehicle inspection functions. Permit management has revenue potential, especially considering the growing concern over scarcity of ground water. Permit administration could be coupled with resources management using more reflective pricing and use policies. This option will need due diligence and preparation support that is outside the scope of the current initiative.

18. **Increase engagement of a broader range of stakeholders.** For example, well drillers and existing permittees have expressed enthusiasm for a public portal where they can view existing permits to get an idea of the water allocations availability before they even go to NWRB. This potential to engage more users opens up new ideas such as using human sensors to improve water stewardship and governance.

19. **Link the water permit allocation policies to strategic planning based on determination of sustainable yields for aquifers.** Presently, water rights are allocated based on a ‘first come, first served’ basis without reference to any strategic policy or planning such as a River Basin Master Plan. The Digital Aquifer’s ability to predict sustainable yields is an
important input to such strategic planning exercises. Tools and guidelines are available from the Department of Public Works and Highways on Integrated Water Resource Management (IWRM) to prepare River Basin Master Plans.

I. INTRODUCTION

20. The work described in this report lays a foundation and points the way forward for a rethinking of how water management expertise can be facilitated and supported within developing and emerging contexts. Much of the expertise regularly required for sound decision making is perpetually in short supply. Beyond the establishment of a prototype system, the research begins to explore the following questions: What exactly is the nature of the expertise distilled by a professional hydrogeologist located anywhere in the world? What are the key tasks of such an expert? How could a machine or a system, capture some (or all of) this knowledge and execute the critical tasks that underlie good-decision making for groundwater management? This kind of thinking must shape the future of the water industry if we hope to make any progress in addressing the many technically under-resourced agencies around the world that are responsible for water management and stewardship.

A. Problem Context/Origins

21. The Philippines has surpassed the Millennium Development Goals for safe water supply, with 92% of households now having access to improved water services. However the challenge for reaching the “last mile” – poor households in usually remote areas – remains formidable. Thus the next goal of achieving universal coverage (by 2025 per Government Water Supply Sector Roadmap and (by 2030 per Sustainable Development Goals) sustainable, safe water services will require concerted effort in enabling policy reforms, capacity building and improved governance of utilities, and bigger and accelerated investments.

22. Water resources are viewed as a key enabler for national development in the Philippines. The NWRB was created to drive this enablement, serving as the water resources regulatory body with functions including policy formulation and coordination, water resource regulation, and economic regulation.

23. The Dublin Principles adopted by the Philippines and the wider international community served as a basis for the thinking about how to ensure that future water policy was more holistic. In particular,

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a. **The ecological principle** – water should be managed comprehensively (and not by independent actions of water using sectors) within the context of the river basin as the management and development unit. The river basin must be the basic unit of analysis with special attention being paid to the environment;

b. **The institutional principle** – water resources management (WRM) is best done when all stakeholders participate and actions should be devolved to the lowest level possible (the subsidiary principle); and

c. **The instrument principle** – water should be managed as an economic good or scarce resource— incentives and economic principles are to be used in improving allocation and enhancing water quality.

24. A range of political, institutional, financial and socioeconomic factors influence how these principles are actually implemented from country to country. The reality that presents itself in developing and emerging economies is that setting a comprehensive management plan and then expecting that a logical sequence of actions and events will unfold according to that plan is unrealistic. The messy water management landscape introduces complexity to decision-making, even at the lowest levels.

25. Because freshwater resources across the Philippines are unevenly distributed over space and time, NWRB must continually ask and reassess questions and decisions related to “how much water do we have now?” and “how much will we have in the future?” To address these questions, decision makers must have continuously updated knowledge of the interactions between surface water, groundwater, and the environmental system. Additionally, any decisions made with regard to water transfer and allocation must take into consideration the diverse objectives that include water supply, cost efficiency, and ecosystem protection.

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8 Ibid.


26. It is anticipated, then, that the water resources management tools of the future should have capability to continuously sense and acquire current insight about the environment to support decision makers who need to take the best actions, just-in-time, to match the current reality.

B. Groundwater Management and Issues

27. Water resources management in the Philippines is organized around 12 major river basins, designated as water resources management and planning units (Map 1). Overall, water supply is three times annual use but there are serious seasonal and geographic shortages, not ameliorated by the high cost of developing storage\(^\text{11}\). Based on comprehensive planning studies\(^\text{12}\), nine cities were flagged as having a high likelihood of future water shortages. Given their growing municipal and industrial water requirements, they have been prioritized for further study and investment (Table 1). While the development of new surface water sources has been proposed as the best option to head off shortages for several cities, public opposition to new dams\(^\text{13,14,15,16}\) and the high cost of surface sources in some instances has increased the interest to explore the groundwater resource potential.

