Towards rational groundwater governance for the Vietnamese Mekong Delta

by

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Abstract

The Vietnamese Mekong Delta (VMD), the rice bowl of Vietnam and the world, is a vital area in economic and agricultural aspects. This area is affected by environmental degradation such as decreased water availability, drawdown, and subsidence due to unsustainable land use practices. The objective of this study is to assess the possibilities of rational groundwater governance in Soc Trang Province, one of the coastal provinces in the VMD. The possibilities depend on one hand on the available physical knowledge, and on the other hand on societal and political priority settings. Based on literature study, the Wheels of Environmental Governance (WEG) assessment framework is suggested, showing the extent to which rational groundwater governance is currently possible by assessing conditions regarding the environmental system, values, stakeholder involvement, legislation, enforcement, economics, and monitoring. To determine whether these conditions for rational groundwater governance are present, the empirical part of this research used mixed methods consisting of a literature study, interviews with experts (from universities and government) and a qualitative survey among laymen in Vinh Chau District. The study shows that rational groundwater governance is currently not possible since the only condition that meets the WEG assessment criteria is that of the system knowledge. The results of this research confirm that groundwater governance has grown in the VMD, but requires intensive improvements regarding the institutional legal framework, monitoring, and full actor involvement. The current incapacities of groundwater governance are of variable natures, and policy prospects towards rational governance are suggested, such as harmonization of the institutional and legal framework, a more open flow of information, and further stakeholder involvement.

Summary

The Vietnamese Mekong Delta (VMD) is a vital area in regarding the economy, agriculture, and aquaculture, the current unsustainable usage of groundwater resources leads to environmental degradation and could be helped by the formulation of rational groundwater governance.

This research assessed the possibilities for rational groundwater governance using the Wheels of Environmental Governance (WEG) assessment framework. This framework assessed whether there is sufficient system knowledge, all values and policy discourses are considered, all stakeholders are involved, and whether legislation and enforcement, and the financial stability and its monitoring lead to rational governance. The WEG assessment framework followed from existing literature, packaged in a more concise and user-friendly manner.

The available water system knowledge regarding drivers towards water resources degradation, and eventually environmental degradation is not enough for modeling purposes, although policies and further knowledge building can be based on it. Moreover, there are policy discourses, clarified by the current extent to which there is pro-environmental behavior, economic difficulties, groundwater extraction motivations, and the suboptimal implementation of policy.

Stakeholder participation is mainly for government authorities where local authorities are often excluded from policymaking and planning, and there is insufficient orientation to one another to come to a coordinated approach. There are difficulties bending national policies to the local scales, and there is too little focus on bottoms up responsibility taking for delta problems. Moreover, concepts of community participation are not applied since local authorities consider their representation of the citizens as participation.

Regulations in the water sector are dispersed and scattered throughout a large number of legal documents, with occasionally identical contents, different hierarchies, and contradiction, leading to confusion. Enforcement mechanisms seem to lack regarding groundwater restriction, adherence to regulations, and abilities for enforceability. Financial arrangements are in place, although there are concerns relating to the lack and transparency of funds. Although monitoring is scheduled for extensive improvements, the lack of data sharing causes monitoring to only limitedly contribute to insights of the effects of financial investments.

These findings state that rational groundwater governance is currently not possible, but give a direction for intervention strategies, which can be summarized as the harmonisation of the current legal and institutional framework, and adjustments to local conditions. Further strategies are the development of local economic circumstances to improve pro-environmental behavior, full stakeholder involvement, an open database, and the consideration of the value of scientific data.

These intervention strategies can be a focus of further study, whereas the limitations of the current legal and institutional framework should be taken as a boundary condition. However, these strategies are key to ensure the sustainable functioning of the VMD as a vital economic area and living environment.

Acknowledgements

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This project consists of the collaboration of the Utrecht University, Can Tho University, Deltares, the Division of Water Resources Planning and Investigation for the South of Vietnam, TNO, and the Southern Institute for Water Resources Research. I would like to thank this project for the opportunity to be part of it, and I hope to have contributed to it by means of this thesis. This thesis would not be possible without the support of others, with that in mind I would like to acknowledge the following people.

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Thomas Hamer, February 1st, 2017, Rotterdam.

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Abbreviations & acronyms

AWD ....Alternate wetting and drying (techniques)
CERWASS......................Centre for Rural Water and Environmental Sanitation
CFM ....Causal field model
DARD ....Department of Agriculture and Rural Development
DoC..............................Department of Construction
DoH ....Department of Health
DoJ...............................Department of Justice
DONRE.........................Department of Natural Resources and Environment
DOST............................The Department of Science and Technology
DoT ....Department of Tax
DPSIR...........................Drivers, Pressures, State, Impact, Responses
FAOLEX........................The legal office of the FAO, the Food and Agriculture Organization
FFM ....Final field model
GDP ....Gross Domestic Product
GMM ....Governance Management Model
IGPVN ....The project "Improving Groundwater Protection in Vietnam"
InSAR ....Interferometric synthetic aperture radar
IWRM ....Integrated Water Resources Management
[KE] ....Acronym used to show a result from the Knowledge Experts
MARD ....Ministry of Agriculture and Rural Development
MONRE........................Ministry of Natural Resources and Environment
MCA.............................Multi-criteria analysis
MDRBO........................Mekong Delta River Basin Organization
NWRC ....National Water Resources Council
(PERG) ....Acronym used to show a result from the Policy Expert Respondent Groups
[P-SURVEYS] ....Acronym used to show a result from the pumpstores surveys
PM ....Policy Model
ppt ....parts per thousand
RBO ....River Basin Organization
RWSS ....Rural Water Supply and Sanitation (policy)
[SURVEYS] ....Acronym used to show a result from the laymen surveys
SIWRP ....The Southern Institute For Water Resources Planning (SIWRP)
SNIAPP.........................The Sub-National Institute for Agriculture Planning and Projection (SNIAPP)
SPSS.............................Statistical Package for the Social Sciences (IBM SPSS Software package)
UNDP...........................United Nations Development Programme
USD..............................United States Dollar (national currency of the USA)
VMD ....The Vietnamese Mekong Delta
VND ....Vietnamese Dong (national currency of Vietnam)
WEG ....Wheels of Environmental Governance (assessment framework)

1. Introduction

1.1. Hydrological challenges for the VMD

The Vietnamese Mekong Delta (VMD) has a land area of 39,712 km^2 and consists out of thirteen provinces, of which one is Soc Trang Province (Van Pham, 2009). This province (Figure 1) is heavily exploited for production by agriculture and aquaculture, consists of an area of 3,311.6 km^2 and has a population of more than 1.3 million people (2014) with a population density of 395 people/km^2 (General Statistics Office of Vietnam, 2016). In the VMD, groundwater exploitation for domestic, agricultural and industrial needs through wells has increased from a limited number before the 1960’s to a vast but currently unclear number of wells (Wagner, Tran & Renaud, 2012; Danh, 2008). While the water demand for agriculture may increase two-to threefold compared with the demand in the year 2000 (IFAD, 2014), groundwater demands in the VMD are also likely to increase in the future, due to a paradox of water availability. This delta has water scarcity in the dry season and too much water in the wet season, which contributes to approximately 80% to 85% of the annual rainfall (van Leeuwen, Dan & Dieperink, 2015).

Due to increasing groundwater extraction, groundwater resources degradation takes place manifesting into steadily declined hydraulic heads in many aquifers over vast areas (Wagner et al., 2012). This extraction has a strong relationship with land subsidence, although there is limited data available (Mekong Delta Plan, 2013; Erban, Gorelick & Zebker, 2014) and there are limited groundwater studies (Danh, Kai, 2015). Land subsidence, in turn, causes large parts of the delta to be sunk below sea-level by 2050 (Ingebritsen & Galloway, 2014). Furthermore, with the rising sea-levels, the Mekong Delta could see much of its total area subjected to flooding and saltwater intrusion. Which could lead to loss of arable land (IFAD, 2014), with tremendous consequences already after one meter of sea-level rise (Solomon, 2007). Additionally, the delta is also affected in terms of food security under threat from saltwater intrusion (Ericson, Vorosmarty, Dingman, Ward & Meybeck, 2006). Considering such problems, technical solutions

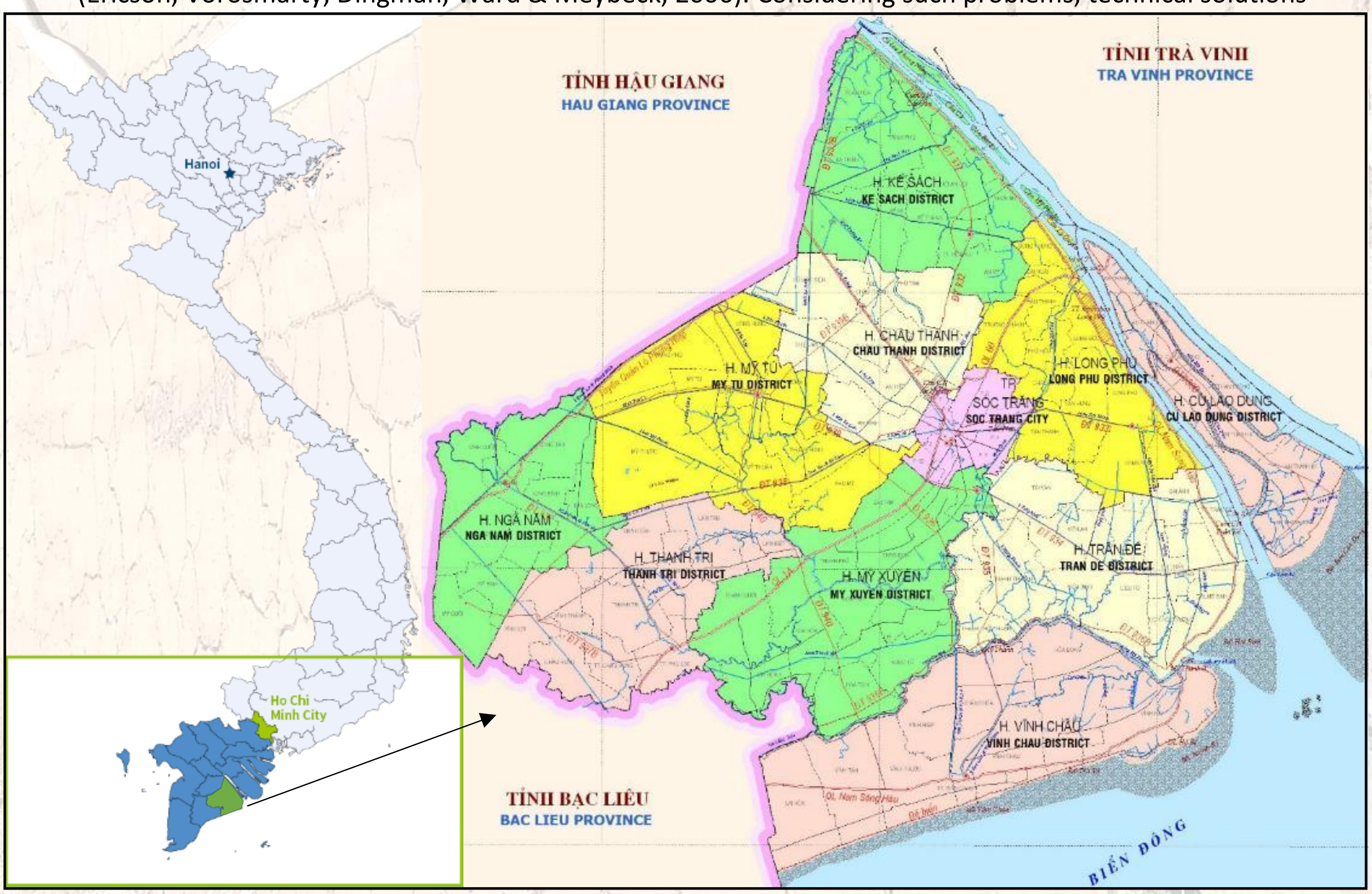


Figure 1 Soc Trang Province and its districts in the VMD, Vietnam (Invest-mekong-delta.com, 2016; Soctrang.gov.vn, 2016)

and monitoring would help, such as monitoring e.g. by GPS for instance as is done in e.g. Iran (Mousavi, Shamsai, Naggar & Khamehchian, 2001). Comparatively, by the usage of water saving techniques such as drip irrigation for crops or alternate wetting and drying (AWD) techniques for rice plants (SciDev.Net, 2014). Further examples are that of monitoring by physical measurements of the groundwater table at measuring stations such as is done in e.g. Taiwan (Chen, Hu, Lu, Lee & Chan, 2007), or the recharge of water into the aquifer (Scanlon, Healy & Cook, 2002). However, environmental governance related literature often examines single-level or uniplanar governance solutions, while in fact the governance of environmental resources is based on multi-level solutions that operate on all scales simultaneously. Here the accommodation and dealing with institutional diversity is essential for adaptive governance (Paavola, 2006).

In the VMD, centralized water resources planning has some problems regarding its effectiveness (Benedikter, 2014; Renaud & Kuenzer, 2012). Additionally, various reasons can underlie unsustainability in groundwater governance for which a rational approach to groundwater governance and hydrological challenges is required.

1.2. Rational policies for addressing these challenges

On the global scale, water resource management has historically been a top-down process, and water management problems were dominantly addressed by additional infrastructure for water supply (Ross & Martinez-Santos, 2010). Since the 1990's, there has been a scalar reconfiguration of state power in favor of regionalization and localization. Centralized state-led development has been replaced by governance emphasizing sustainability, neo-liberal and market approaches and decentralization. This change gives room to increased adaptivity and flexibility in governance, but on the other hand makes it less subject to control and predictability (Varady et al., 2012). Moreover, the global discussion on sustainable groundwater governance focused mainly on demand management through one or a combination of direct management, community management, or indirect management (Mukherji & Shah, 2005).

Now, water management is seen as a much broader collection of issues in terms of water for the environment, diffuse pollution from agriculture, climate change, and its impacts on the variability of water supply (Ross & Martinez-Santos, 2010). Furthermore, there is a focus on integrated management that takes the importance of social learning and culture in mind (Varady et al., 2012). Six types of policy instruments can be classified, regulatory (such as ownership and property right assignments, or water usage regulations), economic (financial incentives or disincentives) (Giordano, 2009; Theesfeld, 2010; Varady et al., 2012), voluntary or advisory instruments (motivation of voluntary actions or behavioral changes without financial incentives) (Theesfeld, 2010; Varady et al., 2012), technical instruments (surveying, monitoring and modeling), managerial and planning instruments (IWRM-plans, land use, spatial planning environmental impact assessment), and behavior-changing instruments (training, sharing of information) (Varady et al., 2012). Combinations occur in policy, and never only one type of instrument is applied (Theesfeld, 2010). The main challenges to successfully implementing instrumental approaches are in the acquisition of sufficient knowledge to set groundwater abstraction levels or prices, establishing sufficient methods for determining abstraction rights distributed among users, and the development of mechanisms to enforce regulation (Giordano, 2009). Furthermore, a holistic approach based on the knowledge and expertise of many disciplines is required for the provision of sustainable and equitable solutions to groundwater issues, but simplifications occur leading to biases. Such biases are found in the cause-effect relationships that underestimate the messy problem it is. Additionally, biases occur due to the consideration of management by plan and control and engineering approaches driven by the small diversity of disciplines (e.g. technical sciences and engineering) that governmental bodies have, and the practice of addressing negative consequences of groundwater overexploitation rather than the socio-economic benefits of this resource. Groundwater management is often determined by the uncertainties and knowledge gaps, cultural backgrounds, subjective preferences and prejudices (Varady et al., 2012).

Knowledge gaps and misconceptions may lead to under- or overestimation and missing of heterogeneity in environmental management (Jones, Dennis, Owen & van Hees, 2003). The rhetoric of capacity building, individual rationality, and especially local knowledge is the backbone of decentralized environmental governance and helps the effective functioning of governmental institutions due to the involvement of individuals. Effective environmental governance, therefore, requires the incorporation of knowledge on the limits of human activities that rely on high intensities of resource exploitation (Lemos & Agrawal, 2006). Furthermore, environmental governance itself can be defined as the establishment, reaffirmation or change of institutions so that conflicts over environmental resources can be resolved (Paavola, 2006).

Moreover, organizing the sustainable and rational use of water resources is not possible when full stakeholder cooperation in nature use in the area is not available (Zilov, 2013). Therefore, the aspect of rationality in water governance can be the aspect of full stakeholder participation, where the varieties of participatory mechanisms can be located and contrasted with professionalized arrangements. Irrationality in participatory progress can be deemed as illegitimacy in public policy or action when citizens have good reason not to support or obey it. Further irrationality here emerges in case there is political injustice when some groups cannot influence the political agenda, affect decision making, or gain information to assess how well policy alternatives could serve their interest. Irrationality can also be deemed as the incapability of state agencies to implement decisions in terms of the lack of information, ingenuity, expertise or resources that are necessary (Fung, 2006).

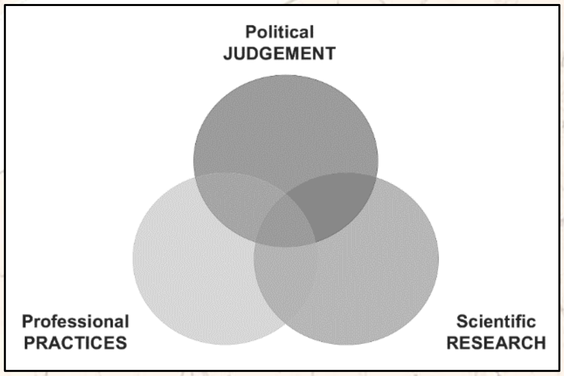


Figure 2 the three lenses of evidence based policy making (Head, 2008).

Evidence-based policy making represents an effort to reform or restructure policy processes to prioritize evidentiary decision making. This type of policy making relies on rational policy making as an exercise in pragmatic judgment, tempering political, ideological or other forms of 'non-evidence-based' policy making by the provision of evidence supporting or refuting specific policies being appropriate for the specific issues at play. Moreover, evidence-based policy making attempts to enhance possibilities for the success of policies by improving the amount and types of information processed in public policy making (Howlett, 2009). Evidence-based policy making helps to answer the questions 'what works?' and 'what happens if we change these settings?'. This evidence has connections to what works for managers and what works for political leaders, whereas this connection in evidence-based policy is the three lenses approach (Figure 2). Policy emerges from politics, judgment, and debate; it is not really deducted from empirical analysis. Evidence in policy making could be divided into three kinds, scientific research (systematic research), practice (program management experience) and political judgment. Correspondingly, there are important divergent perspectives on whether and how to increase mutual understanding (Head, 2008). To come to rational and well-informed decisions a wide range of qualitative and quantitative methods can be utilized by systems analysis, operations research and management theory combined with fully integrated knowledge as related to the problem and circumstances. Therefore, rational water governance can be regarded as making well-informed decisions based on existing policy, available resources and socio-economic impacts (Agarwal, et al. 2000).

An example of rational policy making can be found in the Integrated Water Resources Management (IWRM) concept (GWP, 2000; Mukhtarov, 2007; Agarwal, et al. 2000). IWRM, according to the Global Water Partnership (2000), is ‘‘a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems’’ (Gwp.org, 2010; Karthe, Heldt, Houdret, & Borchardt, 2014). This principle is embodied in the first Dublin principle, which states that effective management demands a holistic approach linking social and economic development with environmental protection and connects water utilization across the whole catchment area or aquifer (GWP, 2000). However, IWRM is criticized for its lack of accuracy (Hering & Ingold, 2012; Karthe et al., 2014), and should be used in recognition of existing boundaries between agencies (Mitchell, 2005). Although space is left open for operational level adaptation to an area’s specific situation due to its broad and holistic character (Karthe et al., 2014; Mitchell, 2005). IWRM is especially interesting for the VMD since it is often regarded to in Vietnamese water governance but barely acted upon in the implementation of policy (Renaud & Kuenzer, 2012). However, the management instruments for IWRM can enable decision makers to perform rational policy making, or put differently, it enables to make rational and informed choices between alternative actions based on agreed policies, available resources, environmental impacts and the social and economic consequences (Agarwal, et al. 2000).

1.3. Research aim and question

The aim of this research is to make an assessment to the degree of the possibilities of rational groundwater governance with regard to the water system in the Vietnamese Mekong Delta. First, it is necessary to assess to what extent sustainable and rational groundwater management is possible in Soc Trang Province based on conditions for rational governance. The Mekong Delta has been described in various literature, however, to come to rational and sustainable policy in water governance, this information needs to be sufficiently helpful in describing the problem and what should be done to undertake action. Therefore, the assessment of water governance in Vietnam and the analysis of the area’s problem generates to the following research question:

To what degree is rational groundwater governance possible in Soc Trang Province in the Mekong Delta, Vietnam?

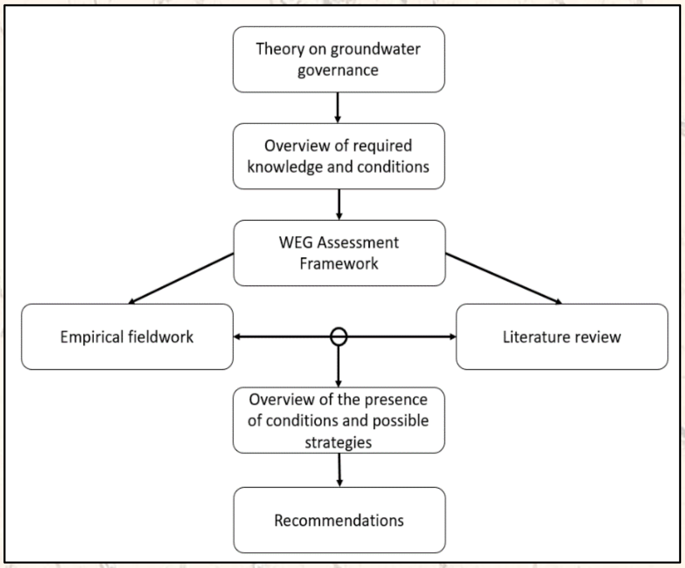


Figure 3 Research framework

Figure 3 shows the steps taken to answer the main question. To answer this question, this framework is designed to give an overview of feasible objectives towards the possibilities of rational groundwater governance. This framework puts theory regarding groundwater governance to an overview of required knowledge and conditions. This leads to a thorough but simple to use assessment framework which assesses to what extent there are conditions that either hamper or facilitate rational governance, based on the data from the empirical fieldwork and the literature review. From there, the overview of the presence of conditions is outlined, together with possible intervention strategies.

These steps lead to the following sub-questions:

1. Under which conditions is rational groundwater governance possible?
2. To what degree are the required conditions present in Soc Trang Province in the Mekong Delta, Vietnam?
3. What intervention strategies are possible based on the presence of these conditions?

1.4. Outline of the report

In the next section, the first sub-question will be answered. Chapter 2 shows which six conditions are required for rational groundwater governance. In Chapter 3, the methodology towards gathering data will be discussed. The assessment of current water governance is done in the following six chapters, corresponding with the six conditions for rational groundwater governance. In Chapter 4, the physical system knowledge is assessed, followed by knowledge on the anthropogenic aspect of the system in Chapter 5. The values and policy discourses are assessed in Chapter 6, followed by the stakeholder involvement in Chapter 7, and the regulations and agreements in Chapter 8. The financial stability of the system is assessed in Chapter 9, and from these assessments, the policy prospects towards rational groundwater governance follow in Chapter 10. The research's discussion and conclusion follow in Chapter 11, which answers the research question and finishes with some recommendations.

2. Required conditions for rational governance

2.1. Introduction

This chapter gives a direction towards rational groundwater governance, which is based on existing approaches and literature. These approaches are the Engineers Method of Hoogerwerf (Geul, 2005), and the Ten Building Blocks approach for sustainable water governance by van Rijswick, Edelenbos, Hellegers, Kok, and Kuks (2014). Consequently, these approaches then lead to a simpler and more accessible way of what conditions are required for groundwater governance in a more equitable and sustainable way and aims to answer the first sub-question:

Under which conditions is rational groundwater governance possible?

2.2. The Engineers Method of Hoogerwerf

Research occurs prior to a design, of which the analysis leads to a blueprint of the issue, its causes, and the interrelating causal processes. This blueprint then leads to a myriad of possible intervention strategies, of which the eventual governance design consists of this blueprint together with the intervention strategies. This governance design forms a new blueprint of the new situation in the problem domain that occurred due to these strategies. Evidence-based policy making is another name of this governance approach, as academics form the research behind it while taking into account the stakes that arise. The Engineers Method of Hoogerwerf defines governance in ten steps (Table 1), where the analysis of the design takes place in step 1, and the local governance issue is analyzed in step 2. In step 3, there is a thorough exploration of available scientific knowledge about the issue and how to address it.

Steps of the Engineers Method of Hoogerwerf	
Step 1	Analysis of the design
Step 2	Analysis of the local governance issue
Step 3	Systematic exploration of available scientific knowledge about the issue
Step 4	Systematic causal analysis
Step 5	Description of the direction, degree, and type of intervention strategy
Step 6	Systematic final analysis
Step 7	Systematic implementation analysis
Step 8	Determination of the most feasible governance option
Step 9	Testing that option in a policy experiment
Step 10	Report and present the findings

Table 1 The ten steps of the Engineers Method of Hoogerwerf (Geul, 2005).

The interesting aspect of step 3 is that a specific issue is often part of a wholly and globally occurring problem, of which the comparison of the knowledge of the more general problem can be used to determine as to how specific the specific problem really is. Scientific knowledge can be compared with results of experts in the field to determine the 'state of the art' of the problem and the approach to this problem. The real issue can be defined with Van Heffen's ladder (Table 2), regarding the kind of problem and which expertise is required to what depth.

	Required scientific knowledge		
Sorts of problems	Governance	Matter and domain	Methodology of experiments
Simple & certain	small	small	none
Simple & uncertain	small	small	small
Complex & certain	large	large	none
Complex & uncertain	large	large	large

Table 2 Van Heffen's ladder (Geul, 2005).

Step 4 is about the understanding of the related factors at play on the local scales, of which the scientific knowledge from the previous step can be utilized for important clues. These clues can be tested and added to from previously gained knowledge, as well as from the insights and experiences from knowledgeable actors in the problem field. From there, a causal field model (CFM) is described with causes and consequences according to available knowledge. Only the found relevant factors are given together with their causal relationship, using arrows where the arrow's point indicates the causality.

Step 5 of this method describes the direction, degree, and type of intervention strategy by means of formulating the end goal, which logically follows from the previous four steps. This step includes the formulation of the possibilities and limitations of the situation, which are the boundary conditions in the field of political, ideological, economic, legal, and ethical conditions, and the perceived opportunities and hardships of experienced local management. This information is used to describe how the problem will develop further if no measures are to be taken, making the optimum design to be performance oriented.

Step 6 makes the connection between knowledge (step 3 and 4) and the target (step 5), it generates insight into how the problem can be affected by adjusting factors in the CFM, in order to make a final field model (FFM). Every causal connection is approached by a set of four questions:

- What is the relative force of this variable for the continued reproduction of the governance-related problem?
- Where in the connections of cause and consequence is the limit of the influence that the client can wield?
- Where can actions be taken, put differently, what power can be exerted?
- How can the client intervene on the points of engagement, put differently, what instruments are available to address the problem with the boundary conditions and the end goal in mind?

The FFM, or the governance tools and effects model, results from this, displaying the problem and its routes to the solution as final-or mid-goal- relationships.

The FFM is then the ground on which in step 7, the setup and organization for policy implementation is built. Where at every final route the following questions can be asked:

- Is a new executor preferred, or is the regular organization sufficient?
- Which responsibilities, structure, capacities and financial means do the implementing actors need?

The answers to these questions give an overview of how actors can be seen as a factor to positively affect the problem to make a governance management model (GMM) (Table 3). Which by multi-criteria analysis (MCA) in step 8 gives the Policy Model (PM) for implementation for the determination of which final route (or a combination of routes) leads to the highest net gains. Basically, the PM is the FFM minus the instrumental possibilities that got eliminated after the MCA.

Possible instruments of potential governance	**Potential organizations for implementation**					
	Which organization?	Which specific task?	Which particular target?	Required information?	Required responsibilities?	Required capacities?
- Instrument 1 - Instrument 2 - Instrument 3 - Instrument 4 - Instrument 5 - etcetera						

Table 3 Governance Management Model (GMM) (Geul, 2005).

Step 9 is where the final plan can be tested in a policy experiment, comparing a group exposed to a new policy to a group that is not exposed, of which the difference in results gives the effect of the policy intervention. Finally, in the 10th step, a report of which a policymaker used the results of this experiment can be suggested (Geul, 2005).

Critique can be given to the Engineers Method of Hoogerwerf since it overrates the importance of the technical-scientific rationality neglecting the social aspects of governance, as well as the political, financial, the legal, and the communicative aspects of rationality. Moreover, the technical-scientific value is overrated as political opinions are often regarded subject to scientific knowledge. While in practice this scientific information is often regarded as additional information to already existing political views. Further critique can be given in the underestimation of the fragmentation of between and within scientific domains, which are formed by the differences between scientific disciplines over each domains' respective backgrounds, approaches, and paradigms. Moreover, the importance of scientific data is commercialized within a society where research can be regarded a weapon to prove own political views and thus their power. Furthermore, the Engineers Method of Hoogerwerf is rather time-consuming as science-based governance strategies often take longer than the allowed time period to effectively intervene into a policy problem (Geul, 2005).

2.3. The Ten Building Blocks approach for sustainable water governance

Rationality on water governance and policy making also relies on integrating policy in the fields of environmental consequences, economic parameters, the foundation of knowledge (scientific, layman's and expert knowledge) and aspects of governance itself. The Ten Building Blocks approach, a three-step interdisciplinary method to approach problems such as increased inundation risks and subsidence, gives a blueprint for this integrated approach based on extensive research.

This method is divided into ten separate 'blocks' to give dimensions (Figure 4) based on water system analysis, economics, law and public administration. First off, this is done by generating knowledge about the water system, values, principles and policy discourses. Secondly, it gives clear insight into an organizational process with sufficient stakeholder involvement, trade-offs between social objectives, attribution of responsibilities and regulations and agreements. This method finally aims to implement an agreed service level by using adequate infrastructure, enforcement, and conflict prevention and resolution (van Rijswick, Edelenbos, Hellegers, Kok & Kuks, 2014).

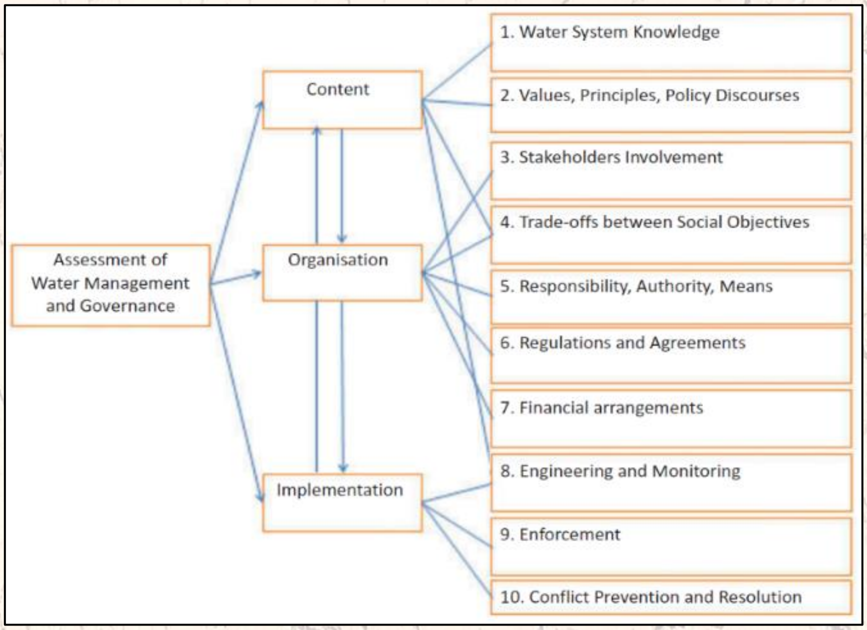


Figure 4 The Ten Building Blocks approach, an interdisciplinary assessment method for sustainable water governance, covering multiple dimensions of water management and water governance (van Rijswick et al., 2014).

Water System Knowledge

In the first building block, the water system is defined as the combination of natural resources and human-made infrastructure, which in turn supports societal functions (e.g. water resource usage) including the system's water ecosystems. Assessment of the water system requires measurements of important characteristics regarding natural processes and infrastructure; for instance, water availability is measured by precipitation at several locations in a river basin. Water resource usage requirements change with the system's societal functions, and environmental changes influence the water system's performance. Impacts of these changes are necessary to assess, as well as to support decisions and their impacts, the modelled (mathematical-physical model based) future impacts, and to take in account uncertainties (e.g. natural variability and epistemic uncertainty). Moreover, insight is required into the impacts of water resources development on the overall availability of water, e.g. water resources may be more exploited and polluted than that the water system can sustain. Furthermore, insight regarding risks associated with the water system are important to assess (e.g. flood hazards) (van Rijswick et al., 2014). According to van Rijswick et al. (2014), the assessment criteria for the first building block is as follows: ''***Is there sufficient knowledge of the existing water system in order to deliver the required service level of societal functions? If not what are the gaps; is sufficient knowledge available to assess the impact on the water system because of changes in the environment and societal functions?***''

Values, Principles, Policy Discourses

The often-neglected dimension of water management is that of the different values, principles, and narratives that water issues touch upon. The values can enable the finding of legitimate and easier to implement solutions once water governance and management is based on shared values. Here, the trust in the integrity of all involved stakeholders and the aim to find a wholly embraced solution is crucial to good water governance. Principles are the concepts used to give shape to how a water system is managed, such as institutional principles (e.g. decentralization), principles of good governance (e.g. proportionality and public participation), and specific environmental principles (e.g. the polluter pays principle). The combination of values and principles play a role to enhance creativity (e.g. new alternatives in policy development and decision making). Narratives are what is going on in a system, and can be considered to be the policy discourses, which are the different ensembles of actors which emphasize certain aspects of water problems and policy measures driven by specific story lines, frames, values, and principles. Not only the facts but also the cultural, social, political backgrounds together with their values and images (the developed methods of dealing with water issues by actors) form the basis of a thorough understanding of the contents of a water issue. Different discourse coalitions emerge, which, in order to become a dominant policy discourse coalition, often collide. Dominant policy discourse coalitions determine what the exact problem is and which solutions seem to be appropriate to counter water issues, but the actual situation of the water system is sometimes ignored (van Rijswick et al., 2014). According to van Rijswick et al. (2014), the assessment criteria for the second building block is as follows: ''***Is there sufficient knowledge of shared or conflicting values, viewpoints and principles (represented by different policy discourse coalitions) for water issues and their consequences for facing water management issues?***''

Stakeholder Involvement

Stakeholder involvement can be assessed by the width and depth of participation that together determines the strength of their involvement. Here, the width (or inclusiveness) is the extent to which each member of a community is offered a chance to participate in each phase of the water policy process. The depth is the degree to which stakeholders are able to determine final outcomes of the governance process (van Rijswick et al., 2014). According to van Rijswick et al. (2014), this building block is assessed by the following criteria: ''***Are all relevant stakeholders involved? Are their interests, concerns and values sufficiently balanced considered in the problem analysis, solution search process and decision-making?***''

Trade-offs between Social Objectives

Water as a scarce economic asset of water management should be allocated or reallocated, which is a political bargaining process where the pros and cons of several options are weighed between legitimate claimants at a given moment. Insights into various social (potentially conflicting) objectives and tradeoffs between impacts of measures are required to guide allocation decisions. Transition or allocation of existing service levels towards new service levels takes usually occurs when the gains outweigh the costs of such a transaction. These service levels require translation into rules, regulations, and procedures and can be achieved by way of water allocation mechanisms (van Rijswick et al., 2014). Therefore, according to van Rijswick et al. (2014), the fourth building block is assessed by using the following criteria: ''***Are agreed service-level decisions based on trade-offs of costs, benefits and distributed effects of various alternatives?***''

Responsibility, Authority, Means

The determination of property rights is the start of the identification of responsibilities and authorities, followed by the authority of the public domain at various administrative levels. The responsibilities of public and non-public actors need to be assigned which creates means to empower authority. The authority should, in turn, have the ability to give guidance to stakeholder processes, the process to lead to powerful collective decisions, to other relevant public authorities, to redistribution of property rights, to control progress, and to take proper measures for efficient operations. Another concept to this building block is that of the participative and integrative capacity of the public domain, of which the participative capacity refers to the input of the policy process that depends on the extent to which all water uses have an equal opportunity to become recognized and expressed. The integrative capacity refers to intra-policy coordination, to inter-policy coordination, and to external coordination between water policy institutions and non-governmental actors. Intra-policy coordination means the internal integration of the water policy field, and the inter-policy coordination means the cross-sectoral integration of water policy with other related fields of policy (van Rijswick et al., 2014). The collection of these concepts give way to the fifth assessment criteria, provided by van Rijswick et al. (2014): ''***are authorities, responsibilities, and means well-organized to deal with water issues at the appropriate administrative scale(s) in a participative and integrative way?***''

Regulations and agreements

Regulations and agreements are the pivot point between the content, described in the first five building blocks and the implementation outlined in the last four blocks. This building block assesses legitimacy, which depends on actual circumstances of the area. The legitimacy of water governance means it is based on shared or agreed values and principles with the inclusion of vulnerable values and groups in society, and in conformity with the rule of law, offering legal certainty regarding rights, duties, and accountability. Moreover, legitimacy includes that is formulated in an enforceable and effective way (with achievable intended goals), decision-making occurs at the most appropriate level, and with a basis of transparent rules that takes all interests into account. Furthermore, legitimacy entails that it offers the right mix of public and private instruments for the intended goal and objective of the policy, and distributional effects should be taken into account to avoid damage to the water system, conflicts and other aspects of various interests and policy fields. Regulations and agreements should furthermore be based on the need for flexibility and adaptability, and on the other hand, be built on the legal certainty and enforceable protection level. Flexibility and adaptiveness can be achieved by the use of less detailed and open norms, with room for substantial development through mutual communication, and the use of substantive rules and standards for a clear responsibility allocation (van Rijswick et al., 2014). These concepts bring the assessment criteria for the sixth building block by van Rijswick et al., (2014): ''***are regulations and agreements legitimate and adaptive, and if not, what are the main problems with regard to the above-mentioned legitimacy aspects?***''

Financial arrangements

A further crucial element for good water governance is the empowerment with financial means, and a sustainable and equitable financing of water management is required to come to reaching required service-level agreements. Several ways to finance water management policy, projects or principles are by cost recovery mechanisms. Examples are a solidarity principle (national budgets or budgets of decentralized authorities cover water policy costs), a profit principle (individuals or organizations that have an interest or profit in water services pay), or other means such as the polluter pays principle (van Rijswick et al., 2014). These concepts bring the pretty straightforward assessment criteria for the seventh building block by van Rijswick et al., (2014): ''***Is the financial arrangement sustainable and equitable?***''

Engineering and Monitoring

Design and management of existing infrastructure are of prime importance, for instance, the volumetric pricing of water resource usage only works where water use is metered. Furthermore, service-level agreements are used to assess whether existing infrastructure needs to be improved and how this improvement would take place. Such service-level agreements are determined by the responsible authorities and agencies after stakeholder consultation, and are based on i.e. trade-offs between societal objectives. The implementation of such agreements takes place in various ways and therefore result in different consequences in spatial and ecological aspects. However, a dominant focus on only one alternative does not represent the interests of everyone involved. Therefore a global design, then a detailed design, and subsequently its implementation can be utilized to make use of available resources in an efficient manner and enables full stakeholder involvement. In order to assess the return on investment in constructing infrastructure, economic analysis has a role. Besides that, economic analysis can be used to evaluate the cost-effectiveness of alternative infrastructural measures, including its maintenance actions. Monitoring of the water system is a useful way to assess to what extent agreed service-level agreements are being met, but it is not the goal in itself (van Rijswick et al., 2014). These concepts bring the assessment criteria for the eighth building block by van Rijswick et al., (2014): ''***Are service-level agreements sufficiently available (implicit or explicit) in order to redesign the existing infrastructure? Are the design and consequences of different alternatives sufficiently available? Is there sufficient monitoring of the system and are the data analyzed?***''

Enforcement

The enforcement of policies is an often-forgotten critical issue in the whole policy process, and water management and water governance assessments primarily only focus on the beginning of the policy process. In this beginning, there is ample attention to public participation and the formulation of the goals, rules, standards, and decision-making processes. Although, attention should be given to the whole process, including the implementation of regulations and agreements, as a lack of enforcement hampers the effectiveness of governance and may lead to conflicts or a decrease of legitimacy. Enforceability starts at the beginning of the water management process and is basically influenced by all the Ten Building Blocks. In general, rules and agreements are easier to enforce when they are based on shared values and principles due to the strong conviction of the need to act in line with the rules. However, individual cases of non-compliance of individuals might occur when following the rules would be less profitable than to deviate from them, and designing regulations and rules that fit every actor's value is not always possible. Furthermore, clear and substantive process norms and standards regarding responsibility allocation are a necessity for enforceability. Water, ecosystems and the rights of vulnerable groups can be regarded as vulnerable values in water governance, the roles of vulnerable values should be recognized, and sufficient protection of their interests with enforcement mechanisms should be in place. Depending on the regulations and agreements, public and private parties can enforce them, and available remedies to achieve objectives are important (van Rijswick et al., 2014). These concepts bring the assessment criteria for the ninth building block by van Rijswick et al., (2014): ''***Are regulations and agreements enforceable by public and/or private parties, and are there appropriate remedies available?***''

Conflict Prevention and Resolution

Conflicts might arise from shared water, while on the other hand opportunities for mutual benefits, cooperation, prosperity and stability may be offered. The Identification of the benefits of cooperation is therefore essential, which allows appreciating water in terms of value rather than in terms of quality, quantities, and ownership, which in turn leads to cooperation. In case a conflict occurs, resolution mechanisms should be in place (e.g. independent mediator, arbiter or court) to act in conformity to final ruling. Additionally, conflict prevention (e.g. by mutually accepted rules and procedures) should be in place to guide the way forward in case a conflict of interests arises (van Rijswick et al., 2014). These concepts bring the quite straightforward assessment criteria for the last building block by van Rijswick et al., (2014): ''***Are there sufficient conflict prevention and resolution mechanisms in place?***''

Reviewing the Ten Building Blocks approach, similar critiques can be given as from Geul (2005) regarding the Engineers Method of Hoogerwerf, and the Ten Building Blocks approach is rather demanding to assign information to since the classification of ''sufficient knowledge'' is rather vague. Understanding such classifications and the multi-disciplinary demanded expertise makes that the Ten Building Blocks approach is rather consuming in both time and funds. These limitations would call for an approach that is less complex, less demanding in terms of time and resources, and just as multidisciplinary and complete.

2.4. Further conditions for rational governance

Water governance is about the identification of, choosing, or adhering to values (e.g. water, safety, agriculture, or urban space) into goals, processes, standards and institutional structures. Furthermore, it is about the choice of competing values and their translation into goals, while the constraints and facilities are about a separate act of policymaking (Gupta et al., 2011). Natural resources management is generally undergoing a major paradigm shift from an exclusively technical experts' task under state patronage (under the assumption of human dominance over nature) to participatory management and stakeholder involvement. Furthermore, due to the increasing awareness of uncertainties and change, a particular group of experts or stakeholders cannot learn on behalf of all other stakeholders. Moreover, biophysical references for scale determination (e.g. river basins) leads to spatial misfits between biophysical and administrative boundaries, which requires bridging authorities amongst all stakeholders to increase collective capabilities and social trust. Additionally, the institutional context of largely informal networks maintains the necessary flexibility for responding to challenges, and formal institutions are often too inflexible and rigid to respond. Within flexible networks, stakeholders (at different scales) are connected and allowed to develop the collaboration (e.g. widely ranging formal and informal relationships such as legal structures or voluntary agreements) driven needs for capacity and trust (Pahl-Wostl et al., 2007).

However, public participation can be interpreted as a collaboration between non-governmental and governmental stakeholders, as a means of educating and informing the public, or as a euphemism for public relations (Huitema et al., 2009). In order to create the necessary conditions for outcome oriented, fit-for-target, anticipatory and adaptive stakeholder engagement, all parties concerned and their responsibilities, core motivations and interactions need to be mapped out first. Secondly, this requires the ultimate line of decision making, together with the objectives for stakeholder engagement and the expected usage of inputs. Thirdly, the proper resources (financial and human) and information sharing are a necessity. Fourthly, processes and outcomes of stakeholder engagement need to be regularly assessed to learn to adjust and improve accordingly. Fifthly, engagement processes need to be embedded in clear legal and policy frameworks, organization structures and principles and responsible authorities. Finally, the type and level of engagement should be customized to the needs and adaptivity to changing circumstances requires to keep the process flexible (OECD, 2015).

Involvement in policy formulation, coordination, communication and the exchange of information between stakeholders and authorities throughout various levels can contribute to an increased awareness and knowledge of each other’s policy objectives, methods, and implementation mechanisms. However, decisions require coherency equipped with a broad set of principles leading to more efficient, equitable and progressive water resources management. Nonetheless, in practice, many stakeholders may build on local knowledge and networks but often face a lack of support and financial, institutional and technical capacities regarding water resources management, hindering them to contribute in a significant way. This limitation leaves the enabling and coordination of the effective roles of different stakeholders an imperative and challenging requirement for rational policy making. Water governance in the agricultural setting is significantly limited by the overall construction oriented focus regarding water management. While the understanding of the formal and informal nature of the elements of water governance for progress towards public policy goals, including its institutions, regulations, partners, and direct and indirect instruments may only be possible afterward. Common global water governance issues include the isolation of water from other policy levers outside the water sector (e.g. the energy or food sectors), and the realization of the limitedness and inflexibility of the water system since the upper limits of water usage are reached (Tortajada, 2010).

The need for sustainable financing is one of the most persistent issues in water governance. However, ultimately, all financing In the water management sector originates from tariffs, national funding and external aid. Moreover, water sector decision makers can only help to create a favorable investment climate and to ensure proper financial resource management. Monitoring activities can be used to reveal hidden connections, expose the limits of water resources, and help to find innovative solutions to problems related to water resources (UNESCO, 2009), but monitoring and evaluation come with high political and administrative costs (Rogers & Hall, 2003).

2.5. Conclusion: assessment framework

Inspired by the Engineers Method of Hoogerwerf (Geul, 2005), and the Ten Building Blocks assessment method for good water governance by van Rijswick et al., (2014), the less complicated and more straightforward Wheels of Environmental Governance (WEG) assessment framework is designed (Figure 5). Similar to the Engineers Method of Hoogerwerf, the WEG assessment framework assesses the issues, which gives clues toward intervention strategies. Given the limited resources and time that the policymaker might have, a compact and less complex assessment method covering the system’s necessary knowledge and conditions is essential to have. In light of this, an assessment method that covers aspects of good governance as thoughtfully and interdisciplinary as the Ten Building Blocks assessment method does, is suggested with the WEG assessment framework. This assessment framework answers the first sub-question, which was:

Under which conditions is rational groundwater governance possible?

The required conditions for rational groundwater governance can be divided into:

- System knowledge
- Knowledge concerning the existing values and policy discourses
- Knowledge concerning the involvement of the stakeholders
    - Whether all stakeholders are sufficiently involved, and whether the responsibilities, authorities, and means are clear.

- Knowledge concerning the regulations and agreements
    - Whether the regulations and agreements are adaptive and legitimate.
- Knowledge concerning the financial stability
    - What the availability of finances are and how it is spent on checking the functioning of regulations.

Where the system knowledge can be divided into the systems physical aspects and the systems problems and driving causes, these conditions of knowledge are closely interrelated since together they form the overall system knowledge. The overall system knowledge itself is a condition for rational governance, which is listed first, as it is the system knowledge that sets the basis for the overall functioning of the system. The knowledge criteria of the values and policy discourses, stakeholder involvement, regulations and agreements, and the financial stability are taken as conditions on the basis of rational governance. These conditions translate into criteria where the conditions can be assessed as to whether each criterion hampers [X] or facilitates [√] rational groundwater governance. The WEG assessment framework puts these criteria as a figurative cogwheel, as in a machine, since every criterion affects the degree to which rational groundwater governance is possible. Once one of the cogwheels stop spinning (as in the criterion for a given condition is not met), the machine halts, referring to the inability of rational governance. The WEG assessment framework aims to keep integrated rational governance uncomplicated and easy to apply, since policies are never made in a fully academic environment and (diverse groups of) stakeholders require clear communication without over complication.

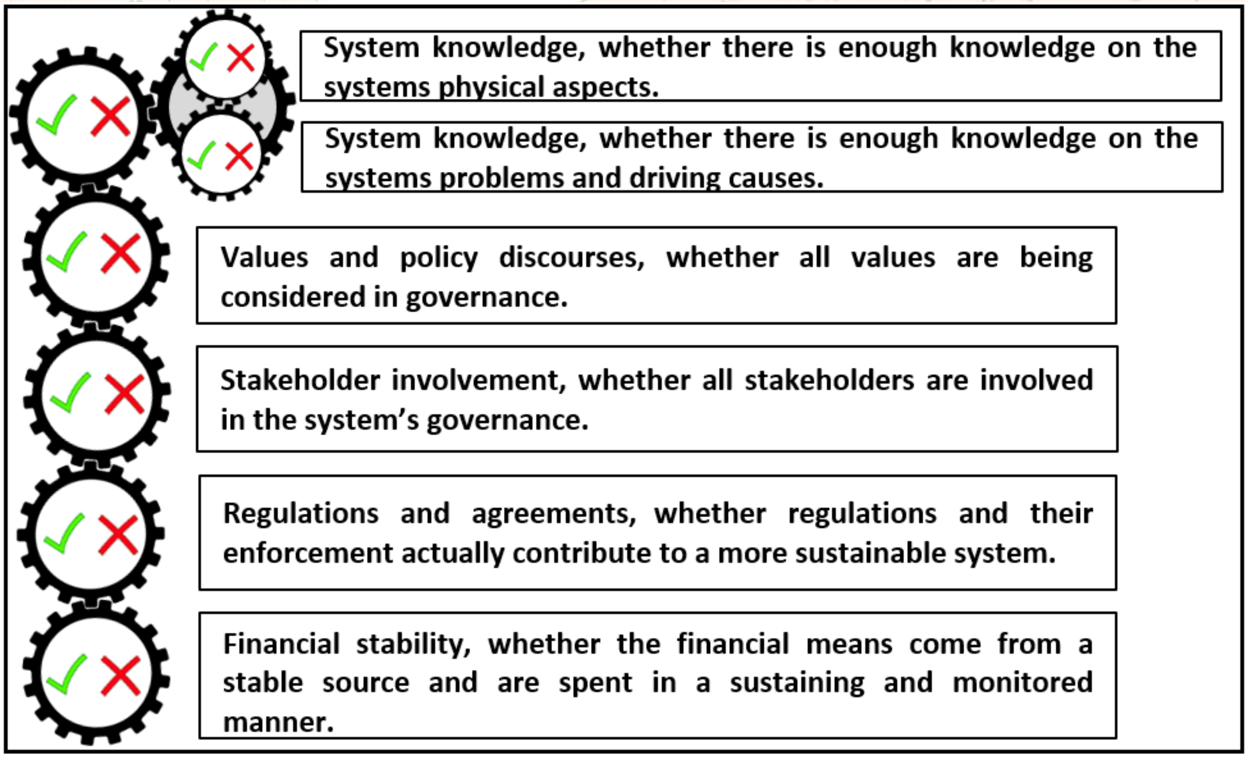


Figure 5 The Wheels of Environmental Governance (WEG) assessment framework

3. Methodology

3.1. Introduction

To assess to what degree rational governance is possible in the VMD, there is a need to gather data from existing scientific literature and knowledgeable key figures, regarding each of the WEG assessment framework criteria. This chapter explains which types of respondents are considered key figures, how they are interviewed or surveyed and how scientific literature study fits into the research in order to give an overview of groundwater governance in the VMD.

3.2. Data collection methods

The following steps were taken to assess which knowledge is required, to what extend this knowledge is available, to evaluate possible knowledge gaps, and to apply this knowledge to the WEG assessment criteria and eventually to policy prospects. Knowledge is specified as what is written in the scientific literature (scientific knowledge), what is known by experts (expert knowledge) in the field in the VMD (specified to Soc Trang Province), and the available information of the farmers (layman's knowledge). For gaining knowledge to appraise each WEG criterion, the data has been collected in five steps, (1) literature study, (2) gathering qualitative data from the scientific experts, (3) policy experts,and (4) a qualitative survey, and (5) the utilization of the WEG assessment towards rational governance.

The literature study builds further on the appraisal of each WEG assessment criterion based on the literature study done in chapter 2. Criteria to assess whether literature study was regarded useful was in the usage of broad but relevant keywords. The main keywords used were related to hydrological aspects and issues of the VMD, Soc Trang Province, Vinh Chau District, (ground) water governance in Vietnam, regulations, and the institutional framework in the area. References used in literature study itself were assessed critically, especially for non-peer reviewed sources. This literature study has been done with the scope that the information should be publicly available using scientific journals (i.e. Elsevier, Springer), published books, respectable and acclaimed news media and professional online material.

From there, steps were taken to collect qualitative data from 16 scientific experts from a regional university (Can Tho University). These respondents were requested to participate on by email; 33 of them were approached, and 16 of them were available (a response rate of 48.48%). Further qualitative data is derived from policy experts, and laymen in order to determine if the qualitative findings generalize to a large sample (Creswell & Plano Clark, 2011). The qualitative interviews with 12 policy experts (representatives of governmental institutions in Soc Trang Province), were held based on the results of the literature study. These respondents were requested by the Can Tho University and selected by the government. Based on the results of the qualitative interviews, and on the literature study, a qualitative survey took place with 90 laymen (farmers) and 9 pump store owners in Vinh Chau District. For all respondents, the informed consent has been organized by asking permission to record the interviews and to use the gathered information for the research. For the surveys, this consent has been specifically asked for in the questionnaire. For the government experts and the laymen-survey, paperwork and an interpreter were required.

Based on all results, further literature study took place, to give a well-researched assessment of each WEG criterion. In order to assess whether the WEG assessment criteria are met, the data is listed on its respective corresponding subjects. Questions on water system knowledge were used to give an answer on the WEG criterion on system knowledge, questions on the interaction with the government were used to answer the criterion on stakeholder involvement, and so on for every criterion.

Most of the data is of a qualitative nature, but the laymen were surveyed for quantitative data as well. For the fieldwork, a mixed method (Creswell, 2003) has been applied, consisting of both quantitative and qualitative data collection methods. Mixed-methods research combines parts of qualitative and quantitative approaches to strengthen the research (Johnson, Onwuegbuzie, & Turner, 2007). In this research, a three steps approach of an exploratory sequential design is made by first exploring the topic through extensive literature study to provide a sound theoretical background. From there, additional literature study is done to add further depth to the research. In this way, the core component of the research is the theoretical framework, which is complimented to by the supplemental components of the interviews and surveys (Morse & Niehaus, 2009).

The WEG assessment criteria give a current overview of the rationality of governance, paving the way for rational governance practices by means of policy prospects. Rational and sustainable groundwater management would be key to reduce groundwater resources degradation and eventually subsidence and other groundwater related problems in Soc Trang Province.

3.3. Interviews and survey

Interviews have been held with experts (Knowledge Experts and Policy Expert Respondent Groups) on their specific knowledge of water resource management and water governance. These two respondent groups have been selected based on their in-depth knowledge and representability in their field, and for this reason, qualitative interviews were held. Each qualitative interview was held for an hour to 1.5 hours, using the questionnaires that can be found in Appendices I.2 and 1.3. Surveys have been conducted with laymen to collect data on their practical knowledge of their farms and the environment.

