igrac
International Groundwater Resources Assessment Centre

WMO

NATIONAL GROUNDWATER MONITORING PROGRAMMES

ASIA & THE PACIFIC

Afghanistan

Capital city: Kabul
Inhabitants: 38 Million

INSTITUTIONAL SETTING AND PURPOSE

The Hydrogeology Department of the Ministry of Energy and Water (MEW) is responsible for monitoring and managing groundwater in Afghanistan. Additionally, two institutions are involved in groundwater monitoring: The Danish Committee for Aid to Afghan Refugees (DACAAR) and the Afghanistan Geological Survey (AGS), both with different purposes and encompassing different study areas. Since 2003, DACAAR has been conducting groundwater monitoring in 29 provinces of Afghanistan, covering almost 85% of the country's river basins.

The purpose of DACAAR's network is to provide long-term scientific information on groundwater quality and quantity, while the purpose of AGS network is to assess seasonal, areal, and potentially climatic variations in groundwater characteristics in the Kabul Basin, as the most populous region in the country.

CHARACTERISTICS OF THE NETWORK

DACAAR's network consists of 363 monitoring wells that provide information regarding the qualitative and qualitative status of the groundwater resource. This is the only national data source on groundwater in Afghanistan.

The monitoring is made manually through Groundwater Monitoring Teams that visit the wells monthly to measure groundwater levels, electrical conductivity (salinity), pH, temperature and ORP and take water samples for quality analysis on a semi-annual basis. The monitoring wells also have drilled, constructed and modified for long time recording using diver/ data logger. Divers/data loggers are reliable instruments for automatic measurement and registration of the ground water level, salinity and temperature over a long time period. The Divers are installed in tube wells and after a while data are up-loaded to a Diver Mate, then downloaded from the Diver Mate to a PC.

The network from AGS started with 71 wells in the Kabul Basin in 2004, with the assistance of the U.S. Geological Survey. The network was made up exclusively of existing production wells and levels are measured once a month using electric tape water-level meters. Both static and dynamic water levels are recorded. In 2010, AGS established similar groundwater monitoring networks in the cities of Mazar-e-Sharif, Sheberghan and Sar-e Pol.

The figure below shows the distribution of groundwater monitoring wells in Afghanistan.

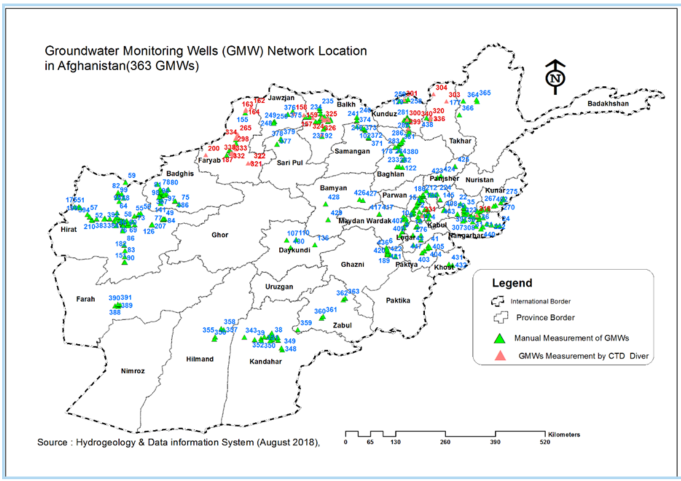
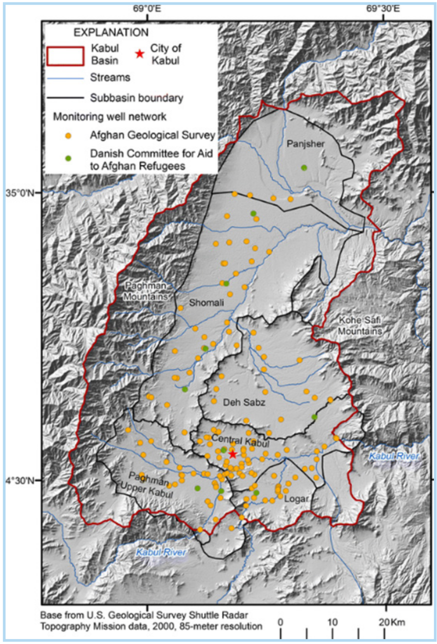


Figure 1 - Distribution of groundwater monitoring wells in Afghanistan (Source: DACAAR)

And the following figure shows the distribution of groundwater monitoring wells in the Kabul Basin, including wells from the monitoring networks of DACAAR and AGS.

Figure 2 – Monitoring wells from AGS and DACAAR in the Kabul Basin, Afghanistan



Static groundwater levels in Kabul city were separately collected by the Hydrogeology Department of MEW from 2007 till 2009 and restarted in 2014 up until now. The measurements are gathered from 104 wells monthly throughout the city. Previously, the department focused only on groundwater monitoring of the major cities: Kabul, Nangarhar, Balkh, Herat, and Ghazni. In 2019, the groundwater monitoring system was created in more than 10 cities of Afghanistan where groundwater static levels are being measured monthly.

PROCESSING AND DISSEMINATION

DACAAR publishes several times a year various reports on groundwater monitoring, mainly on quality and geophysics. The last report on groundwater levels monitoring is the National Groundwater Monitoring Wells Network Finding Challenges and Recommended Solutions in Afghanistan by M. H. Saffi and A. Jawid, 2013. It reports shortly about the National Groundwater Monitoring Wells Network Database (WSG_SWL) that is developed as a part of DACAAR activities.

The long term quantitative and qualitative GMWs data (2003-2019, see figure on last page) were evaluated, mapped and provided in reports and presentations, and findings were presented in national and international conferences. Reports are available in DACAAR's website .

Since the start of their collaboration, AGS and USGS have released more than 40 reports on the quantity and quality of groundwater and surface water resources. For example, the publication 'Groundwater Levels in the Kabul Basin, Afghanistan, 2004–2013' presents water-level hydrographs for stations in 5 sub-basins. In a different publication, the Seasonal Kendall test is used to determine trends. In general, a relatively little change in the water-level trend during the period of record is observed in the Kabul Basin using Seasonal Kendall test (publication 3), with exception of the Central Kabul sub-basin where groundwater level has decreased from several meters to about 25 m.

The information recorded on the field form and the water-level measurements are maintained in project databases by the AGS.

The collected data on static groundwater levels in Kabul city is processed by the Hydrogeology Department of MEW. Monthly static water level fluctuation reports are prepared and published on Facebook page "Afghanistan Water Resources and Hydrology Services" for the public awareness.

Sources

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- **Afghanistan Water Resources and Hydrology Services, Facebook group -** https://www.facebook.com/AfghanistanWaterResourcesDepartment;
- **Danish Committee for Aid to Afghan Refugees (DACAAR) -** https://dacaar.org;
- **Feedback from AGS -** received on 01-02-2020;
- **Feedback from DACAAR -** received on 28-01-2020;
- **Groundwater Monitoring System (DACAAR) -** https://www.dacaar.org/functions/groundwatermonitoring;
- **Hydrogeology Department of the Ministry of Energy and Water in Afghanistan -** personal communication, November 2019;
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- **Taher, M.R., Chornack, M.P., and Mack, T.J., 2014, Groundwater levels in the Kabul Basin, Afghanistan, 2004–2013: U.S. Geological Survey Open-File Report 2013–1296, 51 p. -** http://dx.doi.org/10.3133/ofr20131296
- **USGS Projects in Afghanistan -** https://afghanistan.cr.usgs.gov/water

Australia

Capital city: Canberra
Inhabitants: 25 Million

INSTITUTIONAL SETTING AND PURPOSE

Under the Water Act 2007, the Bureau of Meteorology (BoM) is the institution responsible for delivering water information across Australia to support national decisions. In Australia, groundwater management is vested in the States/Territories. As a consequence, the collection of groundwater data and maintenance of the groundwater monitoring networks is also the responsibility of various organisations including State/Territory water agencies or water authorities. The BoM has been mandated to collate, standardise and disseminate the state collected groundwater information at a national level.

CHARACTERISTICS OF THE NETWORK

In total there are around 910,000 sites with nationally consistent groundwater information across Australia available through the Bureau website. Of these:

- 710,000 have bore log information, including construction, lithology and/or hydrostratigraphy;
- 250,000 have at least one groundwater level measurement, ~2,000 sites are continuously logged with updated groundwater levels released on the Bureau website weekly;
- 200,000 have salinity data; and
- 120,000 have hydrochemistry data.

PROCESSING

Two types of products give an overview of the state of the quantity of groundwater resources in Australia: groundwater level status map and groundwater level trend maps presented as Upper, Middle and Lower aquifer groups (Figure 1).

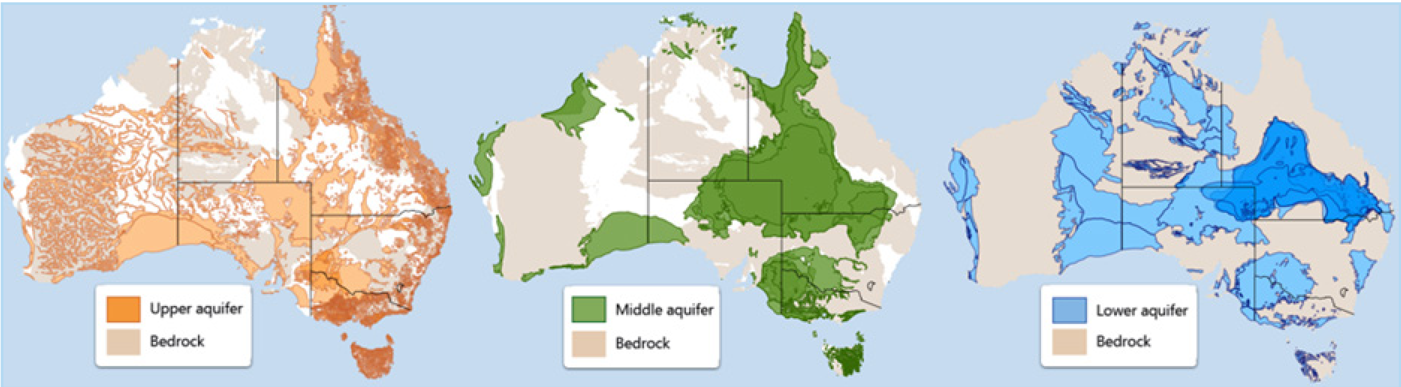


Figure 3 – Upper, Middle and Lower aquifers across Australia

In order to fully understand these maps, it should be noted that all major aquifers in Australia have been grouped by Upper, Middle and Lower aquifer, according to a methodology based on the Victorian Aquifer Framework (VAF), and further modified to extend across Australia. The objective of this aggregation was to make non-groundwater experts aware of the 3D nature of aquifers. The approach used was first to divide Australia into several "groundwater provinces" (Figure 2), and then (using a simplified stratigraphic table) group hydrogeological units into upper, middle and lower aquifer groups. Small and single aquifer systems may not be included in the stratigraphic table given the national perspective of this analysis.