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Map 1. Philippines Water Resources Management Areas
Table 1. Overview of Critical Water Resources Regions

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<thead>
<tr>
<th>City</th>
<th>Concern for Future Shortages</th>
<th>Water Resources Development Plan</th>
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<tbody>
<tr>
<td>Metro Manila (Region III)</td>
<td>HIGH</td>
<td>An estimated 98% of the Metro Manila’s water supply is sourced from the Angat Dam. With the potential for looming shortages, development of the Agos River was seen as the most promising new water resource, but so far, proposals to construct a dam have been rejected. The Kaliwa Dam Project, a 25-year build-operate-transfer contract to build a dam in General Nakar, Quezon appears to be the most promising option. Metro Manila is a restricted groundwater area so no new permits for groundwater withdrawals are being approved.</td>
</tr>
<tr>
<td>Metro Cebu (Region VII)</td>
<td>HIGH</td>
<td>Mananga dam proposed, but cost and dislocation of at least 500 households in Cebu city remains a major obstacle. Additional groundwater resource development not seen as viable for Metro Cebu.</td>
</tr>
<tr>
<td>Baguio City (Region I)</td>
<td>HIGH</td>
<td>Development of the surface water resource is cost prohibitive. Groundwater being explored as the more cost effective alternative</td>
</tr>
<tr>
<td>Davao City (Region XI)</td>
<td>MEDIUM</td>
<td>Projects for both surface water and groundwater resource development are planned. Surface water development projects such as the Saug River Multi-purpose project have been met with opposition from local leaders.</td>
</tr>
<tr>
<td>Angeles City (Region III)</td>
<td>MEDIUM</td>
<td>Focused on groundwater resource development.</td>
</tr>
<tr>
<td>Bacolod City (Region VI)</td>
<td>MEDIUM</td>
<td>Focused on groundwater resource development.</td>
</tr>
<tr>
<td>Iloilo City (Region VI)</td>
<td>MEDIUM</td>
<td>Focused on groundwater resource development.</td>
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<tr>
<th>City</th>
<th>Concern for Future Shortages</th>
<th>Water Resources Development Plan</th>
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</thead>
<tbody>
<tr>
<td>Cagayan do Oro City (Region X)</td>
<td>MEDIUM</td>
<td>The Bulanog-Batang dam was proposed but has been delayed for 15 years. Groundwater resource development was not considered viable for this region.</td>
</tr>
<tr>
<td>Zamboanga City (Region IX)</td>
<td>MEDIUM</td>
<td>Zamboanga currently faces water rationing during the summer. Plans to build a new dam are still in the discussion phase. Groundwater resource development is not considered a viable option for this region.</td>
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28. The total freshwater resource availability in the Philippines was estimated to be 145,990 MCM in 2003. While groundwater accounts for roughly 14 percent of this total, there is significant reliance on the resource in urban areas. As of 2014, a total of 21,460 permits were issued (Figure 1) allocating nearly 200,000 MCM of surface and groundwater resources combined. Of this total, there were 11,423 groundwater permits accounting for a total allocated volume of 3,822 MCM. Overall, more than 50 percent of the water permits managed by NWRB are for groundwater allocations.

29. NWRB’s system for issuing and enforcing these permits is paper-based and manual. To apply for a permit, individuals submit a paper form by mail or deliver completed applications by hand to the NWRB office in Quezon City. Some applicants have even reported making a special flight from the surrounding islands to deliver the permit in person. The average processing time for a water permit is currently more than one year.

30. The current approach for approving permits poses challenges. For example, a 30-year old model that likely does not reflect the current reality of aquifer basins, serves as the basis for making groundwater allocation decisions. Compared to the number of water permit applicants, there are also relatively limited NWRB staff doing field investigation for the water source. The district engineers of the Department of Public Works and Highways (DPWH) are tapped by NWRB to help in the field investigation. All communications among NWRB, DPWH and permit applicants are done through post mail which further delays the approval process.

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C. Past initiatives on data sharing and updating

31. The Government’s past attempts at developing information systems, supported by various development partners, for the water sector were piece-meal and were not sustained. As it relied on a public ‘nodal’ agency model, limited public resources always frustrated the continued renewal and usefulness of the system. This time around, the World Bank and NWRB wanted to explore a different approach that over the medium-term would lead to the development of a system where information drives value for different stakeholders who provide and use data rather than a ‘nodal’ agency model. It is premised on the use of existing (currently paper based) data for continuous updating of what is understood about aquifer systems and on the development of a system that can be modularly updated in the future to integrate different data sources and provide functionality for different stakeholders, for example, a public view of existing wells in a locality and current drawdowns of water.