All these respondents have been interviewed or surveyed in April 2016, at the end of the dry season. These groups of respondents are emphasized below. Gathering of respondents has been done through mediation with the Can Tho University; this was the case with the 16 scientific experts, for which a list of qualified respondents was developed, and the 12 government experts were contacted through the university.

3.3.1. Experts

This part of the field research took place through qualitative interviews. The reason for this is that the goal of this part of the research is to get insight into information through the experts with the opportunity to ask additional questions on the subjects if needed. The expert respondents are distinguished as scientific experts, and policy expert respondent groups, of which the latter often consisted of more respondents at the same time.

The Knowledge Experts

The subjects that were asked to the knowledge experts were based on whether they have ideas on the mitigation or adaptation, regulations, management, and scientific experiences related to groundwater resource- and environmental degradation. Furthermore, they were asked for their ideas on the rationality of groundwater governance, whether there is a connection between these policies and groundwater degradation, and to what extent they think that there is sufficient knowledge for policy making from the central government regarding subsidence. The knowledge experts '[KE],' are listed (Table 4) down below:

KE number	**Workplace(s)**	**Function(s)**
[KE1]	College of Agriculture and Applied Biology, Department of Soil Science	Head of Department and Lecturer
[KE2]	Mekong Delta Development Research Institute	Deputy Director
[KE3]	College of Environmental and Natural Resources, Department of water resources	Lecturer
[KE4]	Department of Agriculture Systems & Mekong Delta Development Research Institute	Head of the Department
[KE5]	College of Agricultural and Applied Biology, Department of Soil Science	Researcher

[KE6]	Climate Change Coordinator Office	Director
[KE7] *[KE7.2]*	Mekong Delta Development Research Institute Farmers Association Can Tho	Researcher Vice – head
[KE8]	College of Environmental and Natural Resources	Head of Department
[KE9]	Department of Civil Engineering	Former Dean of College
[KE10]	Department of Civil Engineering	Researcher
[KE11]	Advanced Laboratory	Head
[KE12]	College of the Environment and Natural Resources	Vice Dean
[KE13]	College of the Environment and Natural Resources	Dean
[KE14]	Geotechnical Laboratory	Head
[KE15]	School of Social Sciences & Humanities, Sociology Department	Head of Department

Table 4 The Knowledge Experts [KE]

The policy expert respondent groups

The subjects which were asked to the policy experts were based on whether- and to what extent there are problems with regard to climate change, salinization, environmental- and water resource degradation in Soc Trang Province. Further questions were related to the current use of groundwater resources, current strategies in (local) policy related to environmental problems, whether there is sufficient knowledge available from the government or science to address such problems, and to what extent conditions are available in their operational area to come to rational groundwater governance. The twelve respondents were interviewed in groups and are referenced to as Policy Expert Respondent Groups '(PERG)'. These respondents are listed in Table 5 and are high placed officials in provincial offices of the Department of Agriculture and Rural Development (DARD) and the Department of Natural Resources and Environment (DONRE). Two of them have their district branches in Vinh Chau District with the DARD and DONRE divisions respectively. The other ten respondents were located in Soc Trang City, three of them at the DONRE and seven respondents at the DARD, with respectively the agency of Land Management, Division of Water Recourses Mineral and Hydrometeorology, the agency of Cultivation and Plant Protection, and the agency of Fisheries and the agency of Irrigation.

PERG1	The People's Committee of Vinh Chau District - DARD		
Position	Vice-head of the Division		
Department	DARD of Vinh Chau District		
PERG2	Agency of Land Management	Division of Water Resources, Minerals, and Hydrometeorology	Division of Water Resources, Minerals, and Hydrometeorology
Position	Head of the Agency	Official	Official
Department	DONRE of Soc Trang Province	DONRE of Soc Trang Province	DONRE of Soc Trang Province
PERG3	The People's Committee of Vinh Chau District - DONRE		
Position	Head of the Department		
Department	DONRE of Vinh Chau District		
PERG4	Agency of Cultivation and Plant Protection	Agency of Cultivation and Plant Protection	Agency of Cultivation and Plant Protection
Position	Vice-head of the Agency	Head of the Cultivation Office	Head of the Agency
Department	DARD of Soc Trang Province	DARD of Soc Trang Province	DARD of Soc Trang Province
PERG5	Agency of Fisheries of Soc Trang Province	Agency of Fisheries of Soc Trang Province	Agency of Fisheries of Soc Trang Province
Position	Vice-head of the Agency	Head of Fisheries, Resources Extraction and Development Office	Head of the Aquaculture Office
Department	Agency of Fisheries	Agency of Fisheries	Agency of Fisheries
PERG6	Agency of Irrigation of Soc Trang Province		
Position	Head of the Agency		
Department	Agency of Irrigation		

Table 5 The Policy Expert Respondent Groups (PERG)

3.3.2. Laymen

This part of the research took place through a qualitative survey (indicated throughout this research with '[SURVEYS]'), where the laymen were selected at random and in representative quantities in each commune of Vinh Chau District (Figure 6). The respondents were approached in Vietnamese, and their surveys took each about 30 to 40 minutes to answer. The questionnaires were rather long and can be found in the Appendix I.1, the surveys have been conducted personally and elaborated where necessary to reduce bias due to non-understanding. This group was approached with surveys rather than with qualitative interviews because of the larger number of respondents, lingual efficiency, and the quantitative nature of some of the questions. Besides that, this was more convenient for both the respondents and the interviewer regarding language and effort. The subjects that were asked to the farmers were about their farm (farm types, size, age, and stocks), livelihood, their wells (such as well depths, and their number of wells), and their water usage (frequency and duration of irrigation). Further topics were about environmental changes (seasonal variations in the humidity of their soil, and their crops over the last decade), adaptation to environmental changes, whether they use other sources of water, and what they expect, received and requested from the government or from other organizations.

In Soc Trang Province, there are 6,130 agricultural households (2010), this is a stable number since 2005, and later statistics seem to be unreliable (Gso.gov.vn, 2016). Divided over the twelve districts in this province, this comes down to 510 farms per district. Using this assumption, made due to the lack of more reliable information, there is a population size [N] of 510 farms in Vinh Chau District. The number of respondents is calculated using Cochran's (1977) sample size formula for categorical data [equation 1.1] and corrected by Cochran's (1977) correction formula [equation 1.2].

$$n_0 = \frac{(t)^2 * (p)(q)}{(d)^2} \qquad \text{[equation 1.1]} \qquad\qquad n_1 = \frac{n_0}{(1+n_0/N)} \qquad \text{[equation 1.2]}$$

For this district 90 agricultural households were surveyed, of which 90% (81 households) [n_1] of them calculated with a margin of error [d] of 10%. A value for the selected alpha level of .025 in each tail =1.96 [t] (due to a z-score of .5 and a confidence level of 95%) is taken, together with an estimated variance

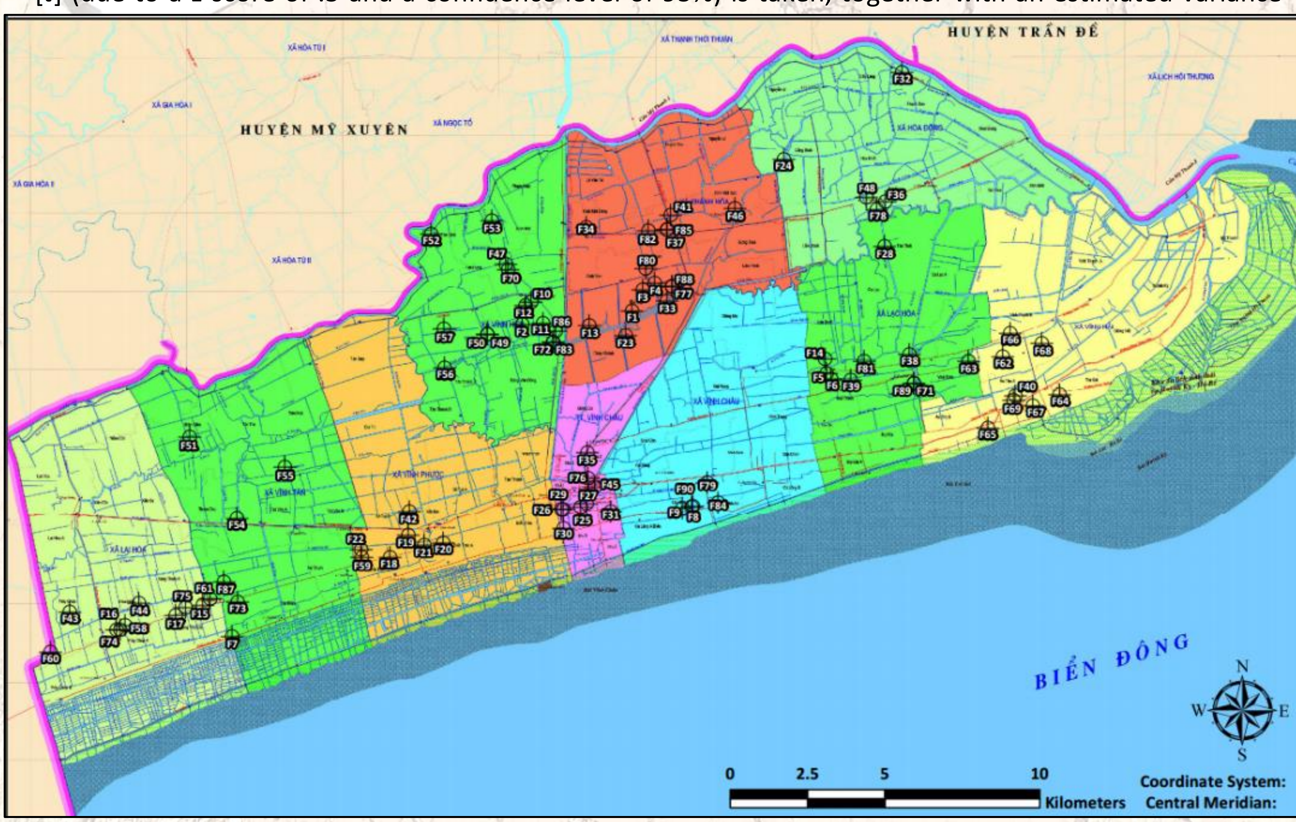


Figure 6 Respondents were selected through Vinh Chau District

[(*p*)(*q*)] of .25 to produce a maximum possible sample size (Cochran, 1977; Bartlett, Kotrlik, & Higgins, 2001). An added 10% (9 households) of the surveyed agricultural households is taken as well to account for the representability of this predominantly agricultural district. Since the surveys were held manually, the response rate is at 100%. In addition, since some of the questions were rather technical in regard to their pumps, and to avoid gaps in information, nine pump store owners were surveyed through a short questionnaire, which can be found in Appendix I.4. The pump store owners were selected randomly for representative surveys throughout Vinh Chau Town (the main town of Vinh Chau District), and pump store owners are indicated throughout this research with '[P-SURVEYS].'

3.4. Methods of data analysis

3.4.1. Data analysis of the fieldwork

The interviews were analyzed by qualitative data-analysis, the interviews were recorded, transcribed and processed through coding.

To limit lingual misunderstanding from the qualitative interviews with the Knowledge Experts, results have been recorded and manually transcribed after first hearing the whole recording, then listed by keywords from hearing it secondly, followed by a literal transcript from hearing it thirdly. This was possible since the interviews with the knowledge experts (each between 1-1.5 hours in length) were conducted in English.

The interviews with the Policy Expert Respondent Groups were of similar length as with the Knowledge Experts, and were conducted in Vietnamese since the interviews were held in groups and due to language preferences of the respondents. To limit lingual misunderstanding with these respondents, there was made use of a professional English to Vietnamese translation and notary service to translate the recordings into English. Overall, although lingual errors may have occurred, the results are likely to be correct as every possible precaution has been taken.

The laymen-survey was analyzed in SPSS, and all data together is then used to assess the WEG criteria towards rational groundwater governance.

3.4.2. Data analysis towards the WEG assessment criteria

The first WEG assessment criterion is an evaluation of whether there is enough knowledge, and is quite different from the other criteria in terms of their assessment. This WEG assessment criterion weighs whether there is enough knowledge on the environmental system, or in this case the water system. Whereas enough knowledge can be regarded as whether there is information regarding every driver, the pressures, the state of the system, the impacts, and the responses of the water system. This knowledge can then be used to take action upon. Where there is insufficient knowledge (knowledge gaps), this should be documented.

This WEG criterion is assessed in a similar (but not the same) way as using the DPSIR method (Drivers, Pressures, State, Impact, Responses). This method is used to identify and quantify the current state of the water environment, together with its impacts and how change occurs over time (EEA, 2008; Sun et al., 2016). Particularly in coastal systems, where pressures (e.g. anthropogenic pressures) are high, the DIPSR framework needs to be integrated across disciplines and organizations regarding the community, government, and academics (Lewison et al., 2016; Sekovski, Newton, & Dennison, 2012). This necessity is reflected in the other criteria, as being conditions for rational governance.

The other four WEG assessment criteria are more an appraisal of whether each condition of a criterion is facilitating or hampering to rational governance, e.g. whether there is enough stakeholder involvement or not. These criteria have been compared to come to an assessment of each respective criterion, with knowledge acquired from the literature study, interview, and survey results. The WEG assessment framework is put to the test in the following six chapters, starting with the system knowledge (chapter 4 and 5), the values and policy discourses (Chapter 6), the stakeholder involvement (chapter 7), the regulations and agreements (chapter 8), and the financial stability (Chapter 9).

4. System knowledge: the physical background

4.1. Introduction

This chapter explains the available knowledge regarding the first WEG assessment on the VMD's physical parameters, which are paramount to fully understand the current problems and the causal relationships behind it. The first WEG criterion for the system's knowledge can be divided into its physical background, following towards a broader and more anthropogenic driven background, and from there to the anthropogenic causes of groundwater degradation in the next chapter. This chapter concludes with to what extent there is enough knowledge on the systems physical aspects for this criterion.

System knowledge, whether there is enough knowledge on the systems physical aspects.

The boundary of the system is Soc Trang Province, and where possible it is zoomed in on Vinh Chau District. System knowledge is here the knowledge of the water system, and where it is more general in nature, the system comprises over the scale of the whole VMD. First, this chapter gives an overview of the aquifers in terms of their hydrogeologic characteristics. From there, the characteristics and the current status of the surface- and groundwater resources is provided in terms of problems such as salinity intrusion. The last section of this chapter covers the climatologic characteristics of the VMD, followed by the conclusion.

4.2. Exploited aquifers and soil characteristics

Subsidence of the pre-Cenozoic basement of the north-west trending Mekong Basin began in the late Neogene period. The deposition and accumulation (160 million tons of sediments per year) over millions of years at the river mouth resulted in the formation of the VMD with a maximum thickness of over 600 m along the axis of the basin. Further formation of the VMD was due to the establishment by plate tectonics and faulting, and alternating periods of alluvial and marine sedimentation during the late Cenozoic period resulted in the accumulation of heterogeneous strata. During the late Quaternary period, the last interglacial high sea-level (roughly 125,000 years ago) flooded extended areas of the coastal VMD, causing exposure to saltwater intrusion and regional salinization of pore water within permeable sediments. The last glacial period occurred roughly 122,000 years ago, accompanied by a sea-level lowering of several tens of meters. During which erosion of earlier Pleistocene sediments culminated to the incision of deep river valleys, with a much steeper hydraulic gradient between inland areas and the ocean. The transgression (19,000 to 20,000 years ago), rapidly filled up paleo river valleys with estuarine, tidal, and fluvial sediments, filling up valleys. This accumulation stopped in the late Holocene period, and fine-grained, low permeable flood sediments, and peat layers came apart from active river channels. These beds formed protective layers preventing regional resalinization of deeper aquifers and preserved freshwater lenses at hundreds of meters depth. Cycles of erosion and sedimentation occurred several times during transitions of glacial and interglacial periods, which resulted in a complex architecture of the VMD with a complex exploration of yielding fresh groundwater resources from the Neogene and Pleistocene layers. Deeper layers (400-500 m deep) are also exploited due to salinization, pollution from surface water and shallow groundwater. There is a very heterogeneous structure of aquifers and aquicludes that intersect, and each hydrogeological unit consists of a low permeable silt, clay, or silty clay upper part and a lower permeable part composed of fine to coarse sand, gravel, and pebble with a medium to high water yield (1 - >5l/s) (Wagner et al., 2012). The hydrogeological units are of artesian basin structure and can be distinguished into the Holocene (qh), Upper Pleistocene (qp_3), Upper-Middle

Pleistocene (qp_{2-3}), Lower Pleistocene (qp_1), Middle Pliocene (n_2^2), Lower Pliocene (n_2^1), Upper Miocene (n_1^3), and the Upper-Middle Miocene (n_1^{2-3}) (Wagner et al., 2012; Van Pham, Dieperink, & Otter, 2016). However, the Holocene aquifer has a more complex composition (Wagner et al., 2012). The groundwater reserves in the VMD are about 26,754,764 m^3/day, of which 22,709,669 m^3/day are static reserves, and 4,045,095 m^3/day are dynamic groundwater reserves (Deltares, 2011).

Holocene (qh)

Holocene outcroppings are dominant over nearly the whole of the VMD, covering an area of around 40,000 km^2. The Holocene aquifer comprises of sediments from lower to middle Holocene sediments (qh_{1-2}) (consisting of alluvial and marine origin, composed of clayey silt and fine sand), and alluvial, marine, and eolian sediments (qh_{2-3}) (comprised of 5-10m thick remnants from paleo seashores). Moreover, it includes upper Holocene sediments (qh_3) (consisting of clayey silt and fine sand accumulated from river valleys and flood plains). Generally, the groundwater levels are between 0.5 and 3m above sea level (Wagner et al., 2012). The quality and yield from this aquifer are generally poor with high levels of pollution, salinity, and occasionally (in some parts of the VMD) with a very low pH due to oxidation of acid sulphate soils (IUCN, 2011). Boreholes in this aquifer are shallow, with depths up to 30 m and low to medium yield (0.1-2.0 l/s) (Deltares, 2011; Wagner et al., 2012), and an distribution area of 5,816 km^2 of fresh groundwater (TDS <1 g/l) (Deltares, 2011).

Upper Pleistocene (qp_3)

Upper Pleistocene outcroppings occur only in the northernmost tips of Kien Giang, An Giang, and northeasternmost tips of Dong Thap and Long An (IUCN, 2011), are widely distributed over the VMD and consists of alluvial and marine alluvial sediments (composed of the Cu Chi and Moc Hoa formations). The Upper Pleistocene aquifer is weakly confined, and consists of an aquitard layer (composed of silt, clay or silty clay) located at depths of 10.1- 37.3 m below surface level, with a thickness of 9.4 - 22.4 m. This aquifer provides low saline fresh groundwater over an area of 8,541 km^2 (in Vinh Hung, Long An Province, My Tho, Tien Giang Province, and Tieu Can and Cau Ngang, Tra Vinh Province) (Wagner et al., 2012; Deltares, 2011).

Upper-Middle Pleistocene (qp_{2-3})

Upper-Middle Pleistocene outcroppings only occur in An Giang Province and are overlain by the upper Pleistocene aquifer. The Upper-Middle Pleistocene aquifer (qp_{2-3}) is widely distributed over the VMD, and its lithology is rather diverse and consists mainly of alluvial, marine alluvial, and marine sediments. This hydrogeological unit consists of a low permeable upper part (consisting of a silt and clay layer of 3.6-13.5 m thick) and a weakly confined lower part (comprised of a highly permeable, well-sorted coarse to fine sand layer of 17.3 – 56.2 m thick). This aquifer is located at a depth of 31.6 – 81.7 m below the surface and has several openings to the overlaying upper Pleistocene aquifer. The Upper-Middle Pleistocene aquifer is a high yield aquifer which provides good quality groundwater over an area of 21,798 km^2 in Tra Vinh, Bac Lieu, and Ca Mau Provinces (Wagner et al., 2012; Deltares, 2011), and large parts of Soc Trang Province (Deltares, 2011).

Lower Pleistocene (qp_1)

The lower Pleistocene sediments are mainly of alluvial origin (in Ca Mau Province they are marine facies). The top part of the lower Pleistocene layer consists of an 8-16 m thick aquitard, and the lower part is an aquifer (composed of a permeable fine to coarse sand layer of 14.2 to 43.9 m thick) with varying depths from northwest to southeast the VMD. This aquifer has several openings with direct hydraulic contact to the upper-middle Pleistocene layer and is commonly exploited in Can Tho, Ca Mau, Kien Giang, and Bac Lieu Provinces (Wagner et al., 2012; Deltares, 2011). This aquifer distributes fresh groundwater for 17,918 km^2 and is exploited for water supply (Deltares, 2011).

Middle Pliocene (n_2^2)

The middle Pliocene layer consists of alluvial to marine sediments and includes an upper aquitard (a clayey or silty clay layer of 4.6-20.6 m thick) and a lower aquifer (strata of fine to coarse sands of 29.9-57.1 m thick) with varying depths from 84.3-223.1 m below surface level. This layer distributes low saline groundwater over two areas of a total about 19,000 km^2 (north of the Tien River, and in Can Tho, Bac Lieu and Ca Mau Provinces (Wagner et al., 2012; Deltares, 2011).

Lower Pliocene (n_2^1)

The lower Pliocene aquitard layer is located at a depth of 196.5-279.2m below surface level and is on average 11.8-20.5m thick. The 40.9-45.4m thick aquifer under this layer consists of fine to coarse sand and is located at a depth of 209.4-296.5m under the surface level (Wagner et al., 2012; Deltares, 2011). This layer consists of alluvial and marine alluvial sediments, and distributes fresh groundwater to 16,198 km^2 to Ho Chi Minh City and Dong Thap, Long An, Can Tho, Bac Lieu and Ca Mau Provinces (Deltares, 2011).

Upper Miocene (n_1^3)

The upper Miocene layer consists of alluvial and alluvial-marine sediments. This layer has an upper less permeable part at a depth of 257.9-364.1m (a silt, weathered silty clay layer of 11.7-24.1 m thick) and an aquifer (a 40.1-71.5 m thick layer consisting of compacted fine to coarse sand) at a 260.6-377.9m depth below surface level (Wagner et al., 2012; Deltares, 2011). This layer distributes low saline groundwater of high quality (Wagner et al., 2012) on areas of 7,612 km^2 in Ho Chi Minh City and Dong Thap provinces (Deltares, 2011).

Upper-Middle Miocene (n_1^{2-3})

The upper-middle Miocene aquifer is the deepest confined aquifer in the VMD, with little boreholes drilled to it. The upper-middle Miocene layer consists of an aquitard (from 508-602 m depth composed of clay and sandy silt) and an aquifer (from 602-798 m depth comprising of compacted fine sand and medium sand). Other boreholes showed that this layer has an aquitard layer from 724.6-914 m consisting of clay

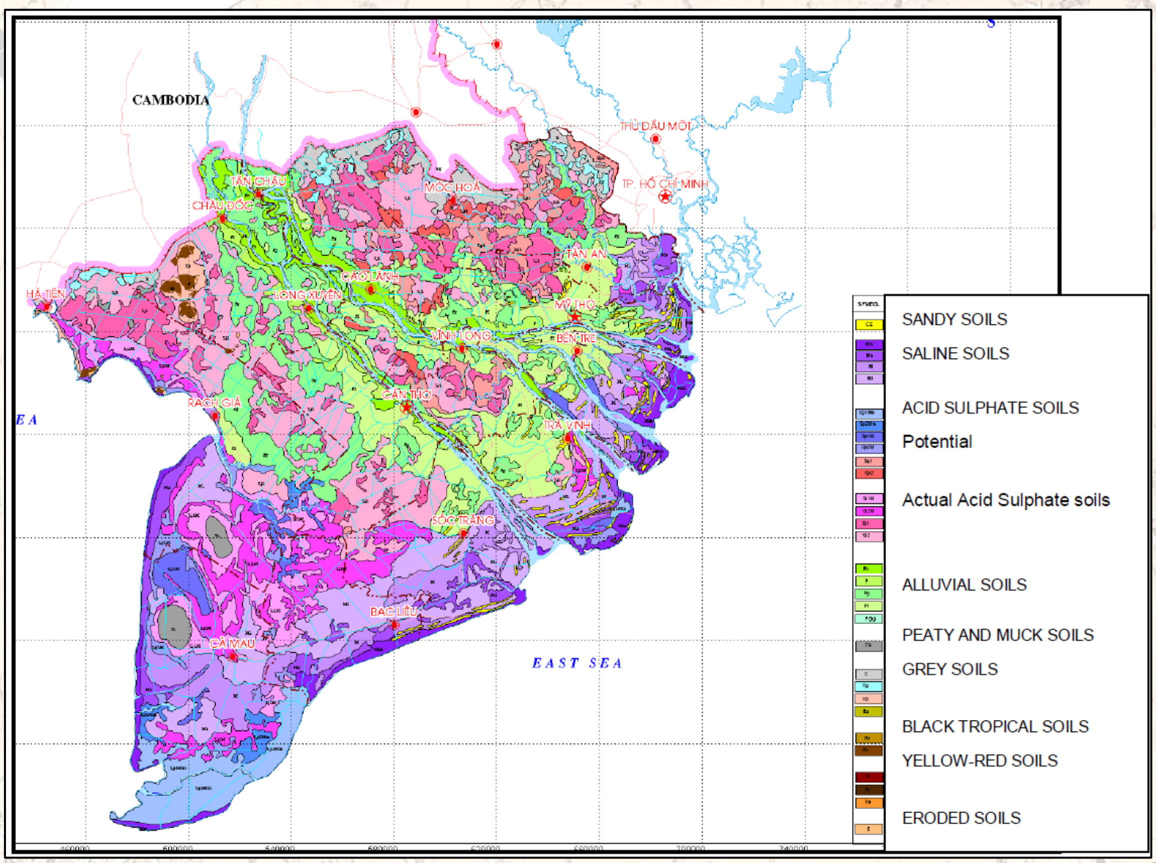


Figure 7 Major soil groups in the VMD (SIWRP, 2011).

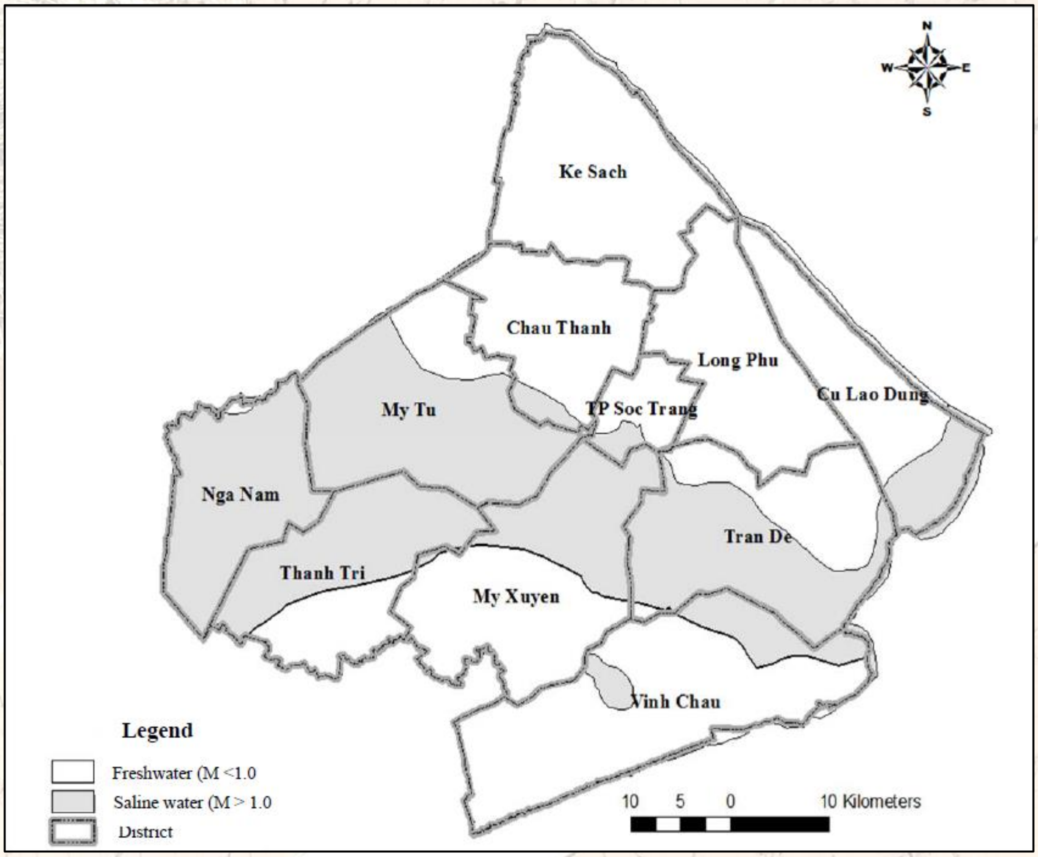


Figure 8 Spatial distribution of brackish and fresh groundwater from the lower Pleistocene layer (Van Pham et al., 2016).

and silty clay, and a pebble and gravel aquifer from 914-1000m below surface level (Deltares, 2011). However, this information is based on just a few drillings (Wagner et al., 2012).

The VMD is a young landmass, developed in the Holocene due to transgression and regression of the sea. Sediments are carried by floodwater along the banks of the Mekong and Bassac rivers, and it is this deposition of sediments that mainly formed the soils in this delta. This process formed ridge-shaped natural levees parallel to the riverbanks with relatively large particles, which gave rise to different distributions of soil texture throughout the VMD. Generally, the further from the riverbanks the finer the soil texture is (Quang, 2009). Major soil groups in the VMD are acid-sulphate soils (~1.4 million ha, 35% of the total area), saline and alluvial soils (~1.2 million ha, 28% of the total area each), and mud, peat, and sandy soil groups are limited. The distribution of the major soil types in the VMD (Figure 7), consists of sandy soil (44,860 ha), severe saline soil (268,600 ha), and moderate and slightly saline soil (624,200 ha). Moreover, it consists of potential saline soil (281,300 ha), potential acid soil (162,900 ha), shallow active acid soil (440,600 ha), and deep active acid soil (821,000 ha). Furthermore, major soil types are shallow active acid – saline soil (1,120,000 ha), peaty acid-sulphate soil (32,030 ha), grey soil (165,400 ha), and hill soil (12,800 ha) (SIWRP, 2011).

The lithology of each layer consists of fine to coarse sand, gravel, and pebble (Van Pham et al., 2016). Moreover, according to Erban et al. (2014), the specific storage S_S is laterally constant in the Vietnamese Mekong Delta with a S_S of 5.5x10^{-4}/m for confining clays and 5.5x10^{-5}/m for aquifer sands. Aquifer cross-sections have been made by Bui Tran et al. (2013), with the relevant cross-section 846a and 846a on a 24° side in Appendix II. Comparing these aquifer cross-sections to the answers to the farmer survey, the height of the aquifer (D) [L], aquifer's hydraulic conductivity K, and the average transmissivity T can be inferred. Since the majority of the farmers (56.66%) are extracting groundwater from the lower Pleistocene layer (123-158m) [SURVEYS], the height from the top to the bottom of the mainly exploited aquifer (D) [L] is considered to be 35 meters for the lower Pleistocene layer in Vinh Chau District (Bui Tran, Cao Xuan, & Ngo Van, 2013)

Farmers that extract groundwater from 50 - 100 meters (30%) do that from the middle Pleistocene layer (65.7-117.8 m) [SURVEYS], in Vinh Chau District this aquifer has a height from the top to the bottom of the aquifer[1] of 52.10 meters (Bui Tran et al., 2013). Table 6 lists the relevant soils (Bui Tran et al., 2013) for determining the aquifer's average hydraulic conductivity [K], which for the Middle Pleistocene layer (65.7-117.8 m) is 4.44 [m/day], and for the lower Pleistocene layer (123-158m) is 16.93 [m/day]. Furthermore, the average transmissivity [T] for the middle Pleistocene layer is 232.33 [m^2/day], and for the lower Pleistocene layer is 592.50 [m^2/day]. In addition, the storativity of the soil in Vinh Chau District is calculated to be 0.001925 [-] (Hamer, 2016). The spatial distribution of fresh and brackish groundwater in the lower Pleistocene layer is highly variable as can be seen in Figure 8 (Van Pham et al., 2016), which implies that farmers that exploit from this aquifer in Vinh Chau District would according to this distribution mainly get fresh groundwater.

Hydrogeological maps for all aquifers can be found in Appendix III (Deltares, 2011). The piezometric surface for the upper middle Pleistocene layer (qp_{2-3}) in the VMD can be (very coarsely) inferred from Figure 9, which shows the direction of the groundwater flow to Ca Mau Province for the rainy season of 1995 (White, 2002);(IUCN, 2011). Although changes in the direction of groundwater flow occurred, with saltwater intrusion as a consequence (IUCN, 2011).

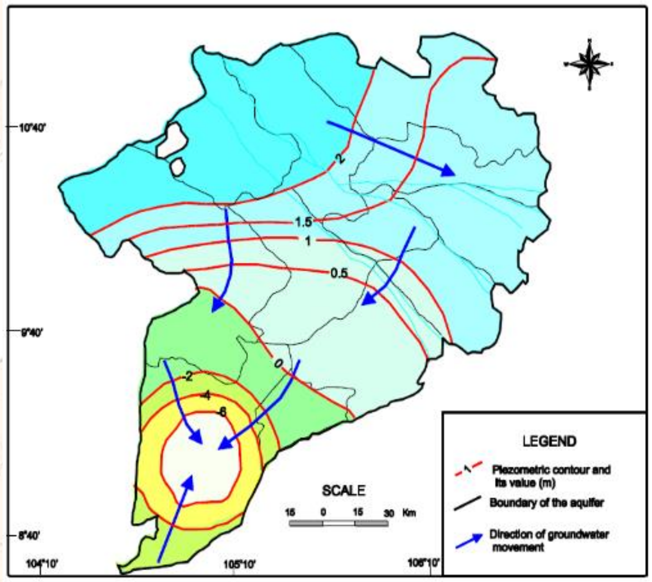


Figure 9 Piezometric surface map (middle upper Pleistocene aquifer) for the VMD after White, (2002) (IUCN, 2011).

	Soil type	Depth layer	D_k [m]	K [m/day]	T
Middle Pleistocene layer (65.7-117.8m) - The second aquifer under h_0	Strong silty sand	65.7 -69.8	4.1	10	41
	Silty sand	69.8 - 79.2	9.6	1	9.6
	Silty sand	79.2 - 91.7	12.5	1	12.5
	Silt	91.7 - 94.4	2.7	0.01	0.027
	Silty sand	94.4 - 101.6	7.2	1	7.2
	Strong silty sand with gravel	101.6-117.8	16.2	10	162
lower Pleistocene layer (123-158m) - The third aquifer under h_0	Medium sand	123-125.3	2.3	10	23
	Silty sand	125.3 - 132.7	7.4	1	7.4
	Coarse sand	132.7 - 133.9	1.2	25	30
	Coarse sand with gravel	133.9-151.5	17.6	25	440
	Coarse sand	151.5 - 154.8	3.3	25	82.5
	Fine sand	154.8 - 158	3.2	3	9.6

Table 6 Relevant soil types, average hydraulic conductivity (K), average transmissivity (T), and the height (D) of the exploited aquifers

[1] In Appendix II cross-sections and locations are given to show exact depths of the exploited aquifer layers, given for nearby aquifer cross sections made in Long Phú and Bạc Liêu Districts, since aquifer cross sections for Vinh Chau District are not available. Although the majority of Vinh Chau district is located on a confined aquifer, which makes the Bạc Liêu District cross section by Bui Tran et al., (2013) the most relevant. Cross-sections 846a, and 846a 24° are located at around Nhà Mát, tp. Bạc Liêu, Bạc Liêu, Vietnam. Exploited aquifer heights are: (1) the upper Pleistocene layer 57.5 – 101 m at Long Phú (east of Vinh Chau), (2) the middle Pleistocene layer 65.7-117.8m at Bạc Liêu (west of Vinh Chau), (3) the middle Pleistocene layer 113-180m at Long Phú (east of Vinh Chau), and (4) the lower Pleistocene layer 123-158m at Bạc Liêu (west of Vinh Chau).

4.3. Surface water and ecosystems degradation

4.3.1. Surface water degradation

In the VMD groundwater is a major water resource, but surface water and rainwater are exploited water resources as well (Mekong Delta Plan, 2013). Groundwater exploitation grew rapidly due to increasing pressures on the surface water in terms of salinity, acidity, domestic waste and suspended sediments (Wilbers, Becker, Nga, Sebesvari & Renaud, 2014). The environment in Vinh Chau District is affected by anthropogenic impacts, such as the production processes in agriculture and aquaculture. In this district, shrimp farming covers up to 70% of land usage, and the waste water from aquaculture affected the ecological environment (PERG3).

Surface water quality in the VMD exceeds thresholds set by Vietnamese water quality guidelines at regard to pH values (max 8.6), turbidity (max 461 FTU), maximum ammonia concentrations (14.7 mg/L^{-1}), arsenic (44.1 µg/L^{-1}), barium (157.5 µg/L^{-1}), chromium (84.7 µg/L^{-1}), mercury (45.5 µg/L^{-1}), manganese (1659.7 µg/L^{-1}), aluminium (14.5 mg/L^{-1}), iron (17.0 mg/L^{-1}), Escherichia coli (87,000 CFU/100 mL^{-1}), and total coliforms 2,500,000 CFU CFU/100 mL^{-1}). This pollution originates from urbanization, metals that leach from soils, aquaculture, and tidal regime phenomena, with significant differences in water quality due to the daily tidal regime and seasonality (Wilbers et al., 2014). However, pesticides and herbicides are deemed a necessity in Soc Trang Province as prevention and treatment of pests on crop and some diseases related to fisheries led to difficulties in treatment. Besides that, human health is also affected, in the form of more complicated to treat fever (PERG1), and due to the occurrence of drought, various insect groups flourish in plants such as rice crops, vegetables and fruit trees (PERG4).

The respondent (PERG1) from the People's Committee of the Vinh Chau District office of the DARD (personal communication, April 2016) said that:

'' There were some strange and new diseases in the field of fisheries and cultivation.''

Further causes of surface water quality degradation can be found in the untreated wastewater discharges, industrial pollution, and the limitedness of sanitary facilities, together with insufficient water supply, and water infrastructure is operating below design capacity. Furthermore, drainage capacity is inadequate in many areas during high river discharge events (e.g. by heavy precipitation) leading to a delay of flood water recession. Moreover, sluices have not been implemented, which are required to prevent saltwater intrusion, and when they exist, freshwater and saltwater needs by agriculture and aquaculture leads to occasional conflict (Mekong Delta Plan, 2013).

4.3.2. Saltwater intrusion of surface water

Most of Soc Trang Province, including Vinh Chau District, has about 4g/L^{-1} of surface water salinization (Đạt, Trung, Srisatit & Likitdecharote, 2011). According to (PERG2), the currently only problem is that of saltwater intrusion, which affected areas by saline intrusion that are generally located on the South of the Hau River, with the main affected channels being Quang Lo Phung Hiep Channel, Hau River, and My Thanh River (PERG2). Saline intrusion is a natural process that is enhanced by anthropogenic influences [KE3], saline water concentrates in the main streams [KE2], and it poses a substantive issue for the VMD [KE8]. Although salinity increased over the last few years, aquaculture stocks can still be maintained (PERG5). Causes of saltwater intrusion are found in the decrease of upstream water flows, tidal influences, aquaculture and agricultural development, and because shrimp farms extract saline groundwater. Moreover, the rising sea-level caused about 50,000 m^2 of rice land to be exposed to saline water. During dry spells, drought in combination with reduced water from upstream due to damming, led to very significant saltwater intrusion [KE2].

In some areas, the agricultural sector often resorts to rainwater and groundwater, since surface water cannot be used because of its high salinity in some areas (PERG3);[KE5]. Freshwater resources in the near future will decline due to salinity [KE1], and saline surface water also affects groundwater availability since it can affect the aquifer [KE3].

In the dry season, dikes are utilized by the government to prevent salinization, and the sluices are used during the rainy season to prevent flooding (PERG2). However, when salinity intrusion is rampant, the sluices are closed, but this, in turn, causes a lack of freshwater resulting in more salinity, drought, and alum (PERG4). Prevention of salinization and keeping fresh water inside the water system is not possible, since there are currently not enough hard engineering measures [KE11].

4.3.3. Ecosystem degradation

Natural values in the VMD are significantly reduced due to rapid population growth and intensive agricultural and aquaculture development over the past decades. Due to concessions made for agriculture, aquaculture, and industrial development, wetlands (e.g. mangroves, ponds, lakes) are adversely affected as overexploitation of natural resources is a major threat to ecosystem health (Mekong Delta Plan, 2013). The anthropogenic influence in this ecosystem should be weighed with the environmental influences. Due to the fluctuation of temperature and salinity, especially in the year 2016, some adverse effects on the ecosystem regarding species diversity were visible, some areas lacked freshwater resources, and it was often the case that there were no closed circulation cycles in these regions. Local resources, such as freshwater fish and shrimp decreased as compared to previous years according to observation by the local citizen. Due to the changing climate, local efforts to exploit coastal resources were hindered, and coastal erosion caused mudflats species to dwindle or to be lost (PERG5).

4.4. Groundwater resources body

4.4.1. Agricultural pollution into the soil

The Ministry of Natural Resources and Environment (MONRE) is working on land pollution issues, but measures have not yet been implemented (PERG2). Land pollution occurs by agricultural usage and due to aquaculture farming practices.

Acid Sulphate soils

Acid sulphate soils are soils, sediments, and peats that occur naturally containing iron sulphides (mainly in the form of pyrite materials) which are benign in anoxic state. However, exposure of acid sulphate soils to oxygen (e.g. by lowering the water table) yields reduction of agricultural productivity, damage to ecosystems and contamination of groundwater resources (Department of Environment Regulation, 2015). Acid sulphate in soils in Soc Trang Province does not directly affect the soil itself but does affect water quality and crops. The usage of shallow acid groundwater and fertilizers on soil that has its top layer removed leads to further acidification, although this is not so common in Soc Trang Province [KE5]. Oxidation occurs due to the lowering of the groundwater level in the acid sulphate soil zone, the soil oxidizes and becomes more acid. Oxidation processes vary with the fluctuation of groundwater levels in the layer under the fertile top soil, resulting in increases and decreases of oxidation intensities [KE9]. Acid sulphate soils and arsenic is in terms of water quality also a problem which drives farmers to drill for deeper groundwater resources [KE13].

Nutrients and nitrates

In the VMD soil degradation is a substantial issue, because when people plant vegetables, large amounts of chemicals, pesticides, and herbicides are used to increase the quality of the soil, to exploit it more and earn more income. Furthermore, the Hau River is very polluted, which is in turn interconnected with the soil [KE15]. The clay layer in the soil might oxidize, and the surface water level could impact the soil because of tidal movements, with small soil particles coming down in low tide making the soil to become weaker. Loading by housing and infrastructure will have more effect because of that since the unsaturated zone will be weaker [KE13]. Soil compaction occurs, and farmers have to use significant amounts of fertilizers such as organic matter to improve soil chemical properties [KE1]. Furthermore, nitrates and other pollutants occur from agriculture, and groundwater wells contain nitrates. However, these chemical substances were found to be below hazardous levels in 1999 by the Center of Water Resource Evaluation (Vo & Huynh, 2014).

Saline intrusion

After shrimp cultivation, rainwater is used to wash away salts in shrimp cultivation ponds in order to grow rice. However, due to drought, rainwater is limited, and there is not enough water to wash out these salts. This rainwater shortage makes that rice is sown without consideration and knowledge of salt contents in the soil, which in turn causes rice plants to die, and farmers' annual routine in farming to be disturbed by a change in climatic circumstances [KE11]. Risks to shrimp farming (e.g. nutrient accumulation in ponds and channels and pollution) lead to a financial trap for farmers, due to debts and no practical way to return to rice cultivation since their land became too saline (Nguyen & Ford, 2010).

4.4.2. Saline intrusion into the soil

Saline intrusion in the VMD (Figure 10) affects vast areas of the delta, of which around 1.8 million ha is subject to increased dry season salinity, and around 1.3 million ha has saline water of 5 g/L^{-1}. Important drivers to saline intrusion are sea level rise, upstream damming, and upstream irrigation. A sea-level rise of 30 cm, together with an increase in dry years and upstream development would cause saline intrusion to expand (Smajgl et al., 2015).

In Cai Nuoc District in Ca Mau Province, farmers switched en masse from rice cropping to shrimp farming in 2000, but their attempts to revert to a rotational system with shrimp farming in the dry season and rice in the wet season failed. Soil salinity is, in general, quite stable throughout the wet and the dry seasons, as was shown in a study done in Cai Nuoc district by Tho, Vromant, Hung, & Hens, (2007). In that study, soil salinity was at a mean of EC_e 29.25 dS m^{-1}, with a mean of EC_e 33.44 dS m^{-1} in the dry season and a mean of EC_e 24.65 dS m^{-1} in the wet season (Tho, Vromant, Hung, & Hens, 2007). In Cu Lao Dung Island in Soc Trang Province, the interaction of surface water and groundwater at the aquifer between 80 m to 130 m under land surface (qh_{2-3}) does not occur, which could be due to a 50 m thick impermeable clay aquitard (possibly an aquiclude). In this aquifer, there is a similarity of ion compositions and low chloride concentrations through the island, illustrating that the tide is the most important factor regarding surface water quality but is without influence to the groundwater (An, Tsujimura, Le Phu, Kawachi, & Ha, 2014).

Water demand for agriculture may increase two-to threefold compared with the demand in the year 2000. With the rising sea-levels, the Mekong Delta could see much of its total area subjected to flooding and saltwater intrusion could lead to loss of arable land (IFAD, 2014). The delta is also affected in terms of food security under threat from saltwater intrusion (Ericson et al., 2006). Salinization and saltwater intrusion are amongst the most pressing environmental issues in the VMD. Saltwater intrusion affects large parts of Soc Trang Province, such as Thanh Tri, Nga Nam, Cu Lao Dung, Tran De and Long Phu, and Vinh Chau Districts (PERG2).

Recently, areas in the VMD and Vinh Chau District, in particular, have been affected by salinization, which affects access to freshwater resources (PERG3). Saltwater intrusion is a very recent development in Soc Trang Province, with saltwater intrusion over 70 km in 2016, affecting areas of the winter-spring rice harvest, and about 20,000 hectares of summer-autumn rice harvest (PERG4). Due to the increase of salinity in groundwater, farmers extract even more saline groundwater to obtain desired salinity levels in aquaculture production ponds (Kongkeo, 1997). Farmers continue to irrigate their lands with increasingly brackish water, leading to more salinity of the soil and aquifer degradation (Foster & Chilton, 2003). Meanwhile, increasing saltwater intrusion lengths cause further salinization (Zhang et al., 2013). Besides that, saltwater intrusion can also occur through the sea since saline water has higher mineral contents and is thus denser than that freshwater is, submarine groundwater discharge (the discharge of land driven fresh groundwater to the seafloor through the leaky confining unit) decreases with the distance offshore (Shishaye, 2016).

Throughout the end of the dry season in previous years, the salinity in shrimp farming areas was at ten parts per thousand (ppt) (PERG1). In Soc Trang Province, environmental monitoring stations started keeping track of salinization since 2011, salinity increased by about eight ppt on average (PERG1); (PERG5), with salinity increases from 4.8 ppt to 11 ppt respective to the area (PERG5). Saline intrusion in Vinh Chau District increased (PERG3), is the biggest problem in Soc Trang Province (PERG6), and has been an issue for years (PERG1).

According to (PERG1), Vinh Chau District has been mainly affected by drought, salinity, high temperature and the large differences between day and night temperature. Moreover, (PERG1) added that these changes are unlike previous years, with the biggest change in Vinh Chau District being the difference in current salinity levels compared to the past decade (PERG1). More salinization makes land difficult to grow crops on and requires ploughing the soil. Therefore significant amounts of organic matter are used to improve chemical properties of the soil. When it is harder to get water, farmers just drill more wells [KE1], they are practically forced to [KE5], and the use of groundwater for irrigation without management policies will result in the depletion of groundwater resources in this area (PERG3).

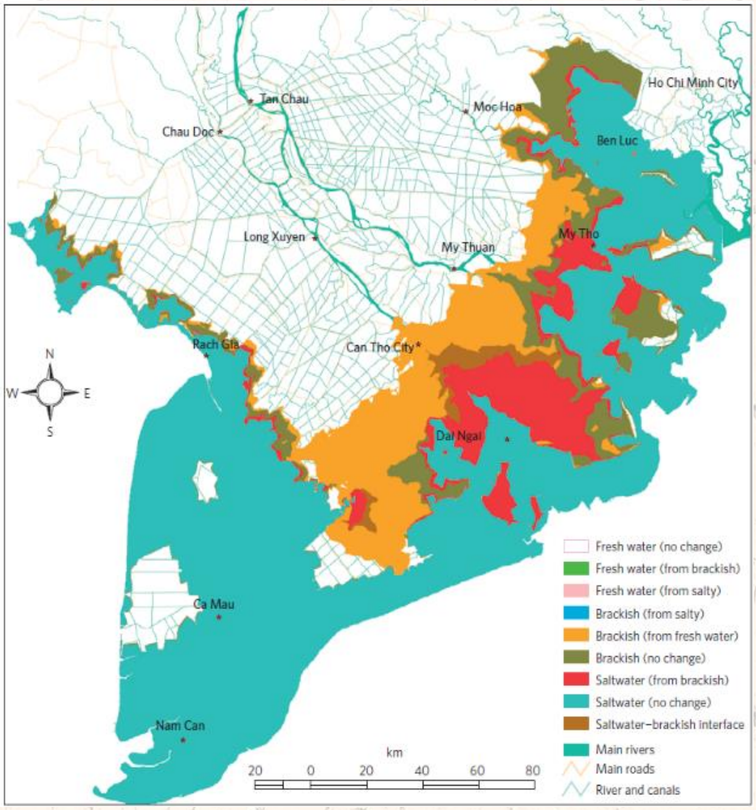


Figure 10 Expansion of saline intrusion in the VMD under pressure of upstream development and sea-level rise of 30 cm (Smajgl et al., 2015).

4.5. Precipitation and drought

The demand for groundwater will only increase in the future; the VMD is in a paradox of water availability as it has water scarcity in the dry season and too much water in the wet season. Additionally, the wet season contributes to approximately 80% to 85% of the annual rainfall and takes place from May to November with heavy rains in June and September (250 – 330 (and maxima up to 683) mm/month) (van Leeuwen et al., 2015). The total annual temperature in Vietnam is projected to increase between 8% and 11% by the year 2100, and overall in the Mekong Delta, evapotranspiration increases. After 2020, groundwater levels are expected to drop drastically increasing the incidence of drought and inter- and intra-seasonal rainfall patterns will become more uncertain as to the overall availability of water resources. The increase in the frequency of extreme rainfall events will exacerbate flooding effects and will concentrate precipitation within shorter time periods resulting in decreased soil moisture and groundwater recharge (IFAD, 2014). Soc Trang Province faces climate change induced hot weather, which (accompanied by El Niño) causes temperatures to increase significantly. As a result, water resources evaporate, causing salinity to increase. In the recent past years, the impact of climate change has affected the Mekong River directly. Due to high temperatures, water evaporates as river surface levels decline, resulting in a lack of water to supply to aquaculture ponds, which in turn can cause prawn to reduce their resistance to disease. Aquaculture in brackish water is not affected much by the changing climate, but temperature rise induced disease to fish stocks leads to damages. Water shortages mainly affect and damage rice paddy fields (PERG5). With the rising sea-levels, the Mekong Delta could see much of its total area subjected to flooding and saltwater intrusion could lead to loss of arable land (IFAD, 2014).

Vinh Chau District is affected by high temperatures since it is located along the coast, the temperature rise, in turn, aggravates salinity and due to the impact of a number of dams in the watershed, salinization rooted in the land (PERG3). Furthermore, In late 2015, the El Niño phenomenon caused loss of available water resources and widespread drought (PERG4). The soil seems to be a lot drier, since, 61.11% of the respondents indicated the that their soil seems a lot drier now than that it was ten years ago, 32.22% of the farmers indicated that the soil is a bit drier, and 3.33% farmers reported no change. None of the farmers indicated the soil in the dry season to be a bit wetter than that it was a decade ago, none of the farmers indicate the soil to be a lot wetter, and 8.88% of the farmers could not answer this question. Moreover, farmers generally got negatively affected by environmental changes to their farm, 36.66% of the respondents reported that they are significantly negatively affected by environmental changes, 37.77% stated that they are negatively affected by such changes, and 8.88% indicated that they are somewhat affected by environmental changes. In addition, 14.44% indicate not to be affected by environmental changes [SURVEYS].

Being affected by environmental changes did not lead to changes in crops or product stock. When asked for the actions undertaken by the respondents, 8.88% of the farmers indicated to have completely changed crops in the last ten years' forced by environmental changes, 30.00% changed their crops partially, and 8.88% indicated to have changed their crops somewhat. Additionally, 45.55% indicated not to have changed their crops due to environmental changes. Furthermore, of the 33 farmers that indicated to be significantly negatively affected by environmental effects, 15.15% completely changed their crops, 24.24% partially changed their crops, 9.09% changed their crops to a minor extent, and 45.45% did not change their crops at all. Moreover, of the 34 farmers that indicated not to be that much affected, 5.88% changed their crops completely, 41.17% changed their crops partially, 11.76% only somewhat changed their crops, and 32.35% did not change their crops at all. Additionally, of the 90 farmers that got asked whether they made changes in their farming system forced by environmental changes, 5.55% indicated that they did, and 91.11% indicated not to have made such changes. Conversely, of the farmers that indicated to be significantly affected, 81.81% did not make changes to their farming system. The farmers that indicated to be not that much or only a little bit affected did not change their farming system as well [SURVEYS].

4.6. Conclusion

The physical knowledge of the first WEG criterion has been assessed, with an emphasis towards a broader and more anthropogenic driven background. The first criterion on the availability of the knowledge on the physical aspects of the system is met.

System knowledge, whether there is enough knowledge on the systems physical aspects.

The VMD's origin is in the deposition and accumulation of sediments over millions of years from the river mouth, and it is this deposition that mainly formed the soils in this delta. Throughout various geologic periods, the complex and heterogeneous structure of aquifers and aquicludes was formed. Each hydrogeological unit has a medium to high water yield (1 - >5 l/s), and can be distinguished into the Holocene (qh), Upper Pleistocene (qp_3), Upper-Middle Pleistocene ($qp_{2\text{-}3}$), Lower Pleistocene (qp_1), Middle Pliocene (n_2^2), Lower Pliocene (n_2^1), Upper Miocene (n_1^3), and the Upper-Middle Miocene ($n_1^{2\text{-}3}$). In this delta, the soil textures are finer the further from the riverbanks. Major soil groups in the VMD are acid-sulphate soils, saline, and alluvial soils, while mud, peat and sandy soil groups are limited. Moreover, the lithology of each layer consists of fine to coarse sand, gravel, and pebble. The layers that farmers in Vinh Chau District mainly extract groundwater from are the lower Pleistocene layer (56.66%), or from the middle Pleistocene layer (30%), these layers are 123-158m and 65.7-117.8 m in depth respectively.

Besides groundwater, also rainwater and surface water resources are utilized. However, pollution of surface water sources occurs due to anthropogenic impacts e.g. production processes in agriculture and aquaculture, rendering it to exceed Vietnamese water quality guidelines. Further sources of pollution originate from urbanization, leaching metals from soils, tidal regime phenomena, industrial pollution, untreated wastewater discharges, and the limitedness of sanitary facilities. However, pesticides are deemed a necessity in Soc Trang Province.