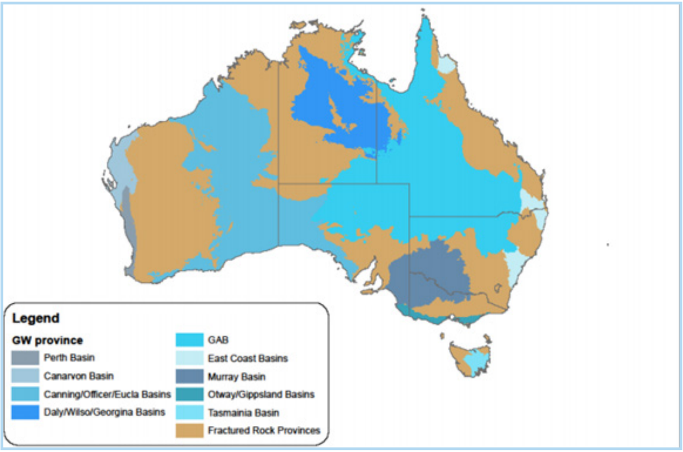


Figure 4 – Groundwater Provinces across Australia

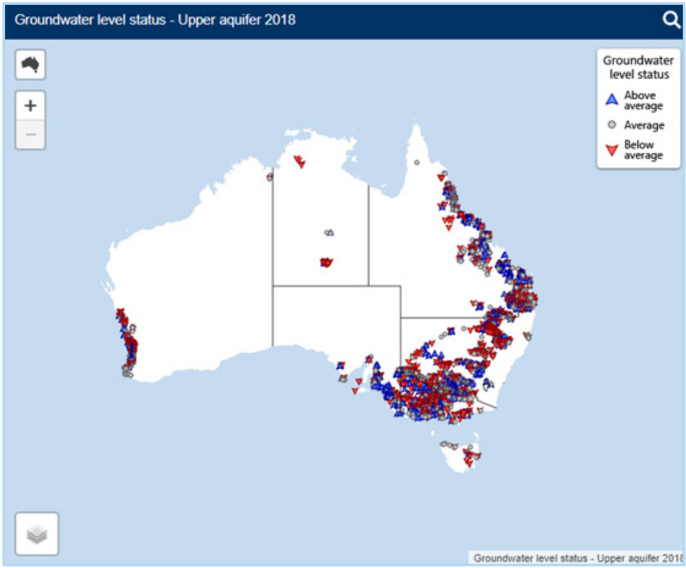


Figure 5 – Groundwater level status for upper aquifer 2018

Groundwater level status maps

Groundwater status maps compare recent groundwater levels at wells with the level for the past 20 years in the upper, middle and lower aquifer layers. Status is reported as either average, below average or above average, Figure 3. Wells classified as average are those where the recent level is between the 30th and 70th percentile when compared to the last 20 years. Wells with a level at or above the 70th percentile are classified above average, below the 30th percentile are classified as below average.

Groundwater level trend maps

Trends in groundwater levels for wells in the upper, middle, and lower aquifers and for 5, 10 and 20 years are presented as groundwater level trend maps, Figure 3, showing short and long-term changes in groundwater levels and how these patterns vary spatially. Trends are only shown for wells that meet a minimum data requirement.

Trend is reported as rising, stable and declining. The threshold for a stable trend is anything within ±10cm/year, which was selected to reflect the typical accuracy of the data.

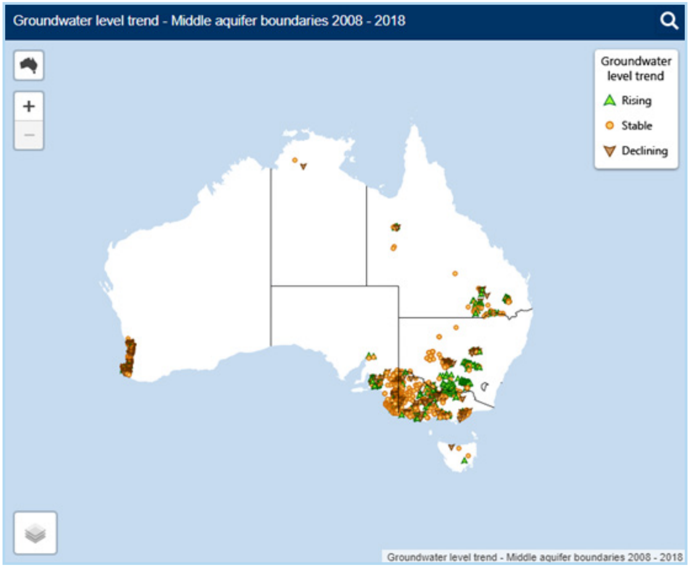


Figure 6 – Groundwater10 years level trend, for middle aquifers

DISSEMINATION

The Australian Groundwater Insight is a map portal providing access to a wide range of groundwater information, designed for non-experts. The Groundwater Status map and the Groundwater Level Trend maps, described above, are available through this portal.

Moreover, BoM provides several groundwater information products through its website. The data are collected from States and Territories, then processed to be nationally consistent and freely available online. Some of these products are:

Australian Groundwater Explorer – Mapping portal for visualising and analysing groundwater bore data including bore locations and logs; groundwater level data; and salinity and other hydrochemistry measurements. Interactive maps, tables and graphs are used to visualise the information. Data can be downloaded in several formats. Groundwater levels are updated weekly for telemetered bores.

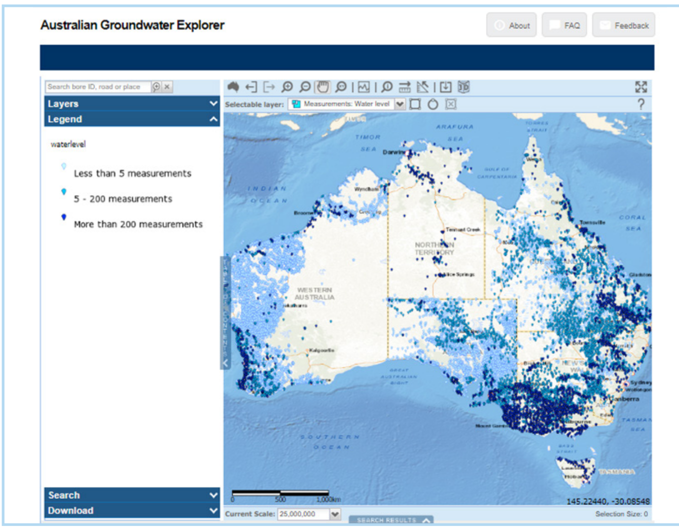


Figure 7 – Australian Groundwater Explorer Homepage

National Groundwater Information System (NGIS) – Database of spatial information on more than 910,000 wells and their attributes. It has been designed for GIS specialists who need access to the full dataset. Water stakeholders such as water agencies, catchment management authorities, consultants, academics, educational institutions, farmers and private industry use the system for groundwater assessment, accounting and modelling purposes. NGIS data are updated annually.

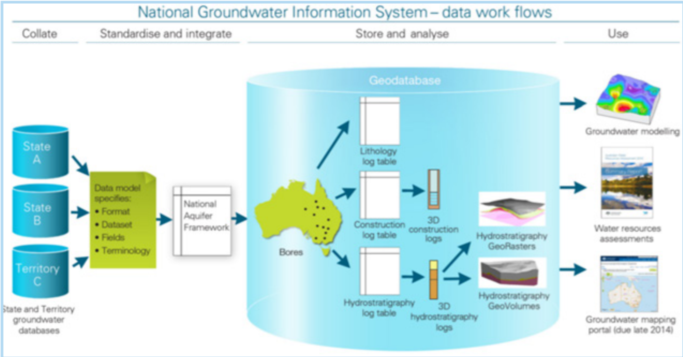


Figure 8 – NGIS data workflow

Groundwater Dependent Ecosystem Atlas (GDE) – Mapping portal providing a comprehensive national inventory of ecosystems that depend on groundwater. The Atlas is a valuable source of information for experts in government, research and industry sectors who work with ecosystems. It supports the consideration of ecosystem groundwater requirements in natural resource management, water planning and environmental impact assessment.

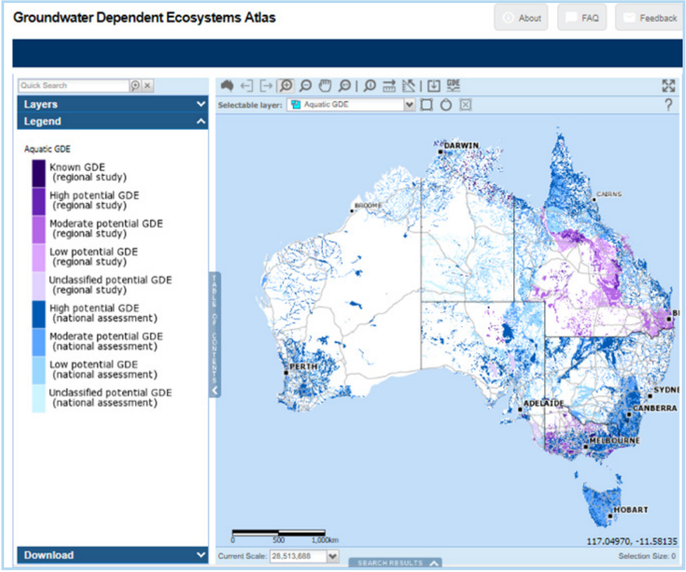


Figure 9 – Groundwater Dependent Ecosystems Atlas

Sources

- **Australian Groundwater Explorer -** http://www.bom.gov.au/water/groundwater/explorer/map.shtml;
- **Australian Groundwater Insight -** http://www.bom.gov.au/water/groundwater/insight/#/overview/introduction;
- **BOM, Groundwater Information website -** http://www.bom.gov.au/water/groundwater;
- **BOM, Ownership of groundwater data -** http://www.bom.gov.au/water/groundwater/explorer/copyright.shtml;
- **Feedback from BOM -** received on 13-02-2020;
- **Groundwater Dependent Ecosystem Atlas (GDE) -** http://www.bom.gov.au/water/groundwater/gde/map.shtml;
- **Groundwater level and trend maps methodology -** http://www.bom.gov.au/water/groundwater/insight/metadata.shtml;
- **Groundwater Provinces across Australia -** http://www.bom.gov.au/water/groundwater/insight/documents/AquiferBoundariesMethod.pdf;
- **Hydrostratigraphy of Australia -** http://www.bom.gov.au/water/groundwater/insight/documents/Hydrostratigraphy.pdf;
- **National Groundwater Information System (NGIS) -** http://www.bom.gov.au/water/groundwater/ngis/; and
- **Victorian Aquifer Framework (VAF) -** https://www.water.vic.gov.au/groundwater/victorias-groundwater-resources/victorian-aquifer-framework.

Bangladesh

Capital city: Dhaka
Inhabitants: 164 Million

INSTITUTIONAL SETTING AND PURPOSE

Several organizations in Bangladesh have established groundwater-level monitoring networks throughout the country, namely: Bangladesh Water Development Board (BWDB), Department of Public Health Engineering (DPHE) and Bangladesh Agricultural Development Corporation (BADC). Barind Multipurpose Authority (BMDA) is a governmental body also in charge of groundwater data collection and monitoring. Amongst them, BWDB is the key organization responsible for monitoring of both surface-and groundwater resources and implementation of water-related development projects in Bangladesh.

The purpose of BWDB's network is to monitor groundwater storage at the national scale in Bangladesh, primarily for the shallow aquifers, besides providing input for national water policy planning and be part of a national climate change monitoring network.

CHARACTERISTICS OF THE NETWORK

The BWDB network has 1,250 monitoring boreholes throughout the country, or one monitoring well per 120 km2. It collects data on groundwater quantity (weekly groundwater levels) and groundwater quality (annual arsenic, salinity, manganese and iron concentrations).

Groundwater level data are collected mainly manually using dippers (groundwater level meters), whereas a few locations are equipped with automatic data loggers.

DPHE has its own network of about 4500 monitoring wells throughout Bangladesh, measuring once a year groundwater levels during the dry season. Readings correspond to the deepest annual groundwater levels in most locations in Bangladesh.

BADC has a network of more than 3000 monitoring wells throughout Bangladesh and published a "groundwater zoning map" for two seasons (at the moment not available online).

