DETERMINATION OF SUSTAINABLE GROUNDWATER MANAGEMENT PRINCIPLES AND THE IMPROVEMENT OF IMPEDIMENTS OF GROUNDWATER MANAGEMENT SYSTEM IN TURKEY VIA UK AND EU IMPLEMENTATIONS

BY

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ABSTRACT

Sustainable groundwater management plays a vital role in the maintenance of groundwater systems. There is a growing body of literature that recognises the importance of sustainable groundwater management. Thus, it is very crucial to look at what are the issues are missed in existing groundwater management systems and how sustainability may be delivered on groundwater systems.

This research describes sustainable groundwater management principles and to identify the impediments of groundwater management system in Turkey using England and EU implementations as examples of good practice. Firstly laws, regulations and reports of water management authorities of Turkey (DSI, SYGM) are investigated in the light of sustainable groundwater management principles. Secondly semi-structured interviews are done with experts in Turkey. Determined impediments are discussed how they may be improved via implementations in England and EU to achieve sustainable groundwater management.

Results showed that there have been much improving groundwater management regulations in Turkey for sustainable groundwater management in the last decade via EU WFD. Still there are gaps needed to reduce. They are argued in depth. Lack of multi disciplinary planning and implementations, unsuccessful sustainable yield implementations and increasing unlicensed wells are mainly needed implementation issues in Turkey to reduce. Analysing of England regulations shows that some implementations of England may be adopted into groundwater management policies of Turkey for instance monitoring system of Met Office and water abstraction charges.

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AUTHOR'S DECLARATION

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement. Where I have quoted or otherwise incorporated material which is the work of others, I have included the source in the references. Any views expressed in the dissertation, other than referenced material, are those of the author.

SIGNED N. Erdoğan **DATE 13. 09.2020**

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LIST OF ABBREVIATIONS

BMC	Basin Management Committee
DSI	General Directorate of the State Hydraulic Works
EIA	Environmental Impact Assessment
EU	European Union
EU WFD	European Union Water Frame Directive
GIS	Geographic Information Systems
GRACE	Gravity Recovery and Climate Experiment
SYGM	General Directorate of Water Management

1. INTRODUCTION

Groundwater is a significant resource. 97% of the earth's freshwater resources are stored in some of the larger aquifer systems as groundwater (Jha et al., 2007). Groundwater is more robust to the climate impacts (Van der Gun, 2012). Aquifers are affected much more slowly by short-term climate condition (Alley et al., 1999). While in drought periods surface water levels drop down under the critical levels (Sakiyan & Yazicigil, 2004), groundwater plays a vital role along drought periods (Famiglietti, 2014).

Groundwater is renewable resource. However renewal period is required long time (100s or 1000s of years) (Margat et al., 2006). Therefore in the most of the major aquifers, aquifer replenishment is very restricted and groundwater mining is observed commonly (Famiglietti, 2014). The term groundwater mining is used here to refer to an extensive and progressive decrease in aquifer (Alley et al., 1999).

Global water security has significant risk (Famiglietti, 2014). Groundwater pumping rate is so greater than naturally replenished amount in most aquifer systems (Alley et al., 1999). The total amount of water consumption from surface and groundwater has increased globally by nine times for last century (Hiscock et al., 2002). For instance, the increasing of domestic, hospital, and industrial water consumptions threats to groundwater resources in most parts of Turkey because of industrialization and urbanization (Baba & Tayfur, 2011). Additionally in many water-scarce areas around the world climate change has increased dependency on groundwater if groundwater storage is sufficient (Van der Gun, 2012).

Increasing groundwater consumption causes declining water table levels, degraded ecosystems, groundwater quality changing and additionally debates among water users (Gleeson et al., 2010; Kinzelbach et al. 2003). Wada et al. (2010) and Famiglietti (2014) believe that land subsidence and salt water intrusion, sea-level rise, river flow depletion, the drying of springs and wetlands and ecological damages are other impacts by groundwater depletion.

Knüppe (2011) and Famiglietti (2014) emphasised that groundwater problems have resulted from population growth, increasing food and energy consumptions and rising welfare level have increased groundwater consumption in some regions.

Groundwater governance includes mechanisms, processes and institutions to provide sustainable consumption and protection of groundwater resources for the benefits of humanity and dependent ecological life (Foster & Garduño, 2013). Lot of groundwater problems as groundwater level decrease are generally related to management failures rather than lack of knowledge about the groundwater resources characteristics such as sustainable yield or pollution vulnerability of aquifers (Knüppe, 2011; Foster & Garduño, 2013).

Groundwater management has some management tools such as defining policy options, translating them into long term targets, establishment of institutions, published procedures, effective monitoring systems, enabling stakeholder participation (Foster & Garduño, 2013). Main groundwater management challenge is that the implementations of policy and plan are not effective in the many regions (Jakeman et al., 2016; Knüppe, 2011). That is why existing governance system, such as highly fragmented groundwater management institutes and its performance, cooperation structures within institutional and political agencies can be impediments (Knüppe, 2011).

To understand why governance policies, resource management and protection are unsuccessful, the initial step has to be the analysis of existing management policies and plans (Foster & Garduño, 2013). Additional steps are planning, developing, and managing water resources to provide sustainable water for both humans and natural ecosystems (Loucks & Beek, 2017).

1.1 RESEARCH AREAS

Two countries are selected. First, Turkey is the main research area (**Figure 1**). Groundwater management impediments of Turkey are investigated. Second, the successful implementations of England are examined to improve the impediments of Turkey.