Despite this pollution, the agricultural sector still uses surface water due to the high salinity contents of groundwater. On the other hand, surface water resources are becoming increasingly saline which leads some farmers to revert to the utilization of groundwater resources. The main causes of surface water salinity are mentioned to be the reduction of river recharge from upstream, tidal influences, development of aquaculture and agriculture, and because shrimp farms extract saline groundwater.

Natural areas and their ecosystems are adversely affected due to concessions made for agriculture, aquaculture and industrial development. Freshwater resources will only decline in the near future, and some areas lack freshwater resources altogether due to increasing salinity levels. Acid sulphate soils pollute groundwater when exposed to oxygen e.g. by lowering water tables. Moreover, pollution from river water (e.g. the Hau River) interconnects with the soil. Aquaculture production also causes salinity to intrude the soil and groundwater resources, leading to a financial trap for farmers due to investment debts and no practical way to return to rice cultivation.

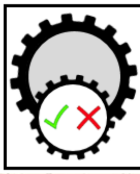
Saltwater intrusion into the soil is a threat to food security while water demands for agriculture may increase two-to threefold compared with the demand in the year 2000. Access to freshwater resources is affected and affects large parts of Soc Trang Province, such as Thanh Tri, Nga Nam, Cu Lao Dung, Tran De and Long Phu, and Vinh Chau Districts. Moreover, farmer practices to irrigate lands with increasingly brackish water and groundwater extraction for obtaining obtain desired salinity levels in aquaculture production ponds only adversely affect groundwater salinization. The rising sea-level also contributes to increasing salinization, since saltwater is denser than that fresh groundwater is. Saline intrusion is considered to be the worst problem in Vinh Chau District, with the largest difference as compared to a decade ago. Whenever it is harder to get water, farmers just drill more wells, and the soil degradation is responded to by the usage of nutrients to enhance soil characteristics, leading to further environmental degradation.

The incidence of drought will increase, and the inter-and intra-seasonal rainfall patterns will become more uncertain. Furthermore, an increase of warm and dry weather conditions lead to further aggravation of salinity intrusion. Farmers in Vinh Chau District generally mentioned their soil to be a lot drier compared to a decade ago; they got negatively affected by environmental changes. Although changes to their farm (e.g. crop or farm system changes) have barely been made.

5. System knowledge: water resource usage

5.1. Introduction

This chapter covers the second part of the first WEG criterion for the system knowledge and concludes with whether that condition is met. The second part of this criterion covers the more anthropogenic impacts on the water system in the VMD and logically follows from the previous chapter to assess the delta on the first WEG assessment criterion. First, the distribution and capacity of the groundwater extraction are covered, followed by the agricultural water usage, regarding aquaculture and agriculture. The sections on water and land utilization interrelate with the degradation of the environment with regard to land use and water resources. The conclusion then argues as to what extent the criterion for enough knowledge on the system is met, regarding the system's problems and driving causes.



System knowledge, whether there is enough knowledge on the systems problems and driving causes.

This chapter explains the utilization of water resources by various actors in the field, which in turn leads to environmental degradation as hydraulic heads lower and subsidence occurs, followed by the impacts of the relative sea-level rise. The last section of this chapter lists local government understanding of the water systems problems and driving causes, followed by an overall conclusion on this assessment criterion.

5.2. Spatial distribution and capacity of pumps and wells

In the VMD, groundwater exploitation for domestic, agricultural and industrial needs through wells has increased from a limited number before the 1960's to a vast but currently unclear number of wells. Recent estimates are that there are more than one million wells in the 2010's (Wagner et al., 2012; Danh, 2008; Danh & Khai, 2015), while other estimates to the number of wells are around 465,000 in the VMD (Vermeulen et al., 2013). Further estimates are that in 2007, an estimated 465,000 groundwater wells extracted a total 1,229,000 m^3/day, in which 50,000 wells in Soc Trang Province extracted around 100,000 m^3/day (IUCN 2011). This extraction led to an 'explosion' of groundwater depletion (Konikow & Kendy, 2005).

In Vinh Chau District, 87.77% of the surveyed farmers indicated to have initially started with one well, and of them, 73.41% did not drill more wells, and 22.78% expanded their water extraction with another well. In Chapter 4.2, the farmers drilled well depths were covered, which were current wells drilled to depths of 50 – 100 meters (30%) in the upper Pleistocene level, or 100 – 150 meters (56.66%) in the middle Pleistocene layer. The average discharge capacity of the pumps is 19 m^3/s (71.11%), 24 m^3/s (17.78%), 13 m^3/s (8.88%), 29 m^3/s (1.11%), and 8 m^3/s (1.11%) [SURVEYS], and the 13 m^3/s, 19 m^3/s, and 24 m^3/s pumps seem to be the most popular in the stores that sell pumps [P-SURVEYS]. Pumping in the day yields different volumes per time period in that day, since it is reliant on the number of farmers using pumps in the vicinity at the same time. Furthermore, pumps are enhanced by additional devices to extract more groundwater, and the depth of the well is also of a factor in the extraction of groundwater [KE7]. Although 99% of the farmers indicated not to have such a device [SURVEYS], and the pump stores indicated not to sell such devices either [P-SURVEYS].

In general, there is a slight increase of wells that the farm households have, as over an 11 year time period (2005-2016) regarding wells under active use, the number of farmers with zero wells decreased from 17.65% to 4.44%. Moreover, the number of farmers with one well increased from 64.71% to 68.89%, and with two wells from 15.29% to 23.33%. There are also differences in ethnicity of the farmer's households, regarding the regression and progression of wells, the table below (Table 7) indicates a general increase in the number of wells. The number of agriculture farms with zero wells decreased from 13.33% to 0%, with one well from 36.36% to 27.42%, and with two wells increased from 38.46% to 47.62%. The number of aquaculture farms with zero wells decreased from 53.33% (8 farms) to 4 farms, farms with one well increased from 36.36% to 41.94%, and with two wells decreased from 30.77% to 23.81%. The number of agriculture and aquaculture combination farms with zero wells decreased from 26.67% to 0%, farms with one well increased from 18.18% to 19.35%, and farms with two wells decreased from 30.07% to 28.57% [SURVEYS].

	2005		**2016**	
Khmer rural households	No wells	40.00%	No wells	0%
	One well	47.27%	One well	43.55%
	Two wells	46.15%	Two wells	61.90%
Kinh rural households	No wells	46.66%	No wells	12.50%
	One well	34.54%	One well	37.10%
	Two wells	23.08%	Two wells	23.81%
Chinese rural households	No wells	13.33%	No wells	0%
	One well	18.18%	One well	19.35%
	Two wells	30.77%	Two wells	14.29%

Table 7 Temporal aspect of wells per ethnicity for Vinh Chau District

In the VMD, groundwater is extracted from shallow tube-wells (80-120 m depth), and groundwater plants extract groundwater from deep wells (200 - 450 m depth). Groundwater is extracted from the Holocene, Pleistocene, Pliocene and the Miocene aquifers, of which the Holocene is polluted (bio-micro pollution)

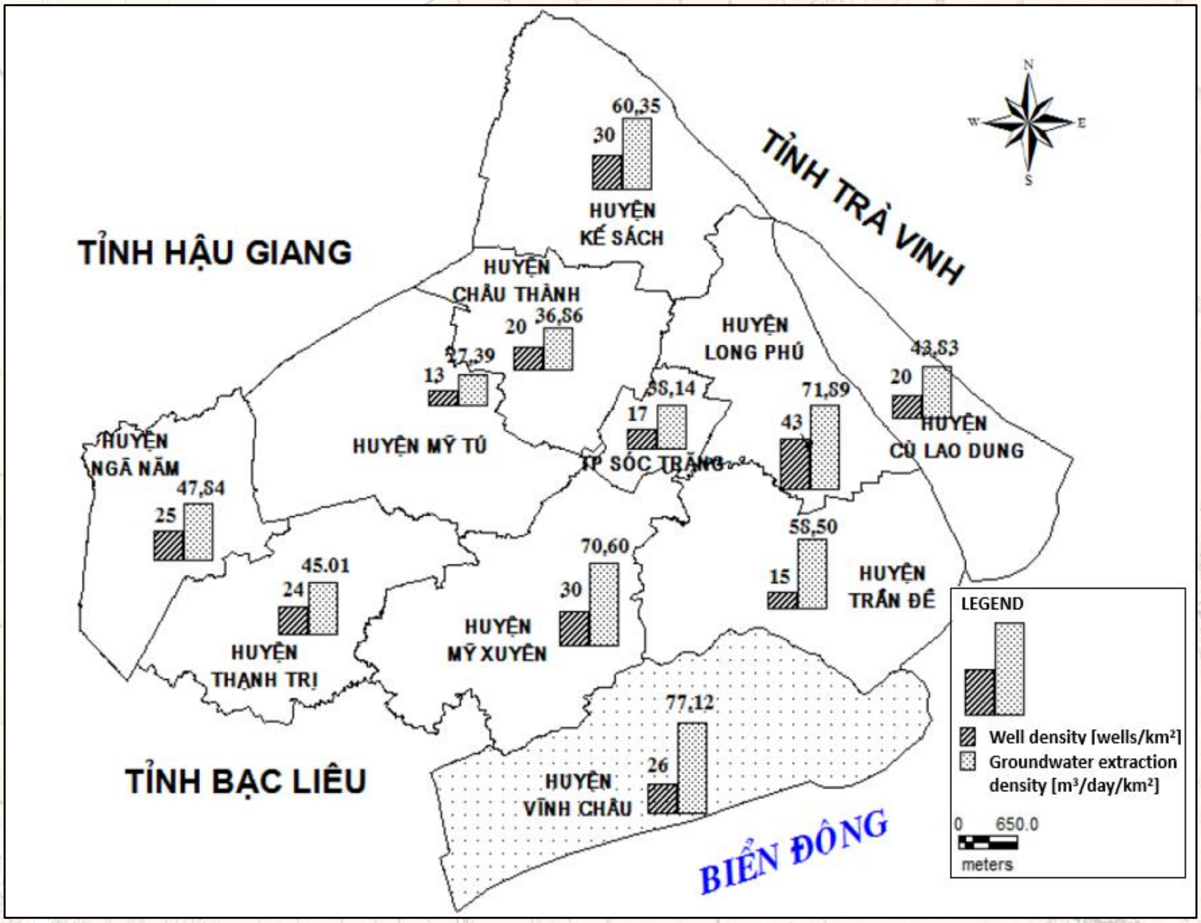


Figure 11 The density of wells and groundwater extraction intensity Soc Trang Province in 2010, where Biển Dông is the sea, tỉnh means province and huyện means district (Vương Thu Minh et al., 2014).

and the Pleistocene is highly polluted by nitrate and chlorine concentrations. Besides that, agricultural practices pollute by using pesticides and chemical fertilizers, and pollution occurs due to worn-out tube wells. Access to clean water is limited due to the pollution from agriculture, aquaculture, and salinization. Groundwater is commonly extracted since it is free of charge, as are surface water and rain water, although rainwater storage is not popular since it is limited by the problem of storing it (Danh & Khai, 2015). In the year 2010, the VMD had 468,230 wells with a total extraction of 1,229,061 m^3/day, of which 97 wells were used for urban supply with an extraction 254,977 m^3/day, for large rural supply 2,430 wells extracted 225,100 m^3/day, and for small rural supply 465,703 wells extracted 748,984 m^3/day. In Soc Trang Province there were 50,111 wells which extracted 100,090 m^3/day, of which 12 wells extracted 31,903 m^3/day for urban supply, 109 wells extracted 8,199 m^3/day for large rural supply, and 49,990 wells extracted 59,988 m^3/day. See Appendix IV for an overview of the groundwater usage for the whole VMD (Deltares, 2011). Farmers use around 100 m^3/household/yr in Soc Trang Province, which can be inferred from the surveys. In Vinh Chau District, farmers use between 74.35 m^3/household/yr to 121.75 m^3/household/yr, or an average of about 100 m^3/household/yr (average 98.05 m^3/person/yr) [SURVEYS]; (Hamer, 2016). A comparison can be had with groundwater usage by rural households around Can Tho City and Hau Giang Province, where rural households that have private tube wells extract around 100 m^3/household/yr (103.66 m^3/household/yr) (Danh, 2008). According to Vương Thu Minh et al., (2014), groundwater extraction in Vinh Chau District is around to 77.12 m^3/day/km^2, which is the greatest rate in Soc Trang Province (Figure 11). Groundwater extraction was most commonly extracted for domestic usage (99.1% in the dry season, 95.5% in the wet season) (Vương Thu Minh et al., 2014).

5.3. Agricultural water resources utilization

Groundwater productivity in Vinh Chau District could potentially, and depending on the aquifer, be 204,634 m^3/day, with extraction of over 36,000 m^3/day which is the greatest rate in Soc Trang Province. Vinh Chau District has over 12,000 wells with a density of 26 wells/km^2, while the average of Soc Trang

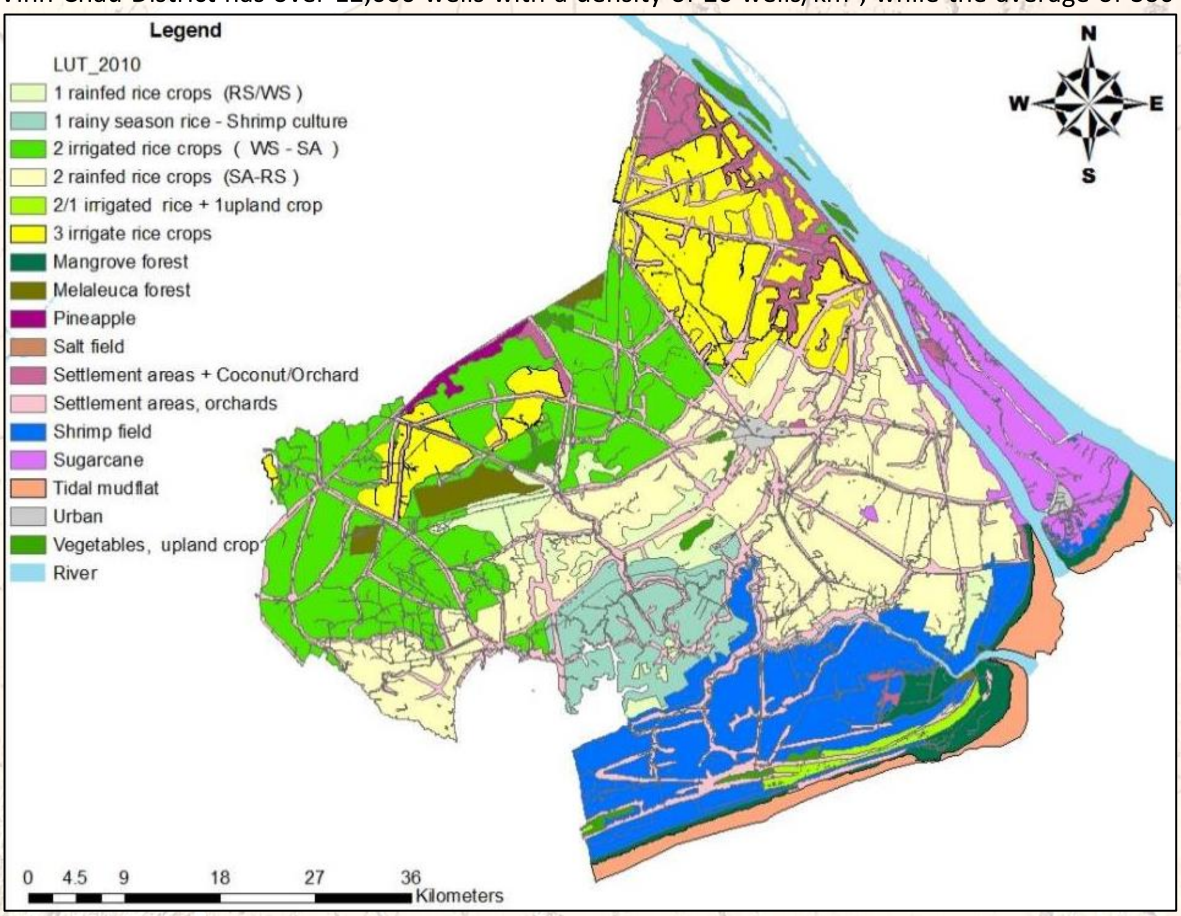


Figure 12 2010 land use map of Soc Trang Province (Van Pham, n.d.)

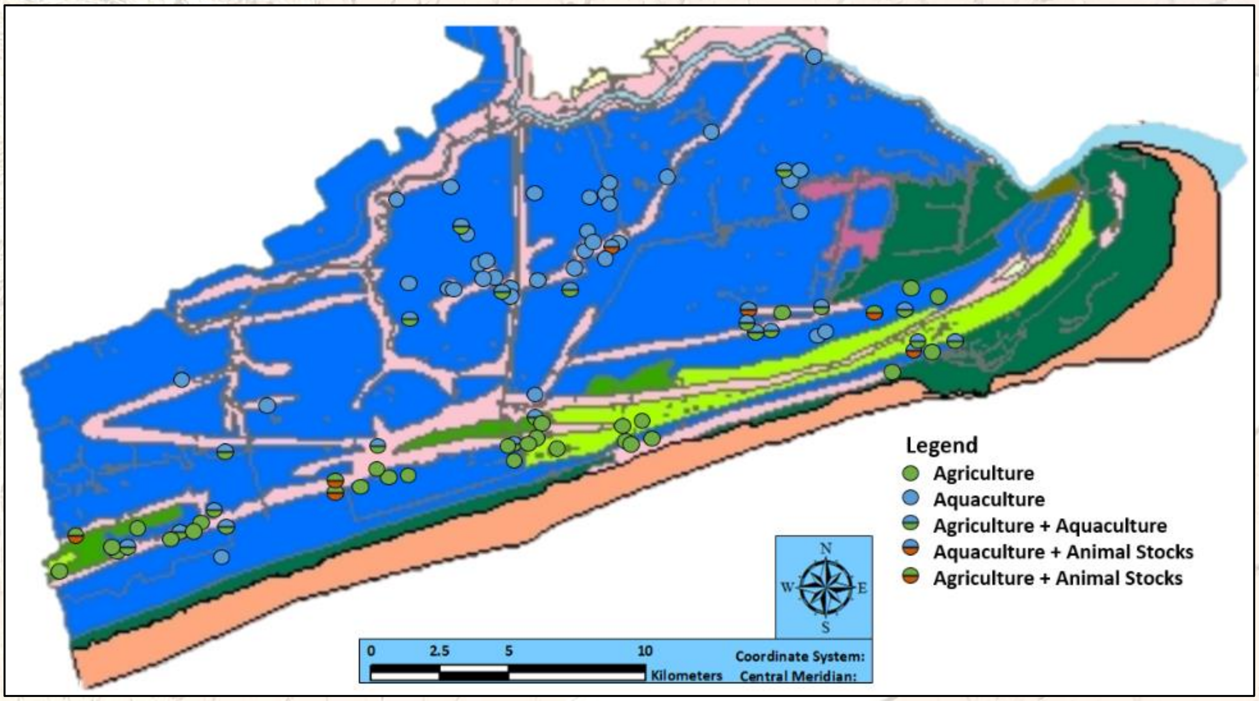


Figure 13 Land use map for Vinh Chau District adopted from Figure 17 and cross-checked with the survey results

Province's well density is 2 wells/km^2. In a study done amongst rural households in Vinh Chau District, 27% indicated to face a lack of freshwater resources in the dry season, and 70% reported rainwater storage as a helpful supplement that they could turn to. Table 8 shows the groundwater extraction in m^3/day and the number of wells in Vinh Chau District (Van Pham et al., 2016). In this district, aquaculture (40% of the respondents), almost exclusively cultivates crustaceans such as shrimp. Moreover, in this district, agriculture (30% of the respondents) cultivates onions (37.09%), and spices (32.25%). Agriculture and aquaculture combination farms make up for 22.20% of the respondents in the area. Additionally, animal stock farms only occur in combinations of agriculture and aquaculture, in combinations of agriculture and animal stock farming (5.6%), and of aquaculture and animal stock farms (2.20%) [SURVEYS]. Between 2000-2010, Soc Trang Province's aquaculture developed by 7,802 ha (1995) to 51,706 ha (2006), of which shrimp farming in the coastal Soc Trang Province increased by 31,510 ha, producing 9,999 tonnes in 2000 and 37,705 tonnes in 2005. In Vinh Chau District, in particular, the rice growing area declined from 22,000 ha (2000) to 2,585 ha (2005), 1,691 ha are used for onion farms, and 552 ha are used for elongated goby production (Joffre, Schmitt, 2010). Agricultural land use as of 2010 can be seen in Figure 12 (Van Pham, n.d.), this land use map seems to be rather accurate as shown in Figure 13 where the agricultural land usage is double checked by the results from the survey [SURVEYS].

	Aquifers			
	Holocene qh	**Upper Pleistocene** qp_3	**Upper-Middle Pleistocene** qp_{2-3}	**Lower Pleistocene** qp_1
Extracted quantities [m^3/day]	125	922	30,446	4,976
Total number of wells	49	996	9,928	1,284

Table 8 Extent of groundwater extraction in Vinh Chau District (Van Pham et al., 2016).

5.3.1. Freshwater use by aquaculture

Along the coast, most of the farmers are active in rice and shrimp cultivation, and each of those farmers, predominantly, have each their own well for dilution purposes [KE11]. Aquaculture uses a lot of groundwater [KE3] since salinity is useful for shrimp farms to make freshwater in basins or ponds more saline using groundwater to improve living conditions for shrimp stocks [KE1];[KE11];[KE12];(Kongkeo, 1997). Moreover, groundwater extraction for dilution purposes occurs especially in the dry season, since there is more evaporation [KE12];[KE2]. Shrimp farms use brackish river water and groundwater, while industrial shrimp farms use some more groundwater, but these farm types extract less groundwater than that onion farms do [KE7]. According to (PERG1), aquaculture production mainly depends on river water and seawater, and not on groundwater resources (PERG1). Although, in Vinh Chau, My Xuyen and Tran De Districts groundwater is extracted for dilution purposes (PERG2), or for domestic use (PERG5).

Looking at similar zones in other parts of the VMD, In Ben Tre province's coastal areas, farmers use substantial quantities of water for shrimp farms. When these farmers do not have enough fresh water, they take saline groundwater, even though it is prohibited by the government [KE1].

Back to Vinh Chau District, aquaculture farmers indicated not to use groundwater in the dry season (50% and 27.77% did not have an answer) and in the wet season (52.77% and 30.55% did not have a reply). They stated that they do not daily supply water to their ponds in the dry season (88.89%) and the wet season (97.22%). Furthermore, they stated to mainly use surface water (48.08%) (of which 32% always and 68% half of the time), followed by seawater (28.85%) (20% always and 80% half of the time). Besides that, they indicated to use rainwater storage (21.15%), of which 27.27%, 45.45%, and 27.27% indicated to use this always, half of the time or rarely respectively. Moreover, a vast minority of 1.92% of these respondents indicated to mainly use groundwater, while in contrast, aquaculture farmers currently have either one (69.44%) or two (22.22%) groundwater wells [SURVEYS]. Therefore, since farmers in aquaculture areas are forbidden to use groundwater for their farms, and that they hide their wells [KE11], these farmers might have given response biased answers.

Agriculture and aquaculture combination farms indicated to mainly exploit surface water (34.48%) (30% always uses surface water, and 70% does this half of the time), followed by the use of seawater (31.03%) (11.11% always uses seawater, and 88.88% does half of the time). This combination of farm types indicated to use rainwater storage (20.69%), whereas 16.67%, 50%, and 33.33% indicated to use this always, half of the time or rarely. Moreover, of the agriculture and aquaculture combination farms, 13.79% indicated to primarily use groundwater [SURVEYS].

5.3.2. Groundwater use by agriculture

In Vinh Chau District, agricultural production depends mainly on groundwater resources (PERG1);(PERG2) in the dry season, and in the wet season rainwater resources are used (PERG4). Groundwater is pumped out excessively [KE15] since there are no other suitable water resources available in the district (PERG2);[KE2]. Throughout the VMD, each province has a main crop that is grown by (excessive) groundwater extraction; the degradation of the availability of groundwater resources and the environment is therefore interlinked with the main agricultural activity of that province [KE7]. Particularly in the coastal areas, such as in Vinh Chau District, upland crops are planted, and groundwater is extracted [KE4]. In this district, farmers usually cultivate onions or other vegetables in the rainy season [KE8], and onion growing agriculture extracts groundwater substantially [KE2];[KE7]. Moreover, onions are cultivated extensively and need to be spread throughout the area in order to avoid a surplus of onions, hence the demand for groundwater [KE11].

Looking closer at how agriculture farmers use their water resources in this district gives a more detailed overview. They mainly utilize groundwater resources (50%), and rainwater storage (31.25%) (of which 20%, 30%, and 50% indicated to use this always, half of the time or rarely respectively). Furthermore, they use surface water (12.5%) (of which both 50% use it either rarely or half of the time), and 6.25% of the agriculture farmers indicated to use seawater either half of the time (50%), or rarely (50%). In the dry season, they use these water sources to irrigate their fields twice daily (62.96%), or twice to thrice daily (18.52%). While in the wet season, they do not daily irrigate their field (37.03%), or they daily irrigate none to once (22.22%), or once (29.63%). Most agriculture farmers currently have one well (62.96%) or two wells (33.33%). Furthermore, these farmers use their pump(s) between 1-3 hours/day (37.03%), or between 5-7 hours/day (29.63%) in the dry season. In the wet season, they use their groundwater pump(s) less than 1 hour/day (29.63%), between 1-3 hours/day (22.22%), and 37.03% indicated not to use groundwater in the wet season [SURVEYS].

5.3.3. Groundwater resource use by animal stock farmers

The livestock sector is not very relevant in Vinh Chau District and mainly occurs in combination with aquaculture (2.2%) or agriculture (5.6%) farming systems [SURVEYS]. They use groundwater resources only for livestock cleaning (PERG1); (PERG2), or for drinking water for their animals (PERG2).

Aquaculture and animal stocks combination farms indicated to either always use surface water (20%), always use seawater (40%), or they indicated to use rainwater storage (40%) (50% uses this always, and 50% does this half of the time). Whereas, agriculture and animal stocks combination farms indicated to primarily use groundwater (60%), or rainwater storage (40%) (50% either uses this half of the time or rarely) [SURVEYS].

5.4. Non-agricultural water resources utilization

5.4.1. Domestic usage

In the VMD, safe water supply is guaranteed to 60-65% of the urban population and considerably lower percentages in rural areas (Mekong Delta Plan, 2013). In a study done in Can Tho's rural areas, there is an estimated 30-50% share of the rural population that has no or problematic access to clean water for their domestic usage (Reis, 2012).

The piped water scheme of the Centre for Rural Water and Environmental Sanitation (CERWASS) is in a critical economic situation. Which is due to a low ability and willingness to pay for piped water, low water rates, rural settlement patterns, and the fact that the privatized urban water supply is separated from the rural water supply. Even if there is a connection to a piped water scheme, mainly rainwater and surface- and groundwater resources are utilized to sustain their water requirements. Moreover, rainwater harvesting is practiced by the majority of rural households. Furthermore, the limiting factor to gain access to clean water is mainly in the financial capacity of households to collect and sustain rainwater storage throughout the year. Further limiting factors are their hygienic awareness, the availability of electricity, and households that are not connected to the piped water scheme have to carry surface water to their

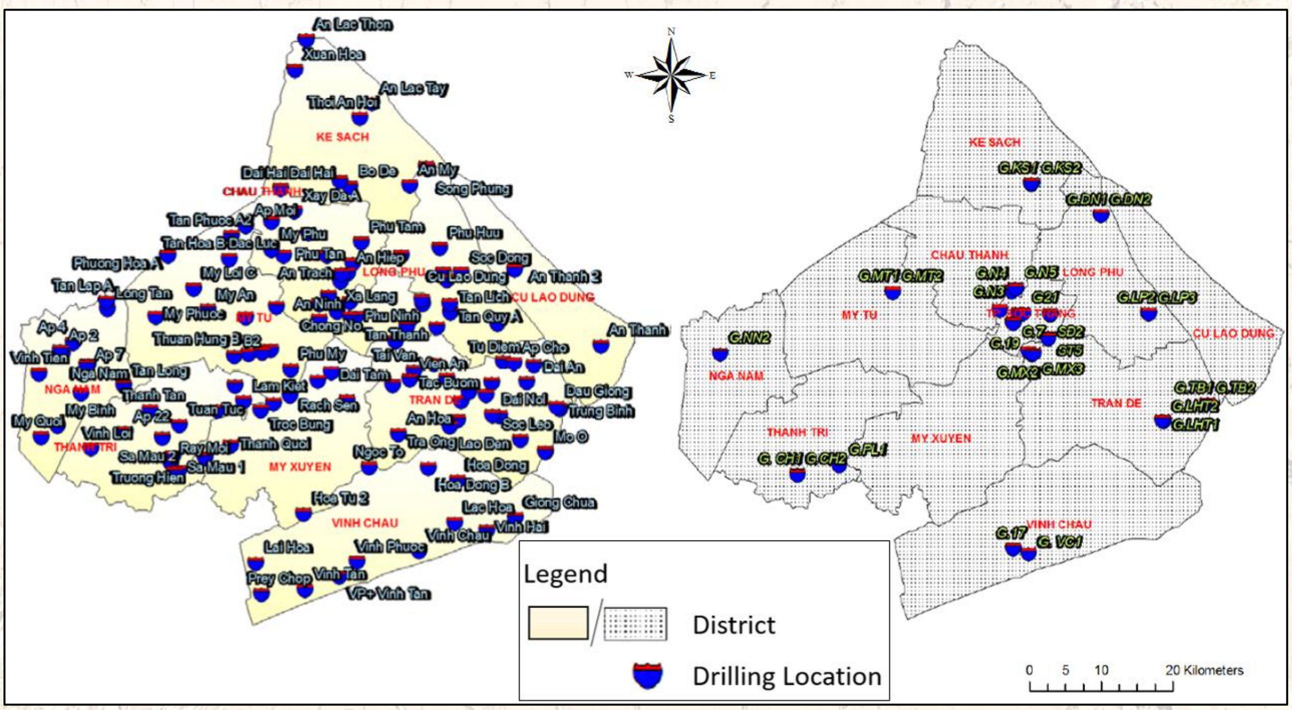


Figure 14 Location of piped water supply related groundwater wells for the rural population (left) and the urban population (right) (Van Pham et al., 2016).

homes manually. According to the CERWASS, rural households use on average 6-7 m^3/household/month, for which they are charged around 2,500 VND/m^3 (0.11 USD/m^3) (Reis, 2012).

However, according to the Ministry of Agriculture and Rural Development (MARD), there was a 92% access to the public water supply network for the total population living in Soc Trang Province, with connections to the aquifers as shown in Figure 14. Information and data on groundwater extraction activities for rural areas are managed by the CERWASS, urban water supply information and data is managed by the Soc Trang Water Cooperation (Van Pham et al., 2016).

In rural areas in Soc Trang Province, groundwater is the main source for domestic usage during the dry season when surface water is salinized and polluted. The willingness to pay for groundwater free from pollution is at 227,910 VND/yr (~10.00 USD/yr) for male respondents and 62,181 VDN/yr (~2.80 USD/yr) for female respondents. Although for health risk conscious respondents, the willingness to pay is at 270,828 VND/yr (~12.00 USD/yr). Respondents that are aware of environmental hazards and quality are willing to pay 154,797 VND/yr (~7.00 USD/yr), while respondents that do not care about the environment are prepared to pay 73,136 VND/yr (~3.20 USD/yr) (Vo & Huynh, 2014).

5.4.2. Industrial Usage

Industrial water usage in the VMD consists mainly of groundwater, although industrial groundwater usage is in both historical and projected usage lesser than that of irrigation usage (Eastham et al., 2008). For industrial usage, only national quantities are available which is 24% of 71,392 million m^3, as 68% is for agricultural usage and 8% is for domestic usage over 2005 (Pech, 2013). In the VMD, water supply plants, industries, and other institutions extract around 350,000 m^3/day, with only the Vietnamese South Central Coast (around 1.5 million m^3/day) and the Red River Delta (around 960,000 m^3/day) extracting more (Wagner et al., 2012). Although the industrial sector in the VMD mainly exists of the food-related industry from aquaculture, fisheries, and rice. Besides that, the contribution of the industrial sector to the GDP in the VMD is significantly below that of the national level. The delta's industrial sector shows many drawbacks such as low production quality, consumption of natural resources and adverse effects to the environment and resources due to environmental pollution. The industrial sector is mainly concentrated in Can Tho City (18%), Long An Province (16%), and Kien Giang Province (11%), with much lower rates for other provinces. Soc Trang Province is one of the least developed areas in terms of industrial economy of the VMD (Nguyen & Ye, 2015). This background would imply that the extent of industrial groundwater usage in Soc Trang Province might be relatively small.

5.5. Reduction of hydraulic heads

Groundwater is exploited for domestic, agricultural and industrial needs, and hydraulic heads steadily declined in many aquifers over vast areas (Wagner et al., 2012). Groundwater level drawdown occurred significantly throughout the VMD in recent years, with monitoring wells indicating a drop of over 15 m at Ca Mau Province since around 1995, this, in turn, led to a cone of depression of nearly 20 m below sea level datum (Erban et al., 2014). In Soc Trang Province, there is over-extraction [KE3], and in Vinh Chau District, groundwater is over-extracted for irrigation [KE5]. Groundwater extraction from greater depths has an increased effect on the rate of subsidence, while farmers continue to drill their wells deeper due to the absence of shallow groundwater. The presence of shallow groundwater is compromised by the decrease of hydraulic head, and the shallow groundwater quality is considered inferior to water from deeper aquifers. Freshwater resources are used for aquaculture and agriculture, but the salinity of fresh water resources in this area is high, which is why farmers dig wells to exploit groundwater for irrigation [KE8]. The groundwater level dropped down over one meter in the Pleistocene layers for the last ten years [KE10], and in Soc Trang Province the groundwater level is observed to decrease annually [KE1]; [KE2]. In Vinh Chau District, it occasionally happens in the dry season that farmers cannot extract groundwater to irrigate their crops due to the drawdown of the groundwater levels [KE10];[KE2]. Due to groundwater level drawdown, farmers in Vinh Chau District have the hardest time to extract groundwater from their tube wells in and around the dry season from November (18.88%), December (31.11%), January (41.11%), February (83.33%), March (97.77%), April (88.88%) and May (35.55%). In the rest of the year, the farmers' pumps seem to extract groundwater easier, with extraction difficulties for (7.77%) in June, (3.33%) in July, (2.22%) in August, (1.11%) in September and (4.44%) in October [SURVEYS].

Vinh Chau District is an area where groundwater levels are gradually declining, and where the potential groundwater storage is lower than the average of Soc Trang Province (Huynh, Lam & Tran, 2013). Additionally, from chapter 4.2 it is clear that 30% of the farmers drilled their wells to depths between 50 - 100 meters (the middle Pleistocene layer (65.7-117.8 m). These farmers have the hardest time to extract groundwater in the months November (18.18%), December (31.81%), January (63.63%), February (86.36%), March (100.00%), April (90.90%), May (45.45%), and June (22.72%). In the rest of the year, these farmers' their pumps seem to extract groundwater easier, with extraction difficulties (9.09%) in July, (4.54%) in August, (0%) in September, and (4.54%) in October. For these farmers, extraction was least hard in May (31.81%), June (63.63%), July (77.27%), August (81.81%), September (90.90%), October (77.27%), November (54.54%), and in December (36.36%). Moreover, in chapter 4.2 it is also evident that 56.66% of the farmers drilled their wells between 100-150 meters (the lower Pleistocene layer (123-158m). For these farmers, extraction was hardest in the months December (13.33%), January (31.11%), February (75.55%), March (97.77%), April (86.66%), and May (26.66%). In the rest of the year, these farmers' pumps seem to extract groundwater easier, with extraction difficulties in (4.44%) in June, (2.22%) in July, (2.22%) in August, (2.22%) in September, (2.22%) in October and (4.44%) in November. For these farmers, extraction was least hard in May (20.00%), June (55.55%), July (64.44%), August (62.22%), September (66.66%), October (62.22%), and November (20%). Overall, drilling wells from deeper aquifers would seem to increase water security for farmers in Vinh Chau District [SURVEYS].

Groundwater extraction in Soc Trang Province is increasingly extracted, which caused a significant consecutive drawdown of groundwater tables. Additionally, precipitation has little effect on the groundwater levels. In Soc Trang City, groundwater levels in the middle-upper Pleistocene (qp2-3), lower Pleistocene (qp1), and the upper Miocene (n13) aquifer layers were drawn down between 2010 and 2015

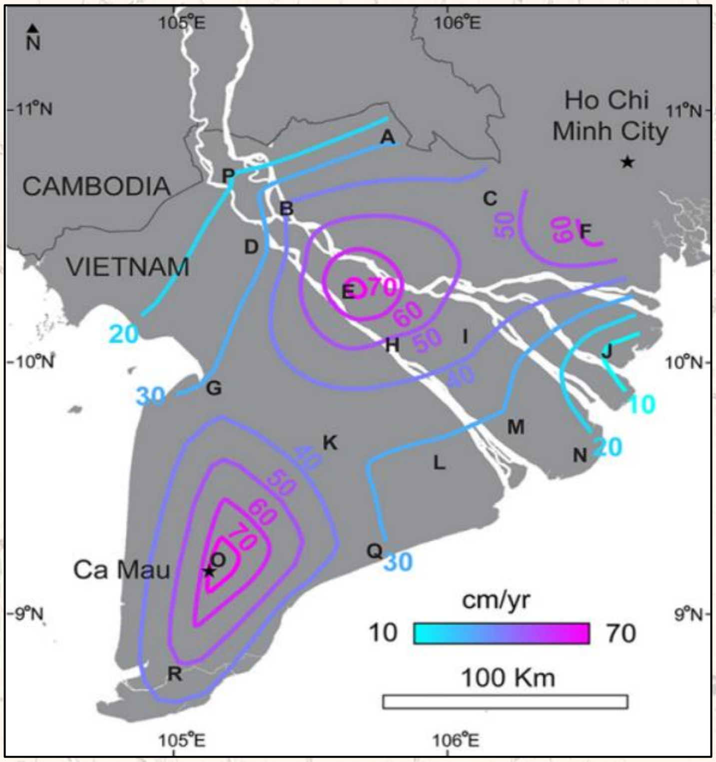


Figure 15 Hydraulic head reduction in the VMD (Erban et al., 2014).

(Van Pham et al., 2016). Groundwater usage in Vinh Chau District leads to a decline in hydraulic head between 28.49 cm/yr to 46.72 cm/yr [SURVEYS];(Hamer, 2016). That result is similar to the observations and predictions of an average ~ 0.3 m/yr between 2006 and 2010 in Soc Trang Province (Figure 15) by Erban et al. (2014). As well as to the rates of 0.5 m/yr in Can Tho City (Wagner et al., 2012), and ~ 0.3–0.5 m/yr over 1993 to 2011 in Can Tho City by Vermeulen et al. (2013).

Hydraulic head declines amongst wells averages to 0.26 m/yr in the VMD, ranging between 0.09 – 0.78 m/yr. The drawdown in the VMD would seem to occur in several strips of each around 100 km wide from Ca Mau Province to Ho Chi Minh City, due to the extraction of groundwater being more prominent in those areas (Erban et al., 2014). Groundwater level drawdown rates in the Middle-upper Pleistocene (qp_{2-3}), lower Pleistocene (qp_1) and upper Miocene (n_{1-3}) layers vary between 0.3 to 0.39 m/yr, with 0.39 m/yr in the Middle-upper Pleistocene (qp_{2-3}) layer. Groundwater level drawdown mainly occurs due to groundwater extraction, whereas climatic factors such as precipitation and temperature have little correlation (Vương Thu Minh et al., 2015).

5.6. Subsidence

In an equilibrium situation, the total pressure equals the sum of the intergranular pressure and water pressure. When water is pumped out of the aquifer, the water pressure and the levels of hydraulic head decrease and the intergranular pressure increases, which causes compaction of the aquifer which in turn slightly reduces porosity. Groundwater is stored in confined aquifers under high pressures, which makes that a seemingly infinite amount of water can be pumped out. This makes that when the aquifer is not perfectly elastic, which is always the case in practice, continuous withdrawal takes place. For aquifers, and especially those that are clayish, this withdrawal can cause permanent compaction and subsidence of the surface. Subsidence is usually a slow process that does not occur simultaneously with the lowering of the hydraulic head (Hendriks, 2010). If the thickness of a decompressing deposit varies dramatically over a short horizontal distance, there will be horizontal deformation and vertical compression which in some

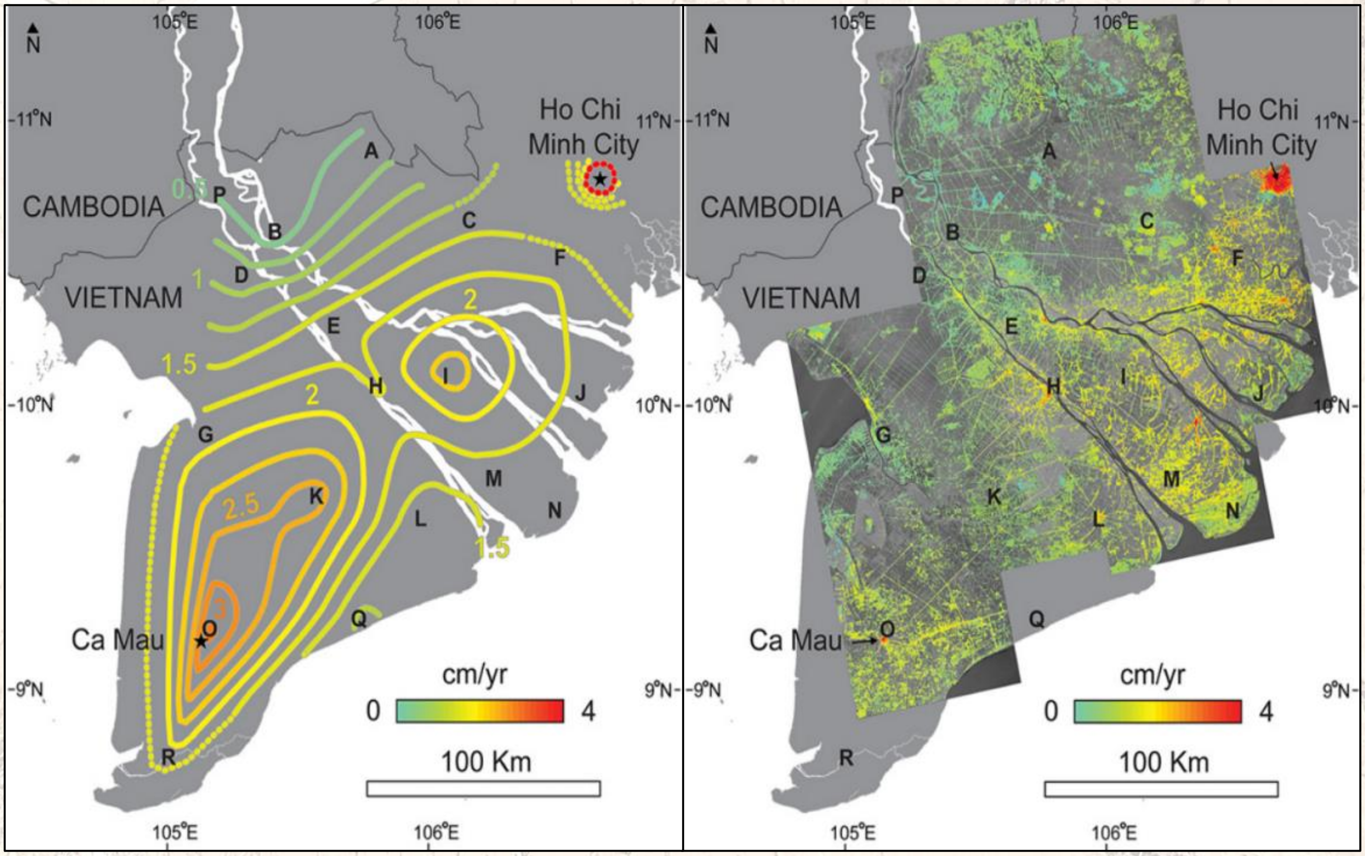


Figure 16 Compaction based subsidence rates (left) and InSAR-based subsidence rates (right) (Erban et al., 2014).

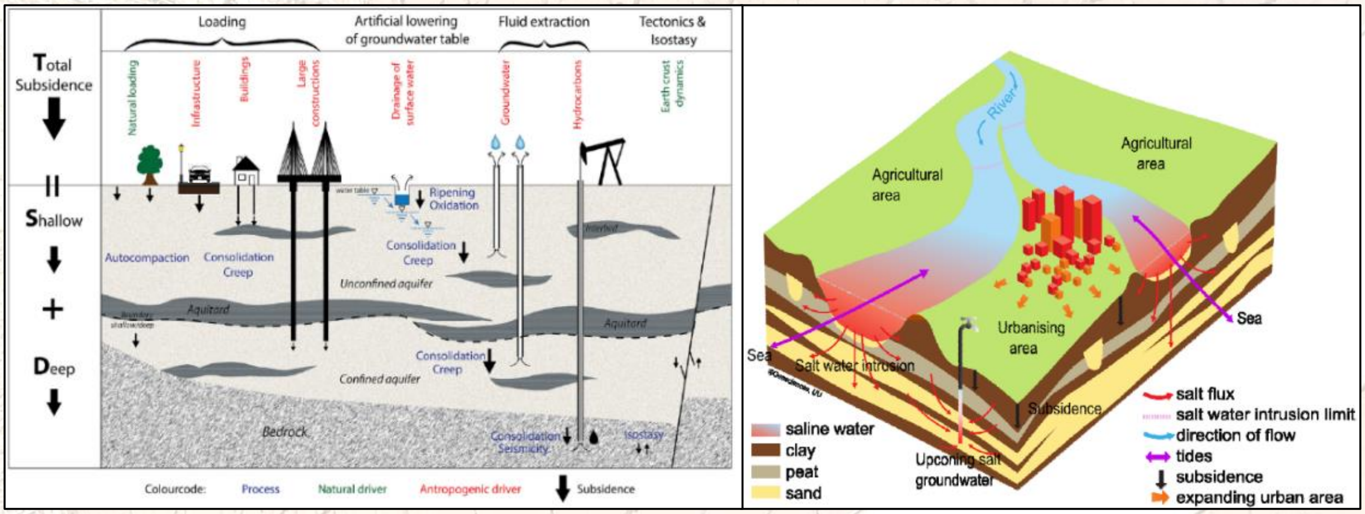


Figure 17 Main subsidence drivers and processes in the upper aquifers (phreatic and confined), with the sum of the main shallow and deep subsidence rates conceptualized in the subsidence balance equation (left) (Minderhoud et al., 2015). Groundwater extraction, subsidence and salinity intrusion are interrelated in urbanizing delta systems (Hoekstra et al., n.d.)

cases leads to fissures. Pumping from aquifers in the alluvial basin in southern Arizona, for example, caused fissures to be as wide as 1.5 m to 3m and as deep as 3 m to 6 m. In the San Joaquin Valley, California extensive irrigation pumping between 1920 and 1980 from aquifers within unconsolidated sediments lowered pore pressures dramatically, causing increased vertical stresses, sediment compression, and subsidence of the surface (Fitts, 2012). Subsidence is more clearly seen in areas with high urbanization, caused by groundwater withdrawal [KE13] and loading [KE12], and in areas where substantial amounts of groundwater resources are being extracted [KE13]. Land subsidence occurs throughout the delta, and there could be a combination with natural compression of the young soil [KE13].

5.6.1. Subsidence due to the lowering hydraulic head

Land subsidence has a strong relationship to groundwater extraction, and deep wells (>100m) extract non-replenishable groundwater (Mekong Delta Plan, 2013). In the VMD in general and in Soc Trang Province in particular, subsidence occurs only in the areas where farmers exploit groundwater [KE4], the problem of subsidence is caused by excessive extraction of groundwater [KE1];[KE3];[KE4];[KE6];[KE8];[KE9];[KE5];[KE10];[KE11];[KE12];[KE13]. Measurements and observations are missing and needs to be quantified, although there is data on wells, it is inconclusive since many farmers do not report their wells to the government [KE3].

Land subsidence in the VMD is caused by sustained, long-term extraction of groundwater, there is few data available but is commonly estimated to be 1-2 cm/yr (Mekong Delta Plan, 2013). Conversely, subsidence rates seem to vary with different studies but are all within ranges of 0.2-5cm/yr. Soc Trang Province is one of the coastal provinces subsiding at an alarming rate of 1 to 4.7 cm/yr caused by excessive groundwater extraction for drinking and agriculture (Schmidt, 2015). Subsidence seems to occur a similar pattern as that groundwater level drawdown does (Figure 16) with average compaction-based subsidence rates (Figure 17, left side) of 1.6 cm/yr, in a range from 0.28-3.1 cm/yr from 2006 to 2010. Measurements using interferometric synthetic aperture radar (Figure 17, right side), which shows consistent compaction based rates from monitoring wells, show subsidence rates of ~ 1 to 4 cm/yr for the VMD. Assuming that rate together with the absolute sea-level rise of 0.2-0.4 cm/yr, a conservative estimated rate of additional potential inundation depth of 0.4-1.6 m could occur in the VMD. Moreover, if current pumping rates would continue, subsidence of ∼0.88 m (0.35–1.4 m) could occur by 2050. This occurrence would show typical deformation for aquifer systems such as are present in the VMD when over-exploited (Erban et al., 2014). However, these interferometric synthetic aperture radar measurements show relatively high subsidence, with groundwater extraction hypothesized to be the main driver to subsidence without quantification of other interrelating drivers (Figure 17) of subsidence. Actual impacts of groundwater extraction to subsidence are unclear due to the absence of reliable ground-based, time series (Minderhoud, Erkens, Van Pham, Bui Vuong & Stouthamer, 2015).

Groundwater extraction can lead to land subsidence due to compaction of susceptible aquifer systems, which typically are the unconsolidated alluvial or basin-fill aquifers consisting of aquifers and aquitards (Galloway & Burbey, 2011). The sedimentary system of the Mekong Delta is characterized by spatially non-uniform deposits and has varying behavior of hydrological and geomechanical properties. Drivers of deep subsidence could be due to groundwater extraction, compression of clay layers and tectonic effects. Shallow subsidence results from the lowering of the groundwater level, loading by urban areas (buildings and infrastructure), or by loading of sediment. Both the problems of deep and shallow subsidence are compounded by salt water intrusion as geochemical compaction of clayey deposits are affected (Tosi, Teatini, Carbognin & Brancolini, 2009).

It is commonly thought that the reason of subsidence is in the over-extraction of groundwater, an abundance of construction on the ground, and due to aquaculture and agricultural development [KE2]. The compaction of aquifer systems is essentially inelastic, meaning that the deleterious effects are permanent. Subsidence can also be caused by oxidation of peat soils which can be linked to the drainage of organic soils (Ingebritsen & Galloway, 2014). Agricultural areas are developed in a way that the oxidation processes occur very strongly, and organic matter makes that compaction of the top layer of the soil occurs more and more [KE2].

Moreover, chemical bonds in the aquifers are weakened by salinization of the soil leading to compaction, and increased salinity in groundwater leads to an increased groundwater extraction by farmers to obtain desired salinity levels in aquaculture production ponds (Kongkeo, 1997). Farmers continue to irrigate their lands with increasingly brackish water, leading to more salinity of the soil and aquifer degradation (Foster & Chilton, 2003). The structure of the soil is weakened by sodium (Na^+), which replaces some cations in the soil and causes expansion when wet and breakage when dry [KE5]. The VMD has developed a distributary network of large river channels with bifurcations and estuaries; of which the latter are gateways for the intrusion of salt water by tidal effects. Land subsidence has effects on the depth of these channels in the delta, which causes a further increase in salt water intrusion lengths along rivers (Zhang et al., 2013).

Extraction of groundwater is a well-known driver of land subsidence, and examples are land subsidence of 300 mm/yr in Mexico City (measured with InSAR), 150 mm/yr Suzhou, Yangtze River Delta, and 220 mm/yr in six Indonesian delta cities. Moreover, groundwater extraction at an aquaculture-dominated coastline at the Yellow River Delta in China induced subsidence rates over 250 mm/yr (measured with Differential InSAR) (Higgins, Overeem, Tanaka, & Syvitski, 2013). Subsidence is an environmental issue that could be of an abstract nature, since out of the 90 farmers, 87.7% stated not to have experienced subsidence, which was described to them as seeing a subtle decrease in land surface and an increase of cracks in concrete and brick walls. 2.2% indicated to have experienced subsidence, and 10% did not know how to response to this question [SURVEYS]. Much of Soc Trang Province (including Vinh Chau District) consists of peatlands (Hanebuth, Proske, Saito, Nguyen & Ta, 2012), which is highly compressible when compared to clay, silt, and sand. Peat compaction can cause subsidence, which might exceed relative sea-level rise estimates (van Asselen, Karssenberg, Stouthamer, 2011).

5.6.2. Subsidence by loading

The settlement of buildings, groundwater extraction, and the rising sea level are important drivers regarding subsidence [KE14]. However, the exact cause of subsidence is unsure since the decrease of the surface elevation might have happened due to compaction of weak soil or loading by buildings [KE9]. The surface in the VMD is very soft, and compression of the soil due to development is an important driver for subsidence [KE7], which can be observed around buildings due to differences in ground surface and the foundation [KE9];[KE10]. Due to the weak Pleistocene soil, compressibility is high, and natural compression also takes place. Besides that, the whole young alluvial layer is a sizeable layer, with its bedrock a few hundred meters under the ground surface [KE13].

Nonetheless, recognition of differences between subsidence and foundations of heavy buildings on weak soils is important [KE9]. Sluices, for instance, are structures of substantial weight, the sluices subside faster than the soil around it when subsidence occurs, resulting in failure of these sluices affecting the water system [KE3].

5.6.3. Subsidence as a cause of hard engineering measures

Another driver of subsidence is that of sediment starvation. Due to upstream damming in the Mekong River (e.g. the Lancang Cascade damming) fewer sediments will come which marks the end of the VMD's growth. If sediments from the Mekong River will not come by e.g. flooding, the delta will go down since sediments are received through upstream flooding [KE13]. Upstream damming of the Mekong River in countries neighbouring Vietnam is a concern [KE15]; [KE1] since there is less flooding due to a decrease of water from upstream the Mekong River [KE1].

As much as 133 dams have been built upstream along the Mekong River, which would trap 96% of the river's former sediment inflow with accelerated erosion and subsidence of the downstream VMD as a consequence (Kondolf, Annandale, & Rubin, 2015). When the sediments stored in the channel are exhausted, only 4% of the former sediments will reach the delta, which calls for strategies to prevent downstream sediment starvation (Kondolf, Rubin, & Minear, 2014). Upstream damming is estimated to lead to substantial economic losses for farmers in the VMD, with a 55-100% reduction in the 160-200 million tons/yr sediment load and a 20-65% reduction of associated nutrient loads. In comparison, the geologically relatively young VMD expanded rapidly as a consequence of a mean sediment deposition of 144 million tons/yr over the last 3,000 years (Smajgl et al., 2015). On the local scale, flood control activities led to a 31% reduction of groundwater storage with a 19% reduction of the inundation area in 1993. While in 1998, a 44% reduction of the inundation area resulted in a 42% groundwater storage reduction (Kazama, Hagiwara, Ranjan & Sawamoto, 2007).