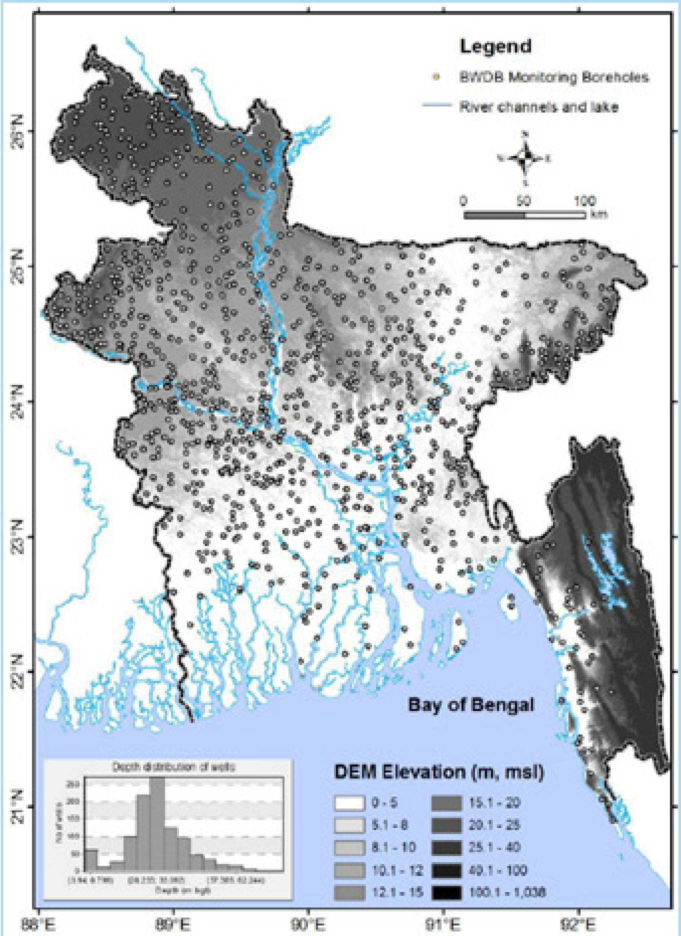
BMDA in Rajshahi area has 14,000 deep tube wells (DTWs) for irrigation, and some of them monitor water levels.

Figure 10 – Dumuria Upazila, Khulna District, Bangladesh, by: Sonia Hoque/REACH

Time-series analyses and spatial mapping are conducted by hydrogeologists working at BWDB.

Groundwater observations from BWDB are not publicly available but they can be purchased directly from BWDB. Additionally, groundwater levels from 2016 for 180 points are available on BADC's website.

Figure 11 – Spatial distribution of the BWDB groundwater-level monitoring boreholes in Bangladesh. Source: Shamsudduha, 2013



Sources

- **Bangladesh Agricultural Development Corporation – Groundwater level data** - http://www.badc.gov.bd/site/page/d931c2f2-c016-4bc5-9483-67ca4bb4ea54/-;
- **Bangladesh Water Development Board (BWDB) -** https://www.bwdb.gov.bd;
- **Feedback from BWDB (indirect) -** received on 16-02-2020;
- **Groundwater zoning map from BADC (not available at the moment)** - http://gwv.gisapps.net;
- **Feedback from BWDB (answer to form)** - received in 2019;
- **Shamsudduha, M., 2013** - Groundwater-fed Irrigation and Drinking Water Supply in Bangladesh: Challenges and Opportunities, in: Zahid, A., Hassan, M. Q., Islam, R., Samad, Q.A. (Eds.), Adaptation to Impact of Climate Change on Socio-economic Conditions of Bangladesh. Alumni Association of German Universities in Bangladesh, German Academic Exchange Service (DAAD), Dhaka, pp. 150-169; and
- **SWIBANGLA: Managing salt water intrusion impacts in coastal groundwater systems of Bangladesh. -** Deltares report number: 1207671-000-BGS-0016.

Cambodia

Capital city: Phnom Penh
Inhabitants: 16 Million

INSTITUTIONAL SETTING AND PURPOSE

The Water Resources Management and Conservation Department of the Ministry of Water Resources and Meteorology (MOWRAM) is in charge of managing the groundwater resources in Cambodia.

The main aim of the Ministry is to address scientific and political issues related to domestic and international water resources. There is no clear identification of national groundwater monitoring programme existence. However, several groundwater monitoring initiatives and local networks are present.

PROCESSING AND DISSEMINATION

The MOWRAM has informed that groundwater levels of shallow aquifers are measured in dug wells, where depths varies from 5 to 10 m. Groundwater levels in deep aquifers are measured using tube wells with depths between 30 to 40 m.

Groundwater data are very limited and not well shared. Currently, few institutions are investing in groundwater monitoring, however, the collected data are not publicly available.

One example of collaboration is the partnership between the MOWRAM and the International Water Management Institute (IWMI). They monitor groundwater levels in Prey Veng and Svay Rieng Province.

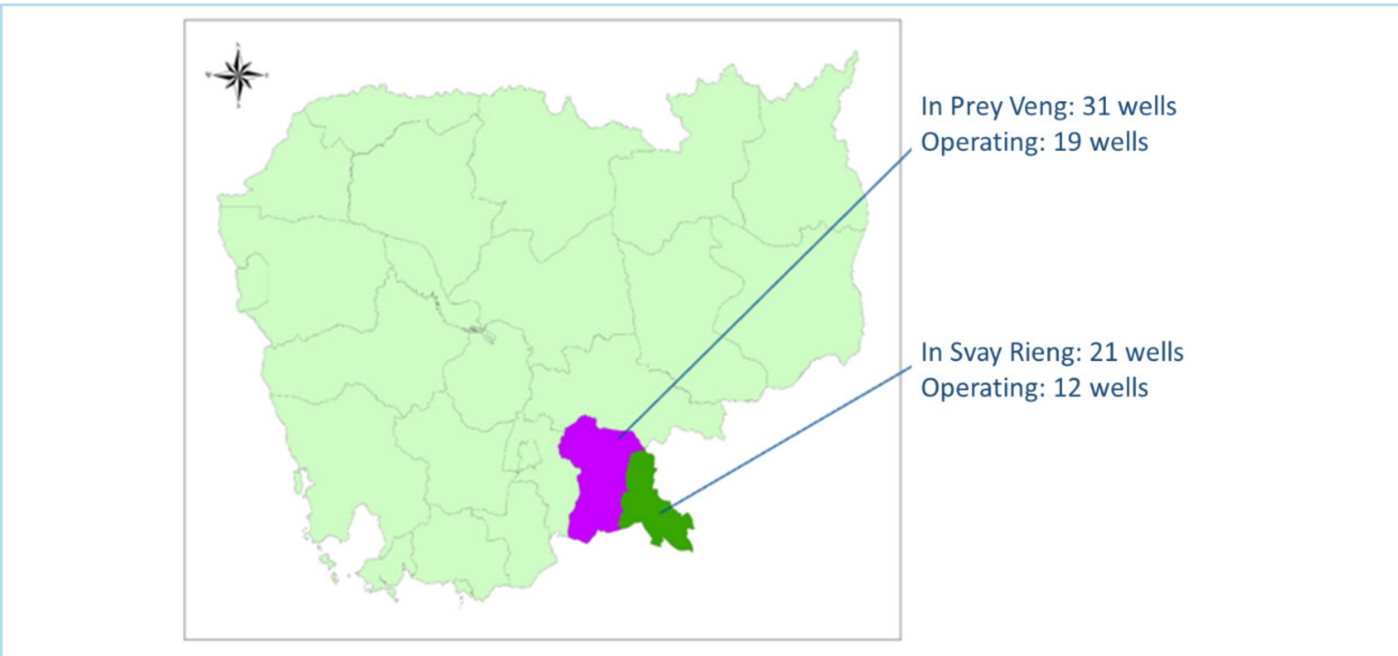


Figure 12 – Spatial distribution of the BWDB groundwater-level monitoring boreholes in Bangladesh. Source: Shamsudduha, 2013

Sources

- **Cambodia's Ministry of Water Resources and Meteorology (MoWRAM)** - https://www.adaptation-undp.org/partners/cambodia%E2%80%99s-ministry-water-resources-and-meteorology-mowram; and
- **Source: presentation from GGMN workshop** - Thailand 2016.

India

Capital city: New Dehli
Inhabitants: 1377 Million

INSTITUTIONAL SETTING AND PURPOSE

India has a parliamentary form of government which is federal in structure with 37 states and union territories (UTs). Many of these states and UTs have their own groundwater departments and groundwater monitoring mechanisms. At the country level, Central Ground Water Board (CGWB) under the Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti is the apex organisation dealing with monitoring, assessment and management of groundwater resources. Groundwater monitoring is done by CGWB through its 29 field offices distributed throughout the country with headquarters at Faridabad, Haryana. There is active coordination between the groundwater departments of the States/UTs and the respective field offices of CGWB. The data and information collected as a part of the nation-wide groundwater monitoring programme and other related data help the government of India (the federal government) formulate policies and prioritise areas for management interventions.

CHARACTERISTICS OF THE NETWORK

Groundwater level monitoring network of CGWB consists of nearly 23,000 monitoring stations (CGWB, 2019). Of these 23,000 stations, nearly 16,500 are open dug wells and the remaining 6,500 are purpose-built piezometers (Figure 1). While the depths of the open dug wells are mostly around 12 – 15 meters, the depths of piezometers vary from 50 to 300 m. Barring a few high frequency automatic measurements, water levels are measured from these monitoring stations four times a year and the measurements are done manually (steel tapes and sounders). The four-time measurements are done over a fixed period of time throughout the country. Such measurements are done during April/May, August, November, January along with collection of water quality samples during April/May for detailed water quality analysis. The measurement months are chosen as per the existing monsoon pattern in the country.

Under the World Bank assisted National Hydrology Project (NHP) efforts are being made to strengthen the network and automate water level monitoring with real-time/near real-time measurements by addition of more piezometers and installation of around 9000 automatic water level recorders with telemetry across India. Efforts are also being made to integrate monitoring data collected by CGWB and other state governmental organisations for better analysis and understanding of water level behaviour over the country on a single integrated platform.

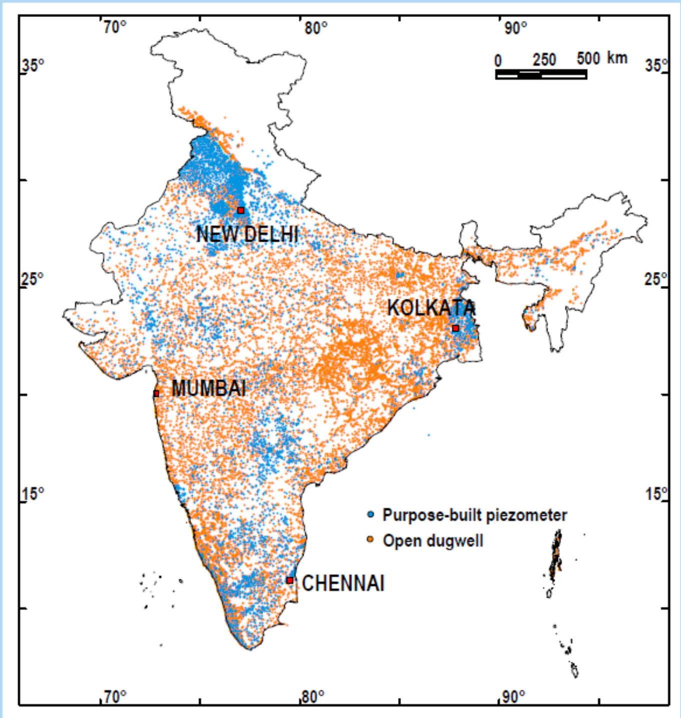


Figure 13 – Distribution of groundwater monitoring stations (dug wells and piezometers) of CGWB. The blank areas on the north and the north eastern regions are part of the Himalayan terrain

PROCESSING AND DISSEMINATION

CGWB maintains a comprehensive database of water level measurements and groundwater quality done through its monitoring stations over a period of nearly 5 decades. The custom-made software Ground Water Estimation and Management System (GEMS) is used for storage, retrieval and analysis of all kinds of groundwater related data collected by the Board and few State Government organisations, including water level data. GEMS provides facility for statistical analysis, GIS based spatial analysis, timeseries analysis, trend analysis, comparisons, preparation of maps etc. Figure 2 shows a sample hydrograph with long term trends generated through GEMS. Results of periodic monitoring are documented and distributed in form of monitoring reports and groundwater year books. These reports are available on the official website of CGWB (www.cgwb.gov.in).

