Assessment of Groundwater Resources in Nam Dinh Province

Executive Summary about Major Conclusions and Recommendations for Water Management

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Background

The province of Nam Dinh is principally endowed with a subtropical climate and abundant surface water resources. However, economic and social developments, combined with the population growth over last decades, have strongly increased pressure on available water resources.

Surface water is the traditional water source and still used in Northern and Eastern areas of Nam Dinh. In South and West of Nam Dinh deeper groundwater resources has been increasingly exploited for domestic as well as economic utilization. Groundwater will be increasingly important for Nam Dinh’s future water supply strategy, since surface water is vulnerable and increasingly affected by climate change, untreated sewage water and industrial waste water. Thus, sustainable groundwater exploitation and management is crucial for life, development and the environment in Nam Dinh.

Facing this background, the IGPVN project studied the status of groundwater resources and their utilization in Nam Dinh province.

Groundwater resources in Nam Dinh

Nam Dinh province is located in the south of the Red River flood plain on the South China Sea. The local geological structure is dominated by a complex sequence of unconsolidated high and low permeable alluvial and marine sediments. Alluvial Pleistocene sediments of the Ha Noi Formation (qp1) have proven to be yielding aquifers and are subject of extensive utilisation since few decades. More shallow aquifers are of minor relevance due to their low yield and high salinization as well as pollution. Further yielding aquifers might be found in deeper Neogene sediments and in the adjacent limestone and siltstone hard rocks.

Since the 1990s, the groundwater extraction in southern and central Nam Dinh province exceeds recharge, resulting in drawdown of groundwater levels in Pleistocene and Neogene aquifers up to 0.7 m/year (Figure 1) as well as an increasing groundwater salinization. The

![Figure 1: Groundwater level in Holocene (qh), Pleistocene (qp) and Neogene (n) aquifers since January 1995 measured in National Monitoring Wells in Nam Dinh Province (Data source: CWRPI).](image-url)
consequences are that nowadays hand pumps must be replaced by electric pumps in order to pump the groundwater to the surface and, thus, increasing the costs for water supply.

**Design of a Groundwater Monitoring Network**

Since the spatial distribution of existing National Monitoring stations is not sufficient for Assessing Nam Dinh`s groundwater resources, IGPVN project has installed a complementary groundwater monitoring network; comprising 23 monitoring wells with maximum depths up to 150 m (location see Figure 2). In these wells groundwater quantity is continuously monitored in Holocene, Pleistocene, Neogene and Triassic aquifers. In order to test the groundwater quality sampling campaigns have been carried out to sample and analyze groundwater in accredited water laboratories. Staff from the National Centre of Water Resources Planning and Investigation (CWRPI) as well as Provincial Departments of Natural Resources and Environment (DONRE) has been trained in technical works to collect data from the groundwater monitoring network.

It is strongly recommended that Vietnamese decision makers provide a budget in order to transfer monitoring network to Vietnamese authorities and continue groundwater monitoring in the future.

**Assessment Groundwater Resources - Summary**

**Groundwater Salinity and Quality**

A horst of crystalline Proterozoic rocks in the NW of Nam Dinh represents a hydraulic barrier between the Western Triassic hard rock aquifers and the eastern RRD. Southward of this barrier, the unconsolidated Pleistocene and Neogene aquifers receive significant recharge of

![Figure 2: Classified post map of dissolved Arsenic in Pleistocene groundwater, measured in Mai 2010 in the groundwater monitoring wells.](image)

![Figure 3: Simple Fe/As filter in a private household nearby Q226, improving taste and quality of drinking water (photo fw).](image)
fresh groundwater from Triassic limestone rocks in West and NW of Nam Dinh. The continuous inflow during several ten thousands of years has established a fresh water “wedge” in Pleistocene and Neogene formations of high drinking water quality.

A large portion of Holocene fine grained sediments are covering and protecting the deeper aquifers from surface water pollution and salinization. High-saline pore waters in these fine grained sediments are major source explaining the elevated salinity in brackish deeper aquifers (Pleistocene and Neogene) in the Red River area East of Nam Dinh. In the West and Southwest, fresh and low saline pore water in qp and n aquifer only persist due to the continuous inflow of fresh water from the adjacent Triassic hard rock aquifers.