Besides that, groundwater is affected by upstream recharge, and every province depends on upstream provinces, e.g. if there is a lot of groundwater usage in An Giang Province, there is less for downstream provinces such as Soc Trang Province [KE3]. Furthermore, in the VMD, upstream of the Mekong river, closed dike systems are built to prevent flooding. During the rainy season, this results in a lack of room for the river. So the water has to go elsewhere, which is one reason why the water level is getting higher and higher. Due to this prevention, water flows through the river instead of naturally flooding the land, affecting natural groundwater recharge. This effect illustrates that management by prevention is practiced instead of adaptation to the water system, this seems to occur frequently [KE12].

5.6.4. Upper surface factors

Since the scarce data on subsidence comes from a study by Erban et al. (2014), which measured using interferometric synthetic aperture radar measurements, upper surface factors could be relevant as well. In Soc Trang Province many farmers sell their top soil (the uppermost fertile soil layer of their field) to companies that produce bricks and for land leveling, which is a very recent development and leads to a decrease in land fertility. The top soil layer is very soft since farmers frequently flow water over for irrigation purposes, the thin layer below becomes very compacted, and because of that (due to clay settlement) siltation occurs. When the upper layer is removed, the compacted layer below has to be made softer for growing. This layer is rather fragile, and, shallow subsidence can occur easily due to the use of heavy machinery [KE5].

Topsoil selling is generally of minor scale [KE13], but there is a need for a good policy on all types of soil mining [KE5]. Besides that, the top layer might subside, and by the usage of dikes the water table drops down, and oxidation happens in some parts of the soil [KE2].

5.7. Relative sea-level rise

Accelerated human induced compaction is a reason the VMD is sinking, putting millions of inhabitants in a vulnerable position with limited coastal barrier protection and much of their surface area below mean sea level (Syvitski et al., 2009). The Mekong Delta region is at risk because of a rising sea-level that may accelerate under climate change (Syvitski et al., 2009; Doyle, Day & Michot, 2010).

Vietnam will be one of the most vulnerable nations to climate change, and its impacts, as an estimated sea-level rise of 1 m would directly result in the loss of more than 5% of the country's land area, 7% of its agricultural land, and 28% of its wetlands. This effect would result in a loss of more than 10% of Vietnam's GDP and affects about 11% of the population (Dasgupta, Laplante, Meisner, Wheeler & Yan, 2008). In the VMD, a sea-level rise of ~ 0.10 m (0.07 – 0.14 m) will compound the potential of flood inundation to ~ 1 m (0.42 – 1.54 m) (Erban, Gorelick & Zebker, 2014). Moreover, a sea-level rise of 0.30 m is expected to shift upstream fluvial flooding towards the lower part of the delta (Van et al., 2012), and one meter of sea-level rise will affect more than one million people (Solomon, 2007). Estimations of the inhabitants at risk by 2050 in the VMD due to effective sea-level rise is at 1,9 million (Ericson et al., 2006; Van et al., 2012), putting 6.51% of the delta's population at risk and a loss of land of 5.82% (Ericson et al., 2006). Sea-level rise in the VMD could inundate vast areas of its east and west coast, which would lead to loss of agricultural land and ecosystems. In the VMD, inundation is mainly caused by the change in upstream discharge volumes and sea-level rise itself (Van et al., 2012).

However, it is the whole combination of environmental and anthropogenic factors that can lead to the relative sea-level rise. The relative sea level rise can be determined by the factors $\Delta_{RSL} = A - \Delta E - C_N - C_A \pm M$, where the factor A is the delta's aggradation rate, which is determined from the volume of sediment delivered to and retained on the delta's surface. For the VMD, the aggradation rate is reduced from 0.5 mm/yr (early 20th century) to 0.4 mm/yr in (21th century). The factor ΔE is the eustatic sea level rise, which is around 1.8 – 3.0 mm/yr, with IPCC projections of another 21-70 cm by 2070. The factor C_N is the natural compaction consisting of natural changes in void spaces within sedimentary layers and is typically around ≤3 mm/yr. More interesting for the VMD is the factor C_A, the accelerated compaction due to anthropogenic contributions such as subsurface mining, human influenced soil drainage and accelerated oxidation. In the Chao Praya Delta in the Gulf of Thailand for instance, accelerated compaction ranged between 50 – 15 mm/yr due to groundwater extraction, and the Po Delta in Italy subsided 3.7 m due to methane mining in the 20th century. The factor M is the highly variable spatially downward vertical movement of the land surface as influenced by the redistribution of the Earth's masses. Subsidence consists out of the factors M, C_N, and C_A, and does not discriminate these components, furthermore it is seldom calculated but measured. The relative sea-level rise rates Δ_{RSL} are however not measured for each factor but rather determined as whole without separation of the eustatic sea-level rise and subsidence; with subsidence usually being spatially variable in delta's larger than 10^4 km^2 (such as the VMD) (Syvitski et al., 2009). Besides that, 80% of the groundwater depletion ends up in the ocean due to run off (two-thirds) and evaporation of irrigated water, leading to a contribution to sealevel rise of 0.02 (± 0.004) mm/yr in 1900 and 0.27 (± 0.04) mm/yr in 2000 (Wada et al., 2016).

The frequency of 1 in 50-year flooding in the combination of the greater intensity and frequency of storms, the rising sea-level, and the lowering of the surface level due to human-induced subsidence is a concern.

Human-induced changes in the Mekong Delta are affecting flooding processes by the industrial use of water, dam building, drainage of waterways, programs for flood mitigation, farming, sand extraction, and irrigation (Oliver-Smith, 2009). In response to the rising sea-level, however, increasing dike heights in the VMD, and Soc Trang Province, in particular, is limited by the load bearing capacity of muddy soils. Therefore, both mangroves and appropriate earth dikes should be utilized to play a major role in coastal protection (Albers & Schmitt, 2015). However, flooding is mainly controlled by hard engineering measures. Although floods occurred in Soc Trang Province around the months November and December, this phenomenon is a thing of the past (PERG4). Vinh Chau District has a 43 km long sea dike system, and any overflow that overtops the dike will be remedied immediately not to affect production. Flooding occurs mainly due to tidal causes and occurs only in the central region of the country such as in An Giang Province (PERG1). There is a dike system since around two decades, and so far, flooding has not occurred (PERG3).

5.8. Local government awareness and knowledge gaps

The system's knowledge is eventually used by the government to adjust their governance on. Therefore it is interesting to assess to what degree the local government is aware of environmental issues and degradation, and whether there are knowledge gaps.

There are limitations to the availability of data, which causes difficulties for management. There should be an initial investigation of the aquifer, and the water content of each aquifer should be clear. This is currently not the case, as there are currently no specific figures available, and there is a lack of information. The central policy is rather complete, but when deployed there are difficulties, depending on the specific situation of each district (PERG2). There are implemented policies made by the DONRE, related to reducing groundwater use (PERG6). Land use for a certain purpose is subject to permission by the related authority agency, and agricultural land and paddy land are managed very tightly (PERG4). The MONRE has studied the problem of subsidence in the VMD in relation to issues of water exploitation, in the form of a national pilot project including expert and inter-province consultancy. However, this project is currently only in its outline form, and the details are only generally known to the local government authorities; for Soc Trang Province there is no research ongoing (PERG2).

The current informal knowledge is that groundwater exploitation affects subsidence, but any document or a specific report on this issue is still missing (PERG3). Data on the relationship of groundwater exploitation and subsidence is not available, but a change in land elevation has been observed in provinces with groundwater exploitation-induced severe water shortages (PERG5). There are higher tides as compared to the previous years. However, it cannot be identified as to whether it was due to sea level rise or due to subsidence, this requires new specific research (PERG1).

Furthermore, Soc Trang Province has some low-lying areas, but it has not yet been determined whether that is due to subsidence since there is a lack of information (PERG2). Even though the problem of subsidence is deemed to be imperative (PERG2), there is not much knowledge regarding subsidence on the district level (PERG6), or on the provincial level (PERG2), except through workshops (PERG6). There is no information available on the issue of subsidence itself (PERG1), or on the relationship with this issue with to groundwater extraction in this province (PERG5);(PERG4);(PERG1).

It is unclear at this point whether subsidence occurs (PERG4), it is unclear which area is lacking groundwater most (PERG2), and because there is no research on subsidence, there are many uncertainties (PERG6). Over-extraction of groundwater will lead to subsidence, but there is no connection between normal groundwater extraction. Subsidence has an impact to the VMD, but this impact is unclear since information is lacking (PERG2).

The respondents (PERG2) from the DONRE of Soc Trang Province (personal communication, April 2016) said that:

''More knowledge is needed to address the problem of subsidence because that is the basis for further research. Because of a lack of information, it is difficult to study problems related to subsidence. One reason of subsidence would appear to be the exploitation of groundwater.''

Moreover, there is a need for further study regarding the directions to manage subsidence, which has not occurred yet (PERG2). Also, even though the risk of subsidence is high in Vinh Chau District, issues regarding subsidence have not been mentioned in this region. Regulations only exist regarding water resource issues rather than specifically about subsidence (PERG3). The information on subsidence comes from the Ministry of Natural Resources and the Environment (MONRE), and the government has announced the problem of subsidence for Soc Trang, Ca Mau, and Bac Lieu Provinces (PERG4).

The respondents (PERG4) from the Agency of Cultivation and Plant Protection of the DARD of Soc Trang Province (personal communication, April 2016) said that:

''The Ministry of Agriculture and Rural Development is very interested in policies related to land subsidence. The Prime Minister and the Deputy Prime Minister were directly here to measure salinity. Soc Trang Province is an agricultural province, and subsidence is a matter of survival.''

Although according to (PERG3), further study is required regarding the relationship between groundwater extraction and subsidence, for the local authority to know whether (and how much) groundwater extraction will cause subsidence. When this knowledge is available, a new basis for an accurate assessment is made (PERG3). The views on the problem of subsidence differ per stakeholder [KE7], and the correlation between groundwater extraction and subsidence still has to be scientifically proven, even though it is mentioned in existing data and publications [KE12];[KE7]. Nonetheless, the scientific community in Vietnam, knows about subsidence, although it is not very detailed in terms of the environment and water resources for deep analysis. However, there is deep knowledge available regarding the soil and the foundation [KE10]. Many state that there are not so many events of flooding and water from upstream, although downstream water levels are still high, which raises the question whether increased water levels are due to the rising sea levels or due to subsidence [KE7].

Respondent [KE12] from the College of the Environment and Natural Resources of the Can Tho University (personal communication, April 2016) said that:

''It is not really clear whether there is subsidence or if it is the sea level that is rising. However, in Can Tho City, roads are broken open, and rocks point out of it, damaging cars and motorcycles.''

5.9. Conclusion

In this chapter, an overview is provided on the existing system knowledge in regards to water resources usage, the criterion for the required knowledge on the systems' problems and driving causes is met.

System knowledge, whether there is enough knowledge on the systems problems and driving causes.

The VMD is a young landmass of which most of the groundwater resources are being extracted from the lower Pleistocene layer (123-158m), (56.66%) or the middle Pleistocene layer (65.7-117.8 m) (30%). There are close to 465,000 - 470,000 wells in the VMD extracting about 1,229,000 m^3/day, while other estimates are that there are more than one million wells in the 2010's. In Soc Trang Province about 50,000 wells extracted around 100,000 m^3/day. Groundwater extraction volumes are around 1,229,000 m^3/day, from about 465,000 to more than one million wells in the VMD. In Soc Trang Province, 100,000 m^3/day is extracted by around 50,000 wells. Most farmers start with one well, of which 22.78% expanded their wells with another well. There is a slight increase in the number of wells that farms have over the last 11 years, with differences per ethnicity. Moreover, farmers that drilled deeper had better access to groundwater resources. Groundwater extraction in Vinh Chau District is the greatest of Soc Trang Province with an average groundwater usage of 98.05 m^3/person/yr, while other estimates are of 77.12 m^3/day/km^2. Elsewhere in the VMD, Around Can Tho City and Hau Giang Province, rural households with private tube wells extract around 100 m^3/household/yr (103.66 m^3/household/yr). With about 26,754,764 m^3/day groundwater reserves in the VMD being increasingly extracted, hydraulic heads declines averaging by about 0.3–0.5 m/yr occur in Vinh Chau District, Soc Trang Province, and Can Tho City, but averaging to 0.26 m/yr for the VMD.

Continued irrigation with increasingly brackish water by farmers to obtain desired salinity levels in aquaculture production ponds, leads to more salinity of the soil resulting into increased aquifer degradation. Meanwhile, chemical bonds in the aquifers are being weakened by salinization of the soil leading to compaction. Unsustainable groundwater extraction leads to groundwater resources degradation, a decline of hydraulic heads, increased salinization levels and eventually subsidence (within ranges of 0.2-5cm/yr according to varying studies), and unsustainable land use leads to pollution. There seems to be plenty of knowledge on the water system to build further knowledge gathering and policy on, and although information is generally scattered, the drivers and pressures and especially the state seem to be rather clear. However, it should be noted that there is not enough knowledge for more advanced environmental analysis (e.g. modeling) purposes, knowledge gaps remain and that further study can, therefore, be recommended. Moreover, there seems to be a gap in scientific understanding and governmental understanding of groundwater resources degradation (e.g. subsidence).

6. Values and policy discourses

6.1. Introduction

In this chapter, the condition regarding the values and policy discourses are addressed. This criterion is important since an environmental system also consists of its inhabitants with their own values at regards to water resources. Moreover, policies and regulations can go against these values or address some values or interest groups more than others. Firstly, the lack of pro-environmental behavior is discussed, followed by economic difficulties, groundwater resource extraction motivations, and fourthly the policy discourses as related to the implementation of policies. Finally, the conclusion argues whether the criterion is met or not.

Values and policy discourses, whether all values are being considered in governance.

From the previous WEG assessment criterion, the overall result of unsustainable groundwater resource usage is that of environmental degradation (e.g. subsidence). Sustainable groundwater resource management is therefore needed. This WEG assessment criterion weighs whether every stakeholder's values are being considered, and which policy discourses are at play in this system. The lack of pro-environmental behavior relates to the existing values, as the functioning of the water system is in the citizen's interest. Moreover, in coastal zones, farmers have little choice but to extract groundwater due to a lack of freshwater resources, although the government values the implementation of the limitation of groundwater extraction.

6.2. A lack of pro-environmental behavior

Farmers use groundwater resources for irrigation, which leads to excessive water extraction (PERG4), and due to people's lack of awareness regarding the extraction and use of water resources, farmers use up to three wells instead of just one (PERG2). The relationship between groundwater extraction and subsidence received some mass media coverage (PERG3), but the hardest job regarding environmental management is with the awareness of some groups of civilians (PERG1);(PERG6). They are not highly aware of environmental protection and adaptation to climate change (PERG1), awareness is currently not there, and water is used in wasteful ways [KE7.2]. The phrase "adapt to climate change" is very abstract to people, while phrases such as "salty", "scorching", and "overheating" are much better understood (PERG1). Farmers in areas designated for aquaculture land use are not allowed to use groundwater for their farms. The authorities in Dong Thap and Ben Tre Provinces are very strictly enforcing this, but the authorities in Soc Trang Province are not, since there is no way to get other suitable water resources than groundwater. Moreover, farmers hide their wells and the usage of groundwater during dry periods will increase significantly in the future [KE11]. A study done by Le Dang, Li, Nuberg & Bruwer, (2014a,b) showed interesting motives towards pro-environmental interventions amongst 598 farmers in Dong Thap, Long An, and Soc Trang Provinces. Farmers are more likely to take interventions as a response to the changing climate when they perceive greater risks of climate change, greater effectiveness of adaptive measures, greater cost influences (electricity, fuel, and water), or due to social pressure. Although, they are less likely to take such interventions when they are subject to wishful thinking, denial of climate change risks, and fatalism (Le Dang, Li, Nuberg & Bruwer, 2014a). These farmers have limited understanding of the importance of climate change adaptation, and opinions are exclusively formed by casual observation via public media (Le Dang, Li, Nuberg & Bruwer, 2014b).

Environmental awareness in the VMD is limited, and the economic status of these households is significantly hampering any form of pro-environmental behavior regardless of their knowledge of environmental degradation (Hak, Nadaoka, & Le Phu, 2016). However, maladaptation, habit, and the perception of the importance of climate variability are additional constraints (Le Dang, Li, Nuberg & Bruwer, 2014b). Furthermore, climate change adaptation relates mostly to farming practices (e.g. planting techniques) rather than a change of their farming system (e.g. agriculture to animal stock farming or vice versa). Migration is considered the last option due to perceived effort- and cost-effectiveness (Le Dang, Li, Nuberg & Bruwer, 2013a). Also, farmers in Soc Trang Province (compared to farmers in Dong Thap and Long An Provinces) have a higher perceived risk of climate change, which might be due to their geographical location and their exposure to climatologic phenomena and sea-level rise. Another interesting aspect of climate change related awareness in the VMD is that there is limited education on it in schools (Le Dang, Li, Nuberg & Bruwer, 2013b).

Back to the economic status as a cause of hampering pro-environmental behavior as mentioned by Hak, Nadaoka, & Le Phu, (2016), economic status would appear to be quite various amongst different ethnicities [SURVEYS]. In Soc Trang Province, there are difficulties since there are many Chinese, and Khmer minorities besides the Kinh people, which causes cultural differences [KE15]. There are mainly ethnic minorities in Vinh Chau District, as over 50% of the citizens in this district are of Khmer ethnicity, which have limited awareness, minimal educational backgrounds, and difficulties in receiving information due to language barriers (PERG1);(PERG4);(PERG5). Their lives are poor; they have minimal educational qualifications, and water saving techniques have not been applied due to poverty. The area that these farmers have for planting vegetables is small, and they mainly have fields from 5,000 to 10,000 m^2, the poor have only a few thousand square meters (PERG4). Agriculture farms are on average 3,841 m^2, while aquaculture farms are on average 14,547 m^2, and agriculture and aquaculture combination farms are on average 19,437 m^2 in size. Regarding their ethnicity, Kinh ethnic farms consist of 35.56% of the farm households, are mainly active in aquaculture (75%), and have on average 10,811 m^2 of land. Whereas Khmer ethnic farms (consisting of 45.56% of farm households) are primarily active in agriculture (51.22%), and agriculture and aquaculture combination farms (26.83%), and have on average 5,122.68 m^2 of land. Chinese ethnic farms (consisting of 18.89% of farm households) are active in both agriculture (23.53%), and aquaculture (41.18%), and combinations thereof (35.29%), and they have on average 1,5618 m^2 of land. In Vietnam, rural income levels are classified by Decision 09/2011/QĐ -TTg to be high at >6.2 Million VND/person/yr, medium at >4.8 - <6.2 Million VND/person/yr, and low at <4.8 Million VND/person/yr respectively. The Kinh ethnicities have either a high (43.75%) or a medium income (40.63%), the Khmer ethnicities have either a medium income (46.34%) or a low income (29.27%), and the Chinese ethnicities have either a high (35.29%), medium (29.41%), or low (17.65%) income [SURVEYS]. Moreover, about 75% of the rural households in Soc Trang Province make less than 2 Million VND/person/month (Ling, Tamura, Yasuhara, Ajima, & Trinh, 2015).

Regarding their environmental knowledge, 38.89% of the farmers in Vinh Chau District think that intensive exploitation of groundwater resources has systematic impacts on the lowering of the water table. This opinion is shared by 37.14% of the Kinh, 42.86% of the Khmer, and 20.00% of the Chinese ethnicities, while nearly none of the farmers explicitly stated not to think this [SURVEYS]. However, according to various studies done in Soc Trang Province, 67.5% of respondents recognized over-exploitation and non-efficient usage of groundwater resources to have a causal relationship with the reduction of the hydraulic head (Van Pham et al., 2016). As described in Chapter 4.5, farmers in Vinh Chau District indicated that their soil would seem to be a lot drier (61.11%), or a bit drier (32.22%) than that it was a decade ago. Furthermore, farmers got significantly negatively (36.66%), or negatively (37.77%) affected by environmental changes, and adaptations were not or barely made [SURVEYS]. According to the various studies done in Soc Trang Province, recognition of negative impacts of climate change (e.g. intensive rainfall events and prolonged dry spells) seemed to exist amongst local residents in the province. Moreover, 12.5% of rural households believed rainfall changes in terms of timing and density would have strong influences on groundwater resources and recharge mechanisms, whereas a remaining 87.5% of the respondents believed such a link to be non-existent. Regarding water quality, 20% of these respondents mentioned changes (e.g. salinity or acidity increases) in their groundwater resources (Van Pham et al., 2016). Regarding subsidence, 87.7% of the farmers in Vinh Chau District stated not to have experienced this [SURVEYS], although the awareness of that specific phenomenon is hindered by its slowness while information from the government is not available [KE1.

Regarding the efficient use of groundwater, 84.44% of the farmers stated not to use improved agricultural farming techniques such as water saving techniques, which was somewhat uniform with the Kinh (90.63%) and Khmer (87.80%) ethnicities. Although the majority of the Chinese (64.70%) do not use such techniques, 35.29% stated that they did apply them. Regarding the causal relationship between groundwater extraction and impacts to the lowering of the water table, 69.23% of the farmers that use such techniques, think that intensive exploitation of groundwater resources has systematic impacts on the reduction of the water table. Whereas, of all the farmers that stated to believe this, 74.26% did not use such techniques [SURVEYS].

Farmers are not aware of the efficient use of groundwater resources and the future impacts behind overuse of these resources [KE2], they currently do not care how much groundwater they use, since this resource is free of charge. Furthermore, there is a lack regarding the supply of information to the farmers, especially regarding techniques and crop diversification [KE15]. The perception of citizens towards water resources is limited. Therefore, when implementing a certain policy, this usually takes a long time to spread and promote (PERG3).

Respondent [KE4] from the Department of Agriculture Systems of the Can Tho University & the Mekong Delta Development Research Institute (personal communication, April 2016) said that:

> *''There is a significant gap between scientific knowledge and real application, they (*the farmers*) simply do not believe it.''*

It would be beneficial for farmers to implement water saving techniques on a big scale because it relates to their costs and capital (PERG4). Water saving irrigation systems are advised to the farmers, but due to high costs compared to their daily life, they just apply these systems for one to two harvests and then resell it to others (PERG4);(PERG1). The installation costs are relatively high which makes that such systems are not widely spread around Vinh Chau District, and only a few agricultural households use such techniques (PERG1).

Another manifestation of economic difficulties faced by the rural households is that farmers sell their topsoil, which is mainly a concern in the dry season. The temperate heats up in the dry season, and the local government is preventing people from taking topsoil because it affects rice cultivation and soil fertility. In 2016, topsoil selling by farmers and companies to businesses happened a lot, while this normally fluctuates per year (PERG2). Although topsoil selling is not allowed, some companies lease land for production, which means that land rights can be practiced (PERG1). Farmers need their extra income, and the government cannot enforce their policies [KE5]. Nonetheless, almost all of the farmers (96.7%) stated not to have sold their (top)soil in the last ten years [SURVEYS]. However, according to the scientific and government experts, many farmers in Soc Trang Province sell their top soil to companies that produce bricks, or for land levelling, which leads to a decrease in land fertility. The effects of this practice have been covered in Chapter 5.6.4.

When implementing provisions related to residential communities and industrial parks, it is good when people are responding to this. However, the drawback here is that people are experiencing economic difficulties. In the immediate future, people have to worry about their nutritional needs, next they care about the environment (PERG3).

6.3. In coastal zones famers have to extract groundwater

Vinh Chau District mainly uses groundwater resources as its main water resource besides rainwater, and the exploitation of groundwater to a certain point will cause depletion of water resources, causing subsidence (PERG3);(PERG2).

The respondents (PERG4) from the Agency of Cultivation and Plant Protection of the DARD of Soc Trang Province (personal communication, April 2016) said that:

> *''Groundwater resources will be diminished substantially; the more water farmers use, the less they have; it occasionally happens that people have to wake up in the night to pump water.''*

However, in coastal areas such as this district, farmers are forced to use groundwater resources due to a lack of other water sources to use (PERG4);[KE7.2];[KE12];[KE7]. Over-exploitation has impacted very strongly to the available amounts of groundwater resources (PERG6), and if exploitation occurs exhaustedly, coastal zones will be severely saline (PERG4). Local and state authorities recommend restricting the usage of groundwater to prevent subsidence (PERG1);(PERG4), but particularly farmers often do not pay any attention to such environmental problems (PERG1). They care about their short-term benefits [KE12], and due to their economic conditions, they must unexpectedly pump water for irrigation (PERG4).

Aquaculture farmers are prominent along the coastal zones of Soc Trang Province [KE11], they require river water and seawater (PERG1), which evaporates resulting in an increase of salinity in shrimp ponds [KE12];(Foster & Chilton, 2003). However, for aquaculture dilution purposes (PERG2);[KE11];[KE12];[KE2];[KE3];[KE1]; (Kongkeo, 1997), or for domestic use (PERG5) groundwater is extracted, especially in the dry season [KE2]. From the survey results in Chapter 5.3.1. can be inferred that aquaculture farmers indicated to have either one well (69.44%) or two wells (22.22%). However, they state not to use groundwater in the dry season (50% and 27.77% did not have an answer) and in the wet season (52.77% and 30.55% did not have an answer) [SURVEYS].

Agriculture farmers in the coastal zones of Soc Trang Province extract groundwater mainly in the dry season, since freshwater is lacking [KE2];[KE11];[KE4];[KE15];(PERG1);(PERG2);(PERG4);[KE7], but rainwater is used in the wet season (PERG4). As mentioned in Chapter 5.3.2, farmers in Vinh Chau District that cultivate onions (37.09%) and spices (32.25%), are using either one well (62.96%) or two wells (33.33%) [SURVEYS], and onion farming would seem to be a cause of groundwater extraction [KE2];[KE11];[KE4];[KE15];(PERG1);(PERG2);(PERG4);[KE7]. However, other regions have other main 'groundwater consuming' crops, interlinking the region's main agricultural activity with environmental degradation [KE7]. As discussed in Chapter 5.3.3, the livestock sector is not very relevant in Vinh Chau District and mainly occurs in combination with aquaculture (2.2%) or agriculture (5.6%) farming systems, and this group of farmers uses various water resources [SURVEYS].

6.4. Suboptimal policy implementation

Agricultural land use in Soc Trang Province changed significantly under the policy of restructuring agriculture since the Central Government and several different sectors invested in the province (Van Pham et al., 2016). In the VMD, the citizens have a minuscule role in water environmental planning and information is not clear for people affected by projects. Under pressure of economic development, the nation is overlooking the environmental costs, while there are limited financial and human resources at regard water-related policy (Le, Chu, Miller, & Bach, 2007). There is a myriad of agricultural policies which aim at improving the farmers' lives, but they are not successful as there was no positive relationship between agricultural policies and technical efficiency. Farmers that benefited from such policies were of lesser ability to efficiently grow rice and to improve their lives. Agricultural policies were, however, partly effective regarding livelihood improvement of larger families (Khai and Yabe, 2012). Although, households in the VMD that benefited from national policy and implementations grew by 4.1%, from 19% in 2009 to 23.3% in 2012 (GSO, 2015; Van Pham et al., 2016).

In the VMD, conflict is caused due to Decision No.1690/QD-TTg (on the fisheries and aquaculture development strategy in Vietnam until 2020), where aquaculture was accepted as a development strategy for the Delta (Van Pham et al., 2016). However, structural measures against salinity intrusion led to conflicts between water users, since aquaculture farmers prefer saline water for their ponds and agriculture farmers require freshwater resources. Especially since coastal communities widely adopted shrimp production and aquaculture as a response to the increasing salinity levels, which also helped them increasing their annual income. This increase is 1,735,- USD (~39.2 million VND) for shrimp and rice crop rotation system, versus $1,019 (~23 million VND) for a two rice crop system (Smajgl et al., 2015). In the coastal VMD, rice and shrimp production causes water conflicts between agriculture, aquaculture, fishing, and mangrove forests (Dang, Nguyen & Nguyen). The continuous expansion of shrimp farming area indicates that the area of cultivable land for staple food is potentially reduced every year (Sakamoto, Cao Van, Kotera, Nguyen Duym & Yokozawa, 2009).

The Vietnamese national government instituted a policy in 2000 (Decree No 09/2000/NQ-CP), which encouraged farmers to use agricultural land more effectively; this policy led indirectly to the conversion of rice areas to shrimp farming. Shrimp farming, in turn, resulted in the expansion of the salinity intrusion zone in coastal zones of the VMD. Increasing salinity protection, in turn, led to social conflict between shrimp farmers and rice farmers, this eventually prompted the government to re-examine regulations to emphasize rice production and for alternative land uses (Can, Duong, Sanh & Miller 2007).

Decision No. 116/1999/QD-TTg by the Prime Minister in 1999 defines three distinct zones within mangrove areas, the first 500-1000m from the mudflats and coast is a zone (full Protection Zone) prohibiting settlement, three felling, soil mining, aquaculture, agriculture and collection of fish and shrimp juveniles. The 100m – 5000m behind the previous zone is the zone (buffer zone) where economic activities, settlement, and conservation measures are permitted with a 60% mangrove area coverage and 40% allowable area for pond conversion. In this zone hunting, tree felling and the collection of wild animals is illegal. Behind the Buffer Zone is the Economic Zone, generally bordered by a road and allows for economic activities to take place without land use restrictions. In the economic zone and the buffer zone the provincial or district authorities allocated over 600 ha in Vinh Chau District to commercial shrimp farms, which leads to conflict and tension with the local population (Joffre, Schmitt, 2010). Moreover, due to floodwater prevention activities, farmers were encouraged to intensify and diversify agriculture in the flood-prone zones, resulting in an increase of environmental pollution and degradation (Nguyen, Le, Nguyen & Miller, 2007). In late 2015 and early 2016, The Central Government asked for reconsideration of such development policies for the VMD's coastal zones due to negative impacts from saline intrusion in the delta (Van Pham et al., 2016)

A further source of conflict is with Circular No. 27/2014/TT-BTNMT, which was issued in 2014 by the MONRE to regulate registration for the extraction of groundwater. This Circular requires such extraction in the delta's coastal zones to be managed and permitted by the government. Within their respective provinces, the DONRE is in charge of issuing guidelines to identify zones where groundwater extraction is allowable, which is still a struggle as a project of determining such groundwater extraction zones is still not set up. Since the DONRE did not yet officially issue the respective guidelines, local residents, businesses, and local governments have had difficulties regarding the management of groundwater extraction activities (Van Pham et al., 2016). Furthermore, Decision No. 11/2008/QĐ-UBND issued by the Soc Trang Provincial People's Committee, based on Resolution No. 149/2004/NĐ-CP and Circular No. 02/2005/TT-BTNMT, was approved on April 14th, 2008. Decision No. 11/2008/QĐ-UBND regulates the required government approval for groundwater exploitation registration, which is required for drilled well depths over 50 m from the surface level (PERG4). However, farmers never register their well even though it is required by the 2008 regulation and the government does not inspect it [KE4]. In the time after 2008, during the time that Decision No. 11/2008/QĐ-UBND was applicable, 38.88% of the farmers drilled a new groundwater well, of which 25.71% immediately registered their well, 5.71% did later, and 68.57% did not [SURVEYS].

6.5. Conclusion

In this section, the consideration of the existing values and policy discourses have been assessed, which sheds light on the criterion for values and policy discourses below. This condition for rational groundwater governance is not met, which is concluded from the analysis of the lack of pro-environmental behavior, economic difficulties, groundwater extraction motivations, and the suboptimal implementation of policies.

Values and policy discourses, whether all values are being considered in governance.

Excessive groundwater extraction for irrigation occurs, and there is a lack of civilian awareness regarding water usage, environmental protection, and adaptation to climate change in Soc Trang Province. Although, the economic circumstances of the households would appear to be the main factor in the hampering of pro-environmental behavior, while environmental awareness is rather limited. However, 38.89% of the farmers think that intensive exploitation of groundwater resources has systematic impacts on the lowering to the water table. Rural households reported environmental changes, and environmental awareness seems to be there to some extent. Nearly all (84.44%) of the farmers reported not to use improved agricultural farming techniques (e.g. water saving techniques). Moreover, the perception towards efficient groundwater usage is limited, and information from the government is not available. Groundwater is the mainly exploited water resource in Vinh Chau District, but in coastal areas, there are practically no alternatives.

Economic circumstances hamper pro-environmental behavior regardless of environmental knowledge, in Soc Trang Province, and there are many ethnic minorities which have limited awareness and are generally poor. Ethnodemographically, in Vinh Chau District, the Khmer are the largest minority (Khmer 45.56%), with either a medium income (46.34%) or low income (29.27%). Moreover, initiatives to advise water saving systems to farmers fail due to high costs compared to their daily life, with water saving irrigation systems being resold shortly after usage by the farmers. Economic hardships also express into the selling of topsoil in the dry season. However, farmers need their income, and the government cannot enforce their policies.

6. Values and policy discourses

There were significant investments in Soc Trang Province from the Central Government, and there were many agricultural policies to improve the farmers' their livelihoods, although they had limited effect. Aquaculture is accepted as a development strategy by Decision No.1690/QD-TTg, but structural measures against salinity intrusion led to conflicts between water users due to different water usage preferences. Especially since shrimp production and aquaculture was widely embraced as being more profitable, this development, in turn, led to more salinity intrusion. More conflicts were caused by Circular No. 27/2014/TT-BTNMT, which regulates the registration of groundwater extraction, but Soc Province's DONRE did not yet determine groundwater extraction zones. Decision No. 11/2008/QĐ-UBND for registration for groundwater extraction for family consumption in Soc Trang Province is another regulation with a similar purpose, but farmers never register their wells, and the government does not make inspections. Not all values are being considered, and there are policy discourses, the WEG criterion for values and policy discourses is therefore assessed as negative for the VMD.

7. Stakeholder involvement

7.1. Introduction

This WEG assessment criterion weighs whether every stakeholder is being involved in the system's governance and whether all responsibilities, authorities, and means are clear to make that involvement count. This chapter gives an introduction of Vietnamese water governance and policy throughout history to give an understanding of the current governance environment, followed by the actual implementation of water governance in practice. The latter is important to make the distinction between how groundwater governance looks like 'on paper,' and how environmental management actually affects every actor in the water system. Furthermore, the position of non-governmental stakeholders and scientists, the bending of national policies to local conditions, and the assessment of groundwater extraction needs are discussed. The conclusion then gives an assessment of whether this criterion is met.

Stakeholder involvement, whether all stakeholders are involved in the system's governance.

The Vietnamese have a long tradition of managing water flows, as the origins of Vietnamese civilization is in the Red River Basin, where hydraulic interventions into the deltaic landscape go back two millennia and where natural events such as floods and typhoons often occur and in substantial magnitude. Hydraulic management in the Mekong Delta commenced far later and into two epochs, the adaptation of civilization to the delta's complex hydroecology and the efforts to tame and control the delta's natural forces with the use of science and modern technology. Of which the latter has prevailed over the last two-hundred years (Benedikter, 2014). To define the conditions set by this WEG assessment criterion, it would be beneficial to look at the history of water governance and policymaking before the year 2000, and the developments in water governance after the year 2000, since after 2002 current policymaking began to make shape.

7.2. Water governance before the year 2000

The human-made risks have been lower when the adaptation of water uses to the ecological complexity, and variability of the natural flow regime has been implemented. For the Mekong Delta, the understanding of the implications of past decisions from colonial times, and the more recent history is crucial for tempering environmental degradation and finding sustainable solutions (Käkönen, 2008). Furthermore, large-scale water engineering in the VMD dates back to the eighteenth century. However, attempts to effectively tap the water resources in the delta were strongly reinforced after the country's reunification in 1976, when the local population was mobilized by the new socialist state to serve at the irrigation front, meaning manual labor in the construction of irrigation, salinity, and flood control infrastructure. This mobilization provided the ground for the intensification of farming systems. The Ministry of Water at that time and its sub-departments began to systematically plan water resources for different ecological areas of the Mekong Delta. The first delta-wide master planning in Vietnam was initiated in the late 1960's (Renaud & Kuenzer, 2012).

The French SOGREAH and the Resource Development Company of the United States and the Netherlands designed various water resource studies and proposals in the south of Vietnam in 1974. In 1993, the UNDP (United Nations Development Programme) and the Netherlands prepared the NEDECO Master plan for the Mekong Delta, which is the first multi-purpose master plan of a national river basin in Vietnam. This plan consists of a long-term development plan, covering a broad range of the use and management of water and the presented final results still constitute the basis of modern Vietnamese water resource management planning in the delta. State management agencies, planning, research institutes, state-owned enterprises, and irrigation and drainage management companies were established to operationalize different plans in this delta. These agencies were specialized and had the mandate of the common people to develop water resources for the common good. These concepts of water resources engineering were developed in the Red River Delta and were used as a blueprint for the Mekong Delta, although differences in hydraulic conditions were often ignored (Renaud & Kuenzer, 2012).

In 1986, the Doi Moi (Renovation Policy) was launched by the Vietnamese government aiming to shift from central planning towards a market-based economy in the reforms of, amongst other things, economic liberalization, decentralization, socialization and changes to state management institutions. This reform had an enormous impact on the policies and provisions for water resources management, as water control and supply services were partly privatized, and the dissolution of state-managed agricultural cooperatives led to the involvement of new style cooperatives registered as private businesses and offering pumping and drainage services. Furthermore, the funding and management of many state-owned enterprises, research, and planning institutes were changed and the 'National Water Resources Strategy Towards the Year 2020' encouraged mobilization and development of private sector investments. The conditions of operation became more moderate for organizations that were non-state owned. After the enactment of the Law on Water Resources No. 08/1988/QH10 over 300 water-related regulations on the implementation and guidance of the Law on Water Resources were promulgated and often amended to cope with the country's development (Renaud & Kuenzer, 2012).

In the VMD and the rest of Vietnam, water management practices deviate to a large extent from existing legal frameworks, policies, and strategies based on IWRM principles. This gap is not due to lacking capacity or resource scarcity but due to the peculiar structural features of the present-day state of Vietnam. The concept of IWRM was introduced and promoted since 1986 (formally started in the context of the first comprehensive water resources sector review of the post-Doi Moi period), and the first national workshop on IWRM was organized in 2001. The announcement of the first Law on Water Resources in 1998 opts for the adoption of IWRM principles and provides for the development of related policy (Renaud & Kuenzer, 2012).

Certain forms of civil organization are tolerated and encouraged upon as long as their activities are confined to social fields and development work. In line with the Doi Moi and based on the announcement of the Grassroots Democracy Decree of 1998, concepts of the idea of public participation in planning processes and community-based development were recognized in the formulation of policy. These concepts have been translated into participation approaches such as 'Participatory Irrigation Management' in many provinces. Other community-based organizations have emerged such as voluntary water user associations, micro-credit groups that engage in water supply, and organization and production groups that take care of the maintenance of irrigation works on a small scale. The national leadership recognized the necessity to draw a line, dividing the state functions and the role of the party based on the principle that governance and state management should be based on laws. Based on this, the power between the executive and legislative state bodies was divided and balanced by empowering the People's Councils and the National Assembly at local levels. The Public Administrative Reform Programme 2001-2010 aimed at improving the efficiency and transparency of state agencies, and to fight corruption which had dire effects on the organization and management of state management functions in, amongst others, the water - sector. The reforms that happened after the Doi Moi reforms provided the constitutional preconditions and rationale for the development of the water policy and legal framework (Renaud & Kuenzer, 2012).

In the last thirty years particularly, the deltas physical shape was modified profoundly due to the need for regulating water flows to control flooding, salinity, and droughts. In this process, hydraulic engineers and planners have played a critical role in the socio-ecological transformation of what makes the Mekong Delta today. Water management nowadays is done at a vast and dense scale of water control infrastructure made of dykes, embankments, sluices and pumping stations (Benedikter, 2014).

7.3. Water governance after the year 2000

Currently, Vietnam's legislation on the water sector consists of a complex system of legal documents adopted by different state authorities. However, harmonization with other laws and secondary regulation lacks in a number of cases (Renaud & Kuenzer, 2012). The legal framework (Nguyen, 2010) (Figure 18) defines the institutional set up of water resources management. Since 1995, The MARD, together with its planning institutes and state management organization, has been in charge of hydraulic engineering, water service delivery, and flood and storm control. Responsibilities lie in the planning, construction and maintenance of dykes, irrigation schemes, sluices, reservoirs, pumping stations, hydro power plants, and other kinds of hydraulic works (Renaud & Kuenzer, 2012). Furthermore, the MONRE is the country's leading authority on the management of land, water, and the environment. At regards to water, this organization is since its establishment in 2002, in charge of water allocation, groundwater, the regulatory management of surface water, and the water quality and water resources assessments (Renaud & Kuenzer, 2012; Van Pham et al., 2016).

A series of institutional reforms was initiated to strengthen its frame for the implementation of IWRM, which brought the issuance of the National Water Resources Strategy towards the year 2020 by the MONRE in 2006. This strategy, which was approved by the Prime Ministers Decision No. 81/2006/QD-TTg, and its resulting policy paper was the first to lay out guiding principles, objectives, missions and implementation measures regarding the prevention and mitigation of adverse impacts caused by water. This strategy aims at providing a framework for all water related policies and implementation plans in the country, confirms the approach of IWRM with the river basin as planning unit, and suggests the establishment of river basin plans for all regions. The approach of IWRM's guiding principles is that effective water governance is to be open, transparent, inclusive, communicative, coherent, integrative,

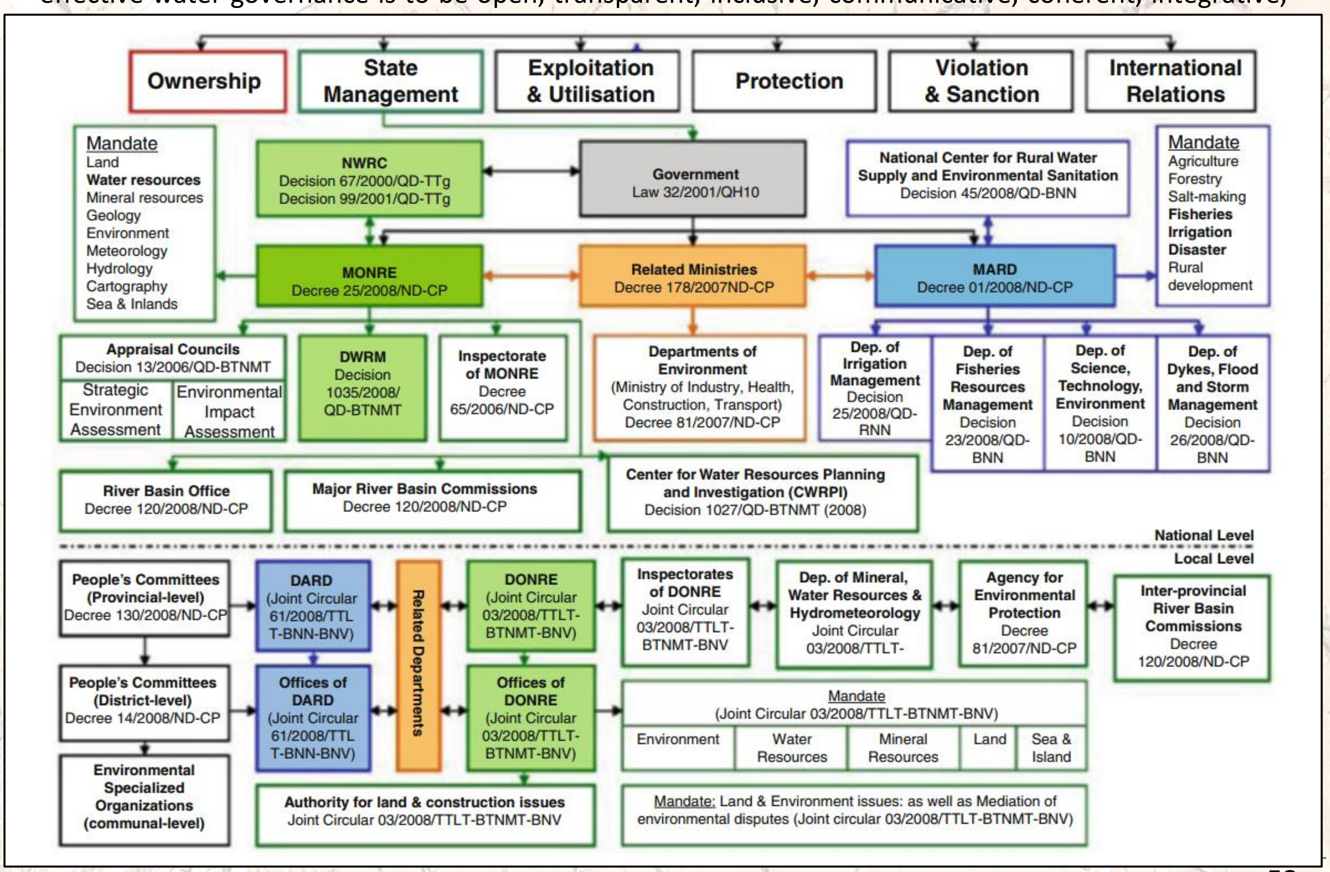


Figure 18 Ownership and management of State water resources in Vietnam (Nguyen, 2010).

equitable, ethical and should be accountable, efficient, responsible, and sustainable in its performance and operation. Conversely, in the Vietnamese water sector, the dominant approach is that of technical water engineering with a major focus on flood control and freshwater provision, and with little regard to the protection of (ground) water resources. However, the VMD is of prime importance for the national food security and agricultural export production which is dependent on the continuous development of innovations in water control (Renaud & Kuenzer, 2012). Currently, the responsibilities and obligations of the MARD and the DONRE are established in two regulations. Decree No. 21/2013/NĐ-CP defines the scope of functions and responsibilities of the MONRE, is issued in 2013 and states that the MONRE is in charge of the management and planning of groundwater resources at the national level. The DONRE plays the same role, but on the respective province and district level. At the commune level, water resources are management by a member of the staff of the People's Committee. According to Decree No. 199/2013/ND-CP issued in 2013, the responsibilities and the scope of functions of the MARD are the management of irrigation for agriculture and aquaculture purposes, and the responsibility for rural water supply programs. Interaction processes from the central government to the commune level policy levels, between different institutions that have role or responsibility in water management, are shown in Figure 19 (Van Pham et al., 2016)

The DONRE is in charge of groundwater management and is working directly under the MONRE and the Provincial People's Committee. Under the DONRE at each province, there is the Division of Water and Mineral Resource and the Division of Meteorology; these are the main authorities to manage groundwater. These divisions are also active at the district level under the authorities of the People's Committee. The DARD is responsible for the management of rural water supply, as described above and specifically through the Center for Rural Water Supply and Environmental Sanitation and the Division of Cooperatives and Rural Development. Monitoring of water quality for daily consumption is the task of the Department of Health (Van Pham et al., 2016). Further stakeholders in the management of water

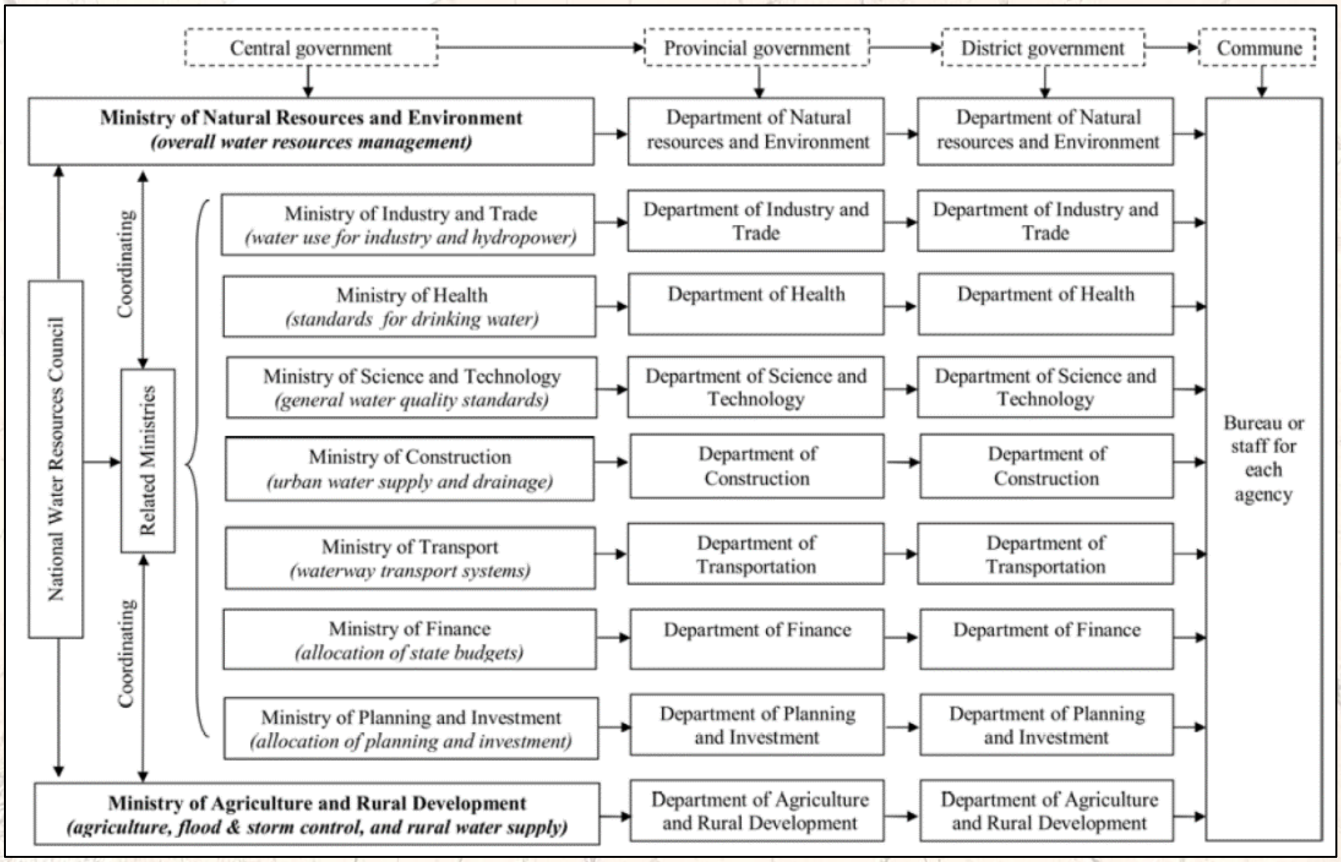


Figure 19 Institutional arrangement of groundwater management from the central government to the commune level (Van Pham et al., 2016)

resources are the Ministry of Construction and the Ministry of Health and other ministries, which shows that the multiple sector reforms did not decrease institutional fragmentation but increased it instead.

Further legislations are the 'National Strategy for Natural Disaster Prevention, Response, and Mitigation to 2020' (Decision No. 172/2007/QĐ-TTg) (Shaw, 2012; Renaud & Kuenzer, 2012), the 'National Rural Clean Water and Sanitation Strategy to 2020' (Decision No. 104/2000/QĐ-TTg), and policy such as environmental policies. Moreover, there is the hydropower development plan, guiding documents for the management of dyke, wetland and coastal management, and several other strategy papers and implementation plans. The National Water Resources Council (NWRC) and the River Basin Office's incorporate different perspectives and concerns on water resources on an advisory and limited basis. Ministries are organized in administrative and professional departments and have research and planning institutes and business agencies. State management agencies are divided into four vertical levels, the central, the province, the district and the commune. National policies are expected to be fully translated by the local departments. However, local governments do not operate in a uniform way (Renaud & Kuenzer, 2012).

7.4. Water governance in practice

Water governance would appear to be quite participative and integrated on paper, but require reconfiguration on the local scales. This necessity is mainly due to conflicting policies and missing coordination between provinces in the VMD. Moreover, authorities, responsibilities, and means would seem to require further organization in order to deal with water issues at the appropriate scales.

Due to over-exploitation and insufficient water usage, groundwater resources in the VMD degraded rapidly in terms of quality and quantity. Moreover, difficulties in groundwater management occur through ineffective co-management between different government agencies, and there is insufficient coordination between actors (local government, management agencies, and end-users). Furthermore, there is a lack of periodical monitoring of water resources exploitation with local citizen feedback (Ky Trung, Thi Le, Thuy Kieu & Van Pham, 2015). Moreover, IWRM in the Mekong delta exists almost entirely, solely on paper, it has not been transformed into practice as is empirically revealed according to Renaud & Kuenzer (2012). However, with saline intrusion to the surface water and increasing pumping practices, IWRM practices should be considered in order to exploit, use and manage groundwater resources in a sustainable way (An et al., 2014).

Moreover, the coordination between the provinces in the VMD lacks, with insufficient orientation on one another to come to coordinated approaches. There is a dominant top-down orientation with the implementation of agreements with national ministries as a focus, and there is too little focus on taking responsibility for delta problems from a bottom-up perspective (Kuks, Bressers, de Boer & Özerol, 2012). While bottom-up planning to adaptation by residents is also needed next to top-down approaches (Ling et al., 2015).

The conventional sector-specific and technocratic approach to water governance appears to be unchanged with the formal existence of the Mekong Delta River Basin Organization (MDRBO). The Law on Water Resources of 1998 mentioned the river basin to be the primary planning and management unit for water, although at the time there was no organization with the mandate to implement this, it gave the provision for a non-business agency under the MARD for the task of river basin planning. From this, the legal grounds for the establishment of River Basin Organizations (RBO's) was made, which had the main task to enable the unified management of the catchment areas across their respective dividing administrative borders. In 2001, the Office of the Cuu Long (Mekong Delta) River Basin was set up, together with other RBO's covering over three provinces and were selected as pilots. In 2006, the responsibility for RBO's was shifted from the MARD to the MONRE, and in 2008 the ministry drafted a new decree on river basin management, which states that each RBO is made up of a council and a secretariat. However, the MDRBO had five staff members and funds were clearly limited to mainly administrative tasks. In September 2008, the Southern Institute of Water Resources Planning under the MARD submitted a draft master plan for the Dong Nai River Basin, which was the first plan since the RBO's legal establishment, and the first step towards IWRM. Although there is criticism on the planning processes, outcomes, and its steps towards implementation. Furthermore, the establishment of RBO's is sensitive regarding the power, finance, and existing conflicts between the MONRE and the MARD, and the RBO's basically function as shells for projects, without resources, decision making power, or other means to come to IWRM (Renaud & Kuenzer, 2012).

Water policy planning targets single subsectors separately from one another, and an integrative approach to water governance appreciating the complexity of water-related problems in the delta is missing. Moreover, the sector specific view of managing water issues has an adverse impact on the appropriateness of current approaches to policy for solving the problems the population has. For example, the lack of access to safe drinking and domestic water is related to the pollution of surface water resources, but in the Rural Water Supply and Sanitation (RWSS) policy, water quality management is not included. Virtually none of the IWRM principles that are emphasized in existing policies are applied in practice, and concepts of participation from the community are adapted to a system where collective interests reign over individual interests and rights. Moreover, elitism and the concept of monolithically organized political power are intrinsic characteristics of the Vietnamese political culture. According to this culture, citizens are considered to be sufficiently represented by local authorities, and that is therefore considered as participation. However, the participation of local communities in water governance translated into practice shows that local authorities are often excluded from policymaking and planning. Furthermore, the Vietnamese approach to water resource management still follows the idea of human domination over nature by technological innovation, which makes it less integrative and neither ecologically nor environmentally sustainable (Renaud & Kuenzer, 2012). Besides that, there is an overall conflict in current land use planning, which is primarily dominated by agricultural production, and rice production is emphasized which in turn hinders crop rotation. Furthermore, inflexibility of land use functions is caused by inflexible property and land use rights (Kuks et al., 2012).