Figure 1 Turkey Borders (Geology.com, 2007)

Surface and groundwater resources have been planned and managed by General Directorate of the State Hydraulic Works (DSI) since 1954 (Voss et al., 2013; Sakiyan & Yazicigil, 2004), and General Directorate of Water Management (SYGM) since 2011 (Figure 2 and Figure 3).

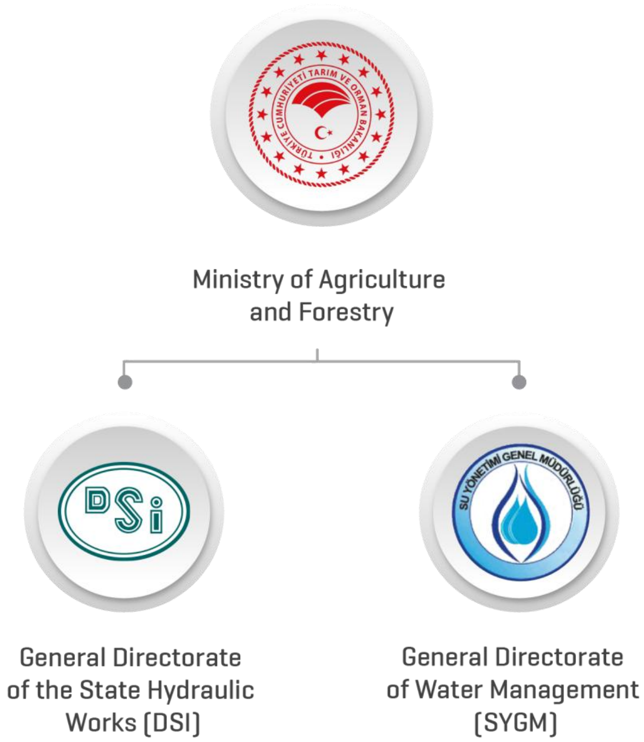

Figure 2 Organisational Chart of Water Governance in Turkey

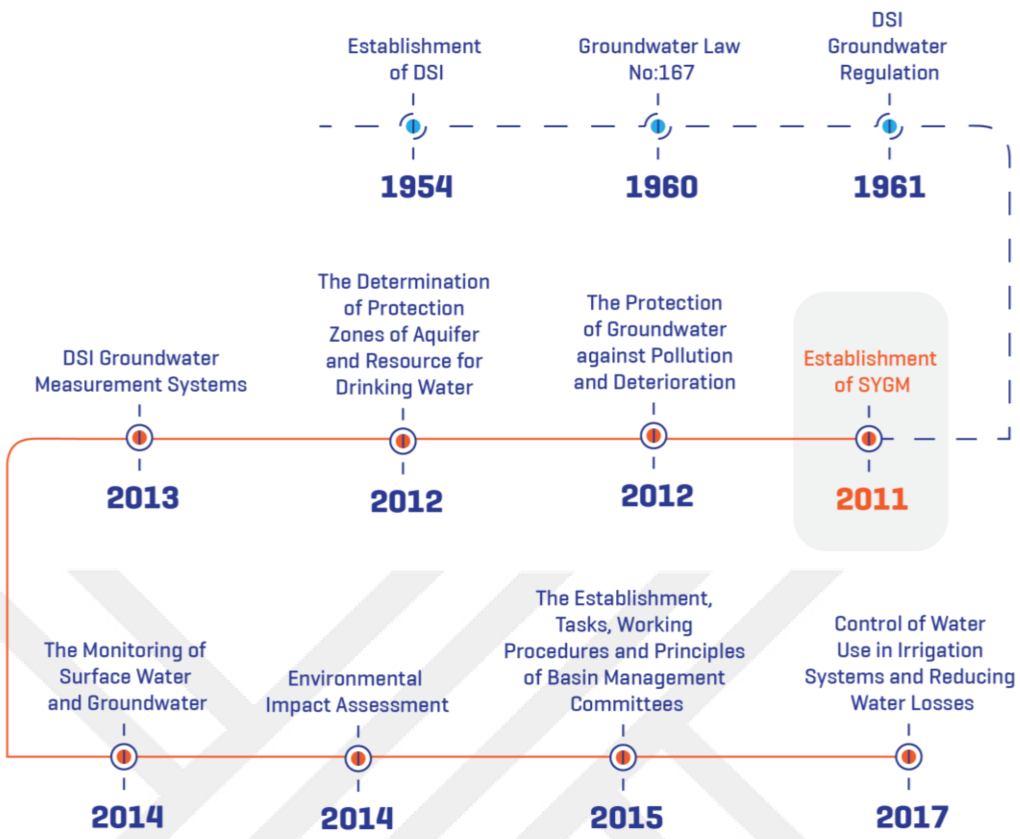

Figure 3 Timeline of Key Groundwater Regulations and the Establishment of Organisations in Turkey

It is expected that the annual per capita water potential in Turkey would be 1000 m^3 in the 2020s. Therefore it cannot be named `water-rich' country (Bayazit & Avci, 1997). Dramatically population growth, increasing welfare and industrialization have caused increasing groundwater demand in Turkey (Bayazit & Avci, 1997). Groundwater level has declined because of over pumping of groundwater for irrigated agriculture during the past two decades (Sakiyan & Yazicigil, 2004).

1.2 RESEARCH OBJECTIVES

This research aims to analyse firstly whether existing groundwater management policies and plans in Turkey have impediments to implement sustainable groundwater management. Second, how these impediments can be improved via executions of policies and regulations of England and European Union (EU).