D. Request of Government of the Philippines

32. NWRB is mandated by the Water Code of 1976 to coordinate water resources management activities at the central and regional levels. This effort involves more than 20 departments, government corporations and bureaus, as well as numerous regional and local...
entities. However, with its small staff, limited financial resources and regional presence, the
agency has been unable to completely fulfill its mandate, concentrating mainly on the approval
(but little enforcement) of water rights.\textsuperscript{26}

33. These issues are not new and have plagued the agency throughout much of its existence. The “connected water management system” would signal a first step toward changing the status quo. To begin this new line inquiry, the Government of the Philippines submitted a formal request to the World Bank for technical assistance on the effort (See Annex 1).

34. The functioning of the water rights regime in the Philippines and its administration by NWRB have been reviewed extensively elsewhere. A dual-report produced by the Water and Sanitation Program in 2003 (Annex 2) is included as an accompanying document to provide interested readers with such background.\textsuperscript{27}

II. TECHNICAL ASSISTANCE OBJECTIVES

35. The key deliverable for this TA is a proof of concept, cloud-hosted, context-aware water rights management system. The purpose of the system is to automate routine and complex tasks and to improve the quality of the information and interpretations available to decision makers, ultimately enhancing NWRB’s capacity for stewardship of the Philippines’ groundwater resource.

36. Specifically, the TA was intended to improve the permit management process (see Annex 3 for the Detailed Water Permit Application Process) by (i) making it easier for applicants to file and complete the water permit application process; and (ii) making data from applicants easily accessible and useful for permit decision-making, billing and more efficient collection of fees and charges. See Annex 5 for the schedule of fees and charges.

37. Key questions underlying the fulfilment of these objectives included:

   a. What is the nature of the expertise required for processing, issuing and enforcing water permits?

   b. To aid the issuing of permits, how do we develop robust, predictive models of aquifer drawdown that reliably indicate how addition of a new well will influence existing wells and the state of water storage in the aquifer?

   c. How would a continuously updated permitting system that supports the processing, issuing and enforcement of water permits be designed and implemented?


\textsuperscript{27} Water and Sanitation Program (2003). Review of the Philippine Water Rights System.
III. IMPLEMENTATION

38. IBM, through its cognitive and smarter planet initiatives in Africa, developed a connected water framework and product portfolio to address the silos and fragmentation in the sector. The Digital Aquifer is an example of one such product that coordinates access to and management of water resources (Figure 2). The idea underlying the building of connected ecosystems is to enhance the value of water and the sustainability of water management solutions. This idea that works for Africa also addresses the challenges facing the water sector in the Philippines. The connection gave rise to a co-creation process with the World Bank to explore how a “connected water ecosystem” could be built around groundwater. The sections that follow describe project scoping, the research partnership and resulting system for the Philippines that grew from the co-creation process.

Figure 2. Overview of the Digital Aquifer Connected Ecosystem Solution for Groundwater

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A. Scoping

39. A World Bank Mission was conducted in October 2014 to identify the data inputs, value drivers and stakeholders that shape the “connected water ecosystem”. It was determined that the most useful implementation of the “connected water ecosystem” would manifest as a water permit management system. Consequently, the two core pieces of work that were identified as critical for NWRB included:

a. A decision support system for groundwater management which would leverage existing groundwater data using non-linear data modeling techniques; and
b. A permit management system that will be in charge of the receipt, processing, decision-making and monitoring of applications for water extraction.

B. Research Agreement and Partnership

40. The World Bank and IBM Research Africa (IBM) entered into a partnership to develop a water permit management system that would improve NWRB’s water information database, with emphasis on first demonstrating a new permit management system. To this end, the World Bank and IBM agreed to complete a pilot implementation for permit management system and to link it to a prototype decision support system on groundwater management.

C. Intellectual Property

41. IBM has exclusive ownership of the context-aware permit management system and grants World Bank a perpetual, royalty free, non-transferrable license to use the system. This license also includes the right for the World Bank to grant a sub-license of the same scope to NWRB.

D. Financial Model

42. Prior to initiating the TA, the team and NWRB worked on understanding the financial implications of operating and maintaining the system and whether this would be affordable and make financial sense for NWRB.

43. A financial model was developed to capture NWRB’s revenue sources and expenditures related to water permits (see Annex 4). The table of fees and charges approved in July 2015 (see Annex 5) was assumed to be implemented from 2016 revenues onwards. Annual water charges comprise 83% of revenues, while application or filing fees and penalties comprise 8% each. This is based on the actual 60% collection efficiency.

44. Meanwhile expenditures related to the water permit system comprise 6% to 7% of revenues. These are composed of the cloud hosting and other maintenance expenses, supplies,
and depreciation of computer equipment and software for the development of the water permit management system. See Figure 3 for the revenue projections from 2015 to 2020.