Moreover, the sustainability of the current policy approach of the RWSS policy is questionable. This policy approach is firmly in the hands of the CERWASS, which is an agency under the DARD and the MARD for the national scale. As shown in Chapter 5.4.1. the CERWASS is in a critical economic situation which averts the comprehensive coverage of all areas with water supply stations and the connection of all households to the networks. The citizens have a low ability and willingness to pay for piped water (many households have a private well), a low water tariff, the separation and privatization of urban water supply, and rural settlement patterns (which makes connections to the water supply complex). Moreover, the use of groundwater for such piped systems is ecologically and environmentally unsustainable as it leads to groundwater depletion and shortages. Such piped schemes in the Mekong Delta are based on groundwater exploitation on a large scale, and it provides a temporary solution that will create more problems in the future. Provincial governments compete over investments in local industrialization and environmental protection standards, and law enforcement has been downgraded to a negligible role (Renaud & Kuenzer, 2012).

Decentralization, unless projects are of a substantial scale in size and funds, exist to a certain extent, however, it does not follow the principle of subsidiarity as the redistribution of decision-making powers, and management responsibilities stop at the provincial level. This issue leaves development for local conditions at district and commune level hindered. In the design of dykes in Can Tho City, for example, the city was divided into five different flooding zones where topography, soil quality, irrigation, and infrastructure was taken in regard. The dykes were designed to control floodwater flows from the Long Xuyen Quadrangle into Can Tho City, as well as its discharge into the Western and Eastern Seas. Local communities were not allowed to participate in its design, and local specific needs were ignored which resulted in conflicts between central planners and the targeted communities. The central planning design included high dykes as being appropriate in most of the floodplains, while local stakeholders constructed low dykes in almost all of the floodplains. This conflict elucidates that farmers clearly prefer low dykes and do not necessarily follow plans made by central agencies. The dyke system did reduce flood damage risks and aided in the development of zones for aquaculture production and infrastructure. However, the dyke system also resulted in natural fish exhaustion, reduction of soil fertility, erosion, altered and lengthened inundation levels, and an increased perceived water pollution. The latter is due to the blocking of the outflow of polluted waters, and the encouragement of the increasing use of agrochemicals and intensive farming in flood protected zones. As a result, centralist dyke system planning has dramatically changed the natural flooding regime in Can Tho City as the governmental perspective focused solely on protecting and improving agricultural production and the prevention of flood disasters (Renaud & Kuenzer, 2012).

Furthermore, there are conflicts such as with Decision No. 11/2008/QĐ-UBND of the Soc Trang Province's People's Committee, which is the Decision on the Registration of Groundwater Resources Usage at Household Level and is in turn based on the Water Resources Law 08/1998/QH10. The conflict is with the renewal of the Water Resources Law 17/2012 QH13, which also renewed the foundation of Decision No. 11/2008/QĐ-UBND. The definition of household groundwater usage of the old Water Resources Law was at 20 m^3/day, and the new Water Resources Law holds this definition as 10 m^3/day (Van Pham et al., 2016). The definition of groundwater for domestic use in Decision No. 11/2008/QĐ-UBND is set at 20 m^3/day, and exceedance for agriculture, forestry, aquaculture, and handicraft production should not exceed this limit. Furthermore, registration is required for drilled well depths over 50 m from the surface level. The DONRE is then responsible for inspection and certification of this extraction within five working days (People's Committee, 2008). From Chapter 6.4. can be inferred that such inspection generally does not occur and that farmers hardly register their groundwater usage.

In Vinh Chau District, groundwater resource management has not been effective either, since monitoring of groundwater was not carried out sufficiently, but according to local regulations, the DONRE of Vinh Chau District should monitor groundwater exploitation activities regularly. Furthermore, the issuance of groundwater resource extraction was not well managed, and many farmers set up their wells without their notice to the local government (Van Pham et al., 2016). Moreover, groundwater resources management is inadequate in Vinh Chau District, where data is still in old software formats, enforcement lacks, and where there are insufficient human capacities for water management (Huynh et al., 2013). Furthermore, there is a lack of specific guidelines on the national level regarding the drilling of wells, the filling up of unused wells, and the regulation on sanctions against violations of legislations on groundwater protection. Furthermore, current sanctions (e.g. fines) are not suitable for specific violations regarding water resources related regulation, which causes a situation where most of the violating organizations and individuals to choose to rather pay the fine than to invest in environmentally friendly systems (Nguyen, 2012).

More than 30 years after the national reunification and 20 years after the Doi Moi policy, a high-modernist worldview prevails, where the national government in Hanoi has problems reading the local conditions, and centralized water resources planning has problems in effectivity since policies and technologies cannot be flexibly bend to local conditions. Policy formation in hydraulic management and infrastructure is often derived from hydro-ecological and infrastructural conditions from the North, not taking the local conditions of the Mekong Delta in regard. Furthermore, the national corps of engineers is very powerful and local stakeholder involvement is insufficiently taken into account when it comes to decision and planning procedures. The principle modus operandi in Vietnam is often that of trial and error, and the development of water resources in the Mekong Delta is done in a very technocratic way (Benedikter, 2014). Furthermore, interpolicy cooperation at the national and provincial level is insufficient, resulting in fragmentation. Policies related to land use functions and water management on a provincial level in the VMD is done by each province's own policies, and the integration of sectoral lines at the provincial level is inadequate. In addition, the integration of sectoral policies should take place at the national level, but this does not function sufficiently either (Kuks et al., 2012). In the Lower Mekong Basin, institutionalizing public participation has its obstacles, and it is important to recognize that a small amount of genuine participation exists which may in time lead to collaboration within intergovernmental development institutions (Sneddon, Fox, 2007).

Environmental changes are likely to occur due to different factors at various spatial and temporal scales, climate change is dynamic, and development orientated processes need to consider a broader socio-political context enabled by an area based adaptation approach. However, the government's sector specific view is inappropriate to address the diverse needs of adaptation (Keskinen et al., 2010). Legislation of water sector management in Vietnam has come a long way during the last decade, and there are significant improvements, but there are further opportunities to improve such regulation. For instance, the water resources management capacity can be enhanced since consistency and coordination in designing and enforcing policies still leave room for achieving more sustainability in the water sector. Furthermore, the state management system of the water sector has not proven its worth in ensuring its effectiveness in a coordinated way (Nguyen, 2012).

7.5. Absence of participatory management and stakeholder involvement

As discussed in Chapter 2.4., there is a general occurring undergoing of a major paradigm shift from an exclusively technical experts' task assuming human dominance over nature to an approach embracing participatory management and stakeholder involvement. Moreover, a particular group of experts or stakeholders cannot learn on behalf of all other stakeholders (Pahl-Wostl et al., 2007). The Mekong Delta Plan, (2013) recommends the guidance of stakeholder processes, the process to lead to powerful collectively supported decisions, to other relevant public authorities, to the redistribution of property rights, to control progress, and to take proper measures for efficient operations (Mekong Delta Plan, 2013). The extent to which approach currently exists is relevant for the assessment of the VMD's stakeholder involvement.

Combining private and public investments (water supply socialization) in rural areas occurred from 1999-2015. This combination had as its main role to improve the awareness of the economical use of water and sanitation. Moreover, it had the main roles to install water supply systems (in low-income remote communities, or large ethnic minority groups), and to support a sound water market with suitable institutional arrangements to increase private investments. However, participation in groundwater resource management is not well coordinated among local governments, management agencies, and resource users. Furthermore, local residents have no say in resource management while local authorities play an important role regarding groundwater management.

Water supply companies directly manage piped water supply from groundwater resources, and the only role for the local residents is to pay for that service. Moreover, the technical staff in local water supply companies indicated severe constraints in case of the occurrence of major technical issues regarding technical capabilities or information. Further shortcomings are the unclarity regarding the cooperation among various departments, and local residents do not know whether the DONRE or the DARD is responsible for checking and maintaining the quality of water supply services (Van Pham et al., 2016).

There are some government policy documents on the management of water resources, and the provincial People's Committee has issued some policy documents aimed at strengthening the application of these policies. However, the issued policies are not considered to require the consultation of non-governmental organizations, and there is no regulation to gather the farmers' their opinions (PERG2). Moreover, government staff involved in local authorities indicated that local residents should not be involved since they do not have technical knowledge, and only when new projects are planned they may give their opinions. However, such consultancy by neither the government at any level, water supply companies, or other actors has occurred (Van Pham et al., 2016).

However, according to (PERG1), the inhabitants their opinions when issuing a document on the use of groundwater resources is necessary, and not just by collecting comments from his division, but also of the other divisions, communes, and wards (PERG1). In a study done in Vinh Chau District, local residents did not show interests in participating in workshops related to government organized groundwater management due to language barriers, and the consideration of groundwater management to be the responsibility of the government (Van Pham et al., 2016). Moreover, in this district, farmers did not ask the (local) government (67.77%), or any organization other than the government (81.11%) for help. Regarding environmental problems, the farmers see a role for the (local) government in providing information (18.88%), in providing funds or subsidies (15.55%), to have a role in solutions by engineering (13.33%), or to provide general (unspecified) help (21.11%). Consequently, 25.55% of the farmers received support in the form of information (26.08%), or funds and subsidies (43.48%). Moreover, the surveyed farmers stated that it is necessary (56.67%) for the government to include their thoughts and concerns before promulgating a legal document on groundwater resources, and 33.33% stated this not to be necessary. Agriculture (48.15%), aquaculture (58.33%), and agriculture and aquaculture combination farms (65.00%) stated the inclusion of their thoughts and concerns to be necessary in this regard. On the other hand, reaching the farmers can be difficult, since they are not very organized, as 83.33% are not affiliated with any social organization [SURVEYS].

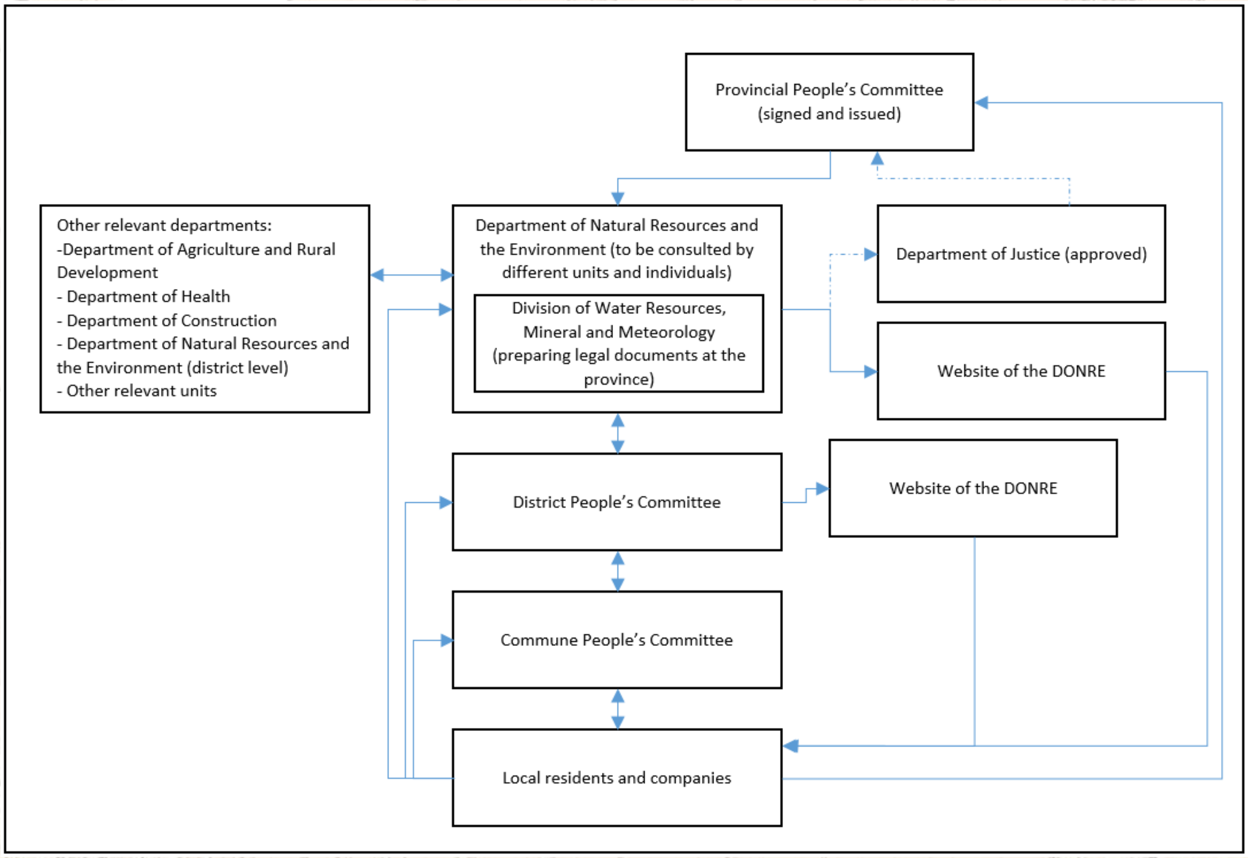


Figure 20 Information flows initiating at the Provincial People's Committee to the other stakeholders (Van Pham et al., 2016).

Interestingly, the law on issuing legal regulation states that different stakeholders should be actively involved with regard to making new legislation and regulation (Van Pham et al., 2016). For example, the Law on the Promulgation of Legal Documents No. 17/2008/QH12 states that, when it occurs that there are complex cases, an assessors council consisting of the representatives of stakeholders, scientists and experts can be appointed by the Ministry of Justice (The National Assembly of Vietnam, 2008). Moreover, the DONRE does not convey policies on groundwater management properly to local communities, which eroded the participation of local residents regarding groundwater management. The DONRE manages groundwater resources, but this authority rather consults relevant departments such as the DARD, the Department of Justice (DoJ), District level DONRE, Department of Health (DoH), Department of Construction (DoC), Department of Tax (DoT) and the municipal or district Peoples Committees. These information flow mechanisms can be seen in Figure 20, which also show the interests of the other relevant departments, but without much-exerted influence (Van Pham et al., 2016).

7.6. Difficulties bending national policy to local implementation

The local government authorities in the VMD are often only involved in the implementation of policy rather than in policymaking and planning, approaches to water resource management follow the idea of human domination over nature by technological innovation. Moreover, the redistribution of decision-making powers and management responsibilities stop at the provincial level (Renaud & Kuenzer, 2012), and water resource development is done rather technocratic manners (Benedikter, 2014), as mentioned earlier.

The rationality of policies depends on province to province, and national policy is very general regarding groundwater [KE12]. The provincial authorities request the local authorities for implementation, and the local authorities then will request the farmers for application with urgent issues to be carried out in advance. The policies tend to reach the inhabitants mainly through mass media (e.g. the radio) (PERG2). However, policies need to be placed into practice, while farmers have no information on them [KE7]. In Vinh Chau District, farmers generally do not know (75.55%) which kind of policies would affect their farm in a negative way. Regarding the farmers that did know (24.44%), policies such as restrictions on the number of allowed wells was chosen first (72,73%), followed by policies that restrict the amount of groundwater that can be extracted (22.73%) [SURVEYS].

7.7. The local scientific community could be more involved

In the VMD, the governance of water resources is challenged by the limited supply of scientific knowledge (Lebel, Garden & Imamura, 2005). Moreover, there is a yawning gap in expertise regarding groundwater models and water quality, and comprehensive models of groundwater with surface water interactions into existing hydrological models are needed. Information is available at the Sub-National Institute for Agriculture Planning and Projection (SNIAPP) and the Southern Institute for Water Resources Planning (SIWRP), but their information is not regularly updated or recent (SIWRP, 2011). Moreover, there is a need for the involvement of regional universities (Jonston, Kummu, 2011).

Regarding the environmental degradation, the government does not yet plan adaptation and mitigation to land subsidence, and there are no plans to do so. Moreover, the local government does not have sufficient knowledge regarding land subsidence and only know about it in general. The staff at the government departments, require the training and technical tools to measure and manage the water system. Additionally, scientists need government databases to be complete enough, and currently, this is not the case [KE3]. The government does not have a good database management system [KE13], and only limitedly shares information, since they do not have data [KE1], or the data is there but separated between offices and individuals [KE13]. Governmental data can be acquired through good relations [KE8];[KE15], but this data is only sufficient for very general use [KE13], and not suitable for detailed study or modeling

[KE13]; [KE8]. Personal government visits by scientists would seem to be required to acquire data from the government, which requires working together with them and procedures to follow [KE13].

Some information costs significant amounts of money (e.g. maps), and the government charges these costs to cover for labour costs; the prices range from 5 million VND (224 USD) to 30 million VND (1345 USD). Cadastral maps are expensive because of their level of detail; administration maps are cheaper depending on the scale, and whether it is an electronic map of not, whereas electronic administration maps are around 10 million VND (448 USD) to 20 million VND (897 USD). Price range per data size, for instance, one commune has 50 files, which comes with a charge of 30 million VND (1345 USD). Although, sometimes, information is given freely through connections and social relationships [KE15]. Extraction data is kept in-house and is only utilized for internal use in the government. The MONRE and the MARD do not exchange information with each other, and the government only uses information from within the government, from within their own departments. When scientists offer work, scientific reports, or data to them, they do not believe the contents and results. The government prefers own internal data over external scientific data [KE2].

Respondent [KE2] from the Mekong Delta Development Research Institute (personal communication, April 2016) said that:

''They choose own data over external data, and outsiders are not believed.''

However, in collaboration projects, data is shared, even though the government will hardly use scientific data, and there is a strong preference towards government data [KE2]. The Department of Science and Technology (DOST) can ask scientists from universities to solve problems. Research proposals can be sent there, and scientists can work independently. Within such studies, scientists are also inspected regarding their work, and eventually, their work forms the basis for policy making. However, this collaboration is practically merely a theory as research often does not become policy or a legal decision [KE6].

Moreover, there is not a proper linkage between scientists and policy makers, scientists have no influence on them, and better collaboration between the scientists and policymakers is required to come to knowledge-based policy making. The DARD sees the difficulties that the farmers face, such as value changes of crops and the occurrence of disease to crops and stock, therefore they request scientists to do research on that. The needs of the farmers are leading in scientific research and recommendations, although these results and outcomes need to be communicated to the stakeholders in the district, from that point on, experiments can be held for conclusions on the longer term to finish the research. Somewhere between there and after completing the research, the outcomes do not reach the farmers, indicating that there is a gap or imbalance between scientific knowledge and farming practices [KE15].

7.8. Groundwater extraction needs to be mapped out amongst all stakeholders

Water requirements of companies and industrial groundwater usage (which have measured and very concentrated water extraction) needs to be mapped since farmers can hardly recall their water usage, whereas corporations and the industry can. This necessity is especially the case with farms since they cannot be measured and are therefore harder to manage regarding their groundwater usage [KE9].

The industrial sector in coastal areas of the VMD uses groundwater because fresh water from the Mekong River is not available there [KE2]. In Can Tho Province, the industry may use surface water only, and it is forbidden for them to use groundwater. Moreover, the industrial groundwater usage is substantial, and there is currently no policy for industrial water use in other provinces [KE6]. In the VMD, in areas where piped water is available, companies and the industrial sector are not allowed to extract groundwater, although enforcement is not very strict on that [KE12].

Also, domestic water consumption in the coastal areas of this delta makes use of groundwater resources due to the absence of fresh water [KE2], which is also the case in the coastal districts of Soc Trang Province [KE7]. Moreover, in comparison with the agricultural water usage, domestic water consumption is limited but difficult to estimate [KE7.2].

Consequently, groundwater resources are utilized for all purposes since it is economical or because there is no other choice, and relevant regulation is not enforced; the regulation is there, but it is just on paper [KE12]. Additionally, it is currently unknown how much groundwater is used for domestic usage, agriculture, and aquaculture, but it is not as much as compared to industrial groundwater utilization [KE10].

7.9. Conclusion

Overall, the condition for stakeholder involvement as shown in the WEG criterion below is not met. In this chapter an overview is given of the history of Vietnamese water governance, linking water resources management and regulation by government authorities to water policy in practice, which showed exclusion of non-governmental stakeholders, and that there are difficulties bending national policies to the local scales. It further indicates that the local scientific community in the delta has issues regarding their involvement, and that there is a need to map out groundwater extraction needs amongst all stakeholders.

Stakeholder involvement, whether all stakeholders are involved in the system's governance.

A major paradigm shift in natural resources management from an exclusively technical experts' task under state patronage to participatory management and stakeholder involvement seems to be virtually non-existent in the VMD. There are difficulties regarding groundwater management since there is ineffective intergovernmental co-management, insufficient coordination between actors, a lack of periodical monitoring that includes the citizens their feedback, and limited water resource awareness. Moreover, the harmonization of legal documents adopted by different state authorities with other laws and secondary regulation lacks occasionally.

The MONRE manages the country's management at regard to water allocation, groundwater, the regulatory management of surface water, water quality, and water resources assessment. Although IWRM is considered in Vietnamese regulation, there is a dominant approach of technical water engineering and with little regard to the protection of (ground) water resources. IWRM has not been transformed into practice in the VMD, coordination between provinces lacks, and there is insufficient orientation to one another to come to a coordinated approach. Additionally, the orientation with the implementation of agreements is dominantly in a top-down hierarchy, and there is too little focus on bottoms up responsibility taking for delta problems. Moreover, there is sensitivity with the establishment of RBO's regarding the power, finance, and existing conflicts between the MONRE and the MARD, although RBO's have no resources or decision-making authority; they basically function as shells for projects.

Water policy planning is done by targeting single subsectors separately without regards to the integration of the complexity of water-related problems in the VMD, and this sector specific view leads to an adverse impact on the appropriateness of current approaches to policy. Furthermore, concepts of community participation are not applied since local authorities consider their representation of the citizens as participation, and local authorities are often excluded from policymaking and planning. Additionally, current land use planning hinders crop rotation and flexibility of land use functions. This sector specific view is inappropriate to address the diverse needs of adaptation, as environmental changes are likely to occur due to different factors at various spatial and temporal scales. Especially, when considering that climate change is dynamic, and development orientated process needs to consider a broader socio-political context enabled by an area based adaptation approach.

Due to competition over industrialization-investments, environmental protection standards and law enforcement can be regarded as negligible. Decentralization exists to a certain extent without following the principle of subsidiarity, hindering development for local conditions (district and commune level) as the redistribution of decision-making powers and management responsibilities stop at the provincial level. Further conflict and confusion are caused by different definitions set for groundwater utilization between the Water Resources Law 08/1998/QH10 and the Water Resources Law 17/2012 QH13, of which Decision No. 11/2008/QĐ-UBND is set on the former law.

A high modernist worldview prevails, with the central government having problems determining local conditions, and policies and technologies cannot be adjusted to local conditions. Additionally, hydro-ecological and infrastructural conditions from the North are often deemed representative for the VMD. Issued policy documents are not required to layman, or non-governmental organizations their consultation, and of local residents is considered that they should not be involved due to their lack of technical knowledge. Unless it is regarding their opinion for new projects, and although such consultancy did not occur, regulation (e.g. No. 17/2008/QH12) states that different stakeholders should be involved in some cases. Local residents are not very interested in participating either since groundwater management is considered a state responsibility and there are language barriers.

Local authorities are often only involved in policy implementation rather than in policymaking and planning, and the rationality of policy making depends on province to province. Moreover, national policies are very general, and both provincial and national policies are communicated through mass media, although the laymen have no information on them.

Very general information can be acquired through good relations, personal visits, or payment. Although extraction data is generally exclusively for internal usage, kept in-house, and is not shared between the MONRE and the MARD. Moreover, the authorities only utilize information from within their own departments, and scientific data is deemed to be inferior to internal governmental data. Furthermore, the collaboration between the DOST and scientists from universities often does not become policy or a legal decision. Although the needs of the farmers are leading in scientific research, scientific outcomes and recommendations are not communicated to the district’s stakeholders.

Overall, not all stakeholder are involved, responsibilities are often unclear, and the width and depth of stakeholder involvement are virtually absent for actors outside the government. Therefore, the WEG criterion concerning stakeholder involvement in the VMD is not met.

8. Regulations and agreements

8.1. Introduction

This chapter addresses the WEG criterion regarding the regulations and agreements condition. Firstly there is a brief overview of regulations on the national, delta, and provincial levels, from there the link is made with the enforcement of these policies. In the conclusion is assessed whether the WEG assessment criterion weighs whether all regulations and agreements are adaptive and legitimate, and whether there are mechanisms in place for their enforcement.

Regulations and agreements, whether regulations and their enforcement actually contribute to a more sustainable system.

8.2. Overview of regulations

Vietnams legislation on the water sector is made out of a complex system of legal documents that is issued by a myriad of state agencies. Numerous water-related documents are specified by general laws and ordinances, and other regulations are systematized and prescribed by specific secondary regulations. In 1999 the first law on Water Resources No. 08/1998/QH10 (adopted in 1998 to provide a foundational framework for managing the water sector) was enacted, which outlined the state management, exploitation, utilization, and protection of water resources, and sanctions in case of violation thereof. Moreover, it regulated the international relations in the management of water resources. To guide the implementation of this law, Decree No. 179/1999/ND-CP was promulgated in 1999. This decree gave a detailed prescription of state management, water resource exploitation and utilization, protection of water resources (especially considering the discharge of wastewater into water sources), the granting of water resources related permits, and the prevention, mitigation, and solutions of overcoming adverse effects of water. These documents form the initial legal basis for water management in the country (Nguyen, 2012). In 2012 the Law on Water Resources 2012 Order No. 17/2012/QH13 was promulgated which provides the management, protection, and use of water resources and the prevention, control, and remediation of harmful effects caused by water and included groundwater and seawater within the nation (Faolex.fao.org, 2012).

In Vietnam, water resources are owned by the entire population and are managed by the state, with the rights of exploitation being a common good to be used to meet their daily life and production demands. This right comes with the obligation to handle water sustainably and to mitigate or prevent harmful effects caused by water. Back to the state management of water, the related laws and ordinances to meet environmental protection and water resources protection were drawn up (Nguyen, 2012) as follows:

- The Ordnance on Natural Resources Tax, 1998
- The Ordnance on Exploitation and Protection of Irrigation Works 2001
- The Law on Land 2003
- The Law on Fisheries 2003
- The Law on Inland Waterway Navigation 2004
- The Law on Environmental Protection 2005
- The Law on Dykes 2006

In recent years over three-hundred legal documents have been developed as secondary regulations to the range of different legal viewpoints at regards to the management, protection and the sustainable development of water resources. Secondary laws are issued by administrative and judicial organizations for the provision of guidelines on the implementation of regulations and are of a lower rank than that of laws and ordinances. Next to that, much legal ground has been set in accordance with the Law on Water Resources and the Decree 179/CP and respective laws and ordinances (Nguyen, 2012). For a full overview of the organization of water-specific regulation see Appendix V, which also shows dispute settlement, key regulations, delivery of state responsibilities together with their hierarchy and key dimensions (Nguyen, 2010; Nguyen, 2012).

The central government in Hanoi makes the governing legislation regarding water resources and environmental degradation. Although there is subsidence in Hanoi, knowledge regarding subsidence from the central government level is not sufficient [KE3];[KE8];[KE9];[KE11];[KE13]. Moreover, they have a narrow field of work, with a sector-specific focus on engineering and water [KE13]. Although there are policies to land use and groundwater resources, there is no specific regulation to control factors leading to subsidence [KE7]. Nonetheless, according to [KE10], the central government has knowledge about subsidence, and although it was disregarded before, the link with groundwater drawdown is just recently recognized [KE10]. Additionally, there are evidence-based adaptive government plans for dealing with sea-level rise at the ministry level, although, for subsidence, such schemes (and evidence) are not there. Nonetheless, the local government tries to consider this issue [KE2].

Regarding sea level rise and climate change, the central government pays much attention to the VMD [KE12]. However, the entire political system has been involved in saltwater intrusion problems and coping with climate change (PERG5). Nonetheless, climate change impact studies are mainly focused on the VMD, and such studies are funded by the central government [KE4].

Respondent [K15] from the School of Social Sciences & Humanities, Sociology Department of the Can Tho University (personal communication, April 2016) said that:

''There is not much concern from Hanoi for the VMD."

According to [KE11], the central government knows about issues in the VMD. However, the central government's budget for projects often has less money in the VMD than what is written in their plans [KE11], as only 80% of the funding arrives, leaving 20% in Hanoi [KE4]. Moreover, decisions from the central government are not always reliable since the decision makers are generally not very knowledgeable about the VMD. The policy makers base their knowledge on the VMD from information online, short online interviews or short visits, but this is not reliable information [KE12]. Additionally, plans of substantive scale made by the central government are often too big for the local government at the district level to manage [KE11].

The provinces affected by climate change, have to make area specific response plans, one of such provinces is Soc Trang Province with the most climate change affected areas determined to be Vinh Chau, Tran De, Cu Lao Dung Districts and part of My Xuyen District. Area specific response plans have been completed and are applied in practice. These plans were issued in 2011 by the central government, and after that, Soc Trang Province applied them in 2013 and 2014. Aquaculture has been specifically planned for this province, for which there is the Decision 01/2012/QD-TTg, which provides some support policies for the production and processing for agriculture and aquaculture. The Agency of Fisheries tries to separate farm-types, such as intensive, and extensive farming areas. However, in Soc Trang Province, more than 80% of the agriculture sector consists of small aquaculture households, resulting in difficulties as farms cannot be divided into separate regions (PERG5).

So far, many laws, decisions, circulars and other regulations have been named throughout the WEG criteria. A full description of these regulations can be found in Appendix VI, which summarizes the laws relating to natural resources and water with a short description in chronological order for the national, delta (VMD), and provincial (Soc Trang Province) scales. This list is formulated after Nguyen, (2012), and Van Pham et al. (2016), and is double-checked through the Vietnamese law library website Thuvienphapluat.vn, (2016) and the legal office of the FAO, the FAOLEX, (2016). A brief summary of current relevant water-related regulations is given below.

Regulations would seem to be well organized at the national level, with regulations determining the provisions on the implementation of a groundwater licensing system (e.g. Decision No. 357/NN-QLN/QĐ), water resource withdrawal permits (e.g. Decree No. 149/2004/NĐ-CP, Circular No. 02/2005/TT-BTNMT, and Circular No. 27/2014/TT-BTNMT), and environmental protection activities (e.g. Law No. 52/2005-QH11). Furthermore, governmental management of water resources (with water being considered a good) and consideration of IWRM (e.g. Decision No. 81/2006/QĐ-TTg). Moreover, regulations consider environmental monitoring (e.g. Decision No. 02/2008/QĐ-BTNMT and Circular No. 20/2011/TT-BTNMT), and recognition climate change and developing IWRM strategies (e.g. Decision No. 1590/QD-TTg). Further national regulations that are interesting are the enhancement of local community livelihoods through environmental and natural resources management (e.g. Decision No. 899/QD-TTg), and the consultation of communities for groundwater resources utilization and water resource management (e.g. Decree No. 201/2013/NĐ-CP). Regulations also consider intergovernmental agency cooperation to study groundwater resources dynamics, issues, and usage (e.g. Document No. 6094/VPCP-KTN), and putting climate change issues under the responsibility of the MONRE (e.g. Law No. 82/2015/QH13). Further interesting regulation is for assessing pollution (e.g. Decree No. 18/2015/NĐ-CP and Decree No. 19/2015/NĐ-CP), water source protection (e.g. Decree no. 43/2015/ND-CP), groundwater resources (e.g. Decree No. 54/2015/ND-CP), and groundwater reserves, usage and subsidence (e.g. Decision No.805/QD-TTg).

On the VMD level, the following regulation is interesting, regarding the targeting of rapid agricultural growth through the development of irrigation networks and infrastructure (e.g. Decision No. 01/1998/QD-TTg and Decision No. 173/2001/QD-TTg), and the development of agriculture production (e.g. Decision No. 173/2001/QD-TTg). Moreover, there is the resolution for agricultural development together with the adaptive capacity building of local governments and residents with climate change in mind (e.g. Resolution No. 24/2008/NQ-CP). Furthermore, the development of medium and small scale electric pump stations and improvement of supply and drainage (e.g. Decision No. 1446/QĐ-TTg), consideration of saline intrusion as a side effect of hydraulic structures and the prevention of negative impacts from climate change (e.g. Decision No. 1581/QD-TTg) are regulated. Further relevant regulation would be the various water supply and drainage system planning regulations (e.g. Decision No. 2065/QĐ-TTg and Decision No. 2066/QĐ-TTg), and water supply system planning research on groundwater resource availability (e.g. Decision No. 395/QĐ-BXD).

On the level of Soc Trang Province, there are fewer regulations, although some relevant legislation is on the regulation of Decision No. 357/NN-QLN/QĐ regarding the extraction, investigation and state management of groundwater resources (e.g. Decision No. 87/QĐ-UBND), and the guidance of domestic groundwater extraction registration (e.g. Decision No. 11/2008/QD-UBND). Moreover, regulation occurs with regard to the enhancement of provincial groundwater resource management (e.g. Directive No. 03/2009/CT-UBND), and an extensive master plan for the province for socio-economic development and the environment (Decision No. 423/QD-TTg). Further regulation is on the costs of environmental monitoring and water resources (e.g. Decision No. 50/2013/QĐ-UBND), and the collection of water resources related fees in the province (e.g. Decision No. 20/2014/QD-UBND).

8.3. Enforcement

Interestingly, in 2013, the World Bank in collaboration with the MONRE investigated Vietnam's land governance indicators and came to the conclusion that the country is amongst the top countries for the creation of legislation, but at the bottom for its enforcement (Vo Danh, 2015). The trade-off between environmental degradation and economic development, should according to the Prime Minister of Vietnam, be carefully considered when new development projects are proposed. This consideration is, according to him, necessary since environmental protection is no longer a problem of the future, but rather a currently existing problem of which current environmental regulation is inadequate (DWRM, 2016). The statement above reflected the Environment Protection Law No. 52/2005-QH11, which states that socio-economic development must in be in accordance with environmental protection. This law furthermore states fines for administrative environmental breaches, and regulates that manufacturing and business- and services establishments have to apply measures to minimize pollution (Van Pham et al., 2016; National Assembly of Vietnam, 2005).

8.3.1. Restriction of groundwater extraction

According to Circular 27/2014/TT-BTNMT on Regulating The Registration For Groundwater Extraction, certain areas require compulsory registration of groundwater extraction. Registration is mandatory for areas with hydraulic levels lower than the low water level specified by the Provincial Peoples Committee, and for areas with hydraulic levels that decline for a consecutive three years. Registration is furthermore mandatory for areas with land subsidence or deformation of works caused by the extraction of groundwater, urban areas, concentrated residential rural areas, and rural areas located in limestone areas or with a weak soil structure. Furthermore, compulsory registration of groundwater extraction should, according to this Circular, occur in areas where saltwater intrusion occurs due to groundwater extraction, delta's, coastal zones with salt and freshwater interlaced aquifers, or in areas where the groundwater is of either a salty or brackish nature. Moreover, export processing zones, concentrated industrial clusters, handicraft villages, and areas that are polluted or are increasingly getting polluted due to groundwater extraction, and areas closer than one kilometre to concentrated zones of pollution (e.g. disposal sites, cemeteries, landfills). Based on aquifer characteristics, the current state of extraction and use of groundwater, and further requirements from local authorities, the Provincial People's Committee then specifies the extent to which the hydraulic head may decline. This drawdown should then in turn not exceed half the thickness of the unconfined aquifer, not exceed the roof of the aquifer and should not be deeper than 50 m to the confined aquifers from the surface level. Furthermore, the extraction should not exceed 10 m^3/day for production, businesses, and services. Registration is furthermore mandatory for domestic usage with wells drilled deeper than 20 m (MONRE, 2014). Based on these descriptions and

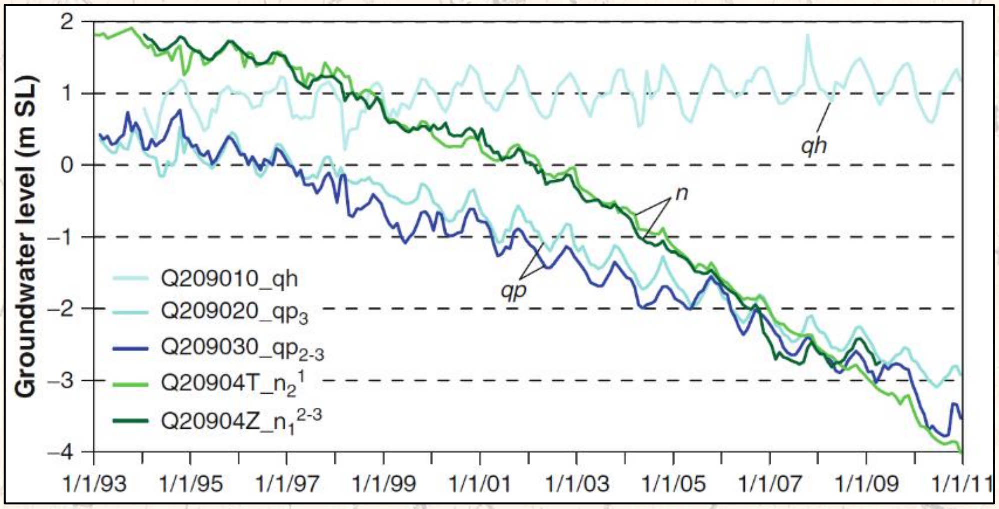


Figure 21 Measurement from the National Monitoring Station (Q209 in Vinh Long Province, elevation 2.1m above sea level), which shows drawdown in the Holocene, Pleistocene and Neogene aquifers from 1993 – 2011 (Wagner et al., 2012)

Chapter 4 and 5, Vinh Chau District (and much of Soc Trang Province), would qualify as an area where groundwater extraction is restricted and the same observation is made by Van Pham, et al. (2016). However, the DONRE did not yet officially issue the respective guidelines for this regulation in Soc Trang Province (Van Pham et al., 2016), which makes that earlier laws count instead. Such regulation would be Decision No. 11/2008/QĐ-UBND issued by the Soc Trang Provincial People's Committee, which requires registration when groundwater exploitation exceeds 20 m^3/day (PERG4). However, registration by farmers does not occur, and the government does not inspect or enforce it either [KE4]. Meanwhile, intensive groundwater exploitation for agriculture and aquaculture in Vinh Chau District continues, and groundwater is considered to be of prime importance for socio-economic development (Van Pham et al., 2016).

Groundwater usage is essential in coastal zones of the VMD and is utilized for domestic, agriculture, aquaculture and industrial purposes. Rapid increases in groundwater usage occurred from 1990 (100 m^3/day) to 2006 (700m^3/day) in Ho Chi Minh City and similar trends have been observed throughout the nation (Wagner et al., 2012). The environmental degradation is covered more thoroughly in Chapter 5.2. which covered that the number of wells that farms have slightly increased from 2005-2016. The number of farms with zero wells decreased from 17.65% to 4.44%, and the number of farmers with one well increased from 64.71% to 68.89%, and with two wells from 15.29% to 23.33% [SURVEYS]. However, the reason behind this expansion is more interesting as the shallow Holocene aquifer (qh) shows a stable trend throughout measurements in Vinh Long Province (Figure 21). The increasing exploitation caused groundwater level drawdown of 25 cm/yr of both the Pleistocene aquifers (qp_3 and qp_{2-3}) and even 40 cm/yr for the deeper Neogene aquifers (Lower Pliocene n_2^1 and the Upper-Middle Miocene n_1^{2-3}) (Wagner et al., 2012). Although Figure 21 sheds light on an example of inland groundwater dynamics near the Mekong River, it would also illustrate well abandonment. In Vinh Chau District, 68.88% of the respondents reported to have no malfunctioning or neglected wells, and 26.66% indicated to have one of such wells. Farmers started with one well initially (87,77%), and of them, 72.15% did not have wells that they do not often use, 25.31% did have one of such wells, and 2.53% has two of such wells. Of the respondents that started initially with two wells, 50% of them indicated not to have malfunctioning or neglected wells, 30% of them had one of such wells, and 20% had two of such wells. Additionally, there was one farmer that started with three wells initially and had one malfunctioning or neglected well [SURVEYS]. Similar results of a field survey in 2014 indicate that since 2012, farmers experienced groundwater degradation in terms of water quality and quantity, and many pumps were left unused since the wells did not yield water anymore. In this water system, groundwater is used for domestic usage (100%), and a significant portion of the rural households uses groundwater resources for agricultural production, whereas 20% of these households make use of the local water supply company (Van Pham et al., 2016). As put by the Vietnamese Prime Minister, environmental degradation is rather a current problem than that it is a futuristic one; the regulation seems to be there as well. However, the current provincial agreed service level is likely to be unsustainable in the long term.

8.3.2. Current adherence to existing regulation

Farmers rarely register their wells, even though it is required by the 2008 regulation (Decision No. 11/2008/QĐ-UBND), and the government does not check it either. Furthermore, abandoned wells are common and pollute groundwater sources by i.e. insecticides and pesticides. Penalties for violations are as low a one million VND (~ 44.35 USD), and enforcement is lacking. Moreover, farmers have wells drilled at spots that are convenient for them to use, without consultation from experts, which makes that wells are not placed at optimal locations [KE4]. As discussed in Chapter 7.8., enforcement is not implemented while groundwater is commonly used as the most economical option, even though there are groundwater usage restrictions.

The MONRE has regulations for the implementation of policies related to residential communities and industrial parks, but they have not regulated them specifically at the provincial level. Therefore, these documents have their difficulties regarding governance. A typical example of this is the Water Resources Act of 2012, and while some provisions are decentralized to the provinces in issuing documents, the province has not issued such documents causing difficulties for governance for the DONRE on the district level in Vinh Chau District. Firstly, there is a need to have planning related to groundwater reserves, and secondly, the division of regions for exploitation should be put into governance. For example, if one specific area has low freshwater resources, freshwater resource extraction should be restricted there, and regions with more water resources can be extracted from instead. Thirdly, there is a need to decentralize the licensing from the provincial level to the district and commune levels. Currently, there are inspection teams to check domestic water extraction, and plans are in development for checking any device (e.g. pumps) using water. The first test is performed with water rig owners to see whether or not they are qualified for drilling and whether they are licensed to handle violations. In Vinh Chau District, there are currently about 25,000 wells, and Soc Trang Province has about 100,000 wells. Moreover, the DONRE in Vinh Chau District has no data on environmental degradation (e.g. subsidence), and there are currently no schemes regarding declining water resources and the improvement of the quality and volume of local water resources (PERG3).

There are annual inspections regarding environmental laws, and according to the law, there would be a violation if overexploitation of groundwater resources causes subsidence. Additional to the need for more inspection, there is a need to improve the communication to the civilians that they need to get permission before exploiting groundwater (PERG2). Moreover, they need to understand that they should exploit sensibly to avoid overexploitation causing environmental degradation (e.g. subsidence) (PERG2);(PERG3). Furthermore, there is a need to strengthen state management, where the improper use of groundwater resources should be dealt with severely according to laws (PERG3).

Communication to the farmers is done by mass media (i.e. radio), which communicates for example that farmers who want to use groundwater must be registered, which is effective to some extent, as a small number of people were contacting the agency for registration (PERG3).

Respondents (PERG3) from The People's Committee of Vinh Chau District - DONRE (personal communication, April 2016) said that:

''With some of the civilians, there is a knowledge gap as to what their views and opinions on this issue (environmental degradation) are.''

Topsoil selling and the improper use of water resources is something that the government is aware of, but sometimes the farmers need extra income, and the government cannot enforce [KE5].

Respondents (PERG5) from the Agency of Fisheries of Soc Trang Province - DARD (personal communication, April 2016) said that:

''Salinization caused difficulties, but it is also an opportunity, depending on each region in the planning of aquaculture. In addition to the challenges caused by the high temperatures, high salinity is also an opportunity for shrimp farms.''

8.3.3. Policies are not prepared for the problem of subsidence

The citizens extract groundwater without consideration of the availability of groundwater resources, the extraction of groundwater resources is a problem, and there are not enough policies to control it. Moreover, farmers usually do not apply water saving techniques, and they do not know how much water they use; farmers just use as much as they want [KE7]. Since subsidence has a connection with unsustainable land use planning and development, it is indirectly affected by policies for development regarding the development of agriculture, and aquaculture [KE13]. However, subsidence is currently not a topic that receives much attention [KE11], and policies only address groundwater management [KE12]. However, according to (PERG2) from the DONRE, there are currently no documents specified on underground water resources (PERG2). Additionally, according to (PERG1), policy from the DONRE states that groundwater extraction requires permission from the competent authorities and is limited to the quantity as specified under the act of illegal and indiscriminate exploitation (PERG1). Nonetheless, stakeholders are generally not aware of subsidence, and the common opinion is that water is not much of an issue in the VMD. This view might have formed over the fact that flooding was rampant in the past, and due to the lack of care about the next generation regarding groundwater availability, pollution, and the exhaustion of groundwater stocks [KE4].

Regarding subsidence and the lowering of the groundwater level, there is a connection with policies and the groundwater level drawdown, which eventually leads to subsidence [KE10]. For example, the government pipeline system would extract groundwater from around 300 meters deep, which would cause subsidence from greater depths [KE6]. Regarding flood control policies, there is a significant effect to the reduction of water recharge into the aquifer, which would impact the water- and sediment flows from upstream causing the surface level to subside further [KE13].

8.3.4. Enforceability and ability to implement legal documents

The policies are available, as the government gives a lot of regulations, laws, and decisions to protect groundwater resources. However, the challenge is with the implementation since a good groundwater observation and monitoring network is required, although this is due to high costs not available or very limited. There is a lack of capacity regarding people, finance, and technical possibilities at the provincial government level. Moreover, the government often just allows groundwater usage, since it is a necessity for the people, it is the choice between problems in the long term or problems on the short, immediate term [KE13]. Vietnam is in need of a system that can review and systematize legal documents on water sector management, since in the recent past years over 300 legal documents were developed (and required) to implement the Law on Water Resources. These legal documents were developed as secondary regulation to sustain the development of water resources from different legal angles and the protection of these resources (Nguyen, 2010).

Regulations on the water sector are dispersed and scattered throughout a large number of legal documents which often have identical contents, different hierarchies and exist in total contradiction. However according to art. 3 of the Law on the Promulgation of Legal Documents of 2008 No. 17/2008/QH12, the development and promulgation must ensure the constitutionality, legality, and consistency of legal documents in the legal system. On the other hand, the legislation lacks a general regulation regarding the instructions of dealing with unfeasible, overlapping and unjustified water sector regulations with other regulations. Therefore, conflicts are caused when overlappings and contradictions have occurred. In the implementation process, local water resources management authorities experience difficulties to find the right regulation to deal with specific cases, and the lack of specific guiding regulations from the national level caused further difficulties. When new situations occur, many local authorities experience difficulties, e.g. the drilling of wells which lacks specific guiding regulations on the national scale on filling up of unused wells, regulations on guiding procedures of filling them, or regulations for the sanctions for a violation of groundwater protection legislation. Moreover, current sanction forms are not suitable for the specific violations of regulations when it comes to the water sector, which results in violation by choice (Nguyen, 2012).

The main obstacles for the protection of water resources are the lack of coherence and stability in the legal system, the many levels of hierarchies and a sheer number of state authorities, and an overly complicated institutional framework for water management due to overlapping and even contradicting regulations. Moreover, obstacles consist of the lack of sufficient financial resources and the lack of stakeholder participation in the establishment of water-related policies. For example, the inability to close idle wells due to lacking financial and technological means in Vinh Chau District, even though Decision No. 14/2007/QD-BTNMT states that closure of such wells is necessary to avoid contamination of water resources. In recognition of such confusion, misunderstanding and difficulties in the process for the implementation of policy, the Prime Minister (in August 2016) advocated for a systematic review and enforcement of the existing legal framework regarding the environment and natural resources to enhance state management effectiveness (Van Pham et al., 2016).

The need for a systematic review and enforcement of the existing legal framework on natural resources seems to be there, although current difficulties make enforcement a difficult task for local authorities. Furthermore, the local government is not always in a position to enforce regulation and agreements. Regulations and agreements are, due to a combination of these factors not always enforceable by public parties in the VMD, and due to the strongly hierarchical and the overly complicated institutional framework on water-related policies, appropriate remedies are generally not available. However, local governments require a decentralization of provincial licensing to local authority authorities, the specification of policies, better tools for strengthening communication to inhabitants, and the strengthening of state management.

8.4. Conclusion

This chapter assessed the regulations and agreements assessment criterion, and this condition for rational groundwater governance is not met for the VMD. This conclusion comes from the evaluation of an overview of regulations on the national, delta, and provincial scales, and from the current setup of regulations and enforcement. The enforcement mechanisms seem to lack regarding groundwater restriction, adherence to regulation, and the abilities for enforceability.

Regulations and agreements, whether regulations and their enforcement actually contribute to a more sustainable system.

The water sector in Vietnam consists of a complex system of legal documents issued by a myriad of state authorities, with numerous prescribed water-related documents specified by general regulation and systematized by secondary regulation. The initial legal basis of water management in the country is laid out by the first Law on Water Resources No. 08/1998/QH10 and its guiding Decree No. 179/1999/ND-CP. With the Law on Water Resources 2012 No. 17/2012/QH13 being the updated water resources law, providing the management, protection, and use of water resources. Water resources are managed by the state and are owned by the entire population, with exploitation rights being a common good and the sustainable handling of water being a common obligation.

Regulations on the national scale determine various registration requirements for water resource extraction and consider environmental protection measures, climate change, IWRM, and the enhancement of community livelihoods. On the VMD level, regulation covers targeting of rapid agricultural growth by various ways of the development of infrastructure and agriculture production. Moreover, on this scale, various water resource-related planning regulations have been made. On the level of Soc Trang Province, regulations would seem to be less extensive and address water resource management and resource investigation. Moreover, a thorough master plan for the province for socio-economic development and the environment is devised.

Vietnam is one of the top countries for the creation of legislation, but at the bottom for its enforcement. Furthermore, current environmental regulation (Law No. 52/2005-QH11) is inadequate for environmental protection. Moreover, Circular 27/2014/TT-BTNMT regulates the registration for groundwater extraction for areas such as Vinh Chau District (and much of Soc Trang Province) where registration is mandatory for extraction. This extraction should not exceed 10 m^3/day for production, businesses, and services, and registration is required for domestic usage with wells drilled deeper than 20 m. However, the respective guidelines are not yet officially issued by the Soc Trang Province's DONRE, which makes that Decision No. 11/2008/QĐ-UBND (which requires registration when extraction exceeds 20m^3/day) counts instead. However, farmers do not register their wells, and the government does not inspect or enforce their regulations.

Environmental degradation is meanwhile ongoing, and farms slightly increased their number of wells between 2005-2016. With as a likely reason that both the Pleistocene aquifers (qp_3 and qp_{2-3}) and the Neogene aquifers are showing substantial declines of hydraulic heads. This decline is illustrated regarding well abandonment, as 26.66% of the respondents in Vinh Chau District indicated to have wells that no longer function. Furthermore, since 2012, rural households experienced groundwater degradation (regarding quality and quantity), and many wells are left unused. Abandoned wells are common and lead to pollution of groundwater sources (e.g. due to insecticides and pesticides), but sanctions are low, and enforcement is lacking. Enforcement of the restriction of groundwater utilization in areas where piped water is available is barely enforced, while civilians consider groundwater to be more economical. There are not enough policies to control groundwater extraction, although it is limited by the DONRE and requires permission from the government. Furthermore, groundwater usage is often allowed by the local authorities since it is a necessity for the people and it is the consideration between problems in the immediate short term or issues in the long term. Even though policies are available, there are financial limitations regarding a proper groundwater observation and monitoring network.

Water sector regulations are dispersed and scattered throughout a large number of legal documents, with occasionally identical contents, different hierarchies, and contradiction. Conflicts are caused in governance due to overlapping and contradictions, there is a struggle to find the right regulation to deal with specific cases, and there is a lack of specific guiding regulations from the national level. Another example is that of Decision No. 14/2007/QD-BTNMT, which states that closure of idle wells is necessary to avoid contamination of water resources. This regulation did not get enforced in Vinh Chau District due to lacking financial and technological means. Regulations seem to be there, although enforcement is generally lacking and does not contribute to the system's governance. The criterion for regulations and agreements is therefore not met for the VMD.

9. Financial stability

9.1. Introduction

This WEG assessment criterion weighs the financial stability, what the availability of finances are and how it is spent on checking the functioning of regulations. Monitoring and financial management are closely interrelated since monitoring gives insight into the effects of regulation and the temporal aspect of spatial development in the system. This section firstly addresses financial arrangements in the delta, to be followed by monitoring mechanisms. In the conclusion, it is argued whether the criterion is met or not.

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Financial stability, whether the financial means come from a stable source and are spend in a sustaining and monitored manner.

9.2. The economic aspect

A rapid development of all sectors in the country was made possible by the system of master planning, but targets for the VMD make limited use of the comparative advantages in natural resources, leave little room for adaptation with actual economic analyses and developments, and spatial diversification within the delta is disregarded. Moreover, the sum of masterplans in the VMD is not realistic regarding the available financing and space (Mekong Delta Plan, 2013). Furthermore, upgrading sea dykes and the construction of large-scale estuary sluice dykes would have varying costs between 5,329 million USD (~120.26 x 10^{12} VND) to 8,176 million USD (~184.52 x 10^{12} VND). In addition, there is uncertainty and financial risk involved with infrastructure investments due to environmental changes and the weak young soil of the VMD (Smajgl et al., 2015).

In the VMD, financing of preliminary surveys, planning of water resources, and the remediation of water source pollution by unknown parties is the responsibility of the government at different levels. Private party interests are charged to private actors, vice versa for public interests, and the central government has a certain financial flexibility when it comes to dealing with water-related hazard. During severe drought and saline intrusion in early 2016, the MONRE financed eight coastal provinces (including Soc Trang Province) with 500 million VND (~22,175 USD) to provide domestic water to households. However, regarding groundwater resources, a general financial problem for policymaking is the perception of 'free water resources,' which led to their inefficient utilization. It was in the mid-2016 that the Prime Minister emphasized the need for the attraction of capital from different sources in society for water-related investments. Furthermore, there was a need for the development of an Environmental Protection Fund, which requires the collaboration between the MONRE, Ministry of Science and Technology, and the Ministry of Finance (Van Pham et al., 2016).

9.2.1 Taxing of businesses and the solidarity principle

Circular No. 40/2014/TT-BTNMT provides for the provision, adjustments, extending and revoking of licenses for groundwater drilling practices, and requires businesses to pay fees to obtain groundwater drilling and extraction activities (MONRE, 2014). Extracted groundwater volumes currently do not have costs associated with it, but large quantities (e.g. industrial utilization) requires DONRE approval and the fees depend on water extraction quantities per day (Van Pham et al., 2016). Circular No. 152 /2015/TT-BTC regulates the taxes on, amongst others, natural water, which is including surface and groundwater resources, and excluding natural water used for agriculture, fisheries, forestry and cooling purposes. The tax rates are calculated by the amount of natural water usage, and Article 10.4 excludes domestic usage (Ministry of Finance, 2015). However, applying taxes on groundwater utilization is challenging to apply since daily groundwater extraction volumes are not monitored (Van Pham et al., 2016). On the local level, in Vinh Chau District, the funding for performance is a challenge. For example, many solutions and projects have been launched, but only stop at information and mobilization stages. However, the performance was limited due to cost limitations. Due to this, the local Vinh Chau District office of the DARD can only implement small projects such as plant breeding to adapt to climate change or water-saving models (PERG1).

9.2.2. The profit principle together with the polluter pays principle

Article 65.1 of the 2012 Law on Water Resources No. 17/2012/QH13, outlined a profit principle for the usage of water resources for non-agricultural business, power generation for commercial purposes, service or production activities, industrial tree plantation, cattle farming, or large-scale aquaculture. The height of these payments is determined based on the quality and type of the water resource, exploitation condition, scope and duration, and the purpose of the water utilization. Furthermore, Article 26.1 states that water users in that category are required to remedy consequences and pay compensation for damage caused, these activities are defined as a decrease in water resource functions, land subsidence, salinization, or water source pollution. Article 26.4 states that draining by pumping activities concurrently with mining and construction works requires pumping to seize immediately to avoid a decrease in the groundwater level, with payment of compensation to be applicable in case of damages. Moreover, anti-leak and overflow measures must be applied to wastewater storage ponds and lakes according to Article 26.5 to avoid water source pollution.