In order to answer these questions:

1- Sustainable groundwater management is described.
2- Main sustainable groundwater management principles are determined.
3- Evaluation criteria are prepared in the light of sustainable groundwater management principles to analyse existing groundwater management policies and plans in Turkey (Appendix A).
4- Data is collected for Turkey.
  - Firstly laws, regulations and government reports are read
  - To analyse the results of the implementations of groundwater laws and regulations in Turkey, experts from Turkey are interviewed.
5- Gaps are identified for Turkey, and English groundwater policies are examined for potential solutions

In the light of results, the gaps of implementation of sustainable groundwater management had been determined.

1.3 STRUCTURE OF DISSERTATION

To address the research areas and objectives presented in Chapter 1, the structure of the dissertation is as follows:

In Chapter 2, the literature review which is about what are the sustainable groundwater management principles are summarized.

In Chapter 3, the used method in this research is highlighted.

In Chapter 4, the results of the evaluation of the existing groundwater management in Turkey are shown.

In Chapter 5, it is argued what are main impediments and how these impediments can be improved via groundwater policies and implementations in England and EU in discussion part.

Finally, in Chapter 6, conclusions and suggestion are shown

2. LITERATURE REVIEW

In this chapter, significant sustainable groundwater management principles were described.

2.1 SUSTAINABLE GROUNDWATER MANAGEMENT

Sustainable groundwater management emphasises that groundwater aquifers should be used permanently (Alley et al., 1999; Loucks, 2000). Abstraction amount from aquifers should not cause unacceptable environmental, economic, and social consequences (Alley et al., 1999). Dottridge and Abu Jaber (1999) believe that when consumption from aquifer is higher than recharge, existing groundwater management is unsustainable.

The safe yield (sustainable yield) was developed from 1915 to 2000 (Kalf & Woolley, 2005). Lastly it was understood that groundwater dependent ecosystems (streams, springs, wetlands) should be considered by sustainable yield therefore sustainable yield must be less than the recharge of aquifer for sustainable environment (M. Sophocleous, 2000). A general definition by The Australian National Groundwater Committee is that "The groundwater extraction regime measured over a specified planning time frame that allows acceptable levels of stress and protects dependent economic, social and environmental values." (Kalf and Woolley, 2005, pg 298).

In general terms, sustainable water management considers balance between the three dimensions of sustainable development: economic efficiency, social equity and environmental sustainability (Durán-Sánchez et al., 2018). Sustainable groundwater management includes technical, economical, judicial, social, institutional principles and governmental structures with sufficient policy (Knüppe, 2011).

2.2 PLANNING

Planning includes forecasting and meeting of future supplies, expectations, objectives, costs and benefit, besides aims to answer new perceptions of how to manage more effectively (Hashimoto et al., 1982; Loucks & Beek, 2017).

2.2.1 MULTIDISCIPLINARY GROUNDWATER MANAGEMENT

Loucks (2000) believes that water resources management is multiple processes. Perspective of a single-discipline is insufficient for water management (Loucks, 1992). Hydrologists and engineers may design and built water resources systems, however the sustainable utilizations and managements of surface water and groundwater need the members of other disciplines such as lawyers, contractors, agronomists, climatologists, environmentalists, economists, chemical and biological experts, social scientists, political and regional scientists (Stout, 1998; Loucks, 1992; Van der Gun, 2012). Therefore sustainable groundwater management has altered into a multidisciplinary system and cooperation to meet multiple objectives (Van der Gun, 2012; Bruce et al., 2009).

Groundwater governance needs lots of experts and agencies to exercise a wide range of roles and responsibilities (Jakeman et al., 2016). Loucks (2000) desribes ideal water resources management group members as who are educated persons from all related disciplines (such as ecologists, economists, engineers, hydrologists), know system requirement and have experiences about dangerous (floods and droughts) and customs in region socially. Jakeman et al. (2016) warn that unclear roles and responsibilities have been problem the implementation of multidisciplinary groundwater management.

Lastly Gleeson et al. (2012) suggest temporary assistance by outside experts and aid organizations if it is required. Technical assistance and supporting research will increase the implementation of sustainable groundwater management (Sophocleous, 2000).

2.2.2 APPROPRIATE SCALE MANAGEMENT PLAN

Central management system has improved and managed water resources for many centuries (Alley & Leake, 2004). However it may have drawbacks such as lack of coordination (Konikow & Kendy, 2005). Centralized management system is being assigned to the local management units because of higher demand, population growth, and providing drinkable water cost (Alley & Leake, 2004).

Appropriate scale groundwater management is significant, additionally it is necessary that management bodies should have vertical integration between local decision makers and central decision makers (Bruce et al., 2009). For regional groundwater resource evaluation and sustainable groundwater management, the basin scale (Alley & Leake, 2004) or aquifer scale (Gleeson, Wada, et al., 2012) groundwater management will be useful (Liu et al., 2011).

Loucks (2000) explains that firstly efficient land scale should be determined to manage water resource systems succesfully. Effective scale for sustainable groundwater management plan should be selected according to catchments economy, environment, ecosystem, resource substitution, and human health. As result, effective central decisions and appropriate scale management plans with coordination may access to achievement (Jakeman et al., 2016).