As mentioned above, saline pore water dominates the composition of groundwater in deeper aquifers (Pleistocene and Neogene) in South-East, East and North-East of Nam Dinh. Moreover, the specific geochemical conditions promote an acceleration of the mobilisation of potentially toxic substances, such as arsenic, ammonia, iron and manganese (Figure 2). In worst case scenarios, consumption of high Arsenic levels can result in skin and other cancer diseases and consumption of nitrite (an oxidation product of ammonia) can result to the sudden infant’s death. Therefore, high yielding Pleistocene and Neogene aquifers in large areas of North, East and SE Nam Dinh, are considered not to be usable for drinking water supply without applying appropriate water treatment technologies. Special caution to groundwater use must be spend on the transition areas of fresh to brackish salinity (1 g/L to 3 g/L) where groundwater is still consumed due to lacking alternatives. Simple household filters are a first mitigation strategy only on a household level (Figure 3).

**Groundwater Quantity & Overexploitation**

The fresh and high quality groundwater in deeper aquifers in central and South Nam Dinh is subject of increasing extraction and usage. Monitoring data since 1990’s show that the groundwater extraction exceeds the recharge since 1995 with a huge impact on the natural geohydraulic system. The new monitoring data show that a regional abstraction cone has developed in Pleistocene as well as the underlying Neogene aquifer. In this area, the natural coastward directed groundwater flow has turned towards the centre of the abstraction cone with horizontal apparent velocities of up to 0.6 m/a (up to 0.2 m/a in n unit). This results in migration of brackish and saline groundwater from East of Nam Dinh as well as from the ocean towards the fresh groundwater area.

The lack of recent and reliable groundwater extraction data is a crucial handicap for understanding the water budget in Pleistocene aquifer and its replenishment. Groundwater age dating indicates a groundwater age of up to 12,000 years in Pleistocene aquifer in the centre of the abstraction cone and even older in deeper Neogene aquifers (Figure 4). This confirms low recharge rates and demonstrates the long time period which is necessary to recover the fresh groundwater resources.

Results of the numerical modeling suggest that exploitation of the groundwater resources will not be reversible, as the demand for freshwater is way greater than the potential fresh groundwater recharge in the model area. With the current model settings, a freshwater intake of about 8000 m³/d stands in contradiction of an estimated extraction of more than
60,000 m³/d (based on reports from DWRPIN, 2009). Taken these figures into account, a sustainable groundwater resource management must be considered as an extremely challenging task for Nam Dinh authorities. Consequently, a change of the strategy of water withdrawal must be considered. The current extraction habits will lead to a faster intake of saline water from the eastern and southern boundaries.

![Figure 4](image)

**Figure 4**: A conceptual cross section demonstrating some major results of this study regarding groundwater salinity and flow in Pleistocene (qp₁, qp₂) and Neogene (n) aquifers. Colours represent fresh (blue), brackish (orange) and saline (red) pore water, italic figures indicate groundwater ages in years (a). Further hydrogeological units: Triassic hardrocks (t₁, t₂) and Proterozoic basement (PR).

**Groundwater Extraction & Use in Nam Dinh**

Facing a lack of groundwater extraction data from Nam Dinh province, the IGPVN project has carried out a questionnaire in Nam Dinh in August 2011. The survey focused the portion of groundwater in communal domestic water supply as well as the average water demand per person. The data have been supplemented by archive data from 2007 (DONRE). The results have shown that the average water consumption per person is ~0.2 m³ per day. Based on the average groundwater usage per commune (see figure) a total groundwater extraction for domestic purpose has been calculated to be more than 180,000 m³/day. The spatial distribution has been mapped in Figure 5. The questionnaire has shown that even high quality groundwater is used not only for drinking purpose but also for washing, irrigation and other purposes where low quality surface water would be sufficient, too.

The relatively high observed total water demand also reflects the higher needs in the summer dry season such as for garden irrigation due to the absence of alternative water sources, such as rain water. Thus, domestic groundwater extraction is expected to be lower in the winter season. However, it must be kept in mind that during this survey, collection of extraction data from mineral water producers or other industrial and agricultural groundwater users was not allowed. Due to lacking commercial groundwater users, the surveyed data are expected to still underestimate total groundwater extraction in Nam Dinh. It is recommended to extend the database by surveys during rainy season and to add data from commercial extraction wells. Nevertheless, the existing data base already represents a useful basis for future licensing and water supply decisions.
Figure 5 - left: Portion of groundwater used for communal water supply in Nam Dinh province based on the information collected during field survey 2011 (n=167). Red line indicates salinity boundary (mg/L) in Pleistocene aquifer. Figure 5 - right: Calculated amount of extracted groundwater (m$^3$/day/km$^2$) based on survey of domestic communal water supply.