Furthermore, Article 6.1 of this law states that project investors involved in the building of water resource exploitation and the usage of facilities to discharge waste water into water sources shall be required to coordinate with local authorities. This coordination consists of the consultancy of local communities, organizations, and individuals in affected locations. Their consultancy is required to give detailed information on their plans for the exploitation and use of water resources and their discharge; project investors have to announce their project and possible effects publicly and pay for those costs themselves. Additionally, Article 28.1 states that the MONRE actively monitors the quantity and quality of water sources, exploitation, and waste water discharge. Furthermore, Article 37 states that individuals or organizations that discharge wastewater into water resources require a license unless this discharge is of small contents. In addition, Article 38.2 states that such organizations or individuals need to abide by their financial obligations provided by law, and an illegal discharge leading to damage is subject to compensation by the polluter. Article 76.4 states that disputes of such license holders arising in water resource exploitation shall be settled by the MONRE, with lawsuits as an option in case of disagreement (The President Of The Socialist Republic Of Vietnam, 2012).

9.2.3. External funding

Different sources of investments are attracted for improving the water supply in Soc Trang Province, similar to other provinces in the VMD. These sources are often of an international nature, e.g. the United Loan (or Grant Aid) from the Dutch Government for the sustainable (surface water and groundwater combination) provision of water for local residents. Another example is that of the financial support from the Danish Government for solar empowered domestic groundwater pumping in three drought prone areas in Soc Trang Province, this project provides 50% of the total costs and the other 50% is charged to the local government. Furthermore, financial support from various donors was provided to build a new residential water supply pipeline in Vinh Chau and Tran De Districts (Van Pham et al., 2016).

Provincial governments can attract national and international investments with the increasingly negative impacts from saline intrusion to the coastal VMD, which in turn provides an opportunity for national government and international donors. However, financial management of government funded programs lacks transparency, and the complicated financial mobilization procedures cause a slow response to natural disasters. Furthermore, mechanisms to ensure proper utilization of financial support are lacking and maintaining water resources as a 'free resource' can only lead to further unsustainable utilization. Moreover, future groundwater taxes require financial impact assessments regarding local households, but they are necessary to tackle unsustainable resource usage (Van Pham et al., 2016).

The Soc Trang Master Plan identifies a range of initiatives that could support education and reforestation. However, the current investment focus on dikes and agricultural production could lead to dependencies and reduction in the adaptive capacity. Moreover, the effectiveness of adaptation strategies may be limited by levels of adaptive capacity and the adaptation governance mechanisms within Soc Trang Province. The importance of social and human capital in responding to coastal issues is stressed by stakeholders without recognizing financial and built capital limits. Furthermore, stakeholders rely on the benefits of donor support in building social and human capital, which makes it clear that over-reliance on donor support does not reflect a sustainable approach (Smith, Thomsen, Gould, Schmitt & Schlegel, 2013). However, to prevent environmental degradation (e.g. saline intrusion) at an early stage, assistance from external donors is recommended by the Master Plan made by the Japan International Cooperation Agency, especially considering the budgetary constraints for the Vietnamese government (JICA & SIWRP, 2013).

9.3. Monitoring Mechanisms

9.3.1. Monitoring

Plans for setting up environmental monitoring networks have been urged to by the Prime Minister to the MONRE in August 2016 (Van Pham et al., 2016), which resulted into Decision No. 90/QĐ-TTg on the approval of the planning monitoring network for resources and the environment from 2016-2025, with a vision towards 2030. Regarding groundwater monitoring until 2030, the aim is to set up 71 nationwide groundwater resource monitoring stations, consisting of between 778 and 1557 monitoring points. At regard to surface water monitoring until 2030, aims were set at a total of 56 stations for the monitoring of nationwide surface water resources. Moreover, this legal decision seeks to monitor various environmental indicators, at regard to nationwide hydrological monitoring towards 2030. To this end, 354 existing monitoring stations will be upgraded, and the total of monitoring stations is aimed to be at 640 stations (Prime Minister, 2016). Currently, there are 16 monitoring locations in Soc Trang Province, which are operated by the DONRE, samples are collected bi-annually and are analyzed at the Center for Environmental Monitoring under the DONRE. Furthermore, there are international donor projects concerning the monitoring of groundwater levels and quality. For instance, the project "Improving Groundwater Protection in Vietnam" (IGPVN) transferred five monitoring stations to the DONRE of Soc Trang Province. However, concerns were raised in a project workshop of the DONRE of Soc Trang Province and the Federal Institute for Geosciences and Natural Resources (the German Government's central geoscientific authority). These concerns were regarding provincial government funds to maintain these monitoring stations, and their (in)compatibility with the existing data processing systems (Van Pham et al., 2016).

The transparency from the DONRE's provincial level to the DONRE's district level seems to be a concern, as monitored data on water levels and water reserves primarily stay at the provincial level. Government authorities have this data, but they do not send this to the district level DONRE, when necessary, the Vinh Chau District authority level must apply for the province for that information. In Vinh Chau District, three monitoring stations are planned to be implemented. Currently, there is only one station near the Vinh Tan Commune People's Committee. Additionally, there are no mechanisms to share information on monitoring data, and land use is inventoried every five years. Moreover, there is no information regarding actions made by the central government on water resources (PERG3). Public environmental authorities lack a good database management system [KE13], either do not have data or only limitedly share information [KE1], or data and other information are fragmented throughout offices and individuals [KE13]. Furthermore, the MONRE and the MARD do not exchange information with each other, and the government only uses information from within the government, within their own departments [KE2].

9.3.2. More monitoring is required

Monitoring is required, as some specific knowledge gaps on the water system appear to be persistent, these are the exact hydraulic conductivity, storage coefficient, and groundwater drilling levels. Moreover, boundary conditions (e.g. head boundary and groundwater level boundary) require further data for groundwater modeling. In addition, there is a need to acquire more recent data regarding the outflow and inflow, since this data is outdated given the changes in land use and environmental problems in the VMD [KE3].

Moreover, there is a destitute amount of knowledge on the issue of subsidence [KE4];[KE10], and there is a need for a deep aquifer survey [KE4];[KE6]. Deep hydrogeological layers must be surveyed since the surface level changes too often [KE6]. Further gaps in knowledge are in the groundwater availability, groundwater origins, upstream and surface water related groundwater inflow, and the groundwater quality [KE4]. Moreover, there is a need to further data on domestic, agriculture, and aquaculture groundwater utilization, as well as on the natural recharge of groundwater from Cambodia, and for the potential storage per aquifer layer [KE10]. More studies are needed, and also, there is a need for monitoring subsidence without only relying on available data [KE6].

9.4. Conclusion

In this chapter is assessed that there are some financial arrangements in place, but that the transparency of funds and the dependency on external funding would seem to be a concern. Furthermore, the current monitoring mechanisms fall short to keep track in the effects of made investments into the region. Overall, the condition for financial stability is not met.

Financial stability, whether the financial means come from a stable source and are spend in a sustaining and monitored manner.

The government is responsible for financing preliminary surveys, planning of water resources, and the remediation of water source pollution by unknown parties, and private party interests are charged to private actors. However, there is a need for the development of an environmental protection fund and the attraction of capital from different sources in society for water-related investments. Fees to obtain groundwater drilling licenses and extraction activities are charged to businesses under Circular No. 40/2014/TT-BTNMT, with fees depending on water extraction quantities per day. Taxes are charged on natural water, with the exclusion of domestic usage under Circular No. 152/2015/TT-BTC, although daily groundwater extraction volumes are not monitored. Moreover, cost limitations cause solutions and projects to stop at information and mobilization stages, leaving only small projects in the governmental toolbox of local authorities. Usage of water resources is subject to an outlined profit principle in the 2012 Law on Water Resources No. 17/2012/QH13, with amounts based on the quality and type of the water resource, exploitation condition, scope and duration, and the purpose of the water utilization. Private parties are required to pay for the consultancy of local communities, organizations, and individuals in affected locations, and for the announcement of their plans and possible effects. Damages caused are required to be remedied, and illegal discharge leading to damage is subject to compensation by the polluter.

With the increasing attention to climate change effects and negative impacts from saline intrusion and other environmental issues, there are opportunities for the National Government and international donors. Additionally, there have been quite a few successful examples of international donor cooperation in Soc Trang Province. However, there is a lack of transparency, a slow response to natural disasters due to complicated financial mobilization procedures, and the mechanisms to ensure proper utilization of financial support are lacking. Furthermore, some stakeholders rely on donor support in building social and human capital, while over-reliance on donor support does not reflect a sustainable approach.

The Prime Minister urged the MONRE for plans to set up environmental monitoring networks, resulting into Decision No. 90/QĐ-TTg on the approval of the planning monitoring network for resources and the environment from 2016-2025. This decision plans for nationwide groundwater (71 stations) and surface water (56 stations) resource monitoring stations. Currently, monitoring in Soc Trang Province is done by 16 monitoring locations, which are operated by the DONRE. There are an additional five external donor funded monitoring stations in the province, but there are concerns whether the province can financially maintain them and whether there is sufficient compatibility with the existing data processing systems. Vinh Chau District has one monitoring station, but monitoring data stays with the provincial DONRE. The district level DONRE, usually, does not get this information, and transparency is a concern. Furthermore, there is not a proper database management system, and information is only shared to a very limited extent, even within the intergovernmental structure. However, Monitoring is needed as there are knowledge gaps and a lack of recently acquired data (e.g. on land use planning), there is a lack of detailed groundwater data and subsidence, and there is a lack of hydrogeological data for modeling purposes (e.g. natural groundwater recharge from Cambodia).

A sustainable and equitable financing of water governance would seem to be hampered by a lack of funds and monitoring for taxing purposes. However, the profit principle and the polluter pays principle appears to be established in national policy by the 2012 Law on Water Resources No. 17/2012/QH13. Financial arrangements would seem to be rather sustainable and equitable in writing, but the practical local government implementation of these policies and a lack of monitoring mechanisms indicate a rather unsustainable financial arrangement. Monitoring is planned for improvement on a national scale, however, with limitations to data availability, monitoring can only limitedly contribute to insights into the effects of regulations and the temporal aspect of spatial development in the system. The criterion for the financial stability condition is therefore not met for the VMD.

10. Policy prospects towards rational groundwater governance

10.1. Introduction

The discussed WEG assessment criteria in the previous six chapters show that rational governance is currently not possible in the VMD, as 4 out of 5 criteria show a hampering effect on rational groundwater governance conditions (Figure 22). This section provides an overview of possible intervention strategies, followed by their strengths and weaknesses, and in the conclusion, the policy prospects at regard to their limits are assessed.

The first WEG assessment criterion for system knowledge facilitates [√] rational groundwater governance in the VMD, although knowledge gaps remain, advanced environmental analysis such as modeling requires more data and further research can be recommended. The second WEG assessment criterion for values and policy discourses is regarded as hampering [X] to rational groundwater governance, since not all values are being regarded, and there are policy discourses regarding agricultural values and current regulation. The third WEG assessment criterion also hampers [X] rational groundwater governance, since there is virtually only governmental stakeholder involvement. Between the MONRE and the MARD and between their local governmental departments (provincial and district level) and the respective People's Committees, stakeholder involvement and sharing of information is not optimal.

The fourth WEG assessment criterion is also deemed as hampering [X] to rational groundwater governance since regulations have not been adjusted to local conditions, are too general, in conflict with other regulation or not yet specified to on the local scales. Furthermore, enforcement is lacking and does not contribute to the system's governance. The fifth and final WEG assessment criterion for the financial stability can be regarded as hampering [X] to rational groundwater governance since there are issues with regard to the transparency of funds, donor dependency, and a lack of monitoring. Monitoring is set for extensive improvement, but cannot be used in a facilitating way to rational groundwater governance due to limitations to the sharing and availability of monitoring data.

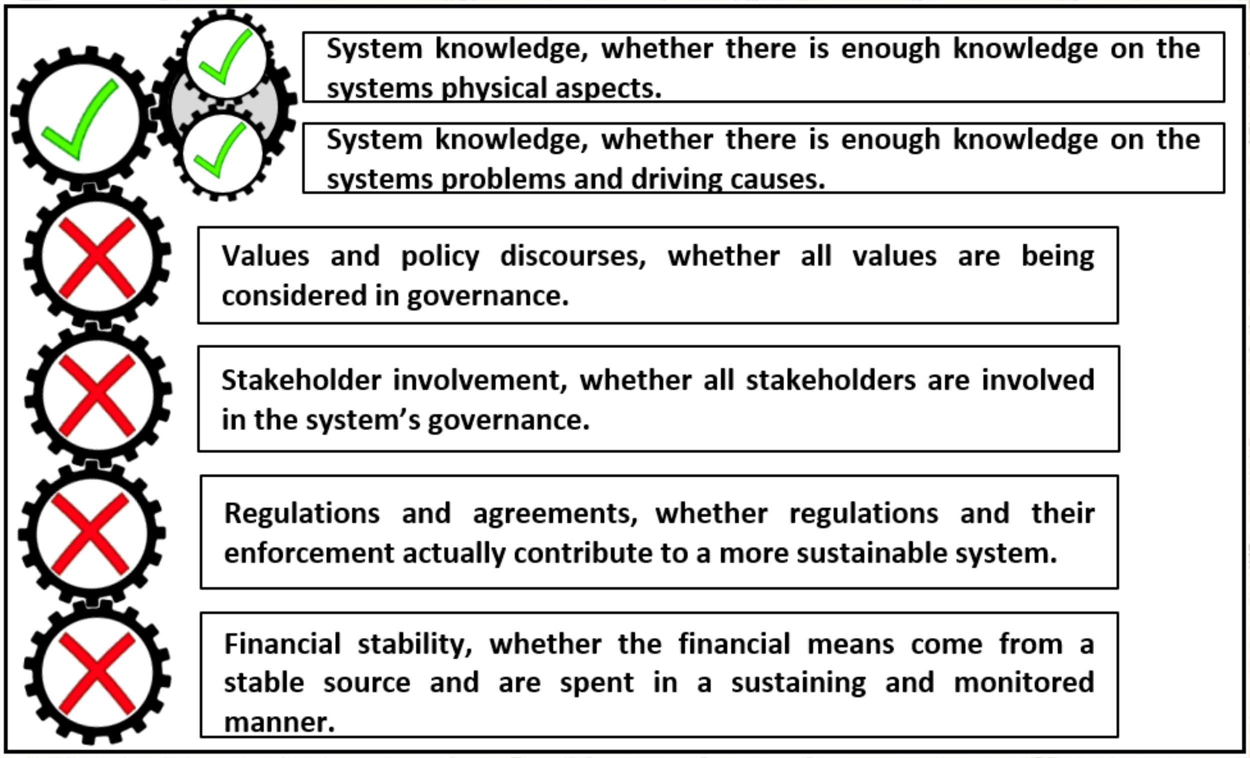

Figure 22 The Wheels of Environmental Governance (WEG) assessment framework for groundwater governance in the VMD

These assessment criteria shed light on how current groundwater governance can be changed towards more rational approaches. Similar to the Engineers Method of Hoogerwerf, the comparison of knowledge on an issue gives insight into the determination of how specific the problem really is. This insight can be utilized for important clues towards intervention strategies. Therefore this chapter aims to answer the remaining research sub-question:

What intervention strategies are possible based on the presence of these conditions?

10.2. Possible intervention strategies

System knowledge

A policy prospect regarding the system knowledge would be to build further knowledge gathering and policies with the current system knowledge as a basis. This advancement is of prime importance since current system knowledge is insufficient for more advanced environmental analysis (e.g. modeling). Some respondents had suggestions for intervention strategies, such as further study on the temporal reduction of upstream water and sediments for the VMD [KE1], recharge mechanisms to the aquifer by technical means [KE9];[KE3], and deep measurements (stable for datum level) to measure subsidence processes [KE9]. Another suggestion is to make annual measurements and to determine causal relationships between subsidence rates, to distinguish areas that subside due to ground water use and which do due to other reasons [KE9];[KE13]. Moreover, water requirements of companies and industrial groundwater usage needs to be mapped out, since farmers can hardly recall their water usage whereas businesses and the industry can [KE9]. An additional intervention strategy could be to plant climate change adaptive crops withstanding drought and salinity, shrimp stock which withstands salinity of 20 ppt, and the usage of water-saving irrigation systems for purple onions (PERG1).

Values and policy discourses

Policy prospects at regard to the values and policy discourses can be found in exploring more ways to improve the awareness of the inhabitants towards the sustainable use of groundwater resources, in a combination of devising policies that could increase their incomes. Moreover, ethnic minorities have limited awareness and are generally with low income; these minorities can be provided multilingual information, e.g. information in the Khmer language for Khmer minorities. The prime reason of non-adaptive and counter environmental friendly behavior is due to the limits of economic capacities of the rural households, agricultural development activities to improve rural livelihoods were of limited effects, and the local authorities cannot enforce their policies. From chapter 6 can be understood that the attempts to develop aquaculture with Decision No.1690/QD-TTg led to conflicts between water users due to different water usage preferences, while shrimp production and aquaculture was widely embraced as being more profitable. Furthermore, there are policy discourses due to the non-enforcement and lack of registration of wells as required for Decision No. 11/2008/QĐ-UBND. Although, there seems to be negligence in the determination of groundwater extraction zones for Circular No. 27/2014/TT-BTNMT. Improving awareness and pro-environmental behavior is likely to come with the development of rural areas, and such development is hampered by a lack of harmonization of existing policies and actor values. Consequently, the harmonization of current governance and the development of rural areas in line with all values are therefore a viable path towards rational governance. Prior to reaching such integrated policy prospects, further study towards farmer’s interests and values at regard to water resources can be recommended.

Stakeholder involvement

Policy prospects are found in the current lack of full stakeholder involvement, as it is virtually only including governmental stakeholders, where local authorities are only involved in the implementation of policies. These prospects can be found in the harmonization of legal documents, improvement of coordination between actors, and the development of periodical monitoring that includes citizen feedback. Harmonization is furthermore recommendable between the responsibilities, coordination, and cooperation between the MARD and the MONRE (and other relevant government authorities on all scales), together with an increase of a bottoms up responsibility taking for the VMD. Furthermore, RBO's should either be assigned more responsibilities or should be removed from the institutional framework, as they basically function as shells for projects. Some legal documents have an ill fit to relating regulation (e.g. the conflicting criteria set for Decision No. 11/2008/QĐ-UBND based on the Water Resources Law 08/1998/QH10, instead of on the Water Resources Law 17/2012/QH13), which calls for a review of how well provincial regulations fit to the most recent national regulations. In addition to that, the Water Resources Law 17/2012/QH13 requires the DONRE to take the responsibility to regularly monitor groundwater exploitation activities, which seems to occur insufficiently and would need to be enforced by the MONRE. Moreover, this ministry would need to make more specific guidelines on the national level on groundwater utilization and drilling, while considering local authority feedback on policy appropriateness.

Moreover, the current approach of human dominance over nature by means of technical water engineering has to make place for principles such as building with nature and sustainable adaptation. In addition, integrated approaches should be considered versus the current approach of targeting single subsectors separately without regard to the complexity of water-related problems and the absence of community participation. Additionally, local authorities should be included in policymaking and planning, as they are more familiar with the local environmental conditions and issues.

Environmental protection standards and law enforcement should be placed above economic interests, since the dependency on the VMD's water system is a necessity for agricultural development in the region. In line with this, the principles of subsidiarity should be included to enable the development for local conditions on the district and commune levels, especially since decision-making powers and management responsibilities currently appear to stop at the provincial level. Furthermore, land subsidence should be considered a consequence from unsustainable land use planning and groundwater extraction, which should be included into governance. To this end, sharing of data between scientific interest groups (DOST and Universities) and the government should be enabled. Furthermore, enforcement strategies together with specific water requirements should be included into governance, which in turn would need to be enforced in an equitable way that considers all interests.

Further policy prospects are found in the full involvement and coordination of stakeholders, or at least in the consideration and coordination of local citizen feedback and inclusion of all governmental layers and interest groups. However, government authorities consider layman or non-governmental consultation negligible and local residents are not interested either. Farmers in the survey did generally not ask the government for help, although they want their thoughts included before the promulgation of legal documents. Policy prospects can, therefore, be found in the clear communication of their incentives related to the sustainable utilization of the water system, together with government consideration of the value of layman knowledge in combination with existing scientific knowledge. Furthermore, groundwater management policies should be communicated clearly to local communities.

Rationality of policy making differs per province, local authorities are often only involved in policy implementation rather than in policymaking and planning, and policies are communicated using mass media (although laymen knowledge on policies is limited). Policymaking can be improved by the inclusion of local authorities, which benefits the extent to which policies are adjusted to local conditions, although similarity to other provincial regulations should be maintained to ensure equity. Citizen awareness towards policies seems to be limited, which could be due to a lack of laymen interest or due to a lack of mass media access. Clear communication by means of personal visits or workshops could improve awareness related to regulations and the environment, and to collect citizens their concerns and feedback.

Some expert respondents had ideas for intervention strategies, such as the provision of technical tools (e.g. models) and other help for the government to manage groundwater extraction in subsiding areas [KE3]. Another intervention strategy would be to start water-efficiency related projects on a larger scale by means of participation in order to ensure cost efficiency, which is helpful since the instability of crop prices leads to uncertainty regarding investments for such installations (PERG4);(PERG1).

Regulations and agreements

The Vietnamese water sector is complex, at the national level, regulations would appear to be well organized, with regulation e.g. towards agricultural development, considering climate change, IWRM principles, and groundwater licensing. However, regulation on the level of Soc Trang Province seems to be less elaborate. Policy prospects can be found in making current environmental regulation sufficient for environmental protection, and respective guidelines should be officially issued by Soc Trang Province's DONRE to avoid confusion. Moreover, sanctions need to be adjusted to avoid that paying sanctions is the economical option between pro-environmental investments and non-compliance to regulation. Furthermore, policies are not enforced which is partly due to limited capacities of local governments or their consideration of groundwater being a necessity for the people. Furthermore, there is confusion relating to enforcement since the water sector regulations are dispersed, scattered, and with occasionally identical contents, different hierarchies, and contradiction.

Policy prospects can be to find the balance between effective enforcement and equity towards local conditions and hardships of rural households. This balance would have to start with a simplification of current regulations towards a more coherent legal framework, with an open legal database and internal search engine, together with the required means regarding human, technical and economic resources to enforce regulation. In areas where the combination of anthropogenic presence with current environmental conditions would make that law enforcement is not equitable towards the citizen, relocation or non-enforcement could be carefully considered.

Some expert respondents had recommendations for intervention strategies, such as the adjustment of decree 27/2014/TT-BTNMT, since it is not strict enough to protect the aquifer. This decree for the nationwide regulation of groundwater states that the groundwater level drawdown should not be more than 50 m from the soil surface to the confined aquifer. However, this certainty range cannot prevent that once the ceiling of the confined aquifer does not have water anymore, the aquifer is not really confined which results in damage. This damage can be prevented by regulating the groundwater level drawdown to be under 20 m to the confined aquifer [KE9]. Another suggestion would be to make use of the legally required registration of the number of people present in households multiplied by spatially representative average water consumption rates to estimate the usage of unmetered wells [KE12].

Financial stability

The fifth WEG assessment criterion shows the policy prospects at regards to the financial stability; there are various mechanisms that ensure funding, for instance from taxes and successful international donor coordination. However, there is a need to increase the transparency for the division of funds, compatibility of donor projects to the DONRE's systems, and most importantly there is a need for monitoring. Whereas, for the longer term, dependency on donor support should be reduced. Monitoring for resources and the environment, in turn, is planned in Decision No. 90/QĐ-TTg which states a plan from 2016-2025, but monitored data usually stays in-house, and there is not a proper database system. Information is generally not shared between the provincial and the local district level authorities, besides that, the national government bases regulations on short visits and online search work. Furthermore, there is limited citizen participation, and scientists have very limited information available to base their research on. These isssues ask for an intergovernmental open or publicly open database to enable a more modern information flow, more stakeholder involvement, and an increase of knowledge-based policy making.

10.3. Strengths and weaknesses of the intervention strategies

The above-mentioned policy prospects for rational groundwater governance can be divided into four categories:

- Full stakeholder involvement
- Improving rural development and livelihoods in combination with law enforcement
- Open database and improvement of awareness
- Harmonization of inter-governmental stakeholder responsibilities, coordination, cooperation and legal documents
- Further research for more advanced environmental analysis

Policy prospects are limited to the extent that Vietnam is a communistic country (Nguyen, 2015) where environmental policy is nowadays done in a very technocratic way (Benedikter, 2014; Renaud & Kuenzer, 2012), with human dominance over nature by technical water engineering (Renaud & Kuenzer, 2012), and a top-down approach (Kuks et al., 2012). Moreover, local authorities are often only involved in policy implementation, and often excluded from policymaking and planning (Renaud & Kuenzer, 2012). These aspects of governance cannot be logically expected to change within a short timeframe, if at all. Therefore, changes from only governmental stakeholder participation to full actor involvement (e.g. the Dutch Polder Model (de Vries, 2014), or other forms of full stakeholder involvement (Reed, 2008)) can only be expected on a much larger timescale. On the other hand, layman knowledge and feedback can still be collected by means of workshops or personal visits by officials, which could improve awareness related to regulations, responsibilities, and environmental issues. These forms of contact could help to improve feelings of perceived equity and involvement, whereas gained knowledge can give insights into development strategies.

Furthermore, informational governance practices regarding the environment in Vietnam are rather bleak and exist mainly through international donors and linkages with the global economy. Monitored environmental data is often considered a tradeable commodity by officials that require off the record payments. Moreover, citizen feedback and complaints are not systematically reported or facilitated due to the reluctance to give civil society more space, although sometimes information is spread through the media to build up political pressure or through informal and formal networks of individuals higher up in the party and state echelon (Mol, 2009). These issues would imply that including citizen's their feedback and complaints into governance could only marginally work and that ideas of an open database could stumble against government resistance due to environmental data being regarded a tradeable commodity. However, monitored data is a necessity to come towards a financially sustainable governance system and towards more advanced environmental analysis, but monitored data usually stays in-house, and there is not a proper database system.

Policy prospects such as changes in certain policies and the harmonization of inter-governmental stakeholder cooperation and legal documents could be slow processes. Whereas, the harmonization of responsibilities, coordination, and cooperation between the relevant government authorities on all scales can be arranged together with the removal of RBO's from the institutional framework. Which can be done from the upper governmental layers, together with harmonization of regulations that cause confusion.

The harmonization of regulations can furthermore be used to enforce that regulations on the provincial scale can be kept up to track with regulations on the national level, and to avoid non-compliance with the law to be most economical option versus pro-environmental investments.

10.4. Conclusion

Various reasons lie at the foundation as to why rational governance is currently not possible, these issues in governance give clues towards intervention strategies. These reasons are found in the policy discourses due to different water usage preferences, and that not all values and stakeholders are involved in policy making. Moreover, there is insufficient information sharing, non-adjustment of regulations to local conditions, regulations are too general, there is conflicting regulation, lack of enforcement, a lack of transparency of funds, and there is currently not enough monitoring data.

The clues towards intervention strategies are found in the expansion of the knowledge on the water system to make modeling and more detailed governance possible, although current knowledge is sufficient for general policy making. Further knowledge building could be in the form of mapping out water requirements per specific group of stakeholder, or drought and salinity withstanding crops or shrimp stocks. Further strategies are found in the increase of awareness, although this should be done in combination of devising policies that could improve the farmer's their economic situation. Moreover, multi-lingual information or personal visits could be intervention strategies to improve awareness, but it is important to realize harmonization of current governance (to avoid policy discourses) and economic development of rural areas.

Further intervention strategies could be found in the present absence of full stakeholder involvement, for instance, local governments should be included in policy making, environmental standards and law enforcement should be placed above economic interests, and decision-making powers and management responsibilities need to be developed to the local scales. Local citizen, all governmental layers, and interest group feedback should be considered in governance together with clear communication of incentives related to the sustainable utilization of the water system. Additionally, scientific knowledge should be involved in policy, including the sharing of data between scientific interest groups (e.g. local universities) and the government. Furthermore, there is a need for further harmonization of legal documents and coordination of government stakeholders and their responsibilities (e.g. between the MARD and the MONRE), together with an increase of a bottoms up responsibility taking for the VMD, targeting multiple subsectors simultaneously.

Furthermore, harmonization of the regulations themselves should be considered since there is confusion relating to enforcement. This confusion occurs since the regulations on the water sector are dispersed, scattered, and with occasionally identical contents, different hierarchies, and contradiction. Environmental regulation should ensure environmental protection, sanctions need to be adjusted to avoid non-compliance to be the most economical choice, policies need to be enforced, and capacities of local governments should be improved. Consequently, the balance between enforcement and equity towards local conditions needs to be found, starting with a simpler and more coherent legal framework and the usage of an open legal database. Regulations should also consider last-resort options such as relocation or non-enforcement where the equity to enforcement balance cannot be found.

Additional strategies are to be found in the transparency for the division of funds, donor system compatibility, and especially in the improvement of monitoring. Although, unfortunately, monitored data often stays within the government departments themselves, and there is not a proper database system. Therefore, an intergovernmental open or publicly accessible database to enable a more streamlined information flow, more stakeholder involvement, and an increase of knowledge-based policy making could be another intervention strategy.

Limitations of these intervention strategies are in the current deep institutional arrangements and backgrounds, which cannot logically be expected to change anytime soon. However, the trade-offs between intervention and environmental degradation need to be carefully considered.

11. Discussion and conclusion

11.1. Introduction

This section covers the discussion and the conclusions of this research and functions as a wrap-up of the whole, where first the limitations of the WEG assessment framework are discussed, followed by the methodological limitations. After that, the conclusions are discussed, superseded by the recommendations towards rational groundwater governance.

11.2. Limitations of the research

11.2.1. Limitations to the WEG assessment framework for rational governance

For the assessment of the system's rational governance, the WEG assessment framework is used, which has its particular strengths and weaknesses. The strengths of this assessment framework would be in its brevity since it is based on acknowledged assessment methods such as the Engineer's Method of Hoogerwerf and the Ten Building Blocks approach, and merges assessment criteria together where it makes sense to combine them. For example, it treats dispute settlement as a part of the regulations criterion as such processes are done within the boundaries of the law. The WEG assessment criteria elucidate the functioning of each criterion as related conditions to each other's functioning. For instance, in a fictitious system, the system knowledge might be sufficient together with regulations, financial stability and the values and policy discourses, but if there is no full stakeholder involvement, rational governance is still not possible. Whereas rational governance is illustrated by the functioning of governance as a whole, hence the five cogwheels that connect as in a figurative machine, with the system knowledge divided into two sub-wheels to make a distinction between the state of a system and its drivers. The rational governance of the system is therefore represented by the machine's cog-wheels running.

The WEG assessment framework's simple buildup makes that it can also be used in practice, whereas e.g. the Ten Building Blocks approach is rather demanding and complex to understand. Another strength of the WEG assessment framework is that it can be used for any field of environmental governance since it is not bound to water governance. For example, the WEG assessment framework could also be used to map out the rational governance of forest fires in e.g. California, or for smog pollution problems in vast metropolitan areas. Moreover, the WEG assessment framework does not have to be fully elaborated to still come to an assessment, as a simple list with bullet points could still give a rather fair overview either. Another strength is that by showing every issue related to each criterion, the opposite of that issue is a clue towards a potential policy prospect, which after assessing its strengths and weaknesses forms into an intervention strategy. These strengths make the WEG assessment framework far more practical to use than current other environmental governance assessment frameworks.

The weaknesses of the WEG assessment framework would be in its dependency on the respective environmental system it is used for, in the case of the VMD, which is essentially a data scarce system, there are fewer facets of the environment to describe. This dependency makes that the WEG assessment framework is likely to be more thorough in data-rich environments. Although, there could also be too much information, for instance, on the legal and institutional framework in Vietnam. Vietnam is amongst the top countries in the world for the creation of laws, which could imply another limitation to this assessment framework since some regulations or agreements could be overlooked. However, to minimize this shortcoming as much as possible in this study, extensive research on laws, regulations, legal documents, and other legal agreements has been conducted. Moreover, this limitation does only limitedly affect the outcome of the extent to which rational governance is possible since the regulations look rather elaborated at regards to groundwater management. The main limitation at regards to regulations and agreements is the lack of enforcement and the contradicting nature of specific laws.

11.2.2. Methodological limitations

The data from the surveys and the interviews formed a data set, and this data was analyzed based on the conditions of the WEG assessment criteria. The qualitative interview response rate was at 48.5% for the knowledge experts and 100% for the policy experts, and although lingual errors may have occurred, the results are likely to be correct as every possible precaution has been taken (e.g. professional translations for the policy experts and multiple transcripts for the knowledge experts). The survey response rate is at 100% since the surveys were held manually in Vietnamese, and in representative quantities in each commune of Vinh Chau District.

However, the validity of the survey data is dependent on the ability of the respondents to recall their groundwater usage, dug well depths (even though they were categorised), temporal aspects of land use and groundwater utilization, contact with the government and other details. Although farmers generally gave complete and detailed information to the survey, the groundwater usage on the aquaculture side is a bit vague since many of such farmers seem to have groundwater wells, but state not to use groundwater in certain or both seasons. This ambiguity could be linked to local policy, where aquaculture is not allowed to exploit groundwater in areas where saline intrusion affects the soil; Vinh Chau District is such an area. This restriction could mean that groundwater extraction insights would mainly count for non-aquaculture farms, but to gain even better insights into groundwater extraction, technical monitoring in situ would be recommendable.

Furthermore, the surveyed area is rather small and could be non-representative for Soc Trang Province, or the VMD in that regard. The results have shown that Vinh Chau District is renowned for onion farming and aquaculture, and that groundwater resources degradation is interlinked with the main agricultural activity in the respective area. This result could mean that facets of groundwater degradation could differ throughout different areas. Therefore, these results would account for coastal areas of Soc Trang Province, but would not necessarily count for the whole VMD. However, within the scope of this research, these results gave an indication towards similar research for more areas throughout the VMD. For a total view of the whole region, further research is recommended.

Limitations of the surveys due to socially desirable answers, possible limitations to the respondent's ability to recall quite technical details, and possible lingual errors could have occurred. Besides that, there could be lingual errors when the data was translated from Vietnamese to English, and lingual errors could also have occurred from the lingual understanding of Khmer or Chinese minorities amongst the respondents. However, to reduce the change of lingual misunderstanding, there was made use of a double questionnaire, one in English and one in Vietnamese. Since the survey questions were made using primarily multiple choice questions, one-on-one translation from Vietnamese and English questions was made possible, and there was only a limited need for translation provided for by help from the Can Tho University.

Besides a lack of literature, there is also a lack of information from the government, and most farmers cannot be contacted by phone or the internet, which means that the method selected for the survey was the most feasible one, with limitations for the dataset as a consequence. Besides that, the surveys were held in the dry season, which could have biased answers to some extent, although questions were asked about the whole year.

A further limitation could be due to a focus on English written literature. Such a limitation was empirically shown in a study done by Amano, González-Varo, & Sutherland (2016), stating that 64.4% of a Google

Scholar search on biodiversity and conversation are in English and that can give a bias and gap in understanding the global environment (Amano, González-Varo, & Sutherland, 2016). However, by means of further desk research English information from Vietnamese sources could still be found.

11.3. Overall conclusion

The environmental degradation of the VMD and Soc Trang Province is dire and is assessed on conditions for rational groundwater governance with the below research question in mind.

To what degree is rational groundwater governance possible in Soc Trang Province in the Mekong Delta, Vietnam?

Currently, rational groundwater governance is not possible in the VMD or Soc Trang Province, as shown by the WEG assessment framework. System knowledge is optimal, however, limited in regards to purposes such as modeling, not all values are considered, and there are policy discourses. Furthermore, stakeholder involvement is basically only for intergovernmental stakeholders which is in its current form even suboptimal as responsibilities are not always clear. Moreover, regulations and agreements are hampering to rational governance as regulations are double, contradict or cause further confusion and enforcement is lacking, which calls for a thorough review and harmonization of the current institutional – and legal framework. The financial stability is assessed last, and is deemed to be hampering to rational governance as well since transparency is suboptimal and monitoring is currently insufficiently exercised with data kept in-house. Possibilities are limited since system knowledge is available, but the incapacities of groundwater governance are of variable natures.

First off, the exclusion of various values in groundwater governance is a problem, as well as is the occurrence of policy discourses. These issues translate into a system where poverty leads to hampering of pro-environmental behavior (more than that awareness is a factor), and restrictions to groundwater resource extraction are not enforced by the local government, nor registered for by the citizen. Furthermore, aquaculture as a development strategy and structural measures against salinity intrusion led to conflicts and increased salinity intrusion due to different water usage preferences.

Secondly, there is insufficient stakeholder involvement, and not all responsibilities are considered, which is elucidated by ineffective intergovernmental co-management, inadequate coordination among actors, and falling short of the harmonization of legal documents with other laws and secondary regulation. There is a practice of water policy planning by means of targeting single subsectors separately without consideration to the integration of the complexity of water-related problems, leading to the adverse inappropriateness of current policy approaches. The paradigm shift from an exclusively technical experts' task under state patronage to participatory management and stakeholder involvement seems to be virtually non-existent in the VMD, except for government stakeholders although local authorities are often excluded from policymaking and planning.

Thirdly, regulations seem to be there, although it is in a somewhat unorganized way and enforcement seems to be generally lacking. There appears to be a rather complex set of regulations nationally, although provincially regulations seem to be limited and the absence of officially issued respective DONRE guidelines hampers implementation. Confusion is caused by the often identical contents, different hierarchies and contradictions in regulations, environmental regulation is inadequate for environmental protection, while enforcement in Vinh Chau District appears to be a struggle with a lack of financial and technological means.

Finally, There are various financial arrangements, from governmental origin (e.g. taxes) and donor support (e.g. monitoring stations), but water resources are not measured and maintaining externally funded monitoring stations is complex. Governmental monitoring occurs and is planned for a considerable revision, but data is not shared. However, daily groundwater extraction volumes are not monitored, and government projects stop at information and mobilization stages. International donors play a role regarding finances and monitoring, but transparency, a lack of proper mechanisms for the utilization of financial support, and a reliance on donor support in Soc Trang Province are a concern.

Current groundwater extraction is unsustainable and results in environmental degradation such as the declines of hydraulic heads and eventually subsidence. To come to a more sustainable system providing the continued water system requirements for the VMD, as the global and national rice bowl and a vital area in economic and agricultural aspects, the current capacities of groundwater governance need to be of a more rational nature.

11.4. Recommendations

How to proceed? When current groundwater governance would be up for a transformation towards rational groundwater governance, a broad array of actions can be taken. Intervention strategies have been suggested based on the available knowledge but should be carefully considered in line with its weaknesses and strengths. However, in the long-term, rational groundwater governance might be possible when government data is easier to gain access to, enforcement mechanisms are in place, full stakeholder involvement is ensured, and full harmonization of policies, legal documents, responsibilities, cooperation and coordination between governmental authorities occurs.

The recommendations to supplement governance with, can be divided into technical measures, (e.g. changing permissible hydraulic head declines from the soil to the confined aquifer, or artificial recharge), adaptive measures (e.g. climate resilient crops and water saving measures), awareness measures (e.g. providing multilingual information on sustainable practices), and development measures, such as livelihood improvement. Moreover, it would be beneficial to allow the broadening of the stakeholder involvement, to include local stakeholders in policy making and local residents to give feedback. There is a rationale to call for a governance overhaul, by means of the enforcement of policy implementation on the local scales by the ministry level governments and the development of specific guidelines from the ministry level government for the provincial government. In addition, adjustments of regulations to make them appropriate for environmental protection, and to avoid deliberate non-compliance for economic reasons can be part of such an intervention. Furthermore, it can be recommended to enable the harmonization of regulation, coordination, allocation of responsibilities, and enforcement mechanisms, to enable the enforcement, transparency of funds and a proper (and modern) database system for full (or intergovernmental) data sharing. In addition, the acknowledgement of lay and scientific knowledge by government actors into governance would be beneficial as it can broaden governmental understanding of the water system.

Policy interventions could be to assess to what extent harmonization of current regulations, agreements, coordination, and responsibilities could fit into the current institutional and legal framework. As well as to find out to what extend stakeholder involvement can be improved together with better access to government and scientific data. These and more intervention strategies could make rational groundwater governance possible in Soc Trang Province and the VMD. However, it can be recommended to find out to what extent the aforementioned intervention strategies would fit into the Vietnamese current institutional and legal framework with regard to groundwater management. This intervention is critical as the current frameworks are rather confusing to local authorities. Furthermore, there seems to be a gap in the development of national regulation and governance to the local scales.

Furthermore, the inclusion of more actors in participatory management would allow for further stakeholder involvement in groundwater governance. Moreover, open sharing of water-related information could make rational governance easier as it leads to further inputs that the government can work with, e.g. from scientists or other interested individuals. To this end, the scientific community should conduct research on what is required for this sharing of information.

It can be recommended for scientists on both the local as on the global scale to continue doing research on the VMD regarding further approaches to rational governance and possibly further intervention strategies. Moreover, further detailed knowledge of the natural sciences sort is required to enable advanced environmental analysis such as modeling. With such knowledge, policies could be put in models or serious gaming decision tools so that their effects can be predicted, leading to more knowledge-based decision making.

Such intervention strategies can prove to be rather demanding on the current institutional backgrounds of the nation. However, the rational governance of water resources is a must for the continued existence of the VMD as the rice bowl of Vietnam and the world in its current productivity levels and economic potential. Consequently, the intervention strategies presented are a way forward towards rational groundwater governance and governance and need to be investigated further. The question as to how such strategies can be made more feasible for the Vietnamese government is a rather difficult one and would be an interesting topic for further research.

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Appendices

Appendix I: Questionnaires for Farmers and Experts

Appendix I.1. Questionnaire for agriculture/aquaculture/livestock farmers

Dear Respondent,

Thank you for taking the time of answering this survey. This survey aims to map out the knowledge from practice, for Soc Trang Province. The reason of this survey is to research the availability and provision of knowledge at regard to the improvement of environmental functioning and water resource efficiency in farms in the Mekong Delta Region. To find out what the practical expert knows, I would like to ask you for your practical experience and ideas.

The information provided will be analyzed completely anonymous, and your privacy is guaranteed. Your answers will be used solely for academic purposes. The answers are to your benefit because the knowledge generated can yield to better yields due to a better understanding of the environment. This survey takes around 20 - 30 minutes to answer.

Put coordinates as seen on (GPS) device: ……………………… , ………………………
(longitude and latitude)

Section I

Do you wish your personal details to be anonymous? ☐ Yes ☐ No

Please indicate on the **map** your neighborhood and please write down the name of your neighborhood here: ____

Full name: ____

Gender: ☐ Male ☐ Female

Age: ___________

What is your Ethnicity? ☐ Kinh People ☐ Khmer People ☐ Chinese People ☐ Other:___________

1. What is your educational level?

☐ Elementary level ☐ Secondary level ☐ Senior level ☐ Vocational level ☐ College or University

2. What is your current Farm-Type(s)?
   - ☐ Agriculture: ____
   - ☐ Animal Stocks: ____
   - ☐ Aquaculture: ____
   - ☐ Mixed, specified:
     - ☐ Agriculture + Aquaculture
     - ☐ Agriculture + Animal Stocks
     - ☐ Aquaculture + Animal Stocks
   - ☐ Other: ____

3. Which crops/animal stock(s)/aquaculture product are you farming? (**more answers are possible**)
   - ☐ Cash crops – such as sugarcane or soybeans
   - ☐ Corn
   - ☐ Fruits – such as coconut
   - ☐ Grasses - such as Rush
   - ☐ Nuts – such as or peanuts
   - ☐ Rice – such as Milles rice or Paddy Rice
   - ☐ Spices
   - ☐ Tuberous roots – such as Cassava or sweet potatoes
   - ☐ Vegetables – such as eggplant or beans
   - ☐ Other agricultural product
   - ☐ Buffalo and Cattle
   - ☐ Chicken

**such as goose, pigeon, turkey, quail, serpent, python and crocodile, etc.*

- ☐ Pigs
- ☐ Water fowl
- ☐ Other livestock* product
- ☐ Bivalve – such as oysters or clams
- ☐ Carp – such as silver carp, common carp, grass carp, bighead carp, catla, rohu or mrigal.
- ☐ Catfish – such as pangasius
- ☐ Crustacean – such as shrimp, crabs or lobsters
- ☐ Perciform (perch like) – such as snakehead, grouper or barramundi
- ☐ Tilapia – any species
- ☐ Univalve – such as sea snails
- ☐ Artemia (Brine Shrimp)
- ☐ Elongated goby (*Pseudoapocrytes elongates, Cá kèo)*
- ☐ Other:____

4. Is there any member in your family that takes part in any social organization? **(More answers possible)**
   - ☐ Ho Chi Minh Communist Youth Union
   - ☐ Communist party of Vietnam
   - ☐ Women Union
   - ☐ Farmer Union
   - ☐ Other: ____

5. What is the status of your livelihood? [income levels are based on regulation: 09/2011/QĐ-TTg]
   - ☐ High Income (> 6.2 Million VND/person/year)
   - ☐ Medium Income (> 4.8 – 6.2 Million VND/person/year)
   - ☐ Low Income (< 4.8 Million VND/person/year)

6. How many people are there currently in your family?
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other_______________

7. Did your family drill more wells after the year of 2008? [because of regulation: 11/2008/QĐ-UBND]
   ☐ Yes ☐ No ☐ I don't know

8. When did you start your farm on this location?
   In the year: _____________

9. How many wells did you start with initially?
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other____

10. How many wells do you currently own?
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other____

11. How many wells do you have at the moment (2016) that you don't often use?
    ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other____

12. How deep was the well drilled? **(The distance from surface to the water resource (aquifer) in meters)**

☐ Pump 1:	☐ <50 m	☐ 50-100 m	☐ 100-150 m	☐ 150 -200m	☐ Other____
☐ Pump 2:	☐ <50 m	☐ 50-100 m	☐ 100-150 m	☐ 150 -200m	☐ Other____
☐ Pump 3:	☐ <50 m	☐ 50-100 m	☐ 100-150 m	☐ 150 -200m	☐ Other____
☐ Pump 4:	☐ <50 m	☐ 50-100 m	☐ 100-150 m	☐ 150 -200m	☐ Other____
☐ Pump 5:	☐ <50 m	☐ 50-100 m	☐ 100-150 m	☐ 150 -200m	☐ Other____

13. During which month is it the easiest for your pump to extract water? **(Multiple answers possible)**

☐ January	☐ February	☐ March	☐ April	☐ May	☐ June
☐ July	☐ August	☐ September	☐ October	☐ November	☐ December

14. During which month is it the hardest for your pump to extract water? **(Multiple answers possible)**

☐ January	☐ February	☐ March	☐ April	☐ May	☐ June
☐ July	☐ August	☐ September	☐ October	☐ November	☐ December

15. How much money (in Vietnamese Dong) did you pay for drilling the well?
    VND: _____________million
16. When did you drill these well(s)? **(Give an answer per well from 1 up to 5 wells, more if applicable)**
    In the year: ______, In the year: ______, In the year: ______, In the year: ______, In the year: ______,

17. How many wells do you have at the moment, which are regularly in use per amount of time?

	Amount of wells being often in use					
At the moment	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well
1 year ago (2015	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well
3 years ago (2013)	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well
5 years ago (2011)	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well
7 years ago (2009)	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well
9 years ago (2007)	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well
11 years ago (2005)	☐ 0 well	☐ 1 well	☐ 2 well	☐ 3 well	☐ 4 well	☐ 5 well

Section II

1. Have you experienced a decrease or increase of product or crop gain over the last 10 years?
    - ☐ Yes
        - ☐ An increase, specified:
            - ☐ + > 50%
            - ☐ + 40% - 50%
            - ☐ + 30% - 40%
            - ☐ + 20% - 30%
            - ☐ + 10% - 20%
            - ☐ + 1% - 10%
        - ☐ A decrease, specified:
            - ☐ - > 50%
            - ☐ - 40% - 50%
            - ☐ - 30% - 40%
            - ☐ - 20% - 30%
            - ☐ - 10% - 20%
            - ☐ - 1% - 10%
    - ☐ No
    - ☐ I do not know

2. Do you use improved agricultural farming techniques? (such as drip irrigation for example)
   - ☐ Yes, ____________________
   - ☐ No
   - ☐ I do not know
3. Did you change crops in the last 10 years' forced by environmental changes?
   - ☐ Yes, I changed my crops completely
   - ☐ Yes, I changed my crops partially
   - ☐ Yes, but I changed my crops only to a minor extent
   - ☐ No
   - ☐ I do not know
4. Would you say that you are negatively affected by environmental changes in your farm?
   - ☐ Yes, significantly
   - ☐ Yes, but not that much
   - ☐ Yes, but only a little bit
   - ☐ No
   - ☐ I do not know
5. How big is your farm? **(Fill in the unit that applies, if the farmer gives a different unit, note that too)**
   ______________ meter^{2,} ______________ ha, ______________ miles^2
6. One example of an environmental change is the problem of subsidence, which basically means the ground is slowly sinking. Did you experience subsidence? **You can recognize it, i.e. cracks in your wall.**
   - ☐ Yes
   - ☐ No
   - ☐ I do not know
7. Did you change your farming system in the last 10 years, forced by environmental changes?
   - ☐ Yes
   - ☐ No
   - ☐ I do not know
8. Did you in the last 10 years sell your (top) soil to companies
   - ☐ Yes
   - ☐ No
   - ☐ I do not know
9. How much soil did you sell soil and how often? ______/month **(State any unit i.e. rice sacks full)**
10. Do you think your soil is drier now than it was ten years ago? **Please provide one answer per season**

	A lot drier	**A bit drier**	**No change**	**A bit wetter**	**A lot wetter**	**I don't know**
Wet season	☐	☐	☐	☐	☐	☐
Dry Season	☐	☐	☐	☐	☐	☐

11. How many times per day do you irrigate your field? **(Please provide one answer per season)**
    ☐ Wet Season: ____________ ☐ Dry Season: ____________
12. Can you give an estimate on your water usage per day for your farm, per season? (**Please provide one answer per season)**

	Wet season	Dry Season

Usage per day	☐ < 1 hour	☐ < 1 hour
Usage per day	☐ 1-3 hours	☐ 1-3 hours
Usage per day	☐ 3 – 5 hours	☐ 3 – 5 hours
Usage per day	☐ 5 – 7 hours	☐ 5 – 7 hours
Usage per day	☐ 7 – 9 hours	☐ 7 – 9 hours
Usage per day	☐ 9 – 11 hours	☐ 9 – 11 hours
Usage per day	☐ I leave it on all the time	☐ I leave it on all the time
Usage per day	☐ I do not know	☐ I do not know

13. Can you give an indication of the capacity of your pump(s)? **(Should be numbered on the pump.)**
Pump 1 _____ kW, Pump 2 _____ kW, Pump 3 _____ kW, Pump 4_____ kW, Pump 5_____ kW

Note: Incase other units are given (for example horsepower), write those down too.

14. Can you give me an indication of the age(s) of your pump(s)? **(Time since you purchased it.)**
Pump 1: _____ [Year], Pump 2: _____ [Year], Pump 3: _____[Year], Pump 4: _____ [Year], Pump 5: _____ [Year]

15. Do you use a device (amplifier) that allows your pump to pump more water? If yes, and give an indication of the capacity of this device? **(Should be numbered on the device.)**
Pump 1: ______ kW, Pump 2: ______ kW, Pump 3: ______ kW, Pump 4: ______ kW, Pump 5: ______ kW

16. Can you give an estimation of your average monthly electricity bill per year from the Vietnam Electricity Company EVN?

	Dry season	Wet season
At the moment	☐ ______thousand đồng	☐ ______thousand đồng
1 year ago (2015	☐ ______thousand đồng	☐ ______thousand đồng
3 years ago (2013)	☐ ______thousand đồng	☐ ______thousand đồng
5 years ago (2011)	☐ ______thousand đồng	☐ ______thousand đồng
7 years ago (2009)	☐ ______thousand đồng	☐ ______thousand đồng
9 years ago (2007)	☐ ______ thousand đồng	☐ ______thousand đồng
11 years ago (2005)	☐ ______ thousand đồng	☐______ thousand đồng

17. Can you give an estimation of your average monthly fuel or gasoline costs per year?

	Dry season	Wet season
At the moment	☐ ______ thousand đồng	☐ ______ thousand đồng
1 year ago (2015	☐ ______ thousand đồng	☐ ______ thousand đồng
3 years ago (2013)	☐ ______ thousand đồng	☐ ______ thousand đồng

5 years ago (2011)	☐ ______ thousand đồng	☐ ______ thousand đồng
7 years ago (2009)	☐ ______ thousand đồng	☐ ______ thousand đồng
9 years ago (2007)	☐ ______thousand đồng	☐ ______ thousand đồng
11 years ago (2005)	☐ ______thousand đồng	☐ ______ thousand đồng

18. How many times do you refill your pump with fuel? ________________________ times
19. What are your thoughts about your daily water usage in general? **(One answer per season)**

In general	**Dry season**	**Wet season**
☐ It increased a lot	☐ It increased a lot	☐ It increased a lot
☐ It increased little	☐ It increased little	☐ It increased little
☐ It remained the same	☐ It remained the same	☐ It remained the same
☐ It decreased little	☐ It decreased little	☐ It decreased little
☐ It decreased a lot	☐ It decreased a lot	☐ It decreased a lot
☐ I do not know	☐ I do not know	☐ I do not know

20. Do you also use other sources for water **(More answers possible)**

☐ Surface Water	☐ Always	☐ Half of the time	☐ Rarely	☐ Other:_____
☐ Rainwater Storage	☐Always	☐ Half of the time	☐ Rarely	☐ Other:_____
☐ Seawater	☐ Always	☐ Half of the time	☐ Rarely	☐ Other:_____

21. What role do you see for the local government to help you with environmental problems? **(More answers possible)**
    - ☐ The (local) government has a role in providing information
    - ☐ The (local) government has a role in providing funds / subsidies
    - ☐ The (local) government has a role in solutions by engineering
    - ☐ The (local) government has a role in providing general help
    - ☐ Other
    - ☐ I do not know
22. Did you ask help from the (local) government? Please specify.
    - ☐ Yes,
        - ☐ I asked the (local) government for information
        - ☐ I asked the (local) government for funds/subsidies
        - ☐ I asked the (local) government for solutions by engineering
        - ☐ I asked the (local) government for other help
    - ☐ No
    - ☐ I do not know
23. Did you receive help from the (local) government? Please specify.
    - ☐ Yes,
        - ☐ The (local) government gave information
        - ☐ The (local) government gave funds/subsidies
        - ☐ The (local) government made solutions by engineering
        - ☐ The (local) government helped otherwise
    - ☐ No
        - ☐ The (local) government did not help me at all
        - ☐ The (local) government did not help me enough
        - ☐ The (local) government said they would help later

- I did not ask them for help
- I do not know

24. Did your family receive help/ support from any organization (such as an NGO) after requesting this?
    - No, I didn’t ask for help or support
    - Yes, but I didn’t ask for help or support
    - No, I did ask for help or support
    - Yes, I did ask for help or support
    - I don’t know

25. Why did you choose the pumps that you have now?

____

26. Does your water taste Salty?

☐ Yes ☐ No ☐ I do not know

27. Does your farm have acid sulfate soil? Did this increase since the last 10 years?

____

Section III

1. Have you registered for the groundwater exploitation license?
   ☐ Yes, from the start ☐ Yes, but later ☐No, but I’m planning to ☐ No

2. Which time in the day do you, on average extract the most groundwater? **(Please provide an answer for the year and per season)**

General	Dry Season	Wet Season
☐ Early Morning (5:00 am - 9:00 am)	☐ Early Morning (5:00 am - 9:00 am)	☐ Early Morning (5:00 am - 9:00 am)
☐ Morning (9:00 am – 13:00 pm	☐ Morning (9:00 am – 13:00 pm	☐ Morning (9:00 am – 13:00 pm
☐ Afternoon (13:00 pm - 17:00 pm)	☐ Afternoon (13:00 pm - 17:00 pm)	☐ Afternoon (13:00 pm - 17:00 pm)
☐ Early Evening (17:00 pm - 21:00 pm)	☐ Early Evening (17:00 pm - 21:00 pm)	☐ Early Evening (17:00 pm - 21:00 pm)
☐ Late Evening (21:00 pm – 00:00 am)	☐ Late Evening (21:00 pm – 00:00 am)	☐ Late Evening (21:00 pm – 00:00 am)
☐ Night (00:00 am – 05:00 am)	☐ Night (00:00 am – 05:00 am)	☐ Night (00:00 am – 05:00 am)

3. Which effects of governance would you regard as having negative effects for your farm?
   - Policies that restrict the amount of wells I can have
   - Policies that restrict the water I can extract
   - Policies that advocate towards my economical yields
   - Other:________

4. Do you think that exploitation of groundwater has systematic impacts on the lowering of the water table?

   ☐. Yes ☐. No ☐. Maybe ☐. I don't care ☐. I don't know

5. Would you say that for management of groundwater resources and implementation of water governance, the government should consider to get the local people's thoughts and concerns before promulgating a legal document?
   ☐ Yes ☐ No ☐ I don't know

Appendix I.2. Questionnaire for Knowledge experts

Dear respondent,
Thank you for taking the time of answering this interview. This interview aims to map out the knowledge from professionals in science, for Soc Trang Province. The reason of this interview is to research the availability and provision of knowledge at regard to the problem of subsidence in the Vietnamese Mekong Delta Region. Subsidence is a problem in this region since the systematic lowering of the surface and the rising sea-level can cause damage to land and infrastructure. To find out what the expert knows, I would like to ask you for your experience and ideas.
Your answers will be used solely for academic purposes. In the report personal details are not included, this is merely for my own paperwork. Anonymity is therefore guaranteed. This interview has in total 7 open questions and takes approximately 20 minutes to answer. If some things are unclear, further elaboration will be given.