2.2.3 DIFFERENT MANAGEMENT APPROACHES FOR AQUIFER TYPES

Some aquifers might be renewed only under available climate circumstances and geographical locations very slowly (Kalf & Woolley, 2005). Isotope and radioisotope data demonstrate that some aquifers were recharged approximately one million years ago by abundant rainfall (Gleeson et al., 2010; Margat et al., 2006). These aquifers are defined as non-renewable resources (Kalf & Woolley, 2005) or fossil groundwater (Margat et al., 2006). There are some examples in Spain, parts of South America, North America and China, inland Australia, the Middle East, and Northern Africa as non-renewable groundwater resources (Kalf & Woolley, 2005).

Meanwhile generally county boundaries and aquifer boundaries are not similar (Rodell et al., 2009). These aquifers are named as transboundary aquifers (Sandoval-Solis et al., 2011). For instance, Tigris-Euphrates Basin is a transboundary basin between Turkey, Syria, and Iraq (Voss et al., 2013).

Problems vary for aquifer types. Gleeson et al. (2010) emphasised groundwater quantity matter in fossil aquifers. Mining of aquifer storage reserves is most important problem in fossil aquifers. They will run short for future generations (Margat et al., 2006; Loucks, 2000). Differently in transboundary aquifers, cordination, transparency and accessibility are important problems, and insufficient monitoring causes lack of hydrological data for transboundary aquifers (Voss et al., 2013; Jakeman et al., 2016; Bruce et al., 2009).

Gleeson et al. (2010) suggest different managing in fossil aquifers. First, it should be managed over multi-generational time horizons with community involvement and a different socioeconomic value of groundwater. Second, extra measures are also required such as reducing irrigation water consumption and minimizing water losses from aquifer system, alternative resources such as desalination, wastewater reuse, and artificial aquifer recharge to non-renewable groundwater resources (Abderrahman, 2006) such as the storage of runoff (Konikow & Kendy, 2005).

Sandoval-Solis et al. (2011) sustainably emphasise that international agreements, the water policies of affected countries and the protection of environment are significant for transboundary water management. Famiglietti (2014) emphasises that groundwater levels and withdrawals have to be gauged and reported internationally. Results should be shared with countries that have political boundaries.

Sustainable groundwater management should consider aquifer types (Alley et al., 1999). Fossil aquifers (non-renewable resources) should be protected and improved for future generations (Loucks, 2000). Transboundary aquifers or basins need independent management with collaboration between the decision makers of shared countries (Bruce et al., 2009).

2.2.4 THE INTERRELATION OF GROUNDWATER AND SURFACE WATER

Sophocleous (2000) mentions relationship between groundwater and surface water. Groundwater abstraction, near surface water, may reduce the availability of surface water resources (Brodie et al., 2007). The changing of altitude of the groundwater table may change the flow directions between groundwater and surface water. Therefore drying streams may be related to the groundwater system (Alley et al., 1999).

Alley et al. (1999) mention that traditional water laws did not consider the physical relationship between groundwater and surface water. Famiglietti (2014) emphasises that most water law and policies in the developed countries have not been renewed. Therefore interconnections between surface water and groundwater have not been shown in these old law and policies.

Groundwater and surface water should be managed as a single source for integrated water resource management (Sakiyan and Yazicigil, 2004; Burgess, 2002; Alley et al., 1999; Gleeson et al., 2012). Kalf and Woolley (2005) believe that sustainable water management is effective with collective management of surface water and groundwater resources.

2.2.5 MODELS

Computer models have critical role increasingly for past several decades. This provides to evaluate alternative approaches for improvements and managements (Loucks 2000; Alley et al., 1999). ‘Modelling is indispensable in the field of groundwater. A tool for prediction and planning is necessary. Ground water models allow us to bring all available data together into a logical holistic picture on a quantitative basis.’ (Kinzelbach et al., 2003, pg 281).

Hydrological models may be used by decision makers who might predict future scenarios and reduce some of the social, economical and environmental impacts for managing water resources sustainably (Ajami et al., 2008; Alley et al., 1999). For instance, the allowed sustainable yield of the basin may be controlled for selected planning period by model results (Kalf & Woolley, 2005). Example by Dottridge & Abu Jaber, 1999 show that the result of modelling of groundwater flow in the upper aquifer of the Azraq is that the existing high abstraction is unsustainable for more than 40–50 years.

Data from field observation will show the effectiveness of model results (Kalf and Woolley, 2005). New drillings and monitoring may improve models (Bruce et al., 2009). Therefore models should be updated periodically with real data from groundwater system (Alley et al., 1999; Bruce et al., 2009).

2.2.6 WATER QUALITY

Most of released groundwater to surface water affect water quality as well as quantity (Konikow & Kendy, 2005). Groundwater discharge to surface water may cause salt intrusion to rivers (Brodie et al., 2007). Meanwhile, returned irrigation water or salt water intrusion may reduce water quality long time later for groundwater. The impacts of these problems should be predicted necessarily along planning (Kalf & Woolley, 2005).

2.2.7 ECOLOGICAL LIFE

The traditional water management did not include to develop and to protect ecological health (Konikow & Kendy, 2005). Groundwater managers did not consider groundwater-fed springs and wetlands in the traditional water management ecologically (Burgess, 2002). However aquatic ecosystems (streams and wetlands) may depend on groundwater, especially along the droughts (Brodie et al., 2007).

New management implementations should not be harmful for environmental and ecological life systems (Loucks, 2000). The sustainable yield must be less than the total recharge to maintain the quantity and quality of river, spring, wetlands, and other groundwater dependent ecosystems (M. Sophocleous, 2000). Therefore water managers have to consider balance between the requirements of people, agriculture, and the environment (Konikow & Kendy, 2005).