Figure 3. NWRB Revenue Projections – 2015 to 2020

45. The improvement of the collection efficiency should be addressed with the enhancement of the current billing and accounts receivable system that will be inter-connected with the water permit management system through an Application Program Interface allowing automatic billing of water charges and imposition of penalties for over-extraction.

46. The potential financial return from implementing the system could be significant. With a more efficient water permit management system, revenues can be expected to further improve as a result of the following benefits:

   a. More water permits granted or refused due to more efficient and faster processing period
   b. Potential to incorporate automatic billing of annual water charges on the anniversary date
   c. Ability to more effectively monitor over extraction and potential to incorporate automatic billing of penalties for water abstraction above the allocated volume.

47. However, even with the efficiency benefits from the system, there are other constraints to NWRB fully realizing these benefits. The most important are:

   a. Rolling out a fully automated, online application process, which is not part of the current proof of concept
   b. Time lags related to the discretionary aspects of the evaluation given the limited number of evaluation team staff

E. Study Methodology and Proof of Concept Development

48. The methods used to address the research questions are outlined as follows:
1. What is the nature of the expertise required for processing, issuing and enforcing water permits?

49. Requirements drive system design, development and implementation. To generate system requirements that specify how the system should function and the tasks it should enable, a cognitive task analysis approach\(^ {29,30,31,32}\) guided our process of gathering requirements. The study team employed elements of this approach to better identify the cognitive elements that underlie goal generation, decision-making and judgments. In general, there were three key steps: i) knowledge elicitation, ii) analysis and iii) knowledge representation.

50. The study team reviewed the state of the existing system and actual workflows (not just the flowcharts documented on paper), identified gaps and proposed key areas where automation could make a difference. Interviews and focus group sessions were used to drive the data collection activities.

51. Key documents reviewed included the NWRB’s permitting flowchart (Figure 4), the most recent permit application form\(^ {33}\), the Water Code\(^ {34}\) and reports and forms related to the evaluation process. Key outputs from this step included a high-level process overview (Table 2 & Figure 5) and a summary of the key requirements for the new system (Figure 6).

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Figure 4. Flowchart of NWRB’s “As-Is” Permitting Process
## Table 2. Subject Matter Expert (SME) Goals and Tools for Permitting

<table>
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<tr>
<th>Permitting Steps</th>
<th>SME Goals</th>
<th>Tools</th>
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<tr>
<td>Screening</td>
<td>Help an applicant determine if his application is viable. Collect payment for viable permits.</td>
<td>Screener uses stand-alone Google Earth installation to check for restricted locations.</td>
<td>Water rights, restricted areas,</td>
<td>Receive permit, check for restricted location, accept payment, send for endorsement, issue permit to drill.</td>
</tr>
<tr>
<td>Endorsement</td>
<td>Allow the public to protest a new application. Obtain technical feedback from relevant local agencies.</td>
<td>Mail used to send endorsements and receive feedback from endorsing agencies.</td>
<td>Protest, community, local consultation.</td>
<td>Send letter to 10 agencies plus local engineer to post notice of application for 30 days; letters of endorsement sent back if no one protests.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Ensure new water allocations will not negatively impact neighbors or overall basin sustainability.</td>
<td>20-year old model and manual calculations used to evaluate and approve new wells.</td>
<td>Well evaluation, aquifer tests.</td>
<td>Review drilling report, calculate specific conductivity based on report, approve well if number is in an acceptable range.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Ensure permittees adhere to water use limits.</td>
<td>Quarterly monitoring reports submitted by permittees.</td>
<td>Economic growth, enforcement, balance.</td>
<td>Permittee submits quarterly report. Reports should be reviewed against allocation to determine over-extraction.</td>
</tr>
<tr>
<td>Administration</td>
<td>Ensure equitable distribution of water rights. Set and manage permitting KPIs.</td>
<td>Request excel reports as needed from permitting staff.</td>
<td>KPIs, stewardship, governance,</td>
<td>TBD.</td>
</tr>
</tbody>
</table>
Figure 5. Simplified View of NWRB’s “To-Be” Permitting Process

Figure 6. Overview of Requirements for NWRB’s New Permitting System
2. To aid the issuing of permits, how do we develop robust, predictive models of aquifer drawdown that reliably indicate how addition of a new well will influence existing wells and the state of water storage in the aquifer?

52. The decision making process for new well approval is not trivial. This is especially the case in the Philippines where a water permit grants a lifetime of access to water. As new wells are added, the total water available for other purposes is decreased and the operation of that well could reduce the quality of access at neighboring wells if the volume requested is too large. For example, if a new industrial well is placed too close to existing wells, a lowering of water levels in the area is possible. If this occurs, there could be interference with the operation of nearby well pumps and others might run out of water.