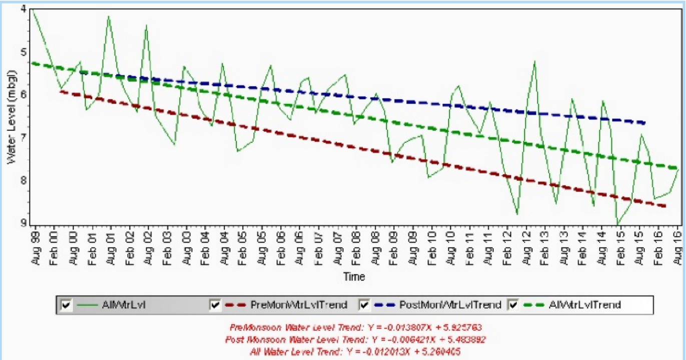


Figure 14 – A sample hydrograph generated from Ground Water Estimation and Management System (GEMS). The hydrograph pertains to the piezometer tapping the deeper aquifer at Dawaleswaram (CGWB, 2017)

Groundwater information in form of maps, hydrographs etc are also disseminated through India Water Resource Information System (India-WRIS), a web-based information system. India-WRIS provides a GIS based interface for visualisation and analysis of water level data. Sample outputs of India-WRIS portal are given in Figure 3, Figure 4 and Figure 5. The user can also overlay available GIS layers like administrative boundaries, basins etc. as per requirement. There is also provision in India-WRIS for downloading validated water level data with geographical coordinates of monitoring stations.

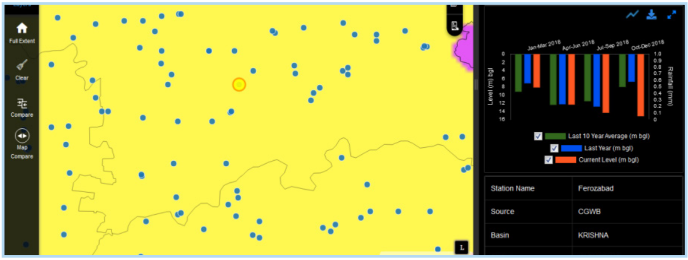


Figure 15 – Sample output of web-based water resource information system of India (India-WRIS) showing comparison of current water level, water level in the previous year and decadal average water level for a selected well

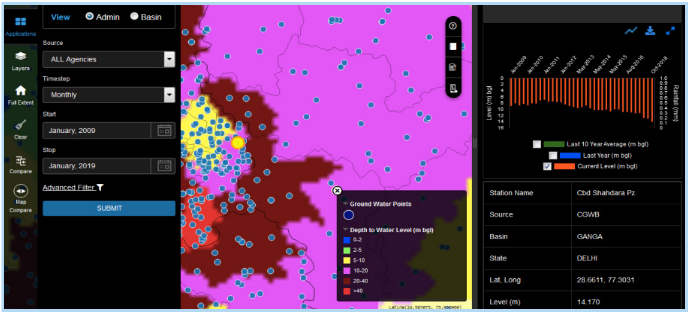


Figure 16 – Sample output of web-based water resource information system of India (India-WRIS) showing long term water levels over a period 2009-2019 for a selected well

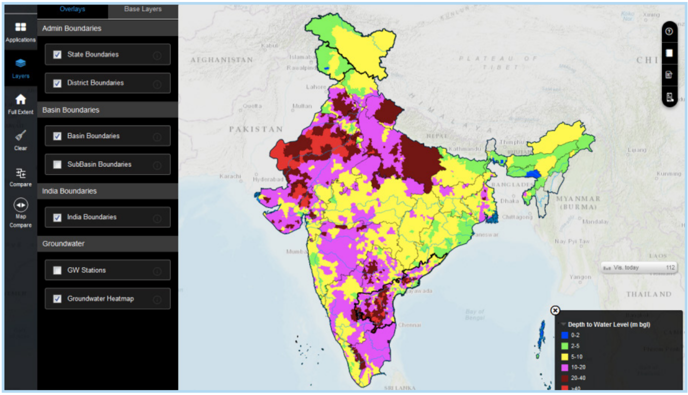


Figure 17 – Sample output of web-based water resource information system of India (India-WRIS) showing spatial variations in depth to water level (groundwater heat map) for Premonsoon (April/May) period 2019

Sources

- **Central Ground Water Board (CGWB), Ministry if Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India** - http://cgwb.gov.in;
- **Feedback from CGWB** - received on 10-04-2020;
- **CGWB (2019) Ground Water Year Book India 2018-19** - Central Ground Water Board, Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, Govt of India, Faridabad;
- **CGWB (2017) Aquifer Mapping and Management of Ground Water Resources, East Godavari, West Godavari and Krishna Districts, Andhra Pradesh. Central Ground Water Board, Southern Region, Hyderabad** - http://cgwb.gov.in/AQM/NAQUIM_REPORT/AP/East%20Godavari,%20West%20Godavari%20and%20Krishna%20Districts,%20Andhra%20Pradesh.pdf;
- **Water Resources Information System, India-WRIS** - http://indiawris.gov.in/wris/#/; and
- **National Hydrology Project (NHP)** - http://nhp.mowr.gov.in/HomeNew/NHPIndexnew.aspx.

Indonesia

Capital city: Jakarta
Inhabitants: 273 Million

INSTITUTIONAL SETTING AND PURPOSE

The Directorate General of Water Resources under the Ministry of Public Works and People's Housing is responsible for the formulation and implementation of policies in the field of water resources management in accordance with the related legislation.

CHARACTERISTICS OF THE NETWORK

The network consists of 51 monitoring wells in Jakarta area, Figure 1. The information on the national groundwater monitoring system in Indonesia is not available.

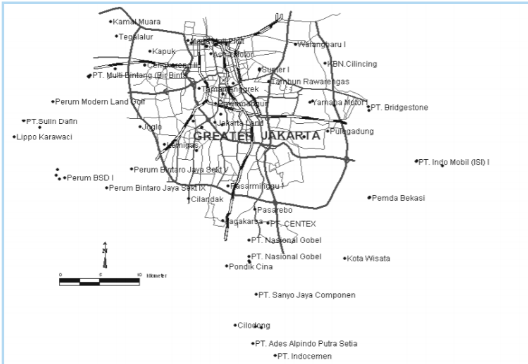


Figure 18 – Groundwater monitoring wells in Greater Jakarta. Source: Delinom, 2008

PROCESSING AND DISSEMINATION

SIATAB is the Water Information System of Indonesia. Metadata on groundwater monitoring stations for Jakarta are available. The Directorate maintains a groundwater database, Figure 2. Data on static groundwater levels, well and pump conditions can be accessed. Groundwater data analysis on the groundwater wells status is presented with pie charts, Figure 3.

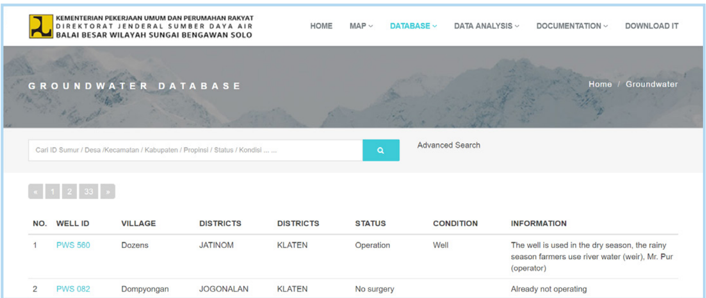


Figure 19 – Groundwater level status for upper aquifer 2018

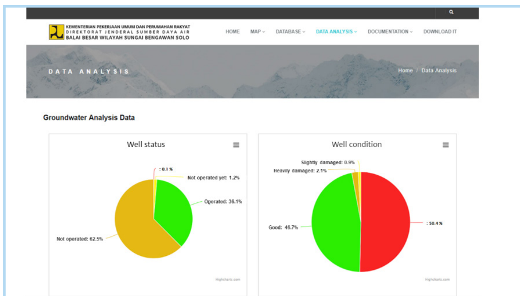


Figure 20 – Groundwater Well Analysis

Sources

- **Database of Groundwater and Raw Water of the Directorate General of Water Resources** - http://sda.pu.go.id/bbwsbengawansolo/siatab;
- **Database of Groundwater and Raw Water. Groundwater Analysis data** - http://sda.pu.go.id/bbwsbengawansolo/siatab/data_analisis.php?table=sumur;
- **Delinom, R.M. Groundwater management issues in the Greater Jakarta area, Indonesia** - http://doi.org/10.15068/00147302;
- **Ministry for Public Works and Human Settlements, Directorate General of Water Resources** - https://www.pu.go.id/organisasi/ditjen-sumber-daya-air; and
- **Water and raw water information systems, Directorate General of Water Resources** - http://103.122.35.6/siatab.

Iran

Capital city: Tehran
Inhabitants: 83 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry of Energy (MOE) and the Ministry of Agriculture (MOA) are responsible for the water resources assessment in Iran. The department of Water Resources Management (WRM), operating under the authority of MOE, is mainly involved in collection of surface and groundwater data, as well as in allocation of water for domestic, industrial and agricultural purposes. Conversely, the MOA is in charge of farm development and irrigation. It regulates the amount of water allocated for agriculture.

In 2014, a groundwater recovery plan was enacted and launched, with the objective of overcoming several problems that Iran has been facing due to the decreasing of groundwater levels in the last 30 years, Figure 1.

The plan covers:

- A collaborative management of the groundwater resources;
- Development of a piezometric network including data metering and transferring tools;
- Establishment of a monitoring and recharge control system (flow meters) on water wells;
- Filling and sealing of unauthorized wells.

In 2016, about 12,000 wells have been available to measure the groundwater level every month. Within the recovery plan, it was expected to repair 8,000 wells. Additionally, wells have been provided with online measuring tools. Up to 2016, 50,000 flow meters have been installed to measure abstraction.

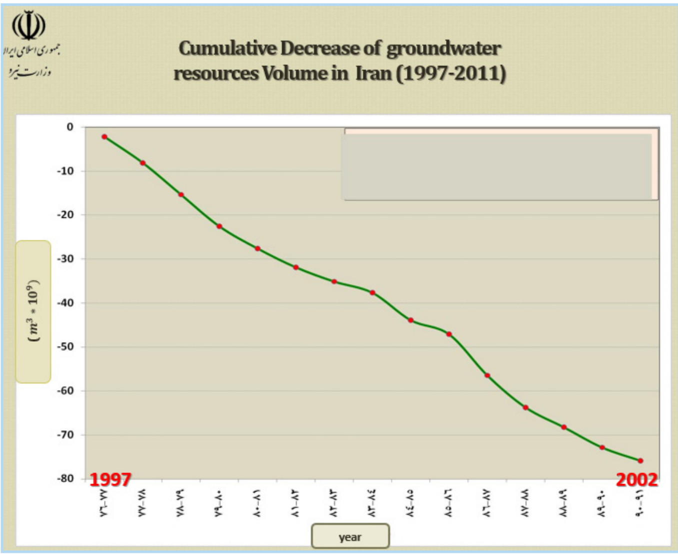


Figure 21 – Cumulative decrease of groundwater resources volume in Iran (1997-2011)

Figure 22 – Water Mill on a Qanat in Boshrouyeh, Khorasan, Iran, by: S. Ghiaseddin

Sources

- **Feedback from WRM** - received on 17-03-2020; and
- **GGMN Workshop in Thailand** - 2016.

Jordan

Capital city: Amman
Inhabitants: 10 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry of Water and Irrigation (MWI) is the governmental body in charge of the national groundwater monitoring network in Jordan.

The objective of the network is to provide data on the long-term state and trends of groundwater in the country. The network also delivers input to the national water policy planning, regulatory agencies and the public.

CHARACTERISTICS OF THE NETWORK

The network is composed of 252 monitoring wells. Next to groundwater levels, groundwater quality parameters (EC, pH, temperature) are measured as well. Both manual and automatic methods for data collection (data loggers, automatic transmission) are in use.

PROCESSING AND DISSEMINATION

Hydrographs (time series analysis) are produced based on collected data from the monitoring network. Data are used to assess state of water resources and to develop models for prediction. Data are available upon request.

Figure 23 – River flows through Wadi Mujib near dead sea coastline

Sources

- **Feedback from MWI** - received on 28-05-2020; and
- **Feedback from MWI (answer to form)** - received in 2019.

(Republic of) Korea

Capital city: Seoul
Inhabitants: 51 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry of Land, Infrastructure and Transport (MOLIT) implements the assessment of characteristics and available reserves of groundwater and establishes a groundwater management plan for the country. MOLIT is also in charge of establishing nationwide and local groundwater monitoring systems.