2.2.8 CLIMATE CHANGE

Climate change and related changes in the hydrological cycle happen difficulties for sustainable groundwater management (Famiglietti, 2014; Sandoval-Solis et al. 2011). The changing of the hydrological cycle because of climate change (Trenberth, 2011) should be guessed and evaluated under different hydrologic conditions for further sustainable water management studies (Sandoval-Solis et al., 2011).

Climate change has different impacts. First, in many regions dry periods have been longer because of climate change (Van der Gun, 2012). Groundwater consumption has increased to meet water demand in these regions (Alley et al., 1999). Second, groundwater recharge has been affected by changes in average precipitation, temperature and seasonal precipitation distribution (Van der Gun, 2012; Alley et al. 1999) . Third, the frequency and severity of floods and droughts have risen, while increasing temperatures has affected winter snowpack on mountainous areas (Konikow & Kendy, 2005; Alley et al. 1999). Lastly vegetation, streams, lakes, wetlands, and springs can be damaged because shallow aquifers have relationship between surface resources (Alley et al., 1999).

Sustainable groundwater management can play vital role to reduce climate change impacts (Alley et al., 1999). Famiglietti (2014) offers that existing water management strategies should be rethought because of altering precipitation, groundwater recharge and extreme events amounts such as flooding and drought. Renewed safe yield should resist the impacts of climate change (Sophocleous, 2000).

2.2.9 TIME SCALE FOR GOALS

Groundwater renewal process is very slow over decades to millennia (Margat et al., 2006; Gleeson et al. 2010). Therefore sustainable water quality and quantity goals should have multigenerational time horizon such as 50 to 100 years (Sophocleous, 2005; Gleeson et al., 2010; Alley et al., 1999).

Prepared long term plans have provided to manage groundwater systems sustainably (Gleeson et al., 2012). That is why this provides opportunity for future generations and ecosystem requirements (stream flows, habitat changes, groundwater levels, and water quality) to access sufficient amounts of fresh groundwater (M. Sophocleous, 2005). It only should be understood by societies, policy makers, water authorities and organisations that groundwater management issues require long-term strategies (Knüppe, 2011; Kalf and Woolley 2005).

2.2.10 SYSTEM RISKS IN GROUNDWATER MANAGEMENT PLANS

Risk assessment should be considered for possible system mistakes and their possible damages. Therefore risks should be estimated to improve groundwater management plans (Loucks, 2000). Negative consequences of risk and their possibilities should be determined and improved by engineers and planners in the planning process. Therefore available quantitative risk criteria are required, which will describe how often failures may occur and how failures may develop in system (Hashimoto, Stedinger, et al., 1982).

In water resource systems, risk assessment and risk management planning should consider who are responsible to solve or who are damaged by those system impacts. Long-term water demand, conservation programs and extreme events as some risks should be evaluated for efficient water consumption under normal conditions (Loucks, 2000).

2.3 IMPLEMENTATION

Implementations of the groundwater management plans are significant for sustainable groundwater resources (Pandey et al., 2011). Effective policy implementations provide benefits for environment, social and economic welfares (Bruce et al., 2009).

2.3.1 SUSTAINABLE YIELD

Seward et al. (2006) emphasize that the definitions of safe yield and sustainable yield are interchangeable. However safe yield includes the terms of economics, water quality, and legal rights while sustainable yield additionally emphasises the significance of environment and society. Therefore sustainable yield provides intra- and intergenerational equity with balance between environment, society, and economy objectives (Alley & Leake, 2004; Gleeson et al., 2012).

Kalf and Woolley (2005) describe a methodology for sustainable yield. There are four steps. First, hydrological and groundwater flow principles should be considered. Second, sustainable yield has to allow the groundwater system to arrive a new steady state in time. Third, providing the quantitative output should be allowed in numerical models and for modellers such as catchment mass balance (hydrological budget), production facility, well site selection in field and drawdown. Lastly a particular sustainable yield derived from models should consider some other criteria such as regional needs, economic and ecological requirements, and limitations by water authority.

Determination of sustainable yield is changing person to person (Kalf & Woolley, 2005; Gleeson et al., 2012; Seward et al., 2006). Therefore Sakiyan and Yazicigil (2004) believe that calculation of sustainable yield is wrong in some management plans such as ignorance of evapotranspiration, flow streams, infiltration, and springs from the aquifer. As result, according to Sophocleous (2000), abstraction would not be higher the natural recharge of groundwater, and loses (evapotranspiration, flow into streams, springs and seeps) should be considered to calculate natural recharge value for sustainable yield.

2.3.2 INCREASING AWARENESS AND WATER-SAVING

De Stefano et al. (2015) believe that water users have critical roles in groundwater management because their decisions generally affect the success or failure of any groundwater policy. Therefore raising awareness of groundwater problems is required for managing groundwater sustainably (Knüppe, 2011; Marios Sophocleous, 2010). For example, Gleeson et al. (2012) demonstrate a project that farmers are collaborative, who work voluntarily and help to collect data of water table depth, precipitation, and groundwater abstraction in Andhra Pradesh in India.

Mainly water resources should be managed and used effectively to achieve the maximum benefits from sources (Loucks, 2000). For instance, improvements in irrigation systems increase efficiency (Konikow & Kendy, 2005; De Stefano et al., 2015). To increase the quality of the existing irrigated hectares, modern irrigation systems are required such as lining irrigation canals reduce loses. This will provide water saving (Konikow & Kendy, 2005; Sakiyan and Yazicigil 2004).