53. This means decision support for new wells, at a minimum, requires a current view of the water withdrawals in the area and a representation of aquifer dynamics that link water withdrawals to water levels.

54. To represent aquifer dynamics, a lightweight and flexible model based on the analytic element method (AEM) was selected. AEM is a mesh free approach that increases the robustness and in many cases the accuracy of the groundwater modeling effort. The flexible input requirements also make it well suited to the data-poor environments typical of developing and emerging economies. More details on the model and its implementation are included in Annex 6 – User Guide for the new permitting system.

55. To demonstrate the implementation of the permit evaluation module, the Laguna area was selected as the focus of study. The map of this area can be seen in Figure 2.1 of Annex 7, Application of the AEM Model to the Santa Rosa Watershed. Data requirements for implementing the AEM in this location are mainly list of permits granted including backlogs; monthly monitoring reports; aquifer location, type and properties; Historical drawdown predictions; Well yields; and Locations, discharges, elevations of the wells at the surface and the depths of the wells. Table 3 provides the details of these data requirements.

<table>
<thead>
<tr>
<th>Data Requested</th>
<th>Received?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permitting Efficiency Evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Laguna Existing Permits List</td>
<td>YES</td>
<td>Excel file with 811 records total, 794 active permits</td>
</tr>
<tr>
<td>- Laguna Backlogged Permits List</td>
<td>NO</td>
<td>Need to receive this list as an Excel file</td>
</tr>
<tr>
<td>- NWRB All permits summary</td>
<td>YES</td>
<td>This information will assist in refining the assumptions for the future processing capability</td>
</tr>
<tr>
<td>- ALL Permits List</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
### Data Requested

<table>
<thead>
<tr>
<th>Data Requested</th>
<th>Received?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ALL Backlogged Permits List</td>
<td>NO</td>
<td>and sustainability of the new permitting system.</td>
</tr>
<tr>
<td>• Laguna Monthly Monitoring Reports</td>
<td>PARTIAL</td>
<td>Ms. Nerizza Berdin provided 3-4 years of monitoring data for several wells in Laguna. But these only cover the 2004 to 2008 timeframe. We have requested additional and more recent data for these wells.</td>
</tr>
<tr>
<td><strong>Aquifer Model Development</strong></td>
<td>PARTIAL</td>
<td>Copy of 30 year old modelling study for Laguna has been identified.</td>
</tr>
<tr>
<td>• Aquifer Location &amp; Type</td>
<td>PARTIAL</td>
<td>To date, 307 scanned permits have been received (from the NWRB IT team) and reviewed for Laguna. Out of the total, 232 were groundwater permits while the remaining 75 were surface water permits. Unfortunately, not all of the 232 groundwater permits had a well evaluation sheet to indicate the static water level and other aquifer parameters. In total, there were 156 files with static water level data and 90 files with the drilling date. Additionally, 10 files had missing geographical coordinates for the water sources. <strong>We need more scanned permits/well logs.</strong></td>
</tr>
<tr>
<td>• Aquifer Properties: Hydraulic conductivity, transmissivity, anisotropy, strativity, specific yield, porosity, aquifer thickness (usually characterized through aquifer tests) for all the inhomogeneities that are part of the domain.</td>
<td>PARTIAL</td>
<td>Need more well data for these evaluations</td>
</tr>
<tr>
<td>• Historical drawdown predictions</td>
<td>PARTIAL</td>
<td></td>
</tr>
<tr>
<td>• Well yields - measured or estimated</td>
<td>PARTIAL</td>
<td></td>
</tr>
<tr>
<td>• Locations, discharges, elevations of the wells at the surface and the depths of the wells</td>
<td>PARTIAL</td>
<td></td>
</tr>
</tbody>
</table>

### Model Development and Validation

56. There are various methods to model a groundwater flow system. Many in the modeling community use finite difference methods (MODFLOW) or finite element methods. A relatively newer approach to groundwater flow is the analytic element method (AEM) developed in the late 1970's by O.D.L Strack and his colleagues. In contrast to finite difference and finite element methods, AEM is a mesh free method – that is, a method that does not rely on having a fixed computational grid.

57. Numerical methods such as the finite difference method and finite element method were originally defined on meshes of data points. In such a mesh, each point has a fixed number of

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35 This data will also aid the demand projections and estimations of water user behaviors.
predefined neighbors, and this connectivity between neighbors can be used to define mathematical operators like the derivative. These operators are then used to construct the equations to simulate flow—such as the Euler equations or the Navier–Stokes equations. But in simulations where the material being simulated can move around or where large deformations of the material can occur (as in simulations of plastic materials), the connectivity of the mesh can be difficult to maintain without introducing error into the simulation. If the mesh becomes tangled or degenerate during simulation, the operators defined on it may no longer give correct values. The mesh may be recreated during simulation (a process called remeshing), but this can also introduce error, since all the existing data points must be mapped onto a new and different set of data points. Mesh free methods are intended to remedy these problems.