Other Ministries sharing the responsibilities in groundwater management are the Ministry of Environment (ME); Ministry of Agriculture, Food and Rural Affairs (MAFRA); Ministry of National Defense (MND); Ministry of The Interior (MOI) and the Ministry of Public Safety and Security (MPSS). The objective of the national groundwater management plan is to conserve and characterize the reserves and amount of exploitable groundwater as well as the conditions for their utilization.

CHARACTERISTICS OF THE NETWORK

Korea has 6 main groundwater monitoring networks: National Groundwater Monitoring Network (NGMN), Figure 1; Groundwater Quality Monitoring Network (GQMN); Seawater Intrusion Monitoring Network (SIMN); Rural Groundwater Monitoring Network (RGMN); Subsidiary Groundwater Monitoring Network (SGMN) and Drinking Water Monitoring Network (DWMN), Table 1. They have in total around 3,500 monitoring wells and most of them are equipped with automatic data loggers and remote transfer units. All of them measure water levels, except for GQMN.

Network	Operated by	No. of stations	Frequency
NGMN	MOLIT and K-water	552 (386 deep, 166 of them include shallow)	Every hour
SIMN	MAFRA and the Korea Rural Community Corporation (KRC)	145 monitoring wells (each station has 1 to 3 wells)	Every hour
RGMN	MAFRA and KRC	176	Every hour
SGMN	MOLIT, local governments	1,803	Every hour for automatic systems (60.8%)
DWMN (private data)	ME and commercial bottled groundwater companies	189	Monitoring data has to be submitted to the local government every month

Table 1 – Characteristics of groundwater monitoring networks in South Korea. Source: Lee and Kwon, 2016

The RGMN was established to monitor groundwater changes produced by agricultural activities. The SGMN (or L(Local)GMN) is intended to fill the gaps in the wells from the NGMN, which are sparsely distributed over the country.

Jeju island

Jeju Island has an independent groundwater monitoring network with 132 monitoring wells. Its objective is to protect the groundwater resource from seawater intrusion or anthropogenic pollution. Water levels are measured every hour. Data as water level, water temperature and EC are available to the public on the website: http://www.jeju.go.kr/jejuwater/index.htm

Total number of wells measuring groundwater levels in Korea including the local network in Jeju Island is 2,997.

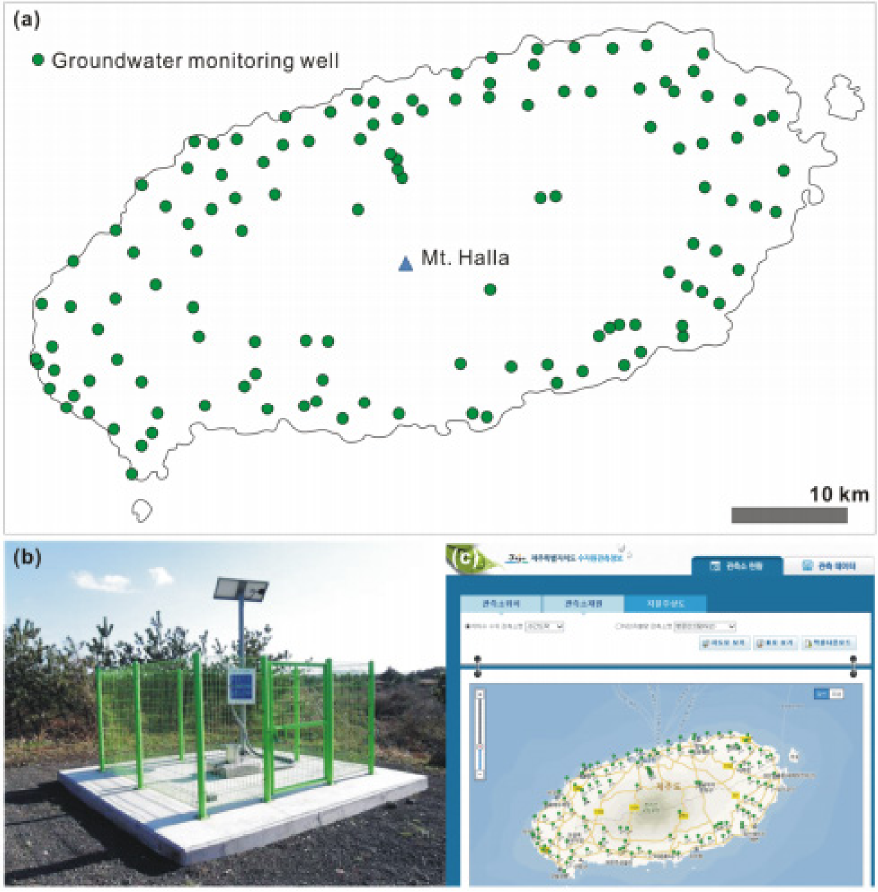


Figure 24 –Groundwater monitoring network in Jeju Island. (a) Location of monitoring wells; (b) Scene of a monitoring well; (c) Webpage with the real-time monitoring on an hourly basis (currently not available). Source: Lee and Kwon 2016

PROCESSING AND DISSEMINATION

All the monitoring data are stored at the National Groundwater Information Center (NGIC). In 2004, Soil and Groundwater Information System was developed to support installing and operating monitoring networks, including data and information accessibility.

Sources

- **Lee J.-Y., Lee K.-K., Hamm S.-Y., and Kim Y., 2017. Fifty years of groundwater science in Korea: a review and perspective** - http://dx.doi.org/10.1007/s12303-017-0015-7;
- **Jin-Yong Lee J.-Y. and Kwon K. D., 2016. Current Status of Groundwater Monitoring Networks in Korea** - https://doi.org/10.3390/w8040168;
- **Ministry of Environment, Groundwater** - http://www.me.go.kr/eng/web/index.do?menuId=130;
- **Ministry of Environment, Korea Environment Industry Technical Institute. Country Report of Korea (ROK), Soil and Groundwater, 2015. Available in** - https://sgw.epa.gov.tw/Resag/Upload/Files/201704181150303fa1d6.pdf; and
- **Soil Groundwater Information System (SGIS)** - http://sgis.nier.go.kr.

Malaysia

Capital city: Kuala Lumpur
Inhabitants: 31.5 Million

INSTITUTIONAL SETTING AND PURPOSE

The Department of Mineral and Geoscience Malaysia (JMG), formerly known as the Geological Survey Department, is the lead agency responsible for matters related to groundwater exploration, tube well development and groundwater data inventory in Peninsular Malaysia, Sabah and Sarawak.

JMG actively participates in international cooperation and is committed in fulfilling obligations set by global frameworks such as CCOP Geoinformation Sharing Infrastructure for East and Southeast Asia. JMG is currently involved in the CCOP-GSJ-GSi Groundwater Phase IV project, which mainly focus on management of groundwater database within CCOP member countries.

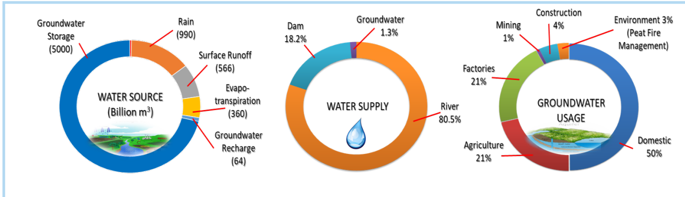


Figure 25 – Groundwater status in Malaysia (National Water Resources Study (NWRS), 2012)

CHARACTERISTICS OF THE NETWORK

Since the beginning of the 5th Malaysia Plan in 1986, 4,758 tube wells (Figure 2) have been developed by JMG for various purposes which benefited 1.5 million people nationwide. JMG has also developed a groundwater database known as HYDROdat and a GIS application known as HydroGIS, for planning, assessing and monitoring activities to safeguard and maintain the quality and potential reserve of groundwater.

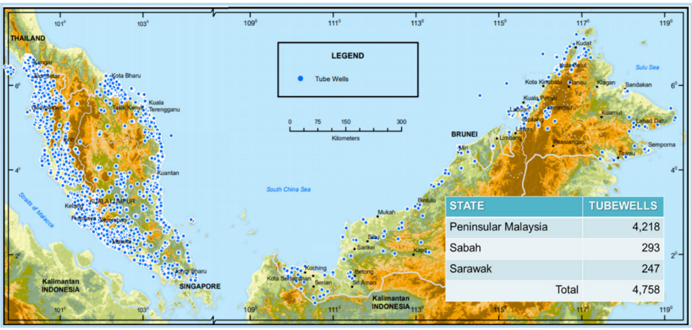


Figure 26 – Tube well location map in Malaysia (JMG HYDROdat, 2018)

Groundwater levels and groundwater quality are monitored at selected wells on a periodic basis, generally twice a year. Field samplings measuring temperature, conductivity and dissolved oxygen are designed for dry (Aug-Oct) and rainy (Jan-Mar) seasons. Two types of wells are used: cluster type that allows sampling of groundwater at various depths, and individual wells that were mainly exploration wells and later converted to monitoring wells. Data gathered from the field samplings will be keyed into HYDROdat and the well locations will be plotted using HydroGIS.

JMG has outlined several new initiatives in line with requirements of the 12th Malaysia Plan and to resolve existing groundwater issues. The 12th Malaysia Plan is critical to implement water sector transformation through mainstreaming groundwater usage for water security and economic growth. Hence, JMG needs to restructure and update the existing groundwater database and monitoring system. The current groundwater database system (HYDROdat) will be upgraded to enhance its capabilities in groundwater evaluation and risk assessment management.

Concurrent to the upgrading of HYDROdat, JMG is working diligently to set up a National Groundwater Monitoring System (NaGMiS); an integrated groundwater monitoring network collaboration with the relevant local agencies and stakeholders. NaGMiS will provide more groundwater data collection and enhance the data coverage comprehensively for a better and more holistic management of groundwater resources.

Sources

- **Department of Mineral and Geoscience Malaysia**;
- **Feedback from Dept. of Mineral and Geoscience Malaysia (Putrajaya)** - received on 10-07-2020; and
- **GGMN South East Asia Workshop** - 2016.

Myanmar

Capital city: Napypyidaw
Inhabitants: 53.7 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry of Agriculture, Livestock and Irrigation (MOALI) is in charge of promoting inclusive and sustainable agriculture. The Ministry also implements Water Use and Management policy with the aim to ensure access to high quality water by using groundwater without damaging the environment and water resources.

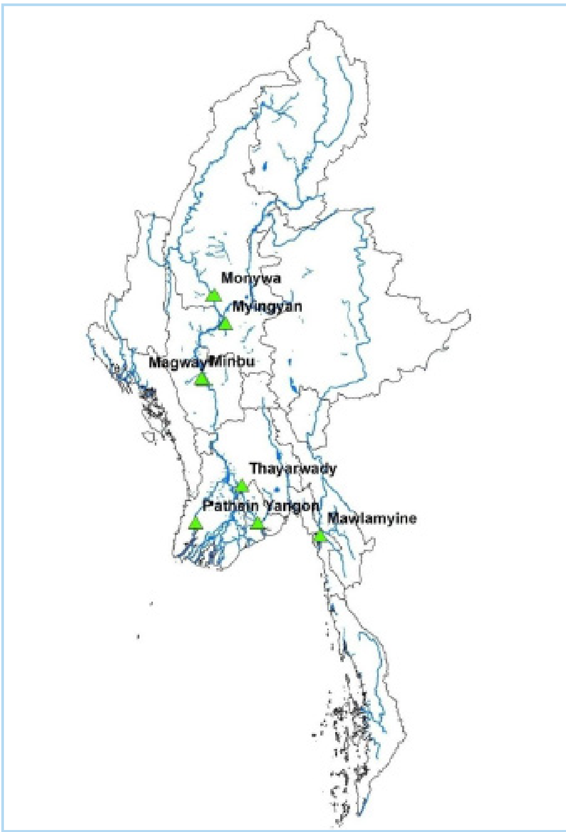
In Myanmar there is no national groundwater monitoring network. However, establishment of the network is in progress by the Irrigation and Water Utilization Management Department (IWUMD) with its Groundwater Division.