2.3.3 BROAD PARTICIPATION

Alley et al. (1999) and Gleeson et al. (2012) believe that applicable and achievable sustainable groundwater management is required collaboration between water managers, local communities, and hydro geologists. They should implement together setting long-term goals, policies and adapted advance measures by back casting.

Public participation is requirement of sustainable management (Knüppe, 2011). Many investigations show the benefits of collaborative resource management, such as promoting public participation (Heikkila & Gerlak, 2005). The collaboration of stakeholders in all levels of decisions processes is an significant factor in integrated groundwater management (Margat et al., 2006; Savenije & Van der Zaag, 2008; Pahl-Wostl et al., 2008).

2.3.4 INTRA- AND INTERGENERATIONAL EQUITY

Groundwater sustainability is defined as a value-focused process of intra- and intergenerational equity (Gleeson and Alley et al., 2012).

First, the new policy and the management of water resources should have the principle of equity (Knüppe, 2011). People have a fundamental human right of access to fresh water resources, which is a basic requirement for human life and survival (Savenije & Van der Zaag, 2008). Therefore benefits should be distributed equally to develop social equity (Margat et al., 2006).

Second, water is not endless hence it must be consumed efficiently for present and future generations (Jha et al., 2007). Future management requires inter-generational equity (Knüppe, 2011). Opportunities to future generations should be significant goals (Margat et al., 2006). Therefore intergenerational equity should be considered, and future generation needs should not be ignored to meet the needs of the present (Giordano, 2009).

2.4 MONITORING

Firstly monitoring is the essential alert in aquifer system to show changes (Margat et al., 2006). Secondly the effectiveness of goals and objectives of management plan can be evaluated with monitoring. That is why monitoring shows real situations in aquifer system. As result of monitoring, groundwater management plans can be renewed easily to manage and improve system (Gleeson et al., 2012; Loucks, 2000; Foster & Loucks 2006).

2.4.1 ACCESSIBLE AND CURRENT DATA

Groundwater management implementations are decided by average conditions therefore existing the longest possible data series historically are useful (Kalf & Woolley, 2005). Ajami et al. (2008) warn that meteorological and hydrological observations can have some errors. Therefore Sophocleous (2000) emphasises to collect new data, which will help what we know today. Gleeson et al. (2010) suggest that new data should be updated continually, and groundwater management plans could be rearranged through new data.

Observations of stream flow, precipitation, and evaporation data are controlled by governments generally, and permission is required to access to these data for some countries. This restriction affects the quality and quantity of hydrological studies (Voss et al., 2013). It is significant that technical parameters and groundwater resource data should be accessible easily with available formats (Margat et al., 2006).

2.4.2 MODERN TECHNOLOGY

Modern technology will increase efficiency in groundwater management. Satellite data procures rapid and practical baseline information such as the movement of groundwater, the distribution of vegetation and surface water, geology and geomorphology (Jha et al., 2007; Loucks, 2000; Konikow & Kendy, 2005).

For instance, Gravity Recovery and Climate Experiment (GRACE) is used method as satellite observations, which provide water monitoring and new data such as total terrestrial water storage (snow, surface water, soil moisture, and groundwater). Significantly groundwater depletion is observed by GRACE. Additionally satellite data will provide saving of time (Voss et al., 2013; Rodell et al., 2009).

2.5 EVALUATION

2.5.1 EFFECTIVENESS OF GROUNDWATER MANAGEMENT PLANS

Mainly, the evaluation of existing and planned water resource systems is a significant process to control their situations under the wide array of probable future demands and hydrologic conditions (Hashimoto, Stedinger, et al., 1982). Evaluation informs to water managers about program performance and identifies developed areas of plans (Carr et al., 2012).

The results of monitoring of implementations should be used to evaluate the effectiveness of management actions (Adams et al., 2003). The effectiveness of policies or regulation in water resource systems will show that policies may protect and develop the expected water management characteristics in the basin for future from the perspective of society and the environment (Sandoval-Solis et al., 2011).

2.5.2 ADAPTIVE MANAGEMENT PLAN

Our knowledge and ability are not sufficient to forecast future outcomes (Seward et al., 2006). Management conditions are changing. For instance population is growing, climate is changing. Therefore sustainable groundwater management should be adaptive, more resilient and connected with new generations in the planning, design, and management periods (Loucks, 2000; Gleeson et al., 2012).

According to adaptive management philosophy, policies and implementations should be continually developed and modified by experiments from the results of evaluation of previous practices during process (Brodie et al., 2007; Gleeson et al. 2012). In order to achieve adaptive management, firstly a couple of long-term targets should be determined (Knüppe, 2011). After that, management targets are regularly re-evaluated. Lastly there should be some rearrangements on some objectives to improve management plan (Seward et al., 2006).

Monitoring is an exactly main component of this adaptive management strategy (Margat et al., 2006). Adaptive management should have sustained long-term monitoring programs to evaluate system (M. Sophocleous, 2005). For instance, safe yield should be renewed according to the monitoring of environmental conditions (Sophocleous, 2000).

Significantly adaptive management approach is suggested instead of rigid and unarguable management style (Seward et al., 2006). Groundwater-based communities may implement policy to access multigenerational goals that may later be modified using adaptive management for sustainable groundwater management (Gleeson, Alley, et al., 2012).

3. METHOD

In this chapter, approach and processes to collect and analyse data are explained.

To better understand issues of sustainable groundwater management and use of policy/regulation to achieve sustainable groundwater management, literature review of sustainable groundwater management was done. Related publications were identified in the literature review part to find the necessary background knowledge.

In the light of sustainable groundwater management, main principles were explained, and evaluation and interview questions were prepared to understand how to improve the sustainability of groundwater management plans (Appendix A and B).