58. Grid based models such as MODFLOW calculate the flow at each node of the grid. All key hydraulic parameters such as layer depth, permeability and water level must be allocated to each node before the model will run.

59. AEM does not require a grid which is important for model areas with scarce data sets. Other ground water modelling such as MODFLOW use conventional grid and require a great deal of data as input to the model. AEM can provide an analytical solution at any point of the model area without grid discretization which is not possible with MODFLOW.

60. As AEM modeling does not require a grid within the model domain the solution is calculated simultaneously over this essentially infinite domain. The key points to understand are then:

   a. Each source/sink is represented by an analytic solution such as wells, river reaches, water bodies, areal recharge.
   b. The solutions are not ambiguous and applies linear equations.
   c. If source/sinks are of unknown value, the values to match observed head are calculated by AEM.
   d. All the analytic functions are then solved simultaneously according to a matrix equation.

61. Annex 7 describes preliminary evaluation of the aquifer model developed using the AEM. In general, the model shows good agreement with field data based on the ability to reproduce static water levels in 13 wells in the Santa Rosa area of Laguna. The aquifer model requires more data for calibration before it can be used to reliably assist the well approval process. In particular, the following steps should be prioritized:

   a. **Develop a complete inventory of major wells**: Well logs provide an exact estimate of the groundwater extraction and this data combined with the recharge rate can be used to provide a range of insights that will improve groundwater management.
b. **Improve information collection for flow rates / heads of rivers**: The other important contributing factor for groundwater flow is the contribution of rivers. Flow rates or heads of rivers at periodic locations can be used to integrate the contribution of rivers into the aquifer model.

c. **Establish key aquifer parameters** such as transmissivity, the storage coefficient and whether the aquifer at a particular site is confined or unconfined. This will assist in the validation of the AEM groundwater model as well as other important indicators in understanding the available water budget.

62. The forward planning flowchart (Figure 7) provides the main steps in a groundwater permit management system by implementation of groundwater modelling to assist in the decision making process for the groundwater permit application. The blue highlighted area shows how the current pilot study fits in the overall management system and the other components are still needed to complete this process.

3. **How would a continuously updated permitting system that supports the processing, issuing and enforcement of water permits be designed and implemented?**

63. Based on the requirements gathering process, the following key functionalities were determined for the water management system:

   a. **Data Collection and Aggregation Hub** (static and dynamic data handling)
      1) Sensor collection component
      2) Form data collection component
      3) Weather data integration component
      4) Satellite data integration component

   b. **Aquifer (or other water model) integration module** that accepts model inputs and generates outputs

   c. **Map Based Data Visualization & Summarization** (timelines that show when a type of water data was added and provision of dynamic summaries of these types)

   d. **Print Reports** (tailored lists generated from initial or derived entities in the database)

   e. **User Management** (login, logout, role-based access, user tracking (what happened when and by whom?))
Figure 7. Forward Planning Flowchart

The flowchart presented in the figure below provides the main steps in a groundwater permit management system by implementation of groundwater modelling to assist in the decision making process for the groundwater permit application. The blue highlighted area shows how the current pilot study fits in the overall management system and the other components are still needed to complete this process.
64. A high level view of the architecture developed to deliver these functionalities is shown in Figure 8.

**Figure 8. Connected Water Ecosystem Illustration**

With the Digital Aquifer architecture and a range of possible inputs, the physical layer senses the environment via intermittent inputs from forms/mobile phones or via real-time sensor inputs.

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**F. System Configuration**

1. **Features of the new permitting system**

65. NWRB’s new context-aware permitting system includes the following functionality: (i) continuous monitoring and forecasting of resource levels, (ii) process automation and workflow management, (iii) data aggregation and visualization, and (iv) decision support.