CHARACTERISTICS OF THE NETWORK

In 2017 Myanmar started with the establishment of nine monitoring stations: 1 station in Sagaing, Bago, Yangon, Ayeyarwady and Mon, 2 in Mandalay, 2 in Magway, Figure 1.

The observation wells are well protected, and the data are measured by automatic data loggers. 58 monitoring station in the Central Basin and 22 in remote areas were planned to be set for the groundwater monitoring in 2017.

Figure 27 – Pilot groundwater monitoring stations in Myanmar



Sources

- **FAO, 2016** - http://www.fao.org/nr/water/aquastat/countries_regions/MMR/index.stm;
- **MOALI** - https://www.moali.gov.mm/en/content/about-ministry;
- **Presentation GGMN** - workshop 2016; and
- **Presentation Ministry of Agriculture, Livestock and Irrigation, Irrigation and Water Utilization Management Department (MOALI)** - March 2017.

Nepal

Capital city: Kathmandu
Inhabitants: 28 Million

INSTITUTIONAL SETTING AND PURPOSE

The Groundwater Resources Development Board (GRDB) under the Ministry of Energy, Water resources and Irrigation is the primary agency from the government responsible for groundwater survey, monitoring and development.

The Kathmandu Valley Water Supply Management Board (KVWSMB) was established by the Government of Nepal as the institution responsible for groundwater regulation and management in Kathmandu Valley. KVWSMB was created to address overlaps in responsibilities between GRDB and the Water and Energy Commission Secretariat (WECS), who is in charge of performing water resource functions at a general level. KVWSMB is responsible for groundwater data collection and processing, groundwater development planning, monitoring, regulation and research.

CHARACTERISTICS OF THE NETWORK

Continuous groundwater monitoring started in 1999 in the Kathmandu Valley, with 50 monitoring wells (8 in shallow and 42 in deep aquifers) under the project “Urban Water Supply Reforms in Kathmandu Valley”. After the project was finished, the Groundwater Resources Development Project (GRDP) (implementing agency of GRDB) continued the monitoring.

Figure 28 – Kathmandu Valley by Aleksandr Zykov

Sources

- **Gautam D. and R. N. Prajapati R. N., 2014. Drawdown and Dynamics of Groundwater Table in Kathmandu Valley, Nepal. The Open Hydrology Journal, 8, 17-26** - https://benthamopen.com/contents/pdf/TOHYDJ/TOHYDJ-8-17.pdf;
- **Shrestha S., Pradhananga D., Pandey V.P. (Eds.) (2012). Kathmandu Valley Groundwater Outlook. Asian Institute of Technology (AIT), The Small Earth Nepal (SEN), Center of Research for Environment Energy and Water (CREEW), International Research Center for River Basin Environment-University of Yamanashi (ICRE-UY). Section II: Groundwater Quantity** - http://people.ucalgary.ca/~hayashi/kathmandu_2016/reading/Shrestha_etal_2012_KVGW.pdf.

New Zealand

Capital city: Wellington
Inhabitants: 4.9 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry for the Environment is responsible for setting national level legislation and regulation on water quality and activities that can impact it. Operational management of groundwater resources is undertaken by local government. Regional councils, of which there are 11 in New Zealand, are responsible for managing water quality and quantity, including activities which can affect aquifers. City councils are responsible for providing clean drinking water, and there are 6 unitary authorities which provide both functions of the regional and city councils.

The Ministry for the Environment periodically reports on the national state of different aspects of the environment, including freshwater and groundwater quality. Nationally, groundwater quality is assessed using the indicators ammoniacal nitrogen, chloride, dissolved reactive phosphorus, chloride, conductivity and Escherichia coli. The latest national report on freshwater was published in 2020.

Central government also provides funding for regional or national scale research to get a better understanding of groundwater resources in New Zealand. For example, a study published in 2019 was undertaken to classify different geological units at a national level in terms of their importance for groundwater flow and storage, as shown in figure 1. Other national level research includes funding for the National Groundwater Monitoring Programme, a long-term research and monitoring programme run in collaboration with all of New Zealand's regional authorities. The "Our Land and Water" National Science Challenge, is another funding avenue. This is a contestably funded research initiative, which funds research on New Zealand's freshwater resources with a particular focus on enhancing the productivity of New Zealand's primary sector.

CHARACTERISTICS OF THE NETWORK

National institutional arrangements require that each Regional Council or Unitary Authority have their own groundwater monitoring programme. The extent of the different monitoring networks varies across regional councils, depending on their size and available resources, as well as the requirements set forth in their Regional plans. However, all regions will have some monitoring of water quality, groundwater resource allocation and groundwater levels. The example of the Tasman District Council is described below.

The district council of Tasman monitors groundwater levels in all major aquifers in the district. The levels are registered at each site every fifteen minutes with data loggers. Currently, Tasman District has 50 automated groundwater level monitoring sites, and the data of these sites are available in real time via telemetry network, Figure 2.

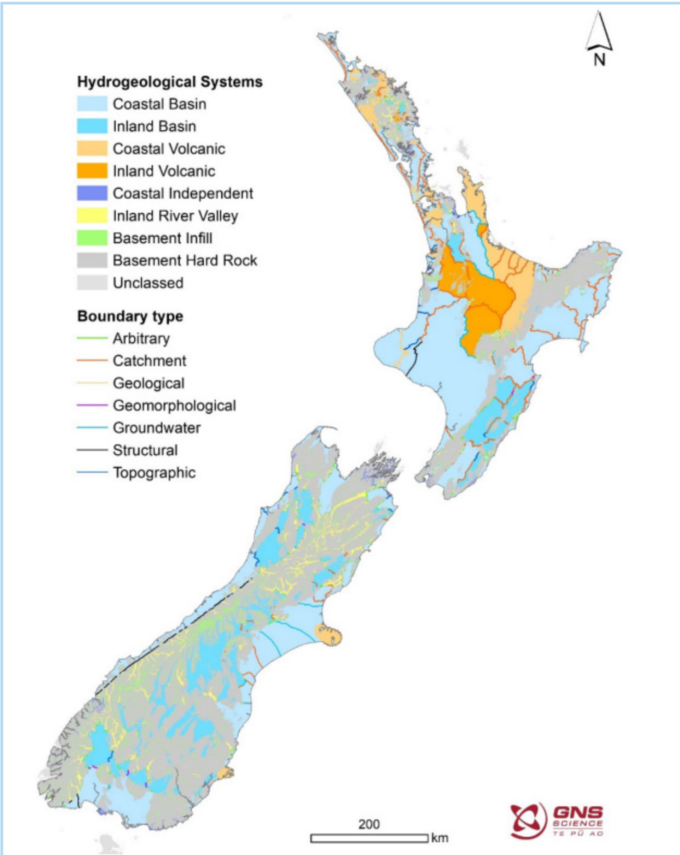


Figure 29 – National map of hydrogeological systems (from Moreau et al, 2019, and provided by the Ministry for the Environment)

PROCESSING AND DISSEMINATION

The Council publishes two groundwater level graphs: for 7 and 30 days, Figure 3. The groundwater levels are analysed as minimum, maximum and average levels and presented in a table format on the website of the Tasman District Council, Figure 4.

Groundwater History

Aquifer: Arthur Marble Aquifer

Catchment: Takaka

Zone: Takaka

Period of analysis: 25 August 1999 to 31 December 2016

Comment: This well is located in the recharge part of the Arthur Marble Aquifer (unconfined) in the central Takaka valley. This well provided long term information on the recharge to the Arthur Marble Aquifer and consequently flows in Te Waikoropupū Springs.

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min level (m)	19.19	22.55	20.62	19.50	20.52	26.63	34.26	31.98	33.98	33.71	21.63	19.39
Year it occurred	2016	2015	2006	2010	2001	2008	2013	2013	2011	2015	2005	2016
Max level (m)	44.98	44.60	46.03	47.26	48.43	47.71	46.51	46.13	44.71	45.38	47.05	48.68
Year it occurred	2012	2004	2016	2014	2011	2003	2003	2010	2012	2011	1999	2011
Average	36.08	35.17	34.46	35.80	37.94	40.49	40.52	40.25	40.05	40.19	38.16	36.58

This table shows the minimum and maximum water levels recorded each month and the year the extreme value was reached during the stated analysis period.

Figure 30 – Groundwater level analysis of the Tasman District Council

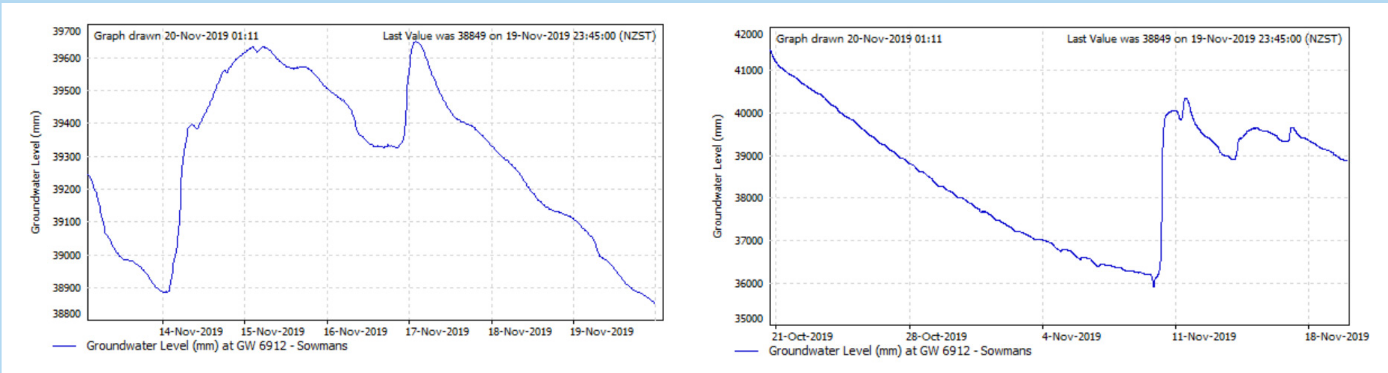


Figure 31 – Groundwater Level for last 7 and 30 days at Arthur Marble Aquifer at Sowmans

Click on the map markers or links below to find up-to-date information on groundwater levels in Tasman District.

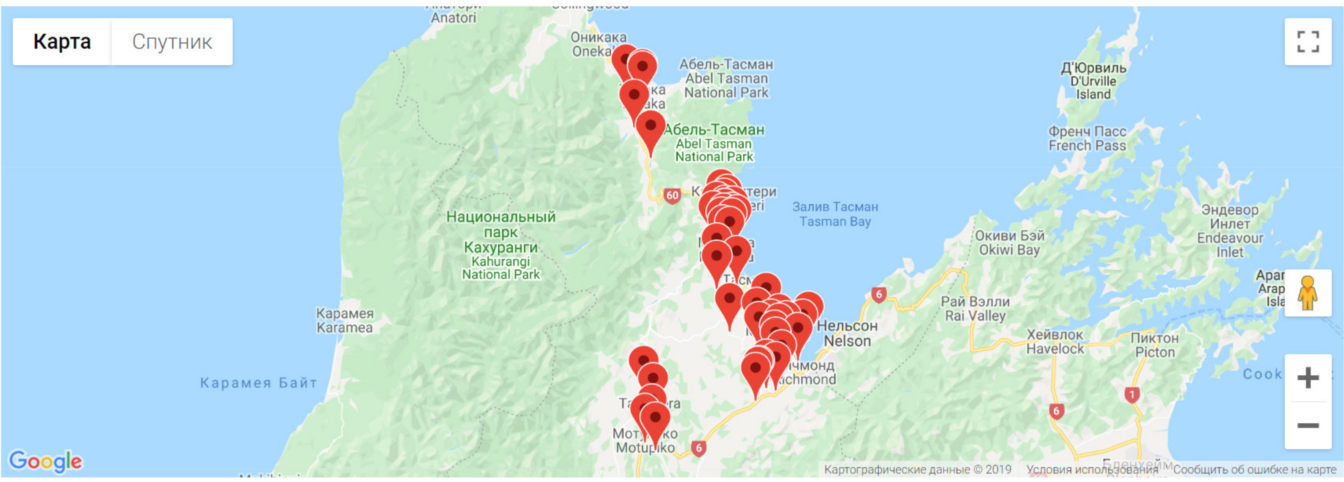


Figure 32 – Groundwater level analysis of the Tasman District Council

Sources

- **Feedback from the Ministry for the Environment** - received on 01-10-2020;
- **Ministry for the Environment, Our freshwater 2020 Report** - https://www.mfe.govt.nz/publications/environmental-reporting/our-freshwater-2020;
- **Ministry for the Environment, New Zealand groundwater atlas** - hydrogeological-unit map of New Zealand: https://www.mfe.govt.nz/publications/fresh-water/new-zealand-groundwater-atlas-hydrogeological-unit-map-of-new-zealand; and
- **Tasman District Council, Groundwater levels** - https://www.tasman.govt.nz/my-region/environment/environmental-data/groundwater-levels.