Table 1 shows investigated regulations, plans and projects of water management authorities of Turkey (DSI, SYGM). To achieve sustainable groundwater management, these laws and policies were compared with determined sustainable groundwater management principles.

Table 1 Investigated Groundwater Management Regulations, Plans and Projects in Turkey

NAME	**YEAR**
Groundwater Law No:167	1960
DSI Groundwater Regulation	1961
Environmental Law	1983
The Protection of Groundwater against Pollution and Deterioration	2012
The Determination of Protection Zones of Aquifer and Resource for Drinking Water	2012
DSI Groundwater Measurement Systems	2013
The Monitoring of Surface Water and Groundwater	2014
Environmental Impact Assessment	2014
The Establishment, Tasks, Working Procedures and Principles of Basin Management Committees	2015
Control of Water Use in Irrigation Systems and Reducing Water Losses	2017
DSI Strategic Plan 2010-2014	2009
DSI Strategic Plan 2017-2021	2015
DSI Strategic Plan 2019-2023	2018

Konya Basin Drought Management Plan	2015
Clima Hydro Project	2014

Requirements and impediments for groundwater management are better understood by scientific experts and water-resource managers (M. Sophocleous, 2000). Qualitative interviewing is an effective tool to learn the opinions and experiments of people (Rabionet, 2011). Semi-structured interviews provide elaboration, clarification and specific examples by informants' responses for researchers (Arksey & Knight, 1999). Therefore to understand how groundwater management plans can deliver sustainable groundwater management, semi-structured interviews were done with experts in Turkey.

Interview questions were prepared from the literature review and some issues from review of the laws and policies. Before interviews, a favourable ethical opinion had been received by the Faculty of Engineering Research Ethics Committee (FREC) for this study of informants (Appendix E).

There are two important water management institutions in Turkey. First, General Directorate of the State Hydraulic Works (DSI) generally is responsible implementations of water resources such as dam buildings, allocations of groundwater abstractions. Second, General Directorate of Water Management (SYGM) concentrates on adaptation of international water regulations, preparing water regulations and management plans. Four informants were selected from these two institutions. Personal information of informants is not explained for their occupational safety. Only average experiences are shown in the Table 2.

Table 2 Informant Codes and Average Experiences

INFORMANT CODE	AVERAGE EXPERIENCE (Year)
DSI01	28
DSI02	7
DSI03	20
SYGM01	7

Interview data provided broad knowledge about some difficulties and impediments of groundwater management plans and policies in Turkey. All data were analysed against the sustainable groundwater management principles identified in section 0.

Finally, in the discussion part, determined impediments of groundwater management of Turkey were discussed how impediments may be improved via implementations in England and EU to achieve sustainable groundwater management.

4. RESULTS

This chapter indicates results of analyses of law’s content and interview data. The results are evaluated in sustainable groundwater principles separately. Analysed regulations, plans and projects from Turkey are shown in the Table 1.

4.1 SUSTAINABLE GROUNDWATER MANAGEMENT

Groundwater Law (1960) aims to provide sustainable groundwater management. It emphasises that aquifers should be used continuously:

‘Safe yield is defined as water amount can be abstracted continuously without detriment to aquifer’ Groundwater Law (1960) - Article 2.

However answers of informants showed that sustainable groundwater management was not implemented in some basins of Turkey. Over abstraction amount from aquifers caused groundwater depletions. There were two main reasons in these basins of Turkey:

In some regions, safe yield were determined wrongly. Water consumption became much more than real safe yield value (DSI01).

Some water users prefer unlicensed wells in the some basins where abstraction was limited (DSI03).

As result, sustainable groundwater management failed in some parts of Turkey. Wrong calculation of safe yield and unlicensed wells are main reason of failure.

4.2 PLANNING

4.2.1 MULTIDISCIPLINARY GROUNDWATER MANAGEMENT

DSI Groundwater Regulation-Article 7 defines profession of needed experts as authorized geologists, hydrogeologists and engineers for hydrogeological investigation report or application projects.

First, all participants believe that geologists, hydrogeologists and engineers are not sufficient for groundwater management, and that the opinions of different experts should be considered for sustainable groundwater management:

Firstly, law does not allow for working different expert in groundwater management. Term of engineers in the law defines geology and hydrogeology engineers. This term does not cover other engineers as agricultural or environmental engineers. Therefore we have only geology and hydrogeology engineers in here (DSI).

Lack of different experts is our gap. For instance, we manage agriculture and irrigation cooperatives. Geology and hydrogeology engineers have to read agricultural reports. I believe that definitely biologist, agricultural and environmental engineers are required in here. Actually SYGM was established since 2011 because of improvement of some gaps of water managements of DSI such as technical experts (biologist and environmental engineers) (DSI01).

DSI Groundwater Regulation limits working other professions (biologist, agricultural and environmental engineers and so on). Only geology and hydrogeology engineers work for groundwater management in DSI. Climatologists, environmentalists, economists, chemical and biological experts, social and political scientists are not involved in preparing and implementing groundwater management plans.

Participants emphasise that groundwater regulations should allow legally working other experts and scientists. After that, environmentalists, biologist, and social scientists and so on will be worked along the preparing and implementation of groundwater management in Turkey.

4.2.2 APPROPRIATE SCALE MANAGEMENT

Groundwater has been managed in Turkey according to groundwater operation areas. Groundwater Law No: 167 mentions that after the determination of borders and structural features of groundwater mass, groundwater operation areas are accepted and announced by DSI. The number, location, depth and amount of wells in the groundwater operation areas are determined by DSI (Article 1 and 4).