66. These features enable the following benefits:

   a. Issue fines more quickly to those who are using water above their allocations as self-reported. By translating paper reports submitted by permit holders, the proof of concept was able to plot permit allocation versus usage charts over the lifetime of the permit (some over 10 years). In the Laguna basin region (pilot area), it was found
that nearly 50% of roughly 40 audited accounts show consumption above allocations. Those using more water than their allocation were industrial users such as those engaged in manufacturing or commercial services and who voluntarily report their usage on a timely basis. A beverage company, in particular, was found to be extracting 10x over its permit allocation. It is likely that such users are not aware of their excess or consider that the consequence for such behavior is low compared to the benefit and therefore, can pay the penalties if charged.

b. Dynamically assess water availability – when permits are issued, cancelled or revoked, system updates to reflect understanding of the water balance.

c. Automate permit processing, screen restricted/sensitive areas more quickly and maintain visibility on overall operational efficiency.

d. Proactively maintain continuously updated aquifer models for water scarce areas. Reduce the need to invest in ad hoc, one-off consultants to build water models.

e. In the future, scenario modeling to address questions such as “What is the result if users in an area are pulling out more water than we want to allow?” and “How will climate change impact water availability?”

2. Permit Management and Administration

67. Annex 8 - Permitting Journey Map illustrates how permit management works in the new system. Permit management and administration were implemented around the following ideas:

   a. Permits have three stages: i) pre-approval, ii) conditional water permit, and iii) final permit stage.
   b. Pre-approval has the following steps: screening, endorsement, protest (may/may not happen), permit to drill issuance, evaluation.
   c. The permit to drill also has four status types that need to be tracked – full compliance, partial compliance, extended, revoked (then it becomes inactive).
   d. A different type of number is used to track each stage.
   e. Permits in each of the three stages have one of two status types – i) active or ii) inactive. Those that are inactive have a range of reasons – cancelled by an agency, revoked by agency, withdrawn by applicant/permittee.

68. Active permits in the conditional and final permit stages subtract from the available water. If a permit becomes inactive for any reason, then the water that was originally allocated to that user is added back to the grand total of water available for that water basin.

G. Support for Migration and Action by NWRB

69. A User Guide (Annex 6) has been developed for the system and familiarization sessions have been held. Overall, the system has been well received by NWRB staff who look forward to having a smart and user-friendly system that can streamline the permitting process. The system
will continue to be available to NWRB until April 2016 to ensure continuity as discussions about long-term funding of the system are being finalized.

70. NWRB’s Executive Director is supportive of migrating to the cloud-hosted permitting system and bullish about being able to allocate sufficient budget to continue using the system. Based on the presentation, he briefed his Board on 16 December, 2015 and the World Bank task team received reports that the Board endorsed the migration and request for budget. The task team will seek written confirmation through a Board Resolution.

71. The USAID BeSecure Project\textsuperscript{36}, working on water resources and climate change, indicated their openness to providing bridge financing for the maintenance of the Digital Aquifer permitting system in the 8 month period in 2016 when the assistance from the World Bank ends and before the NWRB budget is expected to be allocated (2017). BeSecure will provide the team with data from its pilot areas, with priority for Iloilo Province (region with the most advanced progress), but also including its 6 other focus areas, for incorporation into the Digital Aquifer. To formalize and commence this process, NWRB will need to write a letter of request to USAID.

IV. CONCLUSION

72. The proof of concept system discussed in this report validated the technical feasibility of implementing a connected, context-aware system for water management to enhance the capacity for water resources stewardship in the Philippines. The study team documented the development of a system that can automate water management tasks (both routine and complex) and that will improve the quality of the information and interpretations available to decision makers and permitting staff.

73. As discussed in the System Configuration Section, the new context-aware permitting system offers the following functionality: (i) continuous monitoring and forecasting of resource levels, (ii) process automation and workflow management, (iii) data aggregation and visualization, and (iv) decision support. The system developed presents a framework that demonstrates how intelligence can be embedded into the water management process. Inputs accessed more regularly from the environment such as continuously sensed water levels, water abstractions and user complaints about water supply abnormalities will be required to fully realize this intelligence.

\textsuperscript{36} USAID BeSecure Project. https://www.usaid.gov/philippines/energy-and-environment/BeSecure
V. RECOMMENDATIONS

74. The following are recommended:

75. **NWRB to focus on key actions that have a high efficiency pay-off.** Specific actions identified by the Project were: a. Current public notification policies do not allow e-notification to other government institutions and the public. b. Acceptance of application package online is constrained by the requirement to submit legally notarized original documents. A policy allowing preliminary acceptance of scanned documents with original documents to be sent would save time and costs for permit applicants and encourage registration of use. c. Providing information to the public on areas where permits are no longer being issued.