Pakistan

Capital city: Islamabad
Inhabitants: 212.2 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry of Water Resources takes the lead on behalf of the Federal Government for development of the water sector. In this regard, the Scarp Monitoring Organization (SMO) is working under the Umbrella of the International Waterlogging and Salinity Research Institute (IWASRI) of the Water and Power Development Authority (WAPDA).

The Water and Sanitation Agency (WASA) of several major municipalities carry out some groundwater monitoring within urban centres but this does not extend to rural or agricultural areas (Bhatti et al, 2016). In addition to WASA's groundwater monitoring within urban cities, Pakistan Council of Research in Water Resources (PCRWR), Islamabad, is also working on the observation of water table depth. Moreover, the Geological Survey of Pakistan conducts work on groundwater resources exploration.

Provinces may have their own groundwater monitoring programme, as the one from the Directorate of Land Reclamation (DLR) of the Punjab Irrigation Department.

CHARACTERISTICS OF THE NETWORK

Since 1968, SMO conducts hydrological monitoring pre and post monsoon (depth to water table and water quality) biannually in the Indus Basin Irrigation System (IBIS).

Compared to other provinces of Pakistan, the DLR of the Punjab Irrigation Department has a much more systematic groundwater monitoring program with 3,000 observation wells. DLR measures the water levels in piezometers manually, twice a year.

PROCESSING AND DISSEMINATION

Data collected in approximately 9000 observation wells in Punjab and 3000 in Sindh from 49 canal commands of Punjab, Khyber Pakhtunkhwa, Sindh and Balochistan provinces is analysed by SMO and maps are developed using GIS.

The interactive map on the website of Punjab Irrigation Department (https://irrigation.punjab.gov.pk/) presents the aquifer status of last two pre and post monsoon seasons from 2013 till 2018. The depth of the groundwater level is indicated in feet. By changing pre- and post-monsoon periods, it is possible to see the fluctuation of the groundwater level. However, neither time-series not download of data is available.

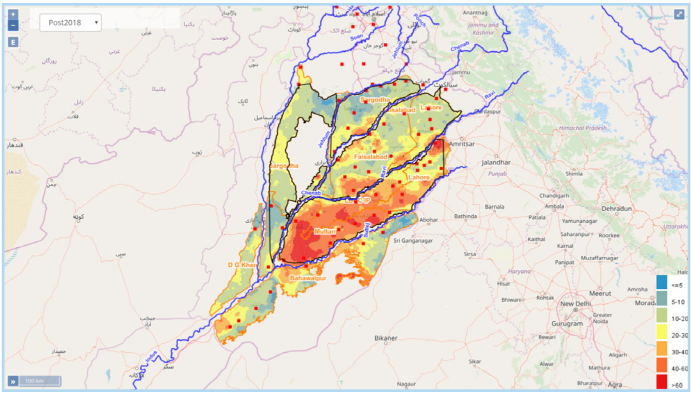


Figure 33 – Groundwater monitoring in Punjab post 2018

Sources

- **Feedback from the Ministry of Water Resources** - received on 10-11-2020;
- **Punjab Irrigation Department** - https://irrigation.punjab.gov.pk/;
- **Year book 2018-19, Geological Survey of Pakistan** - https://www.gsp.gov.pk/images/year-book-2018-19-pdf-final.pdf; and
- **Ministry of Water Resources, Government of Pakistan** - http://mowr.gov.pk/.

Thailand

Capital city: Bangkok
Inhabitants: 69.4 Million

INSTITUTIONAL SETTING AND PURPOSE

The Department of Groundwater Resources (DGR) is responsible for the quantity and quality assessment of groundwater, as well as for the development of protection requirements to support groundwater management. Some of the specific tasks of the DGR are the selection of sampling sites, the analysis and transfer of data.

The objective of the national monitoring programme of Thailand is to identify spatial and temporal trends and to understand the causes of change of the groundwater status.

CHARACTERISTICS OF THE NETWORK

The groundwater monitoring network of Thailand started its operation in 1977. Nowadays it has a total of 1,312 stations encompassing about 2,535 wells. One station included approximately 2 to 8 wells.

Groundwater levels are recorded both manually and automatically. Groundwater quality sampling is performed twice a year. Recently, DGR developed a mobile phone application to assist data collection.

Collected metadata are name and location of the well, ground surface elevation, date of measurement, depth to groundwater, elevation of groundwater surface, note of well status (pumping or not pumping) and any surrounding conditions that might affect groundwater levels. Moreover, a reference point is checked to assure consistency in the measure of groundwater depth.

Figure 34 – Protection of the observation well (left) and the process of reading the measurements (right)

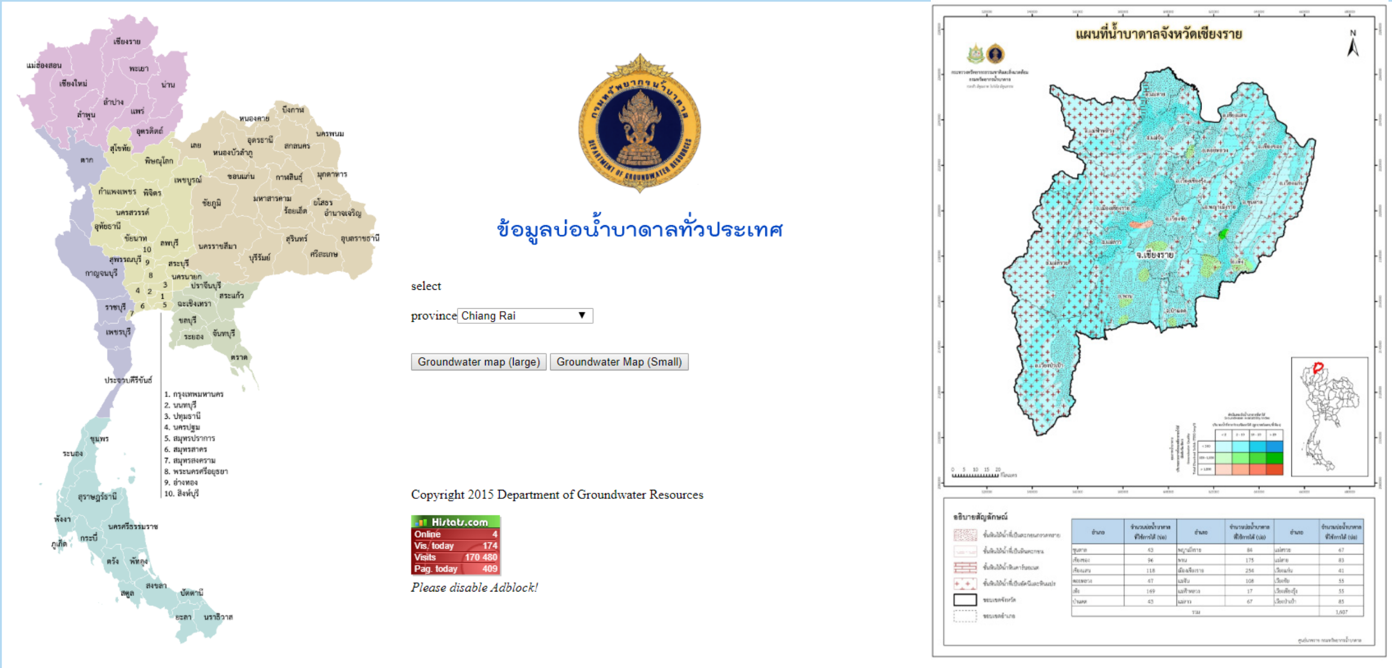


Figure 35 – Groundwater well map in Thailand. Source: Groundwater Resources Information System Group

Groundwater level data are used to make Groundwater level maps (potentiometric surfaces) and maps to represent the changes in groundwater levels. DGR website has a section for groundwater level and status. Currently, DGR manages the Thailand Groundwater Monitoring System (TGMS) (in Thai, link in Sources).

Data are also stored in the Pusuthara Information System (in Thai), where people can register to search, capture and store data. Spatially distributed data (GIS) are also available. The system consists of the Pasuthara database, a portal for groundwater surveillance and monitoring at remote stations and various information portals: for groundwater control, groundwater management in groundwater crisis areas and for conjunctive use.

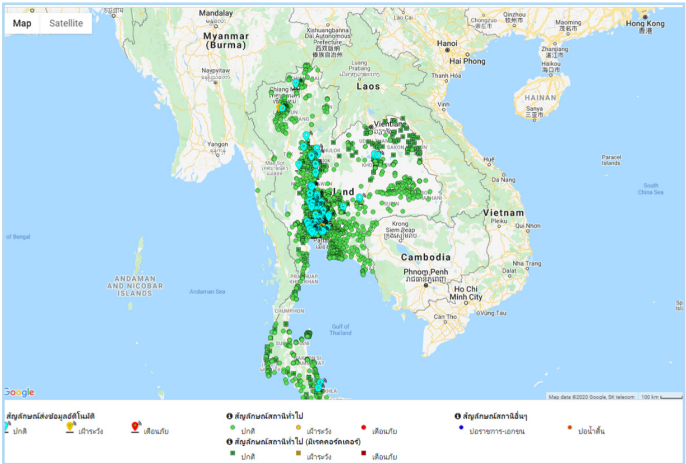


Figure 36 – Thailand Groundwater Monitoring System (TGMS). Source: DGR.

Sources

- **Department of Groundwater Resources** - http://www.dgr.go.th/th/public-service/36;
- **Department of Groundwater Resources, Public service** - http://www.dgr.go.th/th/public-service/41;
- **Feedback from the Department of Groundwater Resources** - received on 09-10-2020;
- **GGMN South East Asia Workshop** - 2016;
- **Groundwater Resources Information System Group, 2015** - http://app.dgr.go.th/newpasutara/xml/Krabi.files/show3.php?d-dlGeo=45&btn2=;
- **Ministry of Agriculture, Livestock and Irrigation. Irrigation and Water Utilization Management Department. Presentation on Pilot Project of Groundwater Monitoring in Myanmar (includes information about Thailand)** - https://www.dwir.gov.mm/images/world-water-day/05_GW%20Monitoring%20in%20Myanmar_U%20Thant%20Zin.pdf; and
- **Thailand Groundwater Monitoring System (TGMS)** - http://tgms.dgr.go.th/#/home.

Vietnam

Capital city: Hanoi
Inhabitants: 95.5 Million

INSTITUTIONAL SETTING AND PURPOSE

The Ministry of Natural Resources and Environment (MONRE) performs the function of state management in the fields of land, water resources, mineral resources and geology; environment, meteorology and hydrology; climate change surveying and mapping, integrated management of natural resources, and protection of sea and island environment. As a part of MONRE, the National Centre for Water Resources Planning and Investigation (NAWAPI) is in charge of groundwater monitoring.

CHARACTERISTICS OF THE NETWORK

Water resources monitoring systems have been developed since 1980s. In 2020, 946 monitoring wells were part of the National Groundwater Monitoring Network of Vietnam, covering aquifers in the Northern Region, North Central Region, Central Highlands, South Central Coast and Southern Region, Figure 1. The collection of data is carried out manually and automatically, with more than 50% of the wells working automatically.