Name: ………
Address: ……………………………………………………………………………………………………….
Age: …….
Position: ………………………………………………………………………………………………………..
Organization: …………………………………………………………………………………………………
Gender: **Male** ☐ **Female** ☐

1. **Can you tell me something about your ideas on the mitigation or adaptation to the problem of subsidence?**

……

2. **Can you tell me something about your ideas on the certainty of available knowledge related to the problem of subsidence?**

……

3. **What are your thoughts on if there is a relation with the problem of subsidence and the current use of groundwater resources in Sóc Trăng Province? Please specify.**

……

4. **What are your opinions on whether there is sufficient knowledge available to address the problem of subsidence? Please specify.**

……

5. **Can you tell me something about your ideas on the rationality (based on knowledge and reason) of groundwater policy making?**

……

6. **Can you tell me something about whether there is a connection between these policies and the problem of subsidence?**

……

7. **To what extend do you think that there is sufficient knowledge for policy making from the central government (in Hanoi) regarding subsidence?**

……

Appendix I.3. Questionnaire for Policy experts

Dear respondent,
Thank you for taking the time of answering this interview. This interview aims to map out the knowledge from professionals in policy, for the Province. The reason for this is to research the availability and provision of knowledge at regard to the problem of subsidence in the Mekong Delta Region. Climate change is a problem in this region since the systematic lowering of the surface and the rising sea-level can cause damage to land and infrastructure. To find out what the expert knows, I would like to ask you for your experience and ideas.
Your answers will be used solely for academic purposes, towards the first steps to a new Delta Masterplan for the Mekong Delta. In the report personal details are not included, this is merely for my own paperwork. Anonymity is therefore guaranteed. This interview has in total 10 open questions and takes approximately 20 minutes to answer. If some things are unclear, further elaboration will be given.

Name: ………
Address: ………
Age: ………
Position: ………
Organization: ……………………………………………………………………………………………………
Department: ……………………………………………………………………………………………………
Gender: **Male** ◻ **Female** ◻

1. **Would you say that there are problems at regard to climate change in Sóc Trăng Province?**

……

2. **Could you name more environmental problems caused by climate change?**

……

3. **To what extend would you say salinization of the soil is an environmental problem?**

……

4. **What are your thoughts on the problem of subsidence and the current use of groundwater resources in Sóc Trăng Province? Please specify.**

……

5. **To what extend do you notice that the citizens are troubled by the problem of subsidence?**

……

6. **What could you tell me about the current strategies in (local) policy related to these problems?**

……

7. **To what extend are there implemented policies related to the problem of subsidence?**

……

8. **What are your opinions on whether there is sufficient knowledge available to address the problem of subsidence? Please specify.**

……

9. **To what extend are conditions available in your operational area to come to rational policy making?**

……

10. **To what extend do you think that there is sufficient knowledge from the central government regarding subsidence?**

……

Appendix I.4. Questionnaire for Pump Sellers

Do you wish your personal details to be anonymous? ☐ Yes ☐ No
Please write down the name of your neighborhood here:____
Full name: ____
Gender: ☐ Male ☐ Female
Age: ___________

Put coordinates as seen on (GPS) device: ………………………. , ……………………….
(longitude and latitude)

1. Can you give an indication on the capacity and power of the 3 most popular pumps that you sell? **(Should be shown on the pump)**

Pump 1 ____ [Horsepower (HP)], ____ [m^3 /h], _____ [Volt], ______ [Hz], Name of pump:_______

Pump 2 ____ [Horsepower (HP)], ____ [m^3 /h], _____ [Volt], ______ [Hz], Name of pump:_______

Pump 3 ____ [Horsepower (HP)], ____ [m^3 /h], _____ [Volt], ______ [Hz], Name of pump:_______

Note: Incase other units are given write those down too.

2. Do farmers often buy a device (amplifier) that allows their pump to pump more water? If yes, could you give an indication on the capacity and power of the 3 most popular devices? **(Should be shown on the device)**

Pump 1 ____ [Horsepower (HP)], ____ [m^3 /h], _____ [Volt], ______ [Hz], Name of device:_______

Pump 2 ____ [Horsepower (HP)], ____ [m^3 /h], _____ [Volt], ______ [Hz], Name of device:_______

Pump 3 ____ [Horsepower (HP)], ____ [m^3 /h], _____ [Volt], ______ [Hz], Name of device:_______

Note: Incase other units are given write those down too.

3. Are pumps generally sold secondhand or in new condition to farmers?
   - ☐ First-hand Pumps (new)
   - ☐ Second-hand Pumps (old/used before)
   - ☐ I don’t know

4. Do farmers generally buy electrical driven pumps or fuel driven pumps?
   - ☐ Electrical driven Pumps
   - ☐ Fuel driven pumps
   - ☐ I don’t know

5. Which pump(s) are most often being sold to agriculture farmers? **(Put name of pump here)**

____

____

6. Which pump(s) are most often being sold to aquaculture farmers? **(Put name of pump here)**

____

____

7. Which pump(s) are most often being sold to live stock/ breeding farmers? **(Put name of pump here)**

____

____

Appendix II: Aquifer cross-sections

The aquifer cross-sections of the aquifer taken at Nhà Mát, tp. Bạc Liêu, Bạc Liêu, Vietnam, which were regarded as representative for Vinh Chau District throughout this research. This aquifer is confined and the cross-sections give a somewhat 'three-dimensional' overview of the aquifer (Bui Tran et al., 2013). The figure on the next page shows the measurement location and gives an overview of the ratio of unconfined (in blue) and confined aquifers (in pink).

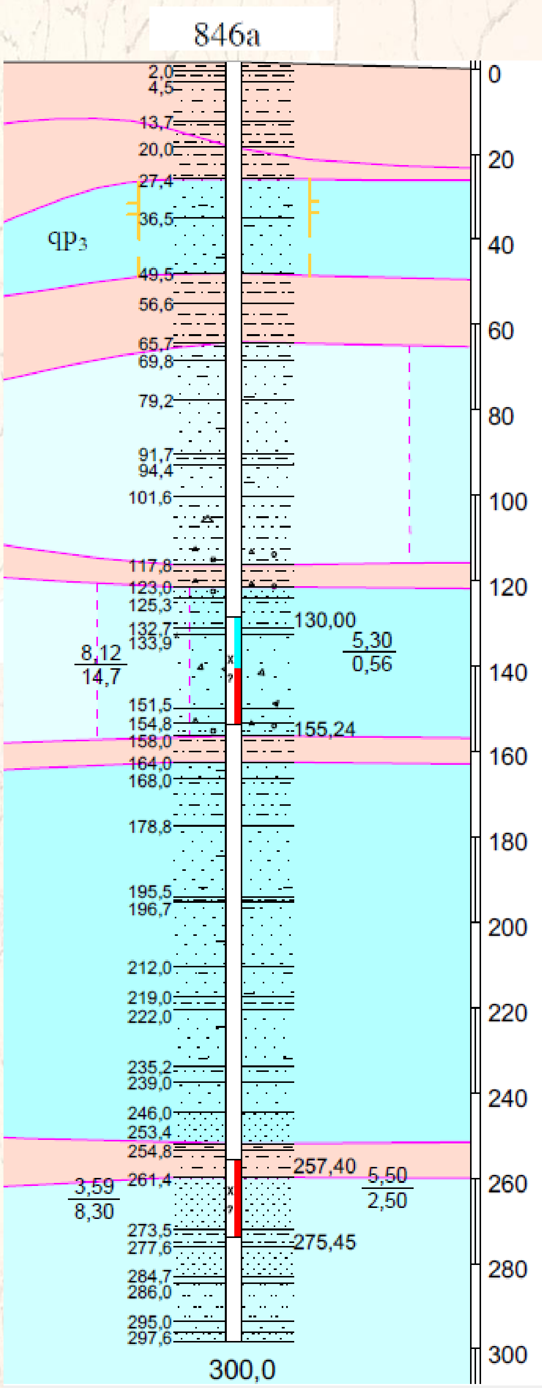


Figure II.1. Cross-section 846a

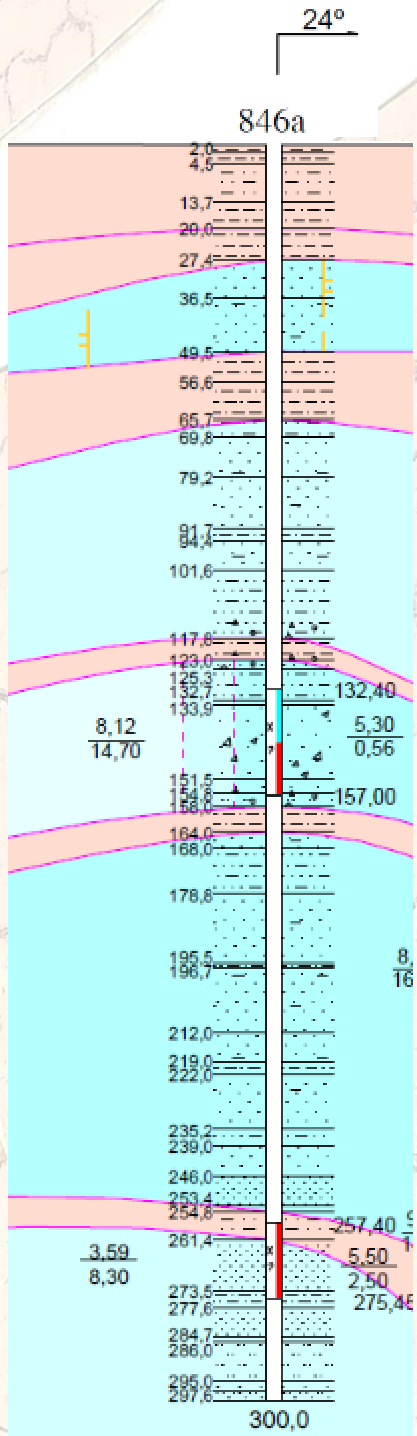


Figure II.2. Cross section 846a with a 24 degree angle

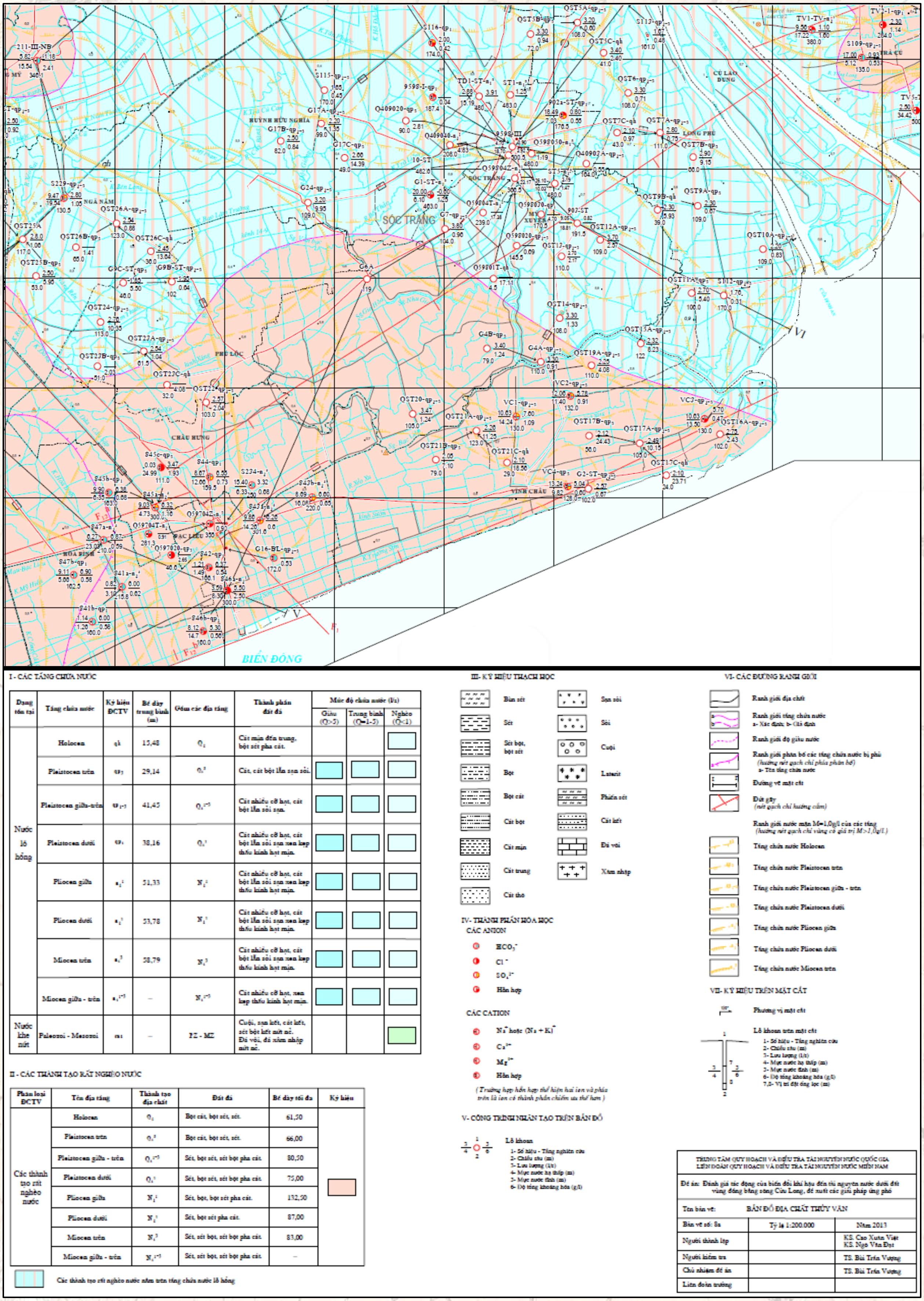


Figure II.3. Excerpt from the whole aquifer map from Bui Tran et al. (2013), concentrated on Soc Trang Province, and the drilling locations in the Bac Lieu Province.

Appendix III: Hydrogeological maps

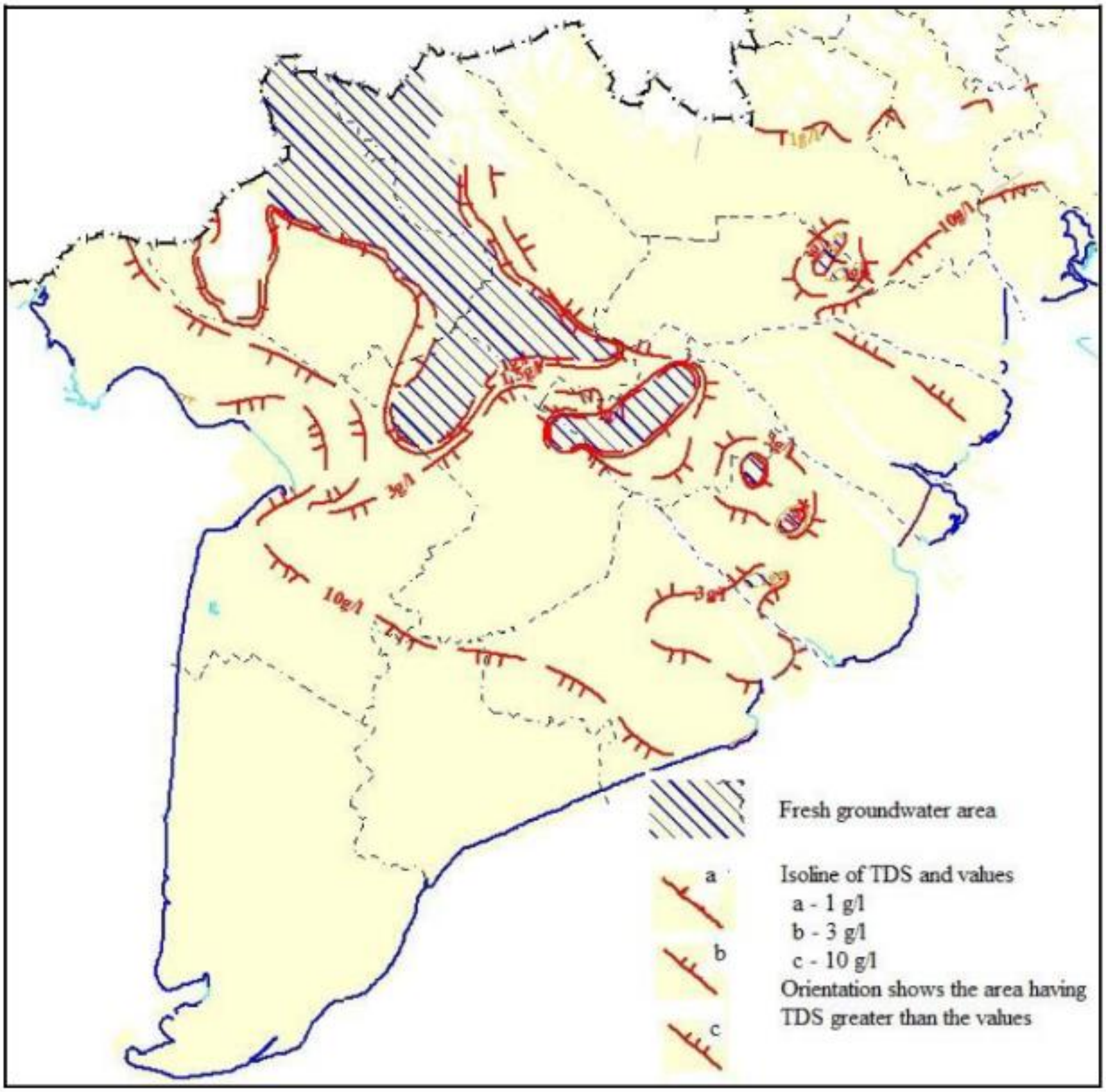


Figure III.1. Hydrogeological map of the Holocene aquifer (Deltares, 2011).

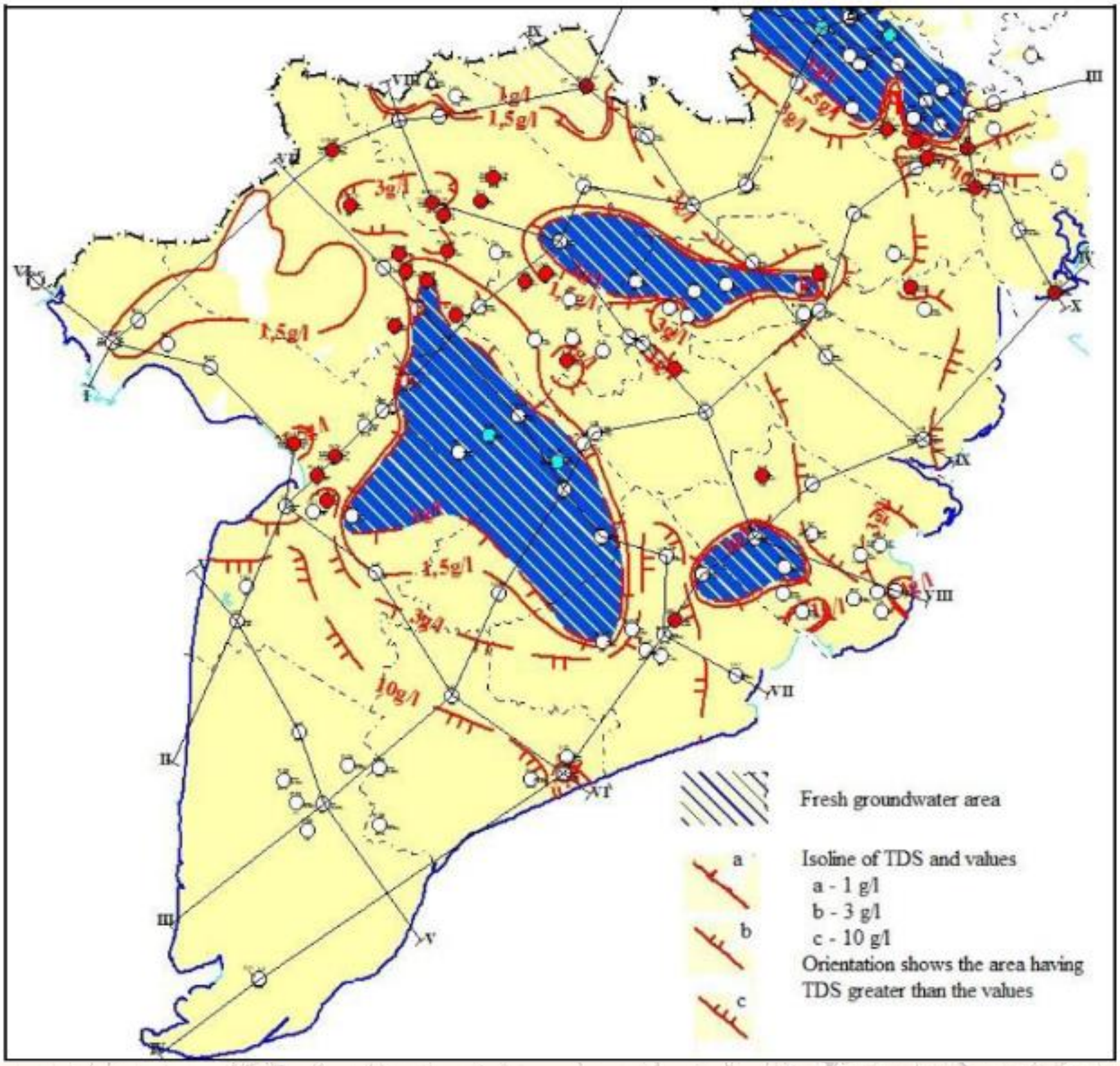


Figure III.2. Hydrogeological map of the Upper Pleistocene aquifer (Deltares, 2011).

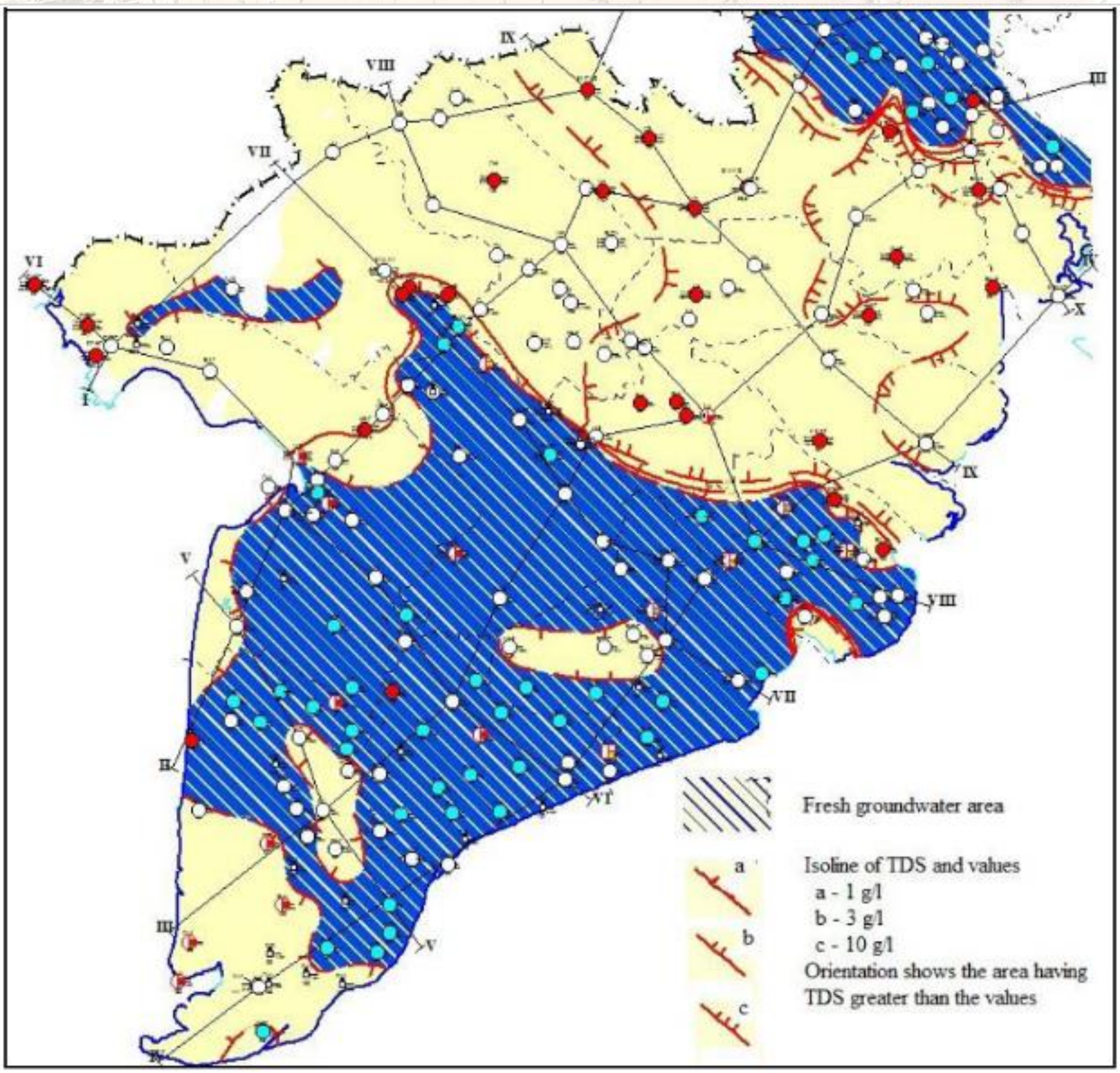


Figure III.3. Hydrogeological map of the Upper-Middle Pleistocene aquifer (Deltares, 2011).

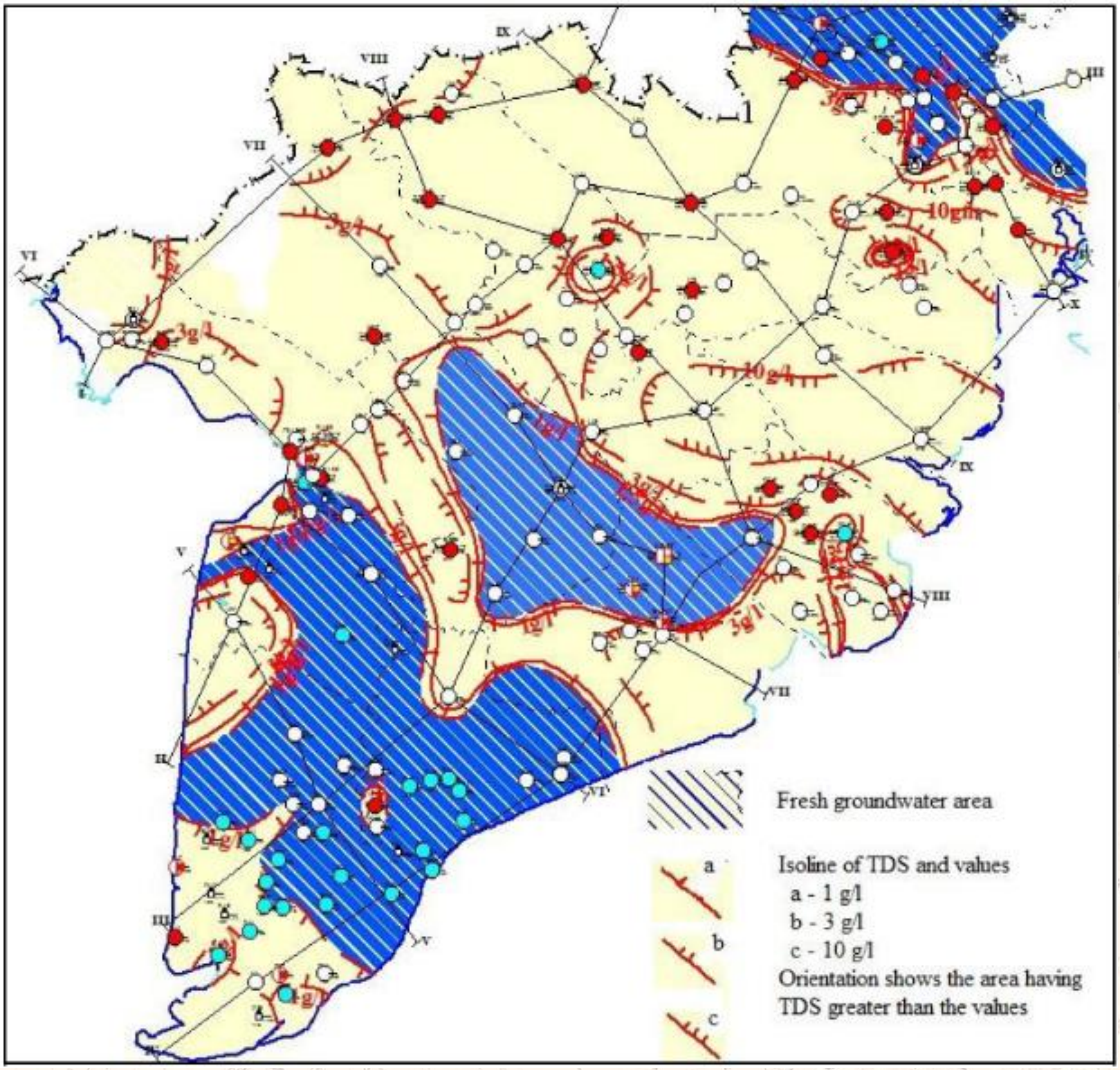


Figure III.4. Hydrogeological map of the Lower Pleistocene aquifer (Deltares, 2011).

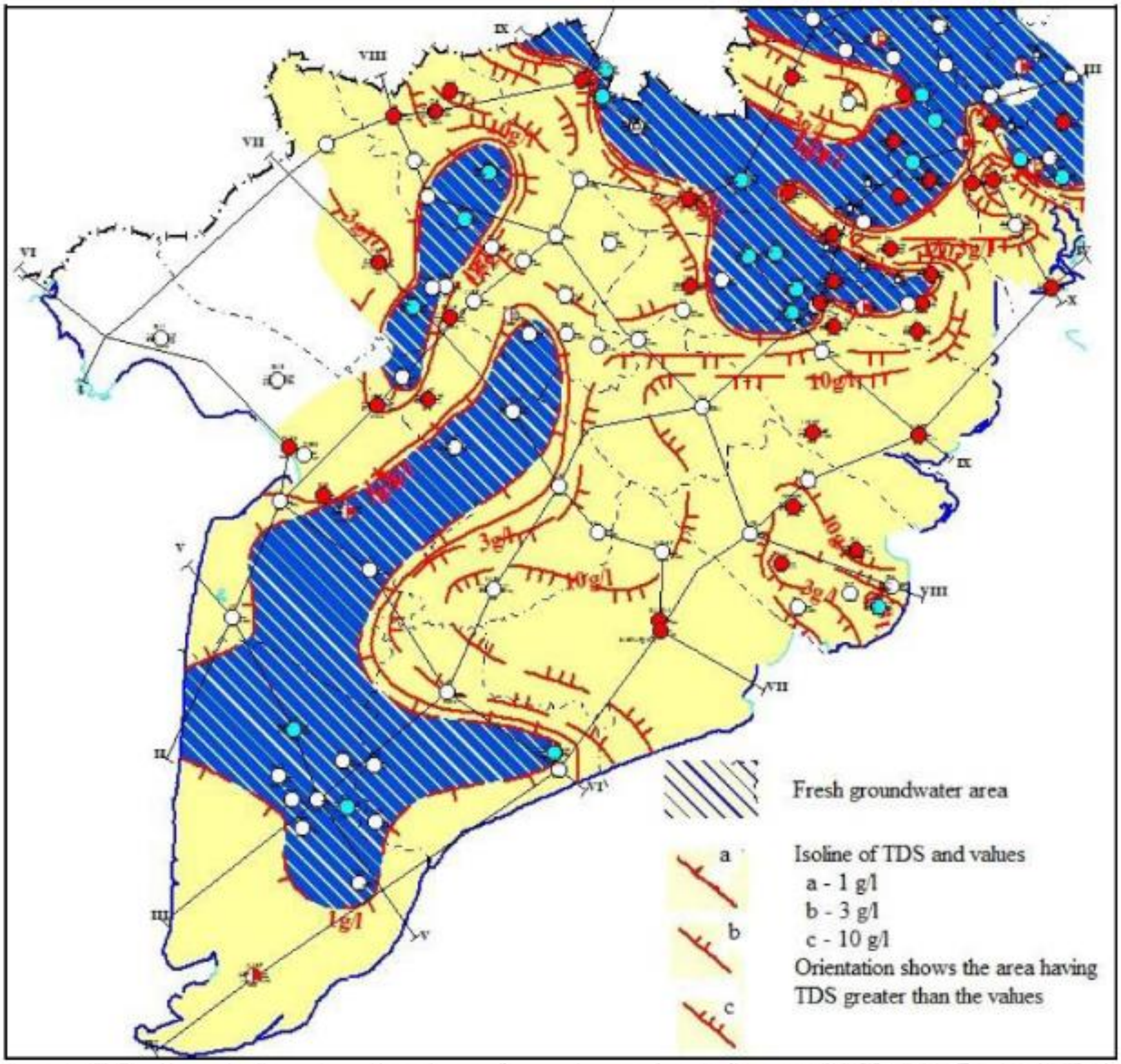


Figure III.5. Hydrogeological map of the Middle Pliocene aquifer (Deltares, 2011).

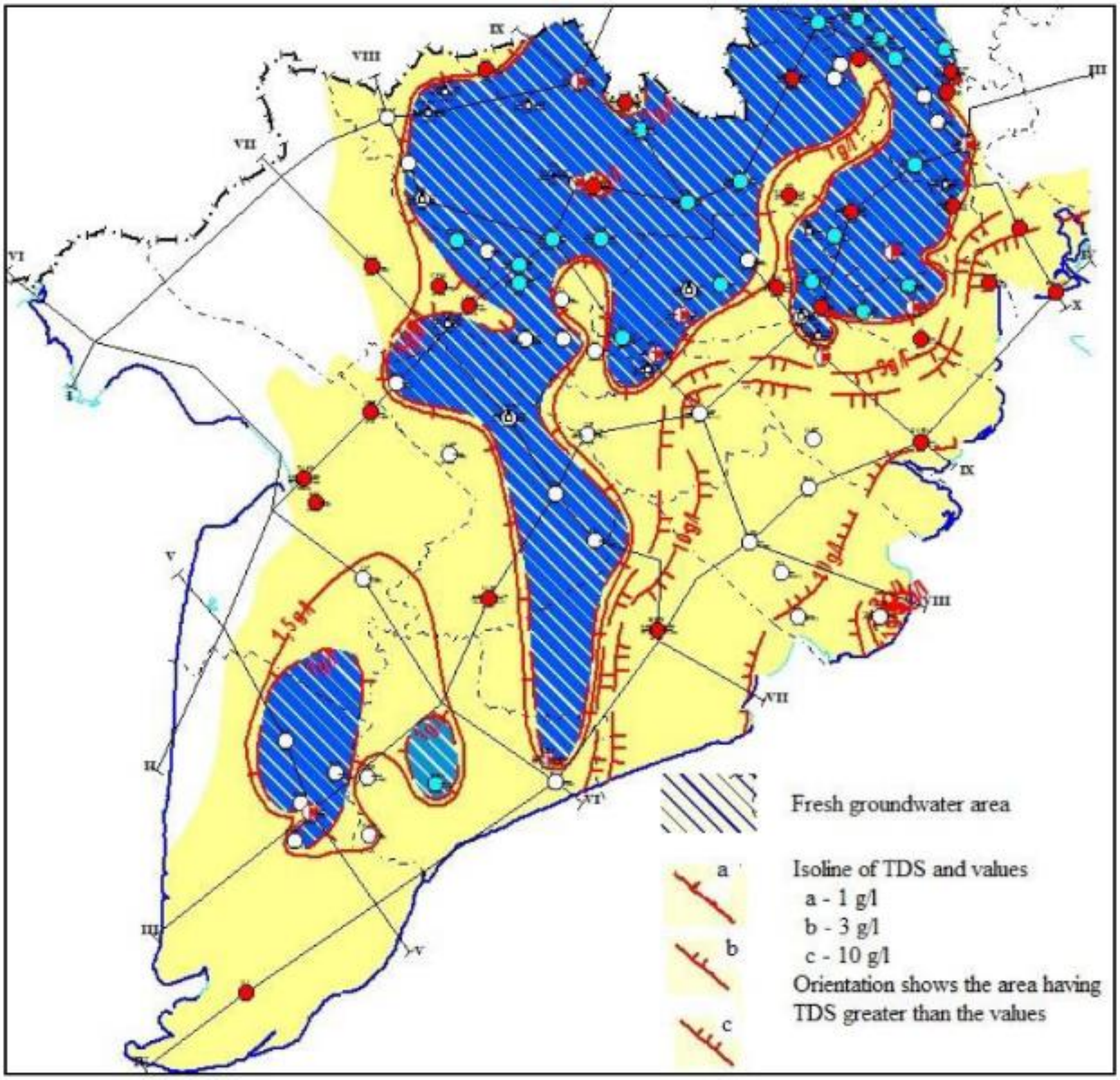


Figure III.6. Hydrogeological map of the Lower Pliocene aquifer (Deltares, 2011).

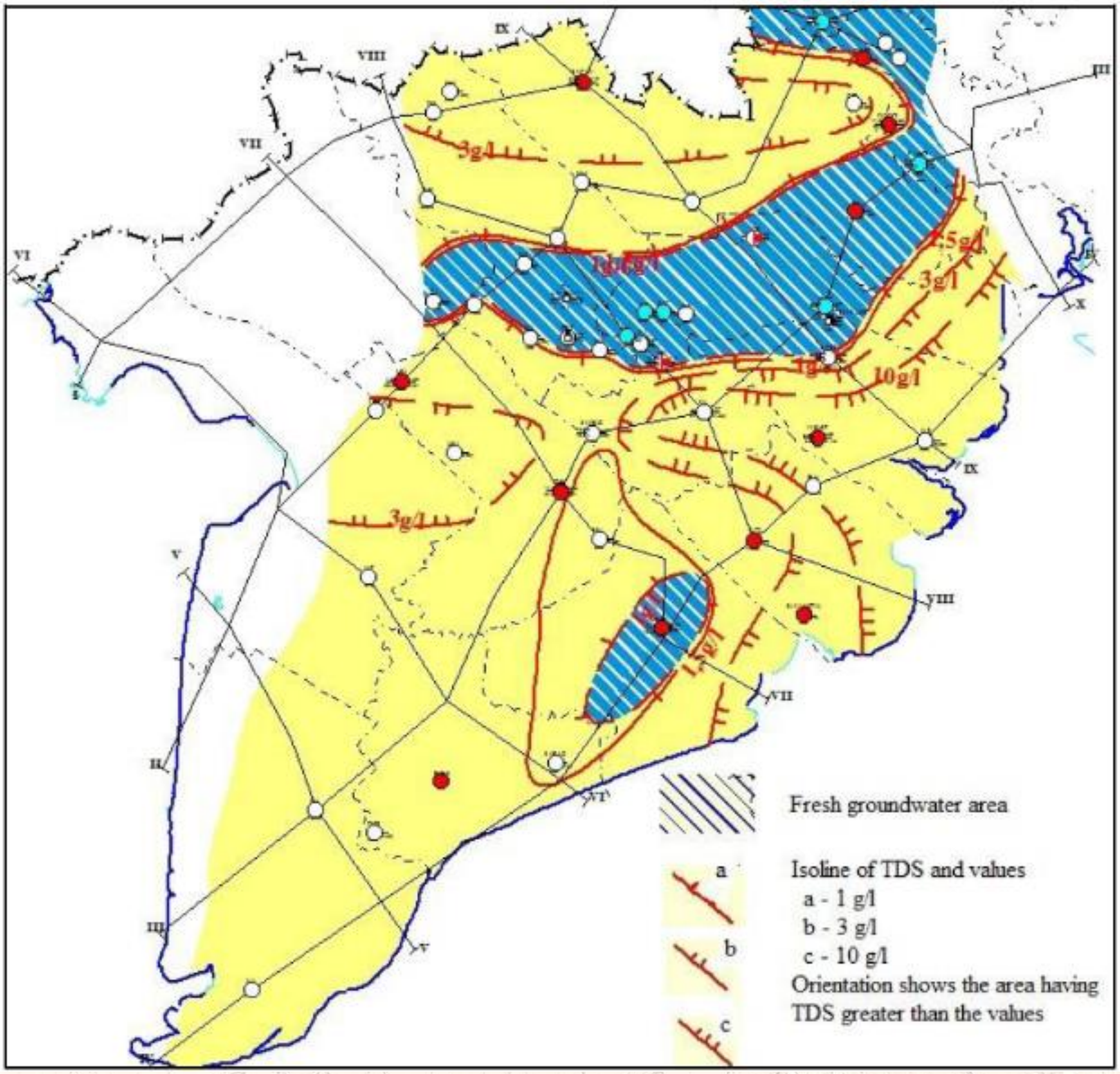


Figure III.7. Hydrogeological map of the Upper Miocene aquifer (Deltares, 2011).

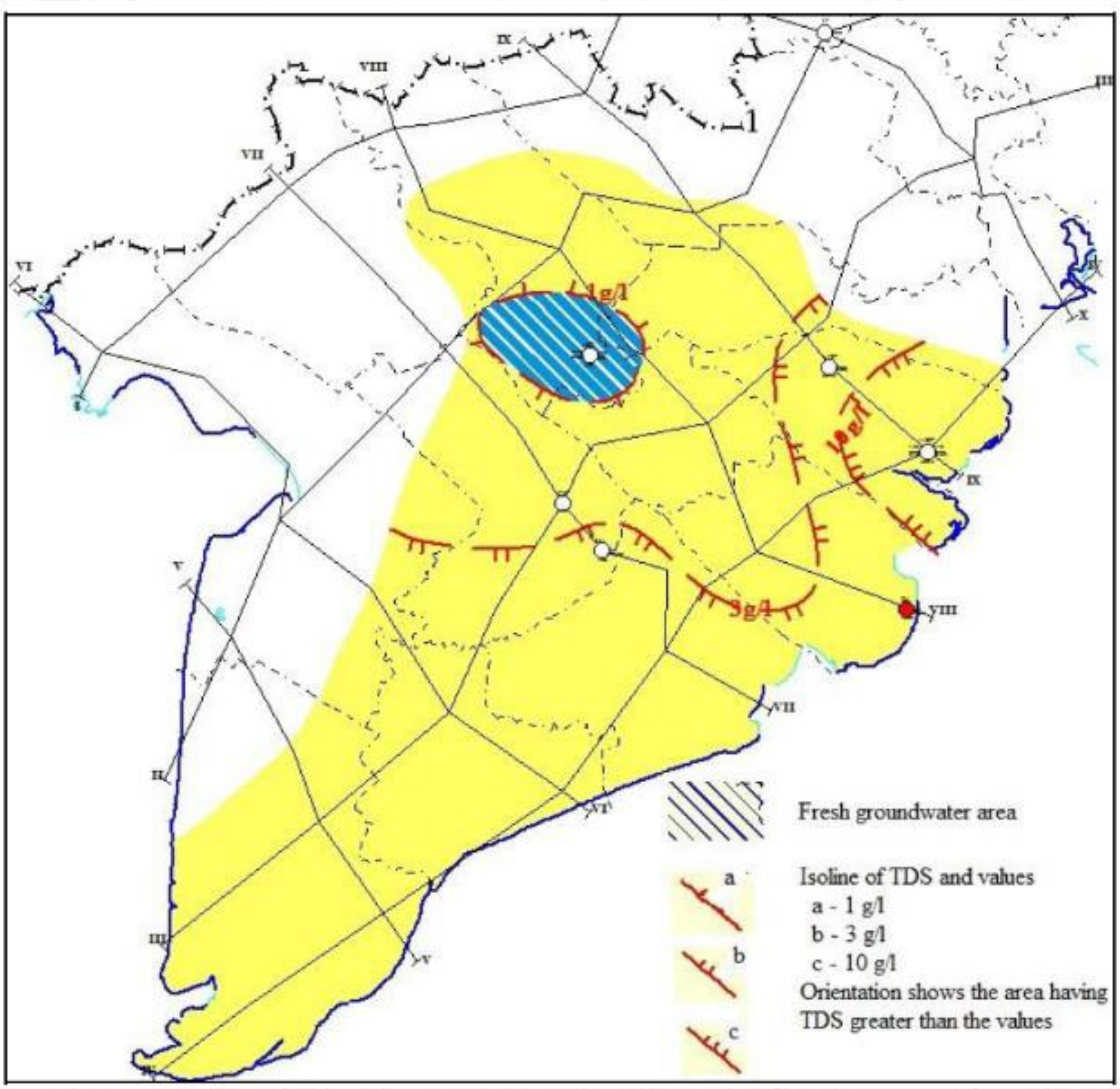


Figure III.8. Hydrogeological map of the Upper-Middle Miocene aquifer (Deltares, 2011).

Appendix IV: Overview of the groundwater usage for the whole VMD

No	Province	Wells	Total amoun (m^3/day)	Urban supply				Large rural supply				Small rural supply			
				Number	Total amoun (m^3/day)	Aquifer	Depth (m)	Number	Total amoun (m^3/day)	Aquifer	Depth (m)	Number	Total amoun (m^3/day)	Aquifer	Depth (m)
1	Trà Vinh	88.923	147.301	8	32.210	qp_{2-3}	100-134	102	8.515	-	98-134	88.813	106.576	-	98-134
2	Sóc Trăng	50.111	100.090	12	31.903	-	-	109	8.199	qp_{2-3}	-	49.990	59.988	qp2-3	-
3	Bạc Liêu	88.741	63.681	1	15.165	qp_{2-3} qp_1 n_2^2	106-138 152-168 245	65	8.612	qp_{2-3} qp_1	80-142 146-154	88.675	39.904	-	-
4	Cà Mau	67.185	134.657	13	46.326	qp_{2-3} qp_1 n_2^2	90-111 206-260	132	7.883	qp_{2-3} qp_1 n_2^2	- - -	67.040	80.448	qp2-3	
5	Cần Thơ	22.643	64.638	-	-	-	-	396	37.942	qp_{2-3}	82-114	22.247	26.696	-	-
6	Vĩnh Long	6.258	8.705	-	-	-	-	4	1.200	-	-	6.254	7.505	-	
7	Hậu Giang	29.656	50.045	-	-	-	-	225	14.728	qp_{2-3}	62-118	29.431	35.317	qp2-3	-
8	Tiền Giang	1.029	37.695	8	21.148	n_2^1	303-307	78	15.415	n_2^2 n_2^1 n_1^3	253-260 253-347 342-464	943	1.132	-	-
9	Đồng Tháp	3.213	44.723	8	17.760	-	-	165	23.315	qp_1 n_2^2 n_2^1	- - -	3.040	3.648	-	-
10	An Giang	4.971	71.917	2	44.930	n_2^2	245-300	6	770	qp_{2-3} n_2^2	- -	4.963	26.217	qp2-3	22-80
11	Bến Tre	2.063	6.683	17	3.342	-	-	20	910	-	-	2.026	2.431	-	-
12	Kiên Giang	96.950	328.970	1	6.240	-	-	49	19.464	-	-	96.900	303.266	-	-
13	Long An	3.487	169.956	27	35.953	-	-	1.079	78.147	-	-	2.381	55.856	-	-
	Total amount	**465.230**	**1.229.061**	**97**	**254.977**			**2.430**	**225.100**			**465.703**	**748.984**		

Figure IV.1. Groundwater usage in the VMD per province and total (Deltares, 2011).

Appendix V: Overview of regulation and management schemes

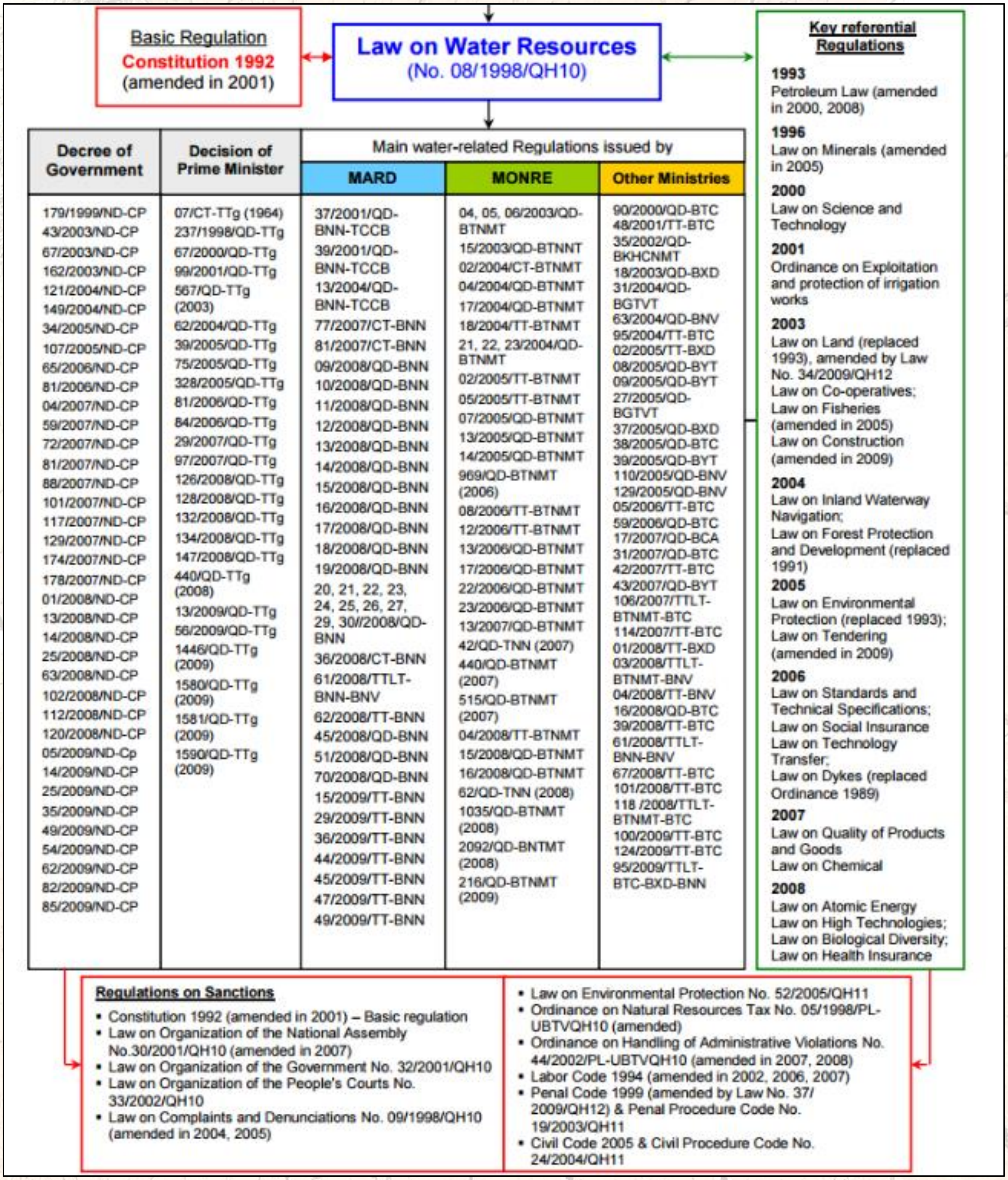


Figure V.1 Key regulations on the water sector in Vietnam (Nguyen, 2010)

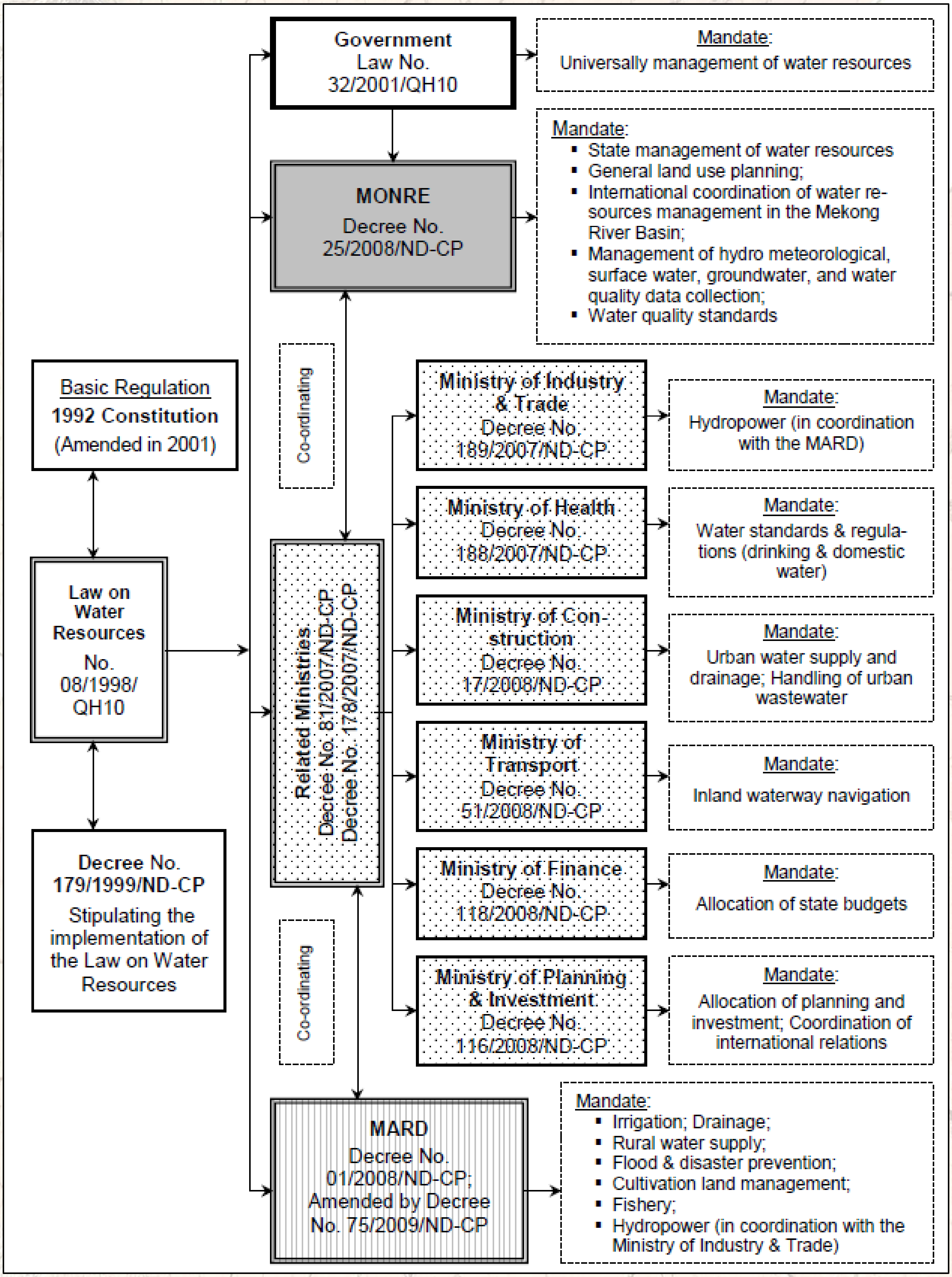


Figure V.2. Delivery of state responsibilities for water resources management (Nguyen, 2010, Nguyen, 2012).