76. To streamline the permit processing time, consultations were made with NWRB management and focus group discussion participants. Email notifications are now integrated in the proposed system to shave at least 30 days off of the permit application time. This can be applicable for:

   a. Sending application package to NWRB by applicants
   b. Sending of posting notice to endorsers (concerned agencies) by NWRB
   c. Receiving letters of endorsement by NWRB from concerned agencies
   d. Sending of permit to drill by NWRB to applicants
   e. Sending of conditional water permit
   f. Sending of final water permit

77. **AEM model will need further verification and calibration and the NWRB hydrogeologists will need to have sufficient training to use and update the model.** The proof of concept tested the AEM in one pilot area. However, a number of assumptions had to be made and data on river flows were not available. The model requires a set of parameters to be entered and so to apply the model in other regions these parameters will be needed: aquifer depth, transmissivity and lake elevation. NWRB staff occasionally come across these information from different sources such as permit applicants and other donor-support projects. A trained user of the AEM model will be able to update the system and continue to test and verify its results. Selection of AEM has been based on the current situation at NWRB to provide an aquifer model that would work on relatively small data sets, uncomplicated hydrogeological features but provide reasonable result reliability. For the medium and long term projections, AEM may be coupled with the grid based models to provide better definition of boundary conditions and water budgets in addition to projections due to changes in climate, land use and population growth.

78. **Further develop the system to automate the collection of monitoring data, identifying and assessing fines for chronic over use.** This would reduce the manpower required to execute the monitoring and enforcement function. One of the options discussed with NWRB, for which they are open, is the outsourcing of the permit application and investigation
process through a public-private partnership (PPP) similar to the Land Transport Office outsourcing of vehicle inspection functions. Permit management has revenue potential, especially considering the growing concern over scarcity of ground water. Permit administration could be coupled with resources management using more reflective pricing and use policies. This option will need due diligence and preparation support that is outside the scope of the current initiative.

79. **Increase the engagement of a broader range of stakeholders.** For example, well drillers and existing permittees have expressed enthusiasm for a public portal where they can view existing permits to get an idea of the water allocations availability before they even go the permitting office. Others are simply interested to know who might be the largest water users in the area. This potential to engage more users opens up new ideas such as using human sensors to improve water stewardship and governance. As discussed in the previous paragraph, there is a potential for business model sustainability given the range of stakeholders who seek to derive value from the connected water system and the possible implications of the system for future water policy in the Philippines.

80. **Link the water permit allocation policies to strategic planning based on determination of sustainable yields for aquifers.** Presently, water rights are allocated based on a ‘first come, first served’ basis without reference to any strategic policy or planning such as a River Basin Master Plan. The Digital Aquifer’s ability to predict sustainable yields is an important input to such strategic planning exercises. Tools and guidelines are available from the Department of Public Works and Highways on Integrated Water Resource Management (IWRM) to prepare River Basin Master Plans.

81. **Improve the administration of permits and extraction reports** to have up to date information on the status of the aquifer and improve enforcement of water rights’ conditions. While the current system will yield efficiency dividends by increasing NWRB’s capacity to cope with some tasks by automating them and building in future modules that will let applicants carry some of the process (such as online application), NWRB will continue to be constrained by its limited staffing complement and footprint (in Manila). For example, it has limited people to conduct field verification and to evaluate applications. One of the most important revenue drivers for the new permitting system will be monitoring and enforcement. A review of the available monitoring data for a small random sampling of water users showed that some were using up to ten times their water allocations. These users have never been assessed fines for over use. There are likely also many cases of illegal abstractions in the location where no new permits are being issued.

82. **Develop on additional modules that enhance interface with different users, including the public; increase NWRB administration efficiency and/or strengthen the governance of groundwater.** The current proof of concept was mainly able to develop the permit processing
and well evaluation modules and currently is only available for use by NWRB staff. However, the system, through application protocol interface, has been built so that modules can be added or so that the system can interface with other data and IT systems. A future version of the platform can consider the following additional modules:

a. An applicant-interface/dashboards so that applicants can apply and transact online and can get information about the status of their applications;

b. A public-interface so that interested entities can understand the ground water status and drawdowns, particularly in critical areas;

c. Accounting system that will integrate the permitting system with the billing and accounting system, including the Government accounting system;

d. Automated water use monitoring. Real-time flow meters could be installed on the premises of the largest water users. This information would feed the system, reducing the need to physical inspections;

e. Automated water level monitoring, if more water level sensors are installed;

f. Weather data integration to provide additional inputs to aquifer recharge and characteristics; and

g. Integration of surface water allocation system.

VI. LIST OF ANNEXES

Annex 1 – Request of the Government of the Philippines

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc0ac

Annex 2 – Review of the Philippine Water Rights System

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc28c

Annex 3 – Detailed Water Permit Application Process

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc28d

Annex 4 – Water Permits Revenues and Expenditures

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc28e

Annex 5 – Fees and Charges

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc290

Annex 6 – Permitting System User Guide

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc295
Annex 7 – Application of the AEM Model to the Santa Rosa Watershed

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc30b

Annex 8 – Permitting Journey Map

http://wbdocs.worldbank.org/wbdocs/drl/objectId/090224b0842cc30d