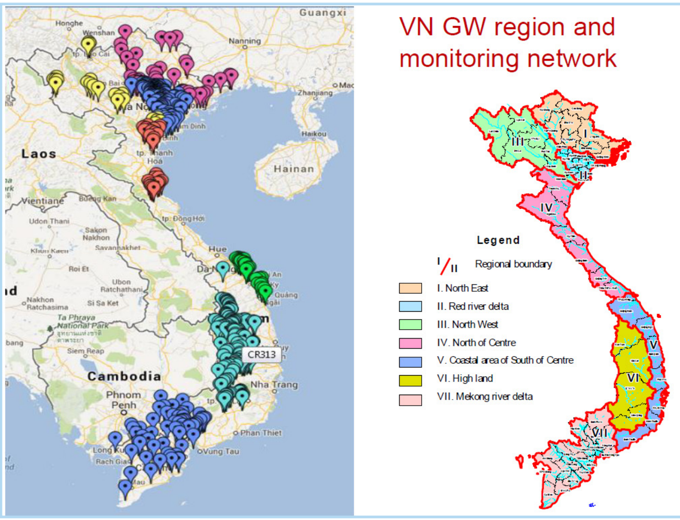


Figure 37 – Groundwater monitoring network in Vietnam. Source: Ministry of Agriculture, Livestock and Irrigation of Myanmar, March 2017, GGMN workshop

The automatic monitoring gauges are capable of monitoring and automatically transmitting data according to pre-set programs. Data is connected and transmitted via GSM/GPRS/3G/4G mobile networks. Through the use of automatic recording gauges and modern data transmission technology mentioned above, the observed data is always ensured synchronous, economical, accurate and timely, making an important contribution to the results and topicality of water resources forecasts and warning bulletins.

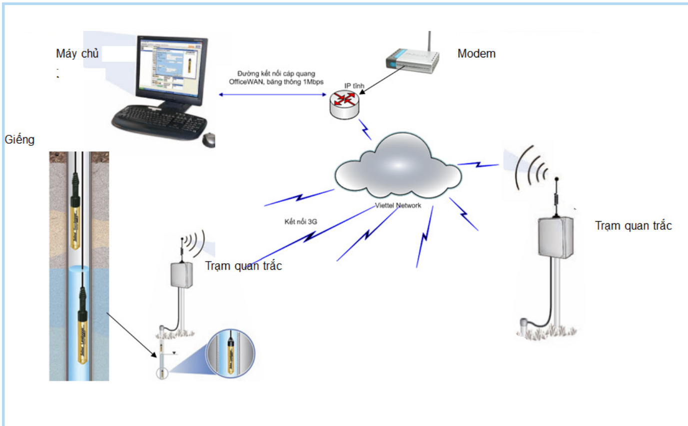


Figure 38 – Flowchart of automatic monitoring technology (Source: MONRE)

PROCESSING AND DISSEMINATION

Data from the field is automatically transferred to the National water resource database developed by NAWAPI, Figure 3. The database was established on the basis of modern technology for storage, unified management, and information sharing and exploitation, which improves cooperation among state agencies and makes a practical contribution to the socio-economic development.

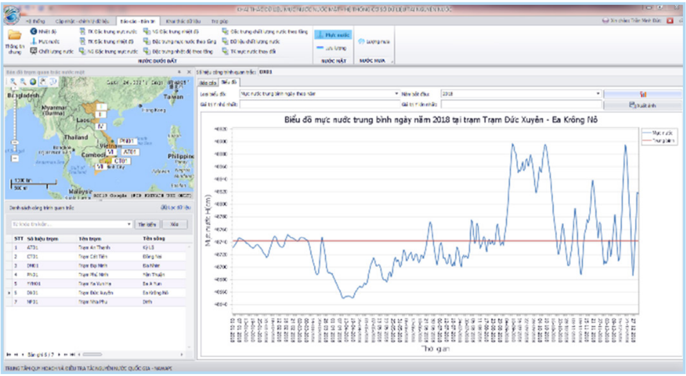


Figure 39 – National database software interface (Source: MONRE)

NAWAPI's database has been put into operation with the task of creating a convenient system for receiving, storing, sharing and exploiting information and data for multiple purposes, in a multidisciplinary way. In the future, the database will be fully integrated with the monitoring systems to be able to access and exploit real-time data.

On the other hand, there is a decentralized monitoring data management system working nationwide, Figure 4. The system provides and supports management tools as well as several types of monitoring data for different management, planning and information needs of society. The system provides data and information on water resources, forecasts and warnings throughout the country, and helps people and businesses to promptly and effectively access to them.

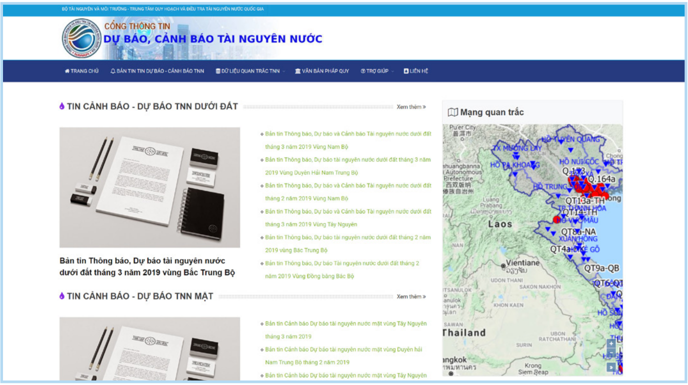


Figure 40 – Real-time water monitoring, forecasting and warning data portal operated by NAWAPI

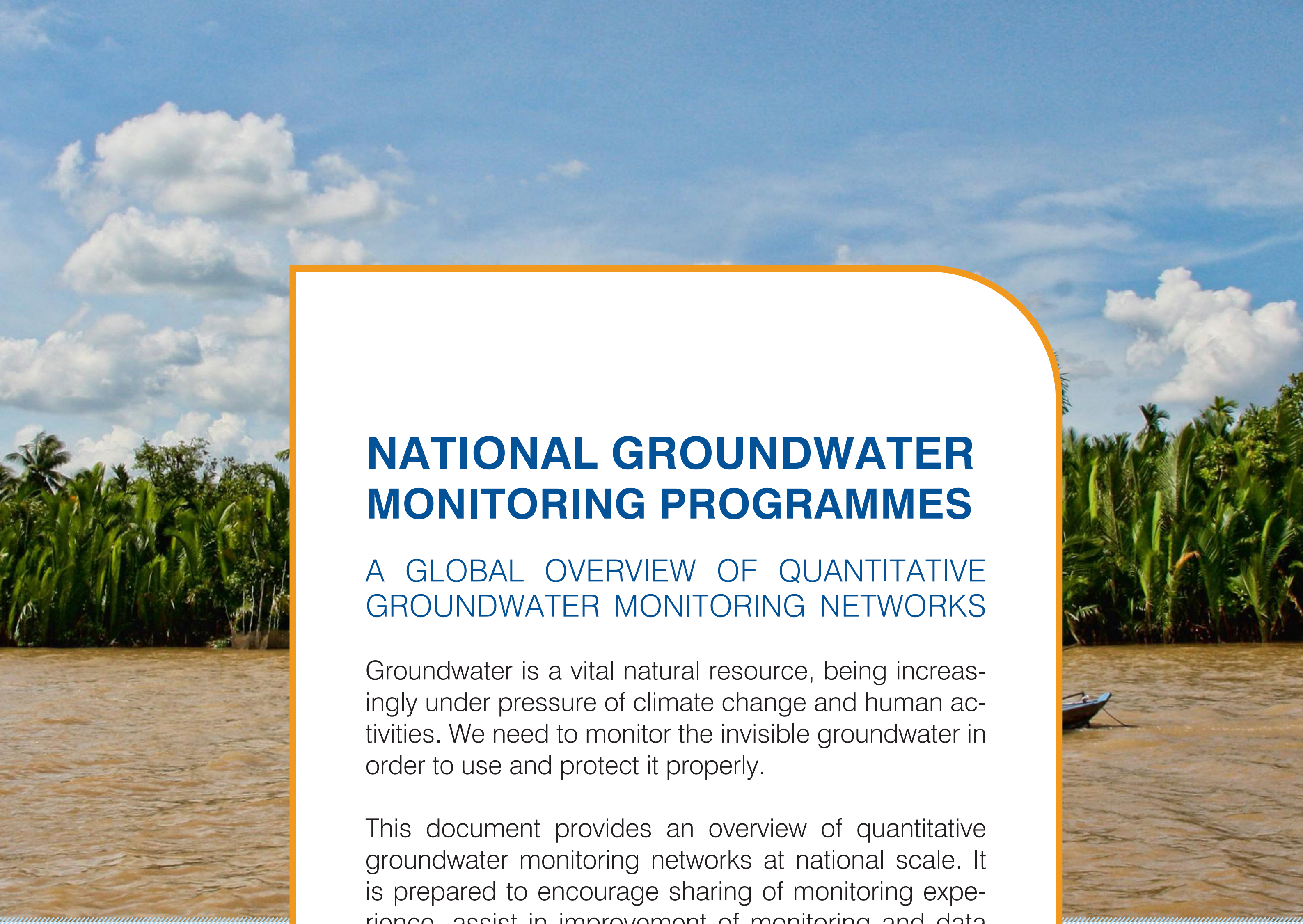
Regarding simulation and computation, NAWAPI invested in one high-performance computer system, including two head node servers, two broker servers, twelve workstation computers, one central storage system, 38 workstations, and three monitors, to improve the quality of simulation and calculation for water resource warning forecasting. In addition, in the field of water quality analysis, NAWAPI also invested in a laboratory with modern analytical equipment with a high level of automation to facilitate observation and analysis of water quality.

In order to improve the quality of water resources warning and forecasting, NAWAPI has built and applied the MO operational system, which integrates models of hydrology, hydraulics, water balance and groundwater, in simulation and prediction works. In particular, this system has modules that allow the construction and management of simulation scenarios, real-time calculations with automatic connection to import, process data, run simulation models, and show results. Moreover, the system can compare scenarios and perform sensitivity analysis, as well as model optimization. Associated models in the MO system are licensed and updated regularly. The MO system can produce forecasts and warnings applied to groundwater resources (monitoring water levels and supporting decision making) in 5 regions (Northern Region, North Central Region, Central Highlands, South Central Coast and Southern Region). In addition, NAWAPI has also applied, combined and converted a number of mathematical models, as the conversion of a numerical model from GMS to Feflow and the calculation of saline intrusion in the Mekong Delta using GMS.

Groundwater data collected through the national monitoring network are stored in NAWAPI's database. Timeseries of groundwater parameters can be downloaded from the web portal, by request only. Monthly, quarterly and yearly notifications, warnings and forecasts are regularly published for localities and people in a timely manner. Those newsletters can also be downloaded easily through the NAWAPI's website and its portal dedicated for water monitoring and forecasting (see links in Sources section).

Sources

- **Feedback from NAWAPI, MONRE - received on 29-09-2020;**
- **GGMN workshop in Thailand - 2016;**
- **NAWAPI's website (1) - http://www.nawapi.gov.vn/index.php;**
- **NAWAPI's website (2) - http://123.16.176.41/nawapinew/ (newsletters);**
- **NAWAPI's water monitoring and forecasting portal - http://123.16.176.41/lawis/public;**
- **MONRE main website - http://www.monre.gov.vn/English/Pages/Home.aspx; and**
- **Real-time water monitoring, forecasting and warning data portal operated by NAWAPI - http://123.16.176.41/lawis/public.**



NATIONAL GROUNDWATER MONITORING PROGRAMMES

A GLOBAL OVERVIEW OF QUANTITATIVE GROUNDWATER MONITORING NETWORKS

Groundwater is a vital natural resource, being increasingly under pressure of climate change and human activities. We need to monitor the invisible groundwater in order to use and protect it properly.

This document provides an overview of quantitative groundwater monitoring networks at national scale. It is prepared to encourage sharing of monitoring experience, assist in improvement of monitoring and data processing and increase awareness of a general lack of groundwater monitoring.

The full report, including analyses and country profiles of other regions is available on the IGRAC website:

www.un-igrac.org/global-monitoring-overview

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