Basin Management Committees were established to manage basins (operation areas).

The Establishment, Tasks, Working Procedures and Principles of Basin Management Committees (2015) aims establishment and maintenance of Basin Management

Committees to implement and monitor basin action, flood and drought management plans.

All participants reported that groundwater is managed basin scale:

Groundwater management in basin scale was started newly. There are management groups in catchments. Those include governor, expert from DSI, and some workers from some other ministers (DSI01).

As results, law supports appropriate scale groundwater management. Groundwater operation areas have been determined, and catchment management groups have been constituted for basin scale groundwater management. Additionally all informants believe that basin scale groundwater management is implemented in Turkey.

4.2.3 DIFFERENT MANAGEMENT APPROACHES FOR AQUIFER TYPES

Groundwater regulations and plans consider aquifer types and different management approaches such as non-renewable and transboundary aquifers. For instance, water management plans are prepared for main catchments in Turkey. Generally catchment scale plans provide different management for aquifer types.

Firstly Konya Basin Drought Management Plan is an important example from closed catchment (non-renewable). Report aims to show measures and to reduce the impacts of drought and thirst. There are 8 targets (Dolsar Engineering, 2015):

- monitoring and evaluation of the changes in water potential and drough period effects
- increasing social awareness and public education
- developing projects to supply water for sub-basins in drough periods such as new reservour
- collaboration and providing technical support
- reducing water demand, promotings of water efficiency and water resources protection and water quality
- reducing the effects of drought on the people, economy and ecosystem in Konya basin
- improving coordination between institutions

- assessment of possible impacts from climate change

Informants reported that management styles change due to aquifer types. Especially fossil aquifer in Konya Basin is managed differently. There have been strict rules in these basins:

We started to manage aquifers according to their types. Fossil aquifers such Konya Basin are managed differently. Abstraction amount was districted in Konya Basin to reduce overconsumption (DSI01).

Secondly SYGM is determined responsible with regulation about collaboration of transboundary aquifers (The Assignment of The Ministry of Forestry and Waterworks, 2011).

Some participants reported that transboundary aquifers are managed in the lights of international laws by Turkey. DSI02 and DSI03 emphasised that cooperation is not provided by other countries. Especially political problems in neighbour countries are main reason:

We depend on international law. We act according to border countries attitude in transboundary aquifers. If they support to manage aquifer both, we are ready to work together (DSI01).

There are significant aquifers in the south border of Turkey as Tigris and Euphrates river basin. There is no cooperation between countries. All countries have individual decisions about transboundary aquifers. Actually nowadays other countries such as Syria and Iraq have political problems in their borders. So they do not focus on water management issues (DSI02).

Results show that aquifer types are considered for groundwater management. Regulations and implementations are coherent for sustainable transboundary and fossil aquifer managements. There are a few problems only related to the political disturbance of other countries.

4.2.4 THE INTERRELATION OF GROUNDWATER AND SURFACE WATER

Surface water and groundwater relationship is mentioned in three regulations.

First, The Monitoring of Surface Water and Groundwater regulation aims to monitor the quality and quantity of surface and ground waters, the changes of quality and quantity due to natural or human impacts.

Other two regulations demonstrate relationship of surface water and groundwater for only water quality issues. First, The Protection of Groundwater against Pollution and Deterioration regulation considers the relationship of pollution of groundwater systems, surface water and terrestrial ecosystems. Second, The Determination of Protection Zones of Aquifer and Resource for Drinking Water regulation defines the protection zones of aquifers and surface water both. Only in a few articles this regulation mentions relationship of groundwater and surface water drainage area for water pollution issue.

These articles are not sufficient to show relationship between surface and groundwater in view of DSI01:

Regulations were prepared by environmental engineers of SGYM, and water quality was focused only. Many important relationship issues were not thought sufficiently while showing relationship between surface water and groundwater. For instance these regulations did not cover the impacts of groundwater abstractions on surface water. I believe that hydrogeologist and geologist are required to show successfully relationship between surface water and groundwater with all (DSI01).

Results show that law makers did not consider sufficiently relationship between surface water and groundwater. They focused on only one issue (water quality). Therefore many important issues were ignored in the three regulations such as groundwater abstraction and surface water relationships. Informant believed that law makers were not experts about understanding relationship between surface water and groundwater. Correspondingly, these regulations need hydrologists to analyse hydrological relationship of surface and ground water thoroughly.

4.2.5 MODELS

Modelling studies were started with the Monitoring of Surface Water and Groundwater Article-6. Article 6 defines that all surface and groundwater masses are determined by ministry.

Informant believes that aquifer modelling is important in Turkey for groundwater management. Modelling experts provide much data that are calibrated with relevant institutions:

I believe that mathematical models are important tools for decision-making institutions to protect water resources in Turkey. Modelling studies are important in river basin protection practices implemented by SYGM.

There is a modelling working group in SYGM, which includes engineers who are experts in modelling. Specialised experts run and interpret models. This modelling working group models much of data such as rainfall flow, long time groundwater level changes, and pollution material and water quality. SYGM contacts with other directorates (DSI, General Directorate of Meteorology and so on) during the data calibration (SYGM01).

For instance, ClimaHydro project was an modelling example by SYGM to determine water budget in all basins by considering climate change impact on hydro meteorological data (SYGM, 2014).

Results show that modelling studies are supported by regulation. Project and answers of participant show that modelling studies have been implemented by SYGM.