**Recommendations for Groundwater Management**

As stated above, increasing overexploitation and salinization of deeper aquifers in Nam Dinh requires an adequate response in frame of new water management strategies from responsible authorities. A large portion of the groundwater recharge originates from Triassic hard rocks in Ninh Binh area in the West of Nam Dinh. This demonstrates the trans-boundary behaviour of water resources, so that the neighbouring catchment area in Ninh Binh province needs to be integrated in GW balance calculations for Nam Dinh province. IGPVN project has studied groundwater recharge as well as groundwater extraction based on the available data as demonstrated above.

Since groundwater extraction must not exceed the amount of recharge to prevent mining of fresh groundwater, it is recommended that decision makers provide funding for improving the existing data base by further technical studies about groundwater recharge and actual domestic and commercial groundwater extraction. Furthermore, funding must be provided for continuous monitoring of the groundwater resources carried out by technical staff with the necessary expertise. But first of all, the responsible authorities must clearly define their requirements for water management and mobilize the necessary resources to reach the envisaged goal.

However, the current exploitation in Nam Dinh already exceeded the aquifer capacities of recharge with fresh water since 1995 and, thus, the responsible authorities must counteract
with new management and mitigation strategies aiming to more sustainable solutions. Thus, a close connection between water policy, science and engineering, and a strong cooperation between different groundwater users such as water supply companies, agriculture, aquaculture and other industries as well as domestic households is crucial. (Ground)Water Resources can only be managed successful in frame of a transboundary approach, integrating all relevant institutions and stakeholder (Integrated Water Resources Management).

Measures to counteract Groundwater Overexploitation & Salinization

Besides the general requirements stated above, the list below provides some practical measures and challenges in order to manage overexploitation and salinization, potentially leading towards a more sustainable groundwater usage in Nam Dinh province.

1. **Controlling extraction**: Continuously updated information about the groundwater extraction status is crucial for managing groundwater resources. This comprises not only governmental (communal) water extraction, but also extraction wells for industrial, agro- and aquaculture purpose as well as an assessment about the decentralized extraction from private households.

2. The national decrees, guidelines about **well registration** and **extraction licensing** measures must be realized consequently and transparently. Stronger criteria are recommended for future extraction well licenses in the area of central and south of Nam Dinh, such as water use only for human consumption and non-economic purpose.

3. Coverage of communal **central water supply** based on treated surface water should be extended continuously to reduce uncontrolled water extraction. However, water quality of a central water supply must be continuously monitored.

4. **Reducing extraction**: Availability of high quality groundwater is a limited national reserve and, therefore, should be kept for drinking water purposes. Thus, it should be used for domestic drinking water supply only and wherever possible replaced by surface water usage. Therefore, necessary actions are:
   - Identification of sources for **groundwater loss or misuse**, together with the design and approval of mitigation strategies. Leaking wells, pipes, tubes and taps are common causes for wasting groundwater.
   - Identification of **alternatives for groundwater usage** with lower priority, such as (i.) application of saline tolerant crops in agriculture, and (ii.) treatment and usage of surface water for industry, aqua- and agriculture and domestic uses other than consumption
   - **Awareness campaigns** should inform local population that they can wash dishes, motorbikes or irrigate their garden with water from the next channel, rather than to waste valuable groundwater. Note that also surface water utilization requires a basic quality control even when not used for consumption.
5. **Optimizing extraction**: Salinization of remaining fresh groundwater can be minimized by applying appropriate exploitation strategies with focus on the W Nam Dinh. This can only be achieved by having detailed knowledge about the local subsurface structure and their hydraulic characteristics.

6. **Conjunctive usage**: Mixing of high quality water with poorer quality water may extend the available amount of water with still acceptable quality for water supply. This should be understood as an intermediate action while realizing the recommendations above.

7. **Groundwater monitoring**: A groundwater monitoring plan need to be established including funding for continuous monitoring of groundwater quality and quantity. Data collection and analysis must be carried out by technical experts with sufficient hydrogeological background. In this frame the IGPVN groundwater monitoring network in combination with the national monitoring network should be the focus for future national and/or provincial groundwater monitoring plans. The current national & provincial monitoring efforts must be synchronized and data exchange to the provincial level improved.