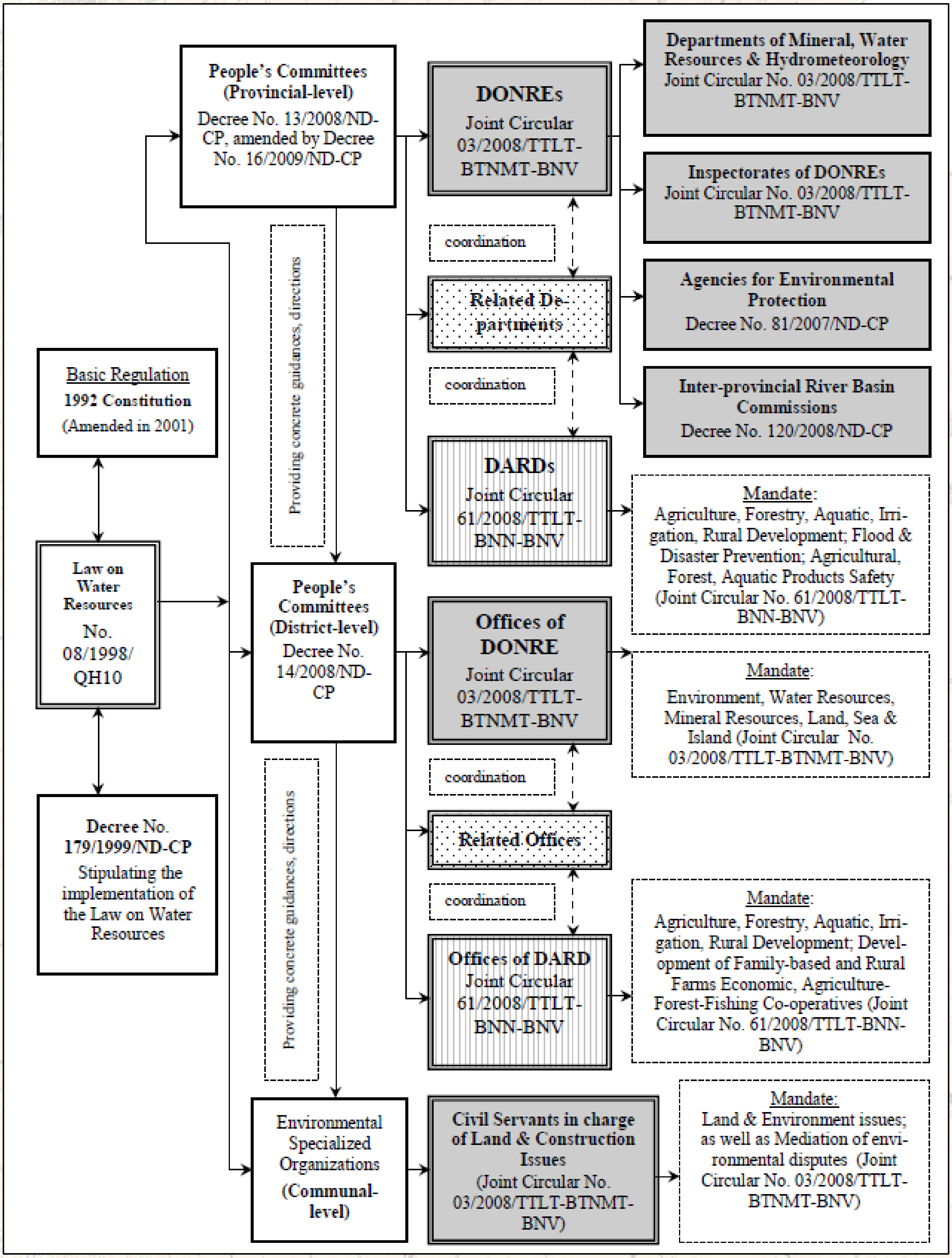


Figure V.3. State management on the water sector at the local levels (Nguyen, 2010; Nguyen, 2012).

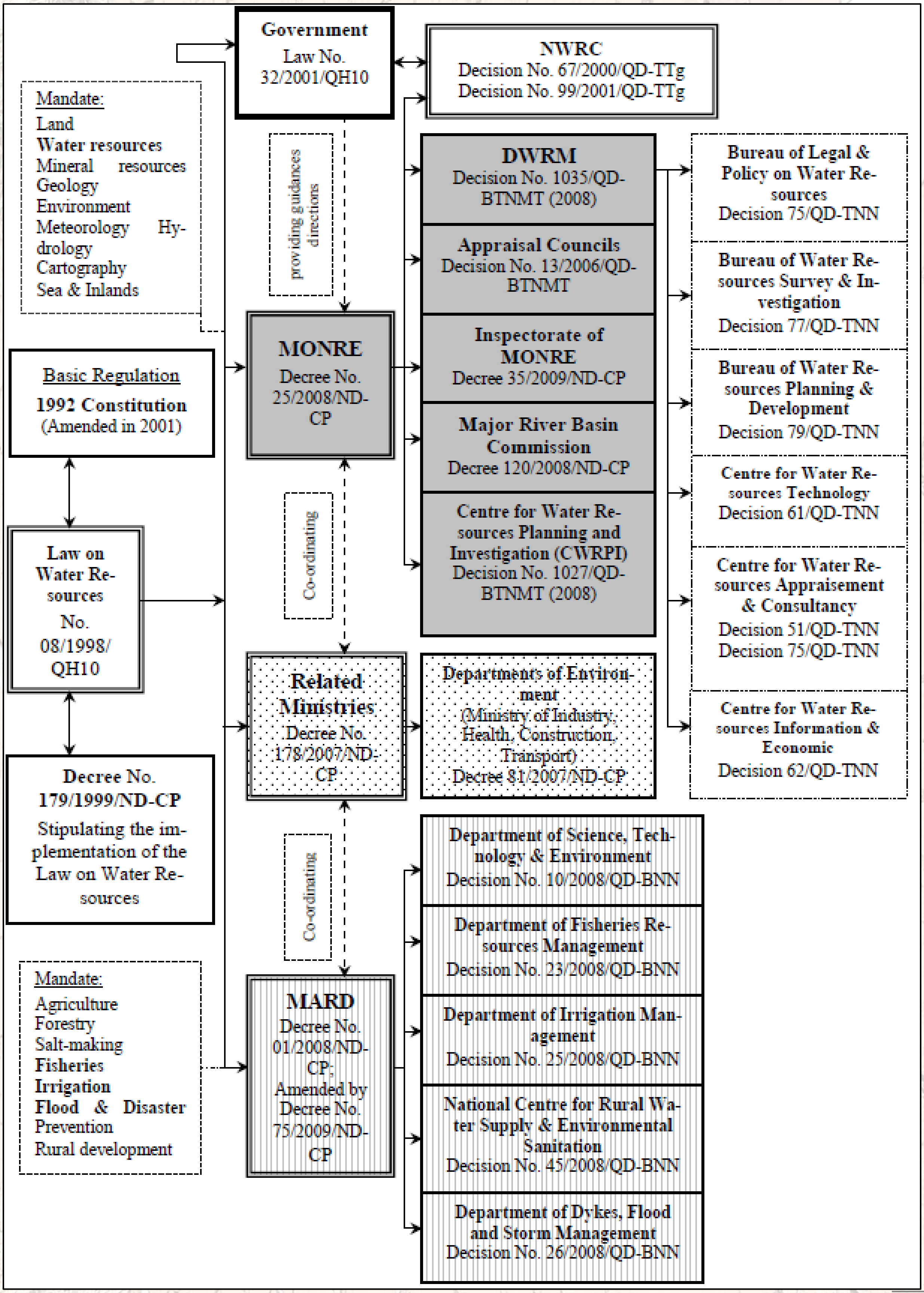
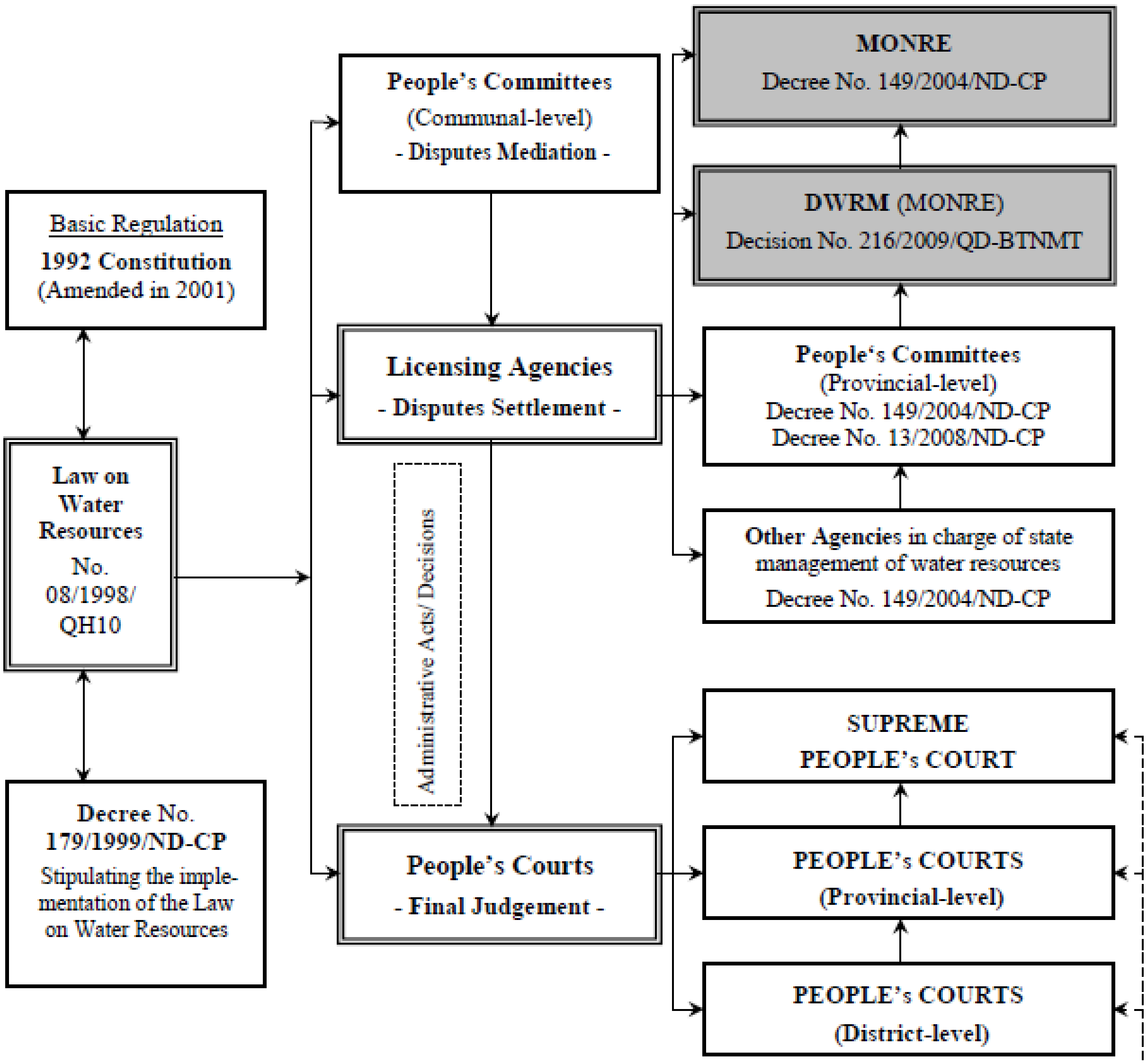


Figure V.4. State management on the water sector at the national level (Nguyen, 2010; Nguyen, 2012).



Related Regulations:

- Constitution 1992 - amended 2001 (basic regulation)
- Law on Organization of the Government No. 32/2001/QH10
- Law on Organization of the People's Courts No. 33/2002/QH10
- Labor Code 1994 (amended in 2002, 2006, 2007)
- Penal Code 1999 (amended by the Law No. 37/ 2009/QH12) & Penal Procedure Code No. 19/2003/QH11
- Civil Code 2005 & Civil Procedure Code No. 24/2004/QH11
- Law on Complaints and Denunciations No. 09/1998/QH10 (amended in 2004, 2005)
- Law on Environmental Protection No. 52/2005/QH11
- Ordinance on Natural Resource Tax No.05/1998/PL-UBTVQH10 (amended)
- Ordinance on Handling of Administrative Violations No. 44/2002/PL- UBTVQH10 (amended in 2007, 2008)
- Other related legal documents

Figure V.5. Dispute settlement system in environmental fields (Nguyen, 2010; Nguyen, 2012).

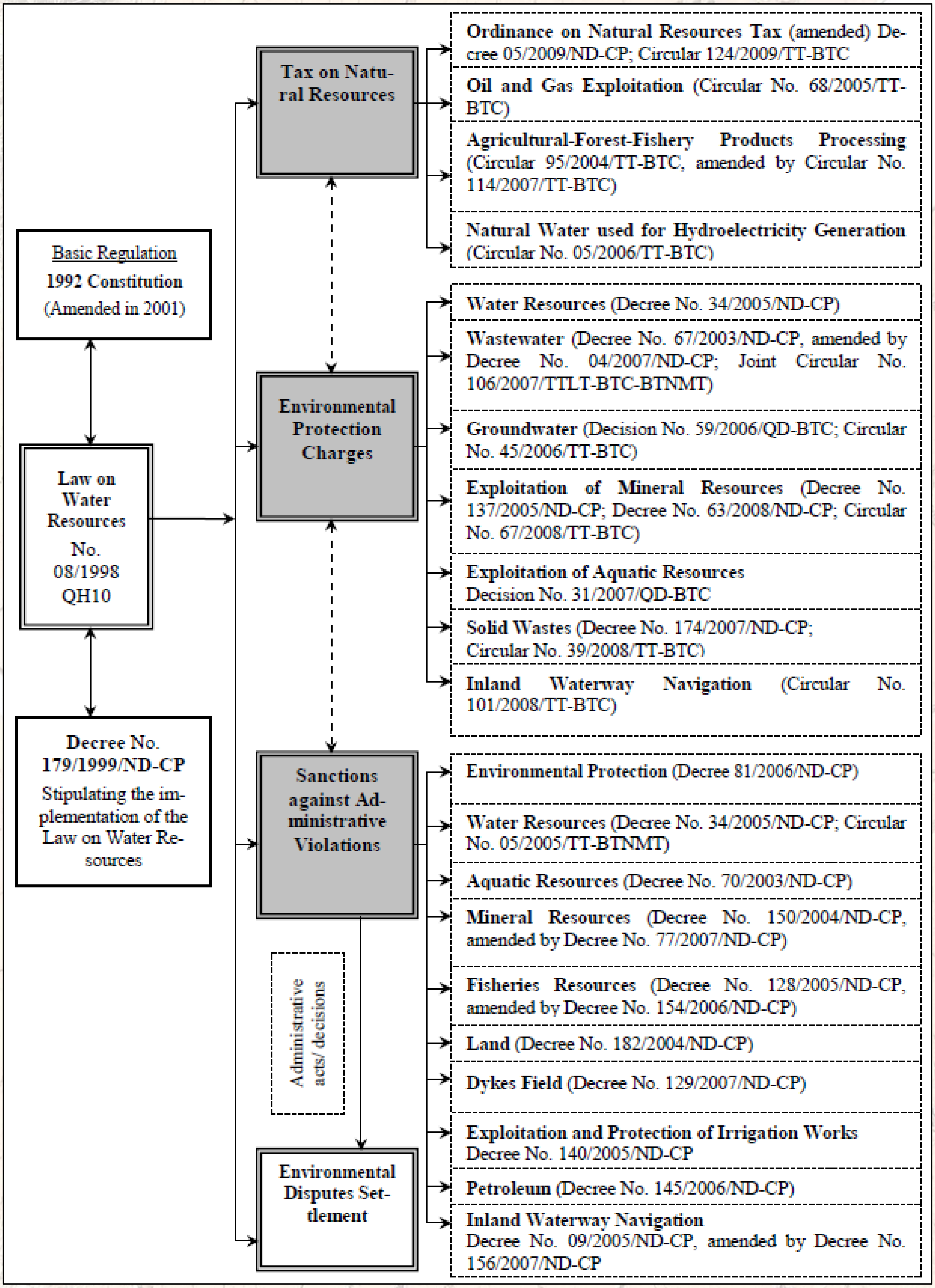


Figure V.6. Key regulations on violations and sanctions (Nguyen, 2010; Nguyen, 2012).

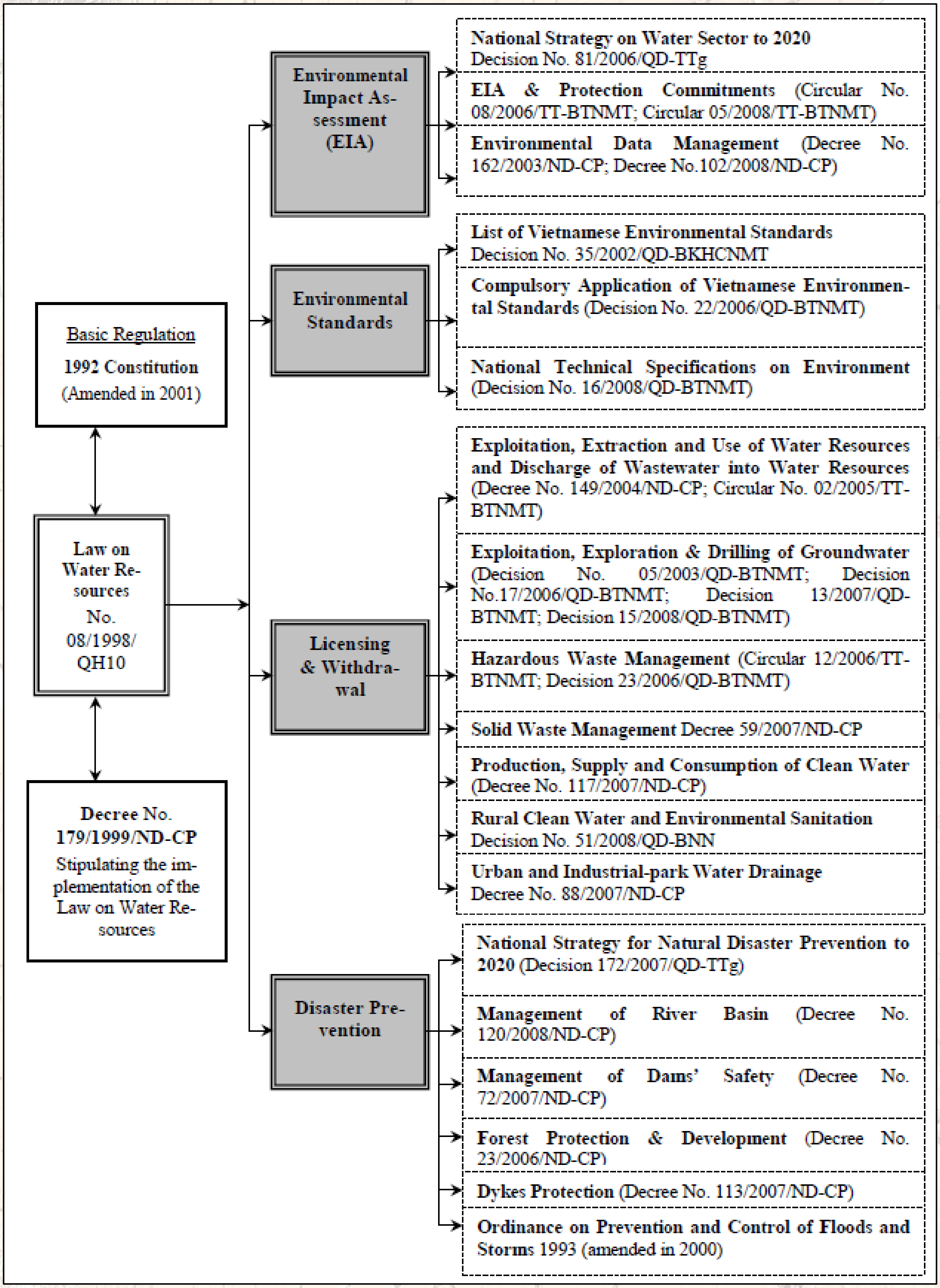


Figure V.7. Key regulations on water resources protection (Nguyen, 2010; Nguyen, 2012).

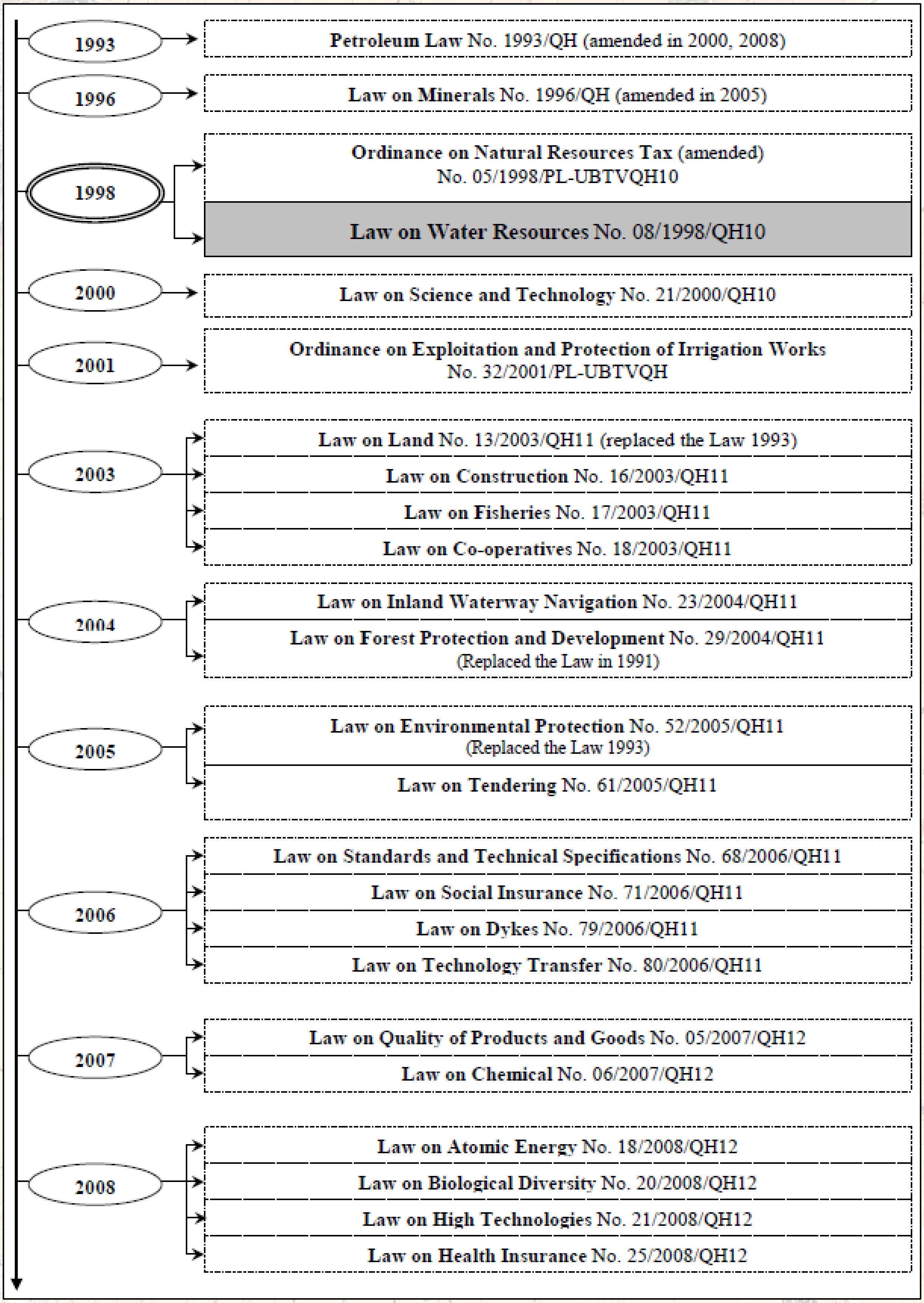


Figure V.8. Key laws and ordinances on the protection of water resources (Nguyen, 2010; Nguyen, 2012).

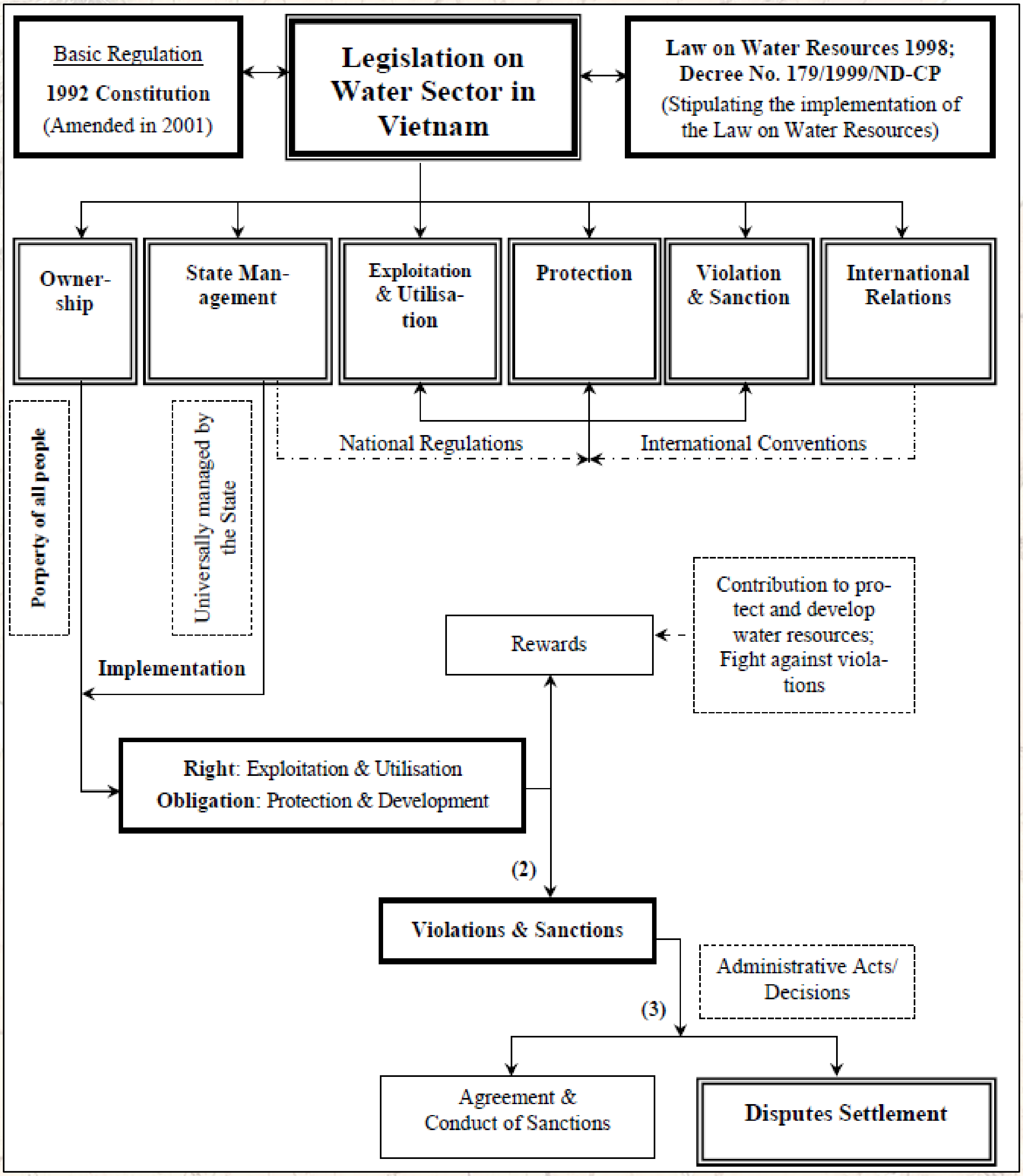


Figure V.9. Position and key dimensions of water sector legislation in Vietnam (Nguyen, 2010; Nguyen, 2012)

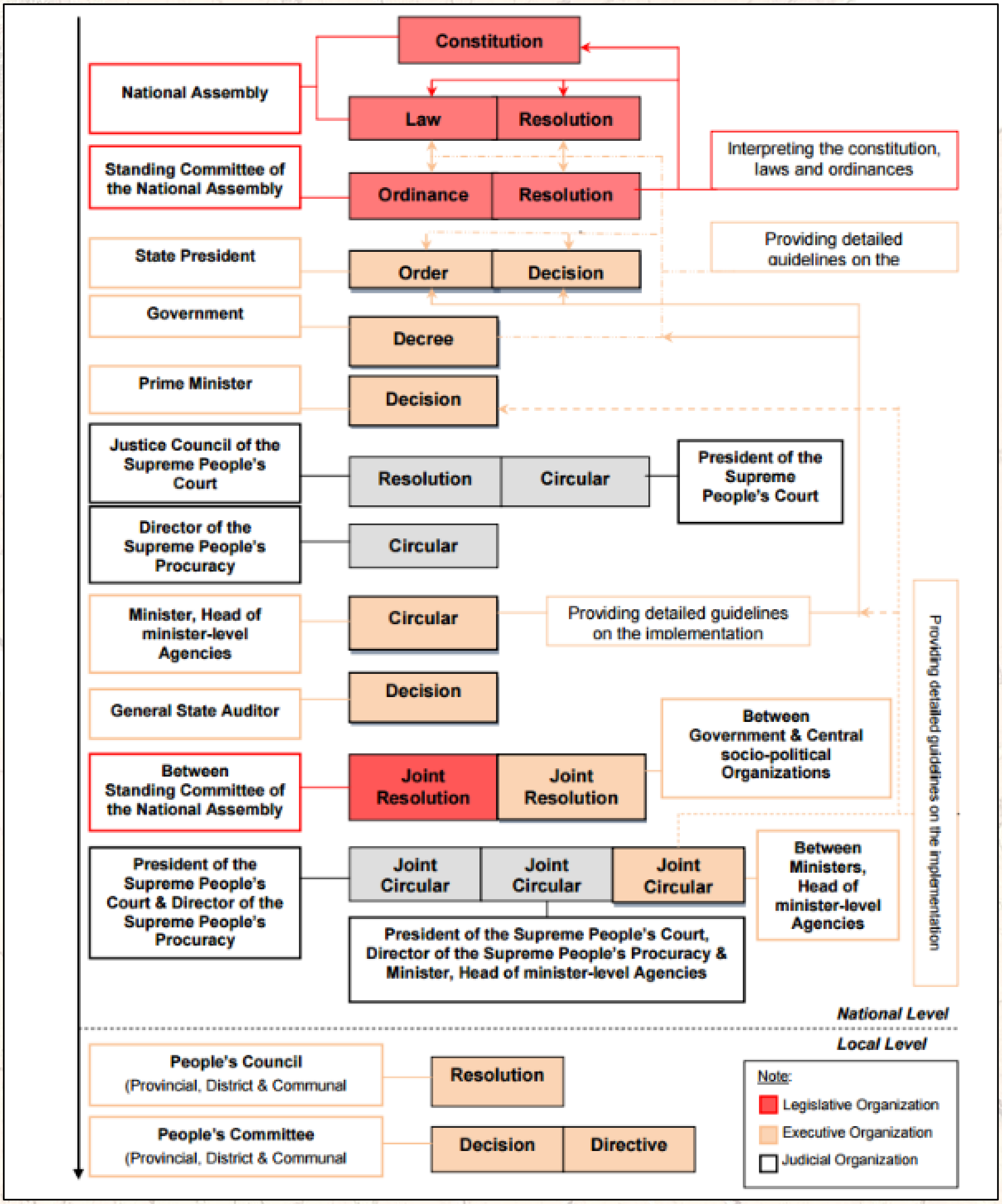


Figure V.10. Hierarchy of legal documents of Vietnam (Nguyen, 2010).

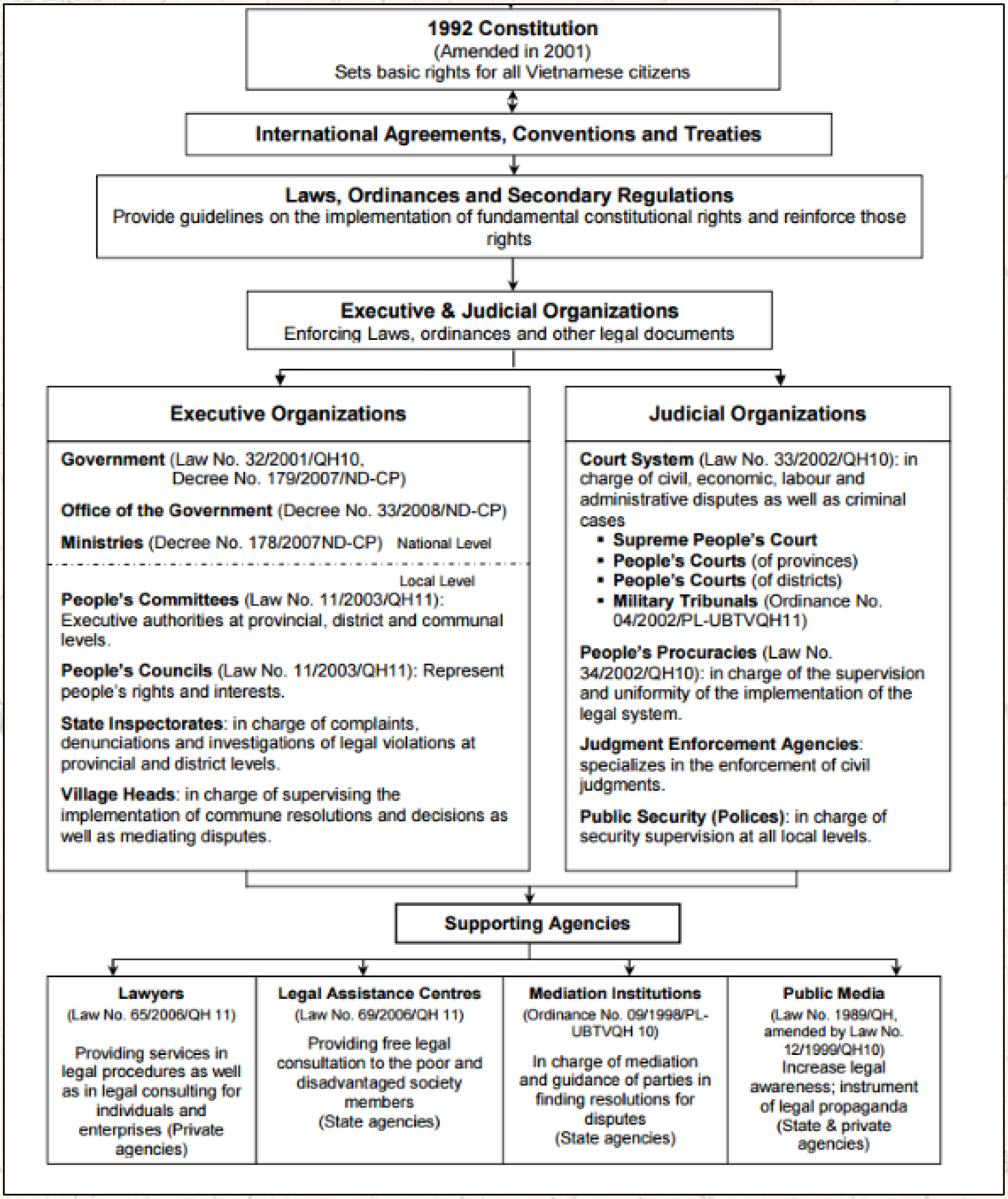


Figure V.11. Legal institutions in Vietnam (Nguyen, 2010).

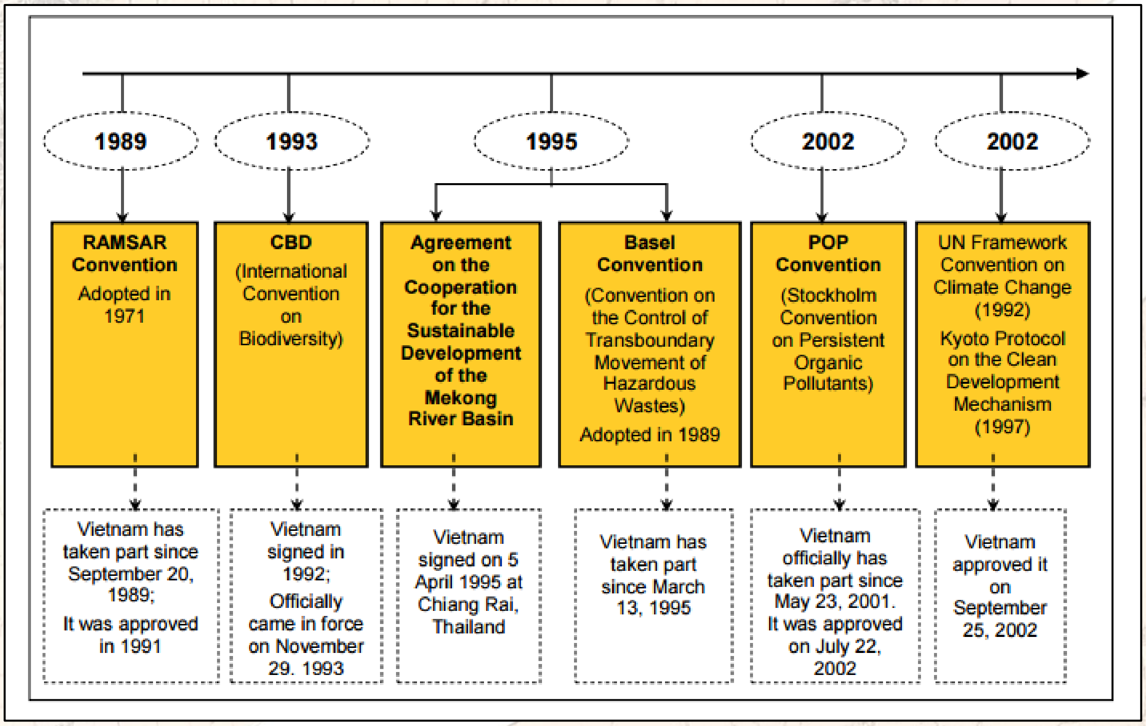


Figure V.12. Key international conventions on environmental protection (Nguyen, 2010)

Appendix VI: Relevant groundwater regulations and agreements

This appendix gives a description of relevant regulation regarding current groundwater governance on the National, Delta, and Provincial level.

Appendix VI.1. Regulations and agreements on the National scale

Decision No. 357/NN-QLN/QĐ by the MARD, in 1997. Regulates the investigation, extraction and state management of groundwater resources. It issues the decision for ''Temporary Provisions on Licensing of Exploration, Exploitation of Underground Water Drilling and Registration of Underground Water Exploitation Works.'' This decision states to issue the interim provisions on the implementation of a groundwater licensing system, which requests the user to apply for a permit at the People's Committees of communes/wards for wells over depths of 30m, and over 90mm in diameter, and further requirements.

Resolution No. 09/2000/NQ-CP by the Central Government, in 2000. Guides a number of undertakings and policies on economic restructuring and consumption of farm produce.

Decision No. 05/2003/QD-BTNMT, by the MONRE, in 2003. This Decision regulates the licensing of underground water exploration, exploitation and drilling practice, and replaces Decision No. 357/NN-QLN/QĐ of the MARD in 1997. The MONRE shall grant, extend licenses, adjust its contents, and revoke when groundwater exploitation of or over 1,000 m^3/day, or when groundwater extraction practices occur in two or more provinces. The provincial People's Committees shall grant, extend licenses, adjust its contents, and revoke when groundwater exploitation of less than 1,000 m^3/day, or when groundwater extraction practices occur within a province. It furthermore sets out steps for application of such licenses.

Decree No. 149/2004/NĐ-CP by the Ministry of Finance, in 2004. This decree on The Issuance of Permits for Water Resource Exploration, Exploitation and Use, or For Discharge of Waste Water Into Water Sources, provides for the issuance, extension, change, invalidation and withdrawal of water resource exploitation, exploitation and wastewater discharge permits.

Circular No. 02/2005/TT-BTNMT, by the MONRE, in 2005. This Circular provides permits for groundwater exploration, exploitation and use, surface water exploitation and use and for waste water discharge, plus it set out required forms for permit application. This Circular is given in furtherance of Decree No. 149/2004/NĐ-CP.

Law No. 52/2005-QH11, by the National Assembly, in 2005. This law gave the regulation of environmental protection activities, policies, measures and resources for environmental protection. Furthermore, it regulates the rights and obligations of organizations, households, ad individuals regarding environmental protection.

Decision No. 81/2006/QĐ-TTg, by the Prime Minister, in 2006. Decision on the national water resources strategy until 2020, which states that water resources are government managed and that individuals have rights to access these resources, albeit responsible in order to protect such resources, IWRM is considered, water is considered a good and should be managed according to market rules. Furthermore, cooperation among different stakeholders is required for sustainable use of available water resources and for protection of residents from water-related risks.

Decree No. 92/2006/ND-CP, by the Prime Minister in 2006. This decree provides for the responsibility, formulation, appraisal and managing of the overall planning of socio-economic development throughout the nation. This decree aims to ensure uniformity and consistency through planning, planning and socio-economic development in terms of construction and land use planning, development (Master Plan) planning, sustainable and effective economic development, matching the socialist-oriented market economy and international orientation, and ensuring an advanced and scientific based planning scheme.

Planning for the overall socio-economic development is established for the period of 10 years, with a vision from 15-20 years, and shown for each period of 5 years. This decree got revised (with changes and supplements to various articles) in 2008 under Decree No. 04/2008/ND-CP by the Prime Minister.

Joint Circular No. 01/2008/TTLT-BTNMT-BTC, by the MONRE, 2008. This circular guides drafting and allocation of environmental funds related to projects, ensuring protection to local budgets and decentralized expenditure.

Decision No. 02/2008/QĐ-BTNMT, by the MONRE, in 2008. This Decision issues the economic norms to technical operations regarding environmental monitoring, such as monitoring of the soil, groundwater and acid rain.

Decision No. 1590/QD-TTg, by the Prime Minister, in 2009. Decision on the strategic orientation on the development of water resources in Vietnam, which covers mainly that developing IWRM strategies in order to meet multi-objectives of socio-economic and environmental development until 2020, with a vision towards 2050. This decision aims to enhance water-related risk management capacities and the identification of suitable adaptation measures for vulnerable areas, to meet current water demands without the constraint of future development demands, enhancement of climate change and sea level rise resilience, the development of suitable water governance systems with special attention given to water scarce areas, and the recognition of the climate change and increasing water demand induced threat to water resources.

Decision No. 800/QD-TTg, by the Prime Minister, in 2010. This decision aims to enhance rural development in the nation by means of modern infrastructure, rational economic structure and forms of production organization, with an emphasis on environmental protection as a mean for sustainable development of the country, mainly mentioning surface water and hydraulic infrastructure for water control. However, groundwater resources were not mentioned as much.

Circular No. 20/2011/TT-BTNMT, by the MONRE, in 2011. This Circular gives economic-technical estimates on various environmental monitoring fields, of which water resources (groundwater and the soil in article 2), and various emissions.

Decision No. 491/QĐ-TTg, by the Prime Minister, in 2009. This decision sets criteria for a National Target Program for the developing new rural areas.

Decision No. 342/QĐ-TTg, by the Prime Minister, in 2013. This decision amends some criteria set in the Decision No. 491/QĐ-TTg that sets criteria for a National Target Program for the developing new rural areas.

Circular No. 41/2013/TT-BNNPTNT, by the MARD, in 2013. This circular guides implementation of a national set of criteria for new rural areas, which serves as a basis to evaluate the accreditation of these criteria and standards. It applies to all communes in the country, agencies, units, organizations and individuals in the National Target Program.

Decision No. 899/QD-TTg, by the Prime Minister, in 2013. Decision on the approval of the project 'Proposal to Restructure the Agricultural Sector Towards Increasing Added Values and Sustainable Development', which aims to enhance the livelihoods of local residents and to manage development by means of a better management of environmental and natural resources management.

Decree No. 201/2013/NĐ-CP, by the Central Government, in 2013. This Decree provides for the consultation of communities in the exploitation and water resources usage, waste water discharge into water sources, surveys (baseline) of water resources, the licensing of water resources, and the protection of water resources.

Circular No. 27/2014/TT-BTNMT, by the MONRE, in 2014. This Circular aims to regulate the registration, extension, modification, and re-issuance of groundwater extraction licenses and is based on Decree No. 201/2013/NĐ-CP.

Decision No. 459/QD-TTg, by the Prime Minister, in 2014. This Decision defined the structure, functions and authorities of the National Council on Water Resources, which main task is to consult the Prime Minister on planning of water resources, water diversion, the transboundary uses and conflict, and the development and evaluation of important water related projects.

Document No. 6094/VPCP-KTN, by the Office of the Government, in 2014. This document states that the MONRE has to cooperate with the Ministry of Construction, the MARD, and the respective People's Committees in ,amongst others, the VMD's provinces in order to evaluate the implementation of joint use of groundwater, study on groundwater resources dynamics and related issues to the surface such as land subsidence, and the proper use and sustainable management of groundwater resources. This document stated that the decision on the short and long term should be completed end June 2015.

Law No. 82/2015/QH13, by the National Assembly, in 2015. This law regulated the overall management of natural resources and the environment. Furthermore, it regulated rights, obligations and responsibilities of agencies, organizations and individuals in the protection, management and usage of natural resources and the environment in the nations. Moreover, this law put climate change issues, and sea level rise under the responsibility of the MONRE.

Decree No. 18/2015/NĐ-CP, by the Central Government, in 2015. This decree regulates the environmental protection planning, strategic environmental assessment, environmental impact assessment and environmental protection plans in order to assess pollution of both surface- and groundwater resources.

Decree No. 19/2015/NĐ-CP, by the Central Government, in 2015. This decree regulates the detailing of the implementation of a number of articles on the Law on Environmental Protection (No. 52/2005-QH11), and assessed surface-and groundwater resources pollution.

Decree no. 43/2015/ND-CP, by the Prime Minister, in 2015. This decree provides guidelines for water source protection corridors establishment and management, with a focus on mainly surface water resources rather than groundwater resources.

Decree No. 54/2015/ND-CP, by the Prime Minister, in 2015. This decree approves national programs to identify groundwater resources in water-scarce areas for (domestic) water supply.

Decision No.805/QD-TTg, by the Prime Minister, in 2015. This Decision approves national programs to investigate groundwater reserves, usage and land subsidence in, amongst other, the VMD.

Appendix VI.2. Regulations and agreements on the Delta scale

Decision No. 01/1998/QD-TTg, by the Prime Minister, in 1998. This Decision ratified the overall socio-economic development master plan for the VMD from 1998-2010, targeting rapid agricultural growth in the delta though the development of irrigation network and infrastructure. This decision took flooding issues, iron release from acid sulfate soils, and saline intrusion in consideration to ensure Vietnam's objective of food security.

Directive 17/2000/CT-TTg, by the Prime Minister, in 2000. This Directive directs the management of annual flooding from the Mekong River in the VMD.

Decision No. 1144/QD-TTg, by the Prime Minister, in 2000. Supports local residents to overcome adverse consequences of annual flooding events in the VMD. Furthermore, it aids them in restoring their production after such events.

Decision No. 173/2001/QD-TTg, by the Prime Minister, in 2001. Aims at the improvement of agricultural and aquaculture systems in VMD through enhancement of existing irrigation structures between 2001 to 2005.

Decision No. 173/2001/QD-TTg, by the Prime Minister, in 2001. This decision was made to give direction on the restructuring of socio-economic development and agriculture production in the VMD.

Resolution No. 24/2008/NQ-CP, by the Central Government, in 2008. This resolution on the comprehensive development of agriculture, farmers and rural areas has an objective to develop intensive agricultural and aquaculture systems based on favourable natural conditions and many and various investments from the Government. Important issues considered are the enhancement of adaptive capacity of local governments and residents at regard to the negative impacts of climate change, and the introduction of structural measures to enhance their ability to minimize negative impacts from upstream flooding and saline intrusion. Furthermore, the development of a comprehensive irrigation system for intensive development of agriculture and aquaculture, and the enhancement of (surface) water supply system for industrial and domestic activities. To date however, attention to surface water issues and structural measures was rather there than that groundwater was, saltwater intrusion and drought has not received much consideration from the government either.

Decision No. 492/QĐ-TTg, by the Prime Minister, in 2009. This decision validates the proposal for the establishment of the key economic development zone in the VMD.

Decision No. 1446/QĐ-TTg, by the Prime Minister, in 2009. This decision authorizes the development of medium and small scale electric pump stations in the VMD in line with overall socio-economic development and irrigation planning in specific locations of the delta. Further target was directed at the improvement of supply and drainage of agricultural and aquaculture production through investments of building electric pump stations in development planning approved areas and where embankments have been completed.

Decision No. 1581/QD-TTg, by the Prime Minister, in 2009. This decision validates the construction master plan for the VMD, which states that intensive investment is required for implementation of structural measures in order to improve the current system. Saline intrusion was considered a side effect from hydraulic structures for routing out floodwaters from the delta, and further considered surface water issues (e.g. sanitation and flooding) and governance. Next to that, this plan deemed sea dikes and other related structural installation suitable measures for the protection of coastal lines and the prevention of negative impacts of climate change and sea level rise. This plan further states that the main source of water supply is surface water, and the utilization of groundwater sources if there is a need for it. Moreover, only domestic and industrial consumption activities were considered.

Decision No. 2065/QĐ-TTg, by the Prime Minister, in 2010. Authorization of the master plan for water supply for the VMD’s key economic region through 2020.

Decision No. 2066/QĐ-TTg, by the Prime Minister, in 2010. Authorization of the master plan for drainage for the VMD’s key economic region through 2020.

Decision No. 939/QD-TTg, by the Prime Minister, in 2012. Endorsement of the overall master plan for the VMD’s socio- economic development until 2020 into a key region for agricultural and aquaculture development.

Decision No. 395/QĐ-BXD, by the Ministry of Construction, in 2014. Authorization of the water supply system planning for the domestic and industrial consumption in the VMD, and the emphasis on the importance of research on groundwater resource availability for centralized water supply.

Appendix VI.3. Regulations and agreements on the Provincial scale

Decision No. 87/QĐ-UBND, by the People's Committee Soc Trang Province, in 1998. This decision is for the implementation of Decision No. 357/NN-QLN/QĐ which was issued by the MARD, 1997, on the regulation of the investigation, extraction and state management of groundwater resources.

Decision No. 11/2008/QĐ-UBND, by the People's Committee Soc Trang Province, in 2008. This decision is based on Decree No. 149/2004/NĐ-CP and Circular No. 02/2005/TT-BTNMT, and guides domestic groundwater extraction registration for Soc Trang Province.

Directive No. 03/2009/CT-UBND, by the People's Committee Soc Trang Province, in 2009. This directive aims to enhance groundwater resource management in Soc Trang Province.

Decision No. 423/QD-TTg, by the Prime Minister, in 2012. This decision on the approval of the master plan on socio-economic development of Soc Trang Province till 2020, to turn Soc Trang Province into a province with relatively high income in the VMD. This masterplan plan covers development strategies to build Soc Trang Province into a province with developments such as a hi-tech and sustainable agriculture and for the development in line with the national development process. The management of land, water, forest, sea and mineral resources is to be enhanced, and supplemented to by master plans (and other plans) that cover, multi resource usage, intergovernmental coordination between ministries and central sectors on the marine resources and the environment, including integrated coastal zone management planning. Forest coverage in Soc Trang Province is supposed to be at 5% in 2015 and 5,5% in 2020, 98% in 2015 and 100% in 2020 of households have access to clean water and in 2015, 100% of (hazardous and medical) waste shall be collected and environmentally friendly treated, over in 2015 40% and in 2020 80% of is supposed to be collected and treated. By 2020, 100% of industrial areas should have concentrated wastewater treatment systems, step for step development of waterways (e.g. ports and navigable channels) to link marine and road infrastructure into a complete transport network, stable depths of channels will be attained by means of regular dredging, seawater prevention works, and key pump stations will be completed. Upgrading the irrigation systems will be considered in My Tu, Thanh Tri, Nga Nam and Chau Tanh Districts, and aquaculture irrigation systems in coastal areas in Long Phu, Cu Lao Dung, Vinh Chau, and in various zones in My Xuyen District. Furthermore, irrigation infrastructure of catfish rearing will be considered in Ke Sach, Cu Lao Dung and Long Phu Districts. This Master Plan furthermore covers the building and consolidation of dikes and embankments for seven provincial irrigation zones, and upgrading various sea dikes in Long Phu, Cu Lao Dung, Vinh Chau, Tran De districts. Moreover, a river estuary dike in Vinh Chau District, and a river dike system in Cu Lao Dung is planned. In addition, water supply systems are planned to supply clean water for urban domestic consumption and production, as well as research and upgrades for water supply systems in Soc Trang City, Vinh Chau Town, and Nga Nam Town (including various industrial areas in the province). This plan furthermore covers centralized water supply or household-based water supply in rural areas, as appropriate depending on geographical locations. Furthermore, wastewater treatment centers are planned to treat pre-discharge wastewater to protect the environment in various urban, and industrial areas.

Decision No. 50/2013/QĐ-UBND, by the People's Committee Soc Trang Province, in 2013. This decision for the regulation of the cost of operations on environmental monitoring of land, water resources, and acid rain in Soc Trang province, stipulates unit prices to monitoring activities and other activities for sampling, sample analysis and environmental management. This decision is based on Joint Circular No. 01/2008/TTLT-BTNMT-BTC, Circular No. 20/2011/TT-BTNMT, and Decision No. 02/2008/QĐ-BTNMT.

Decision No. 36/2014/QD-UBND, by the People's Committee Soc Trang Province, in 2014. This decision is based on Decision No. 491/QĐ-TTg, Decision, No. 342/QĐ-TTg and Circular No. 41/2013/TT-BNNPTNT, and guides the application (Decision No. 800/QD-TTg) of the appraisal of communes against the criteria set for new (modernized) rural areas in the province.

Decision No. 20/2014/QD-UBND, by the People's Committee Soc Trang Province, in 2014. This decision guides collection, payment and utilization of administrative fees regarding to the water resources in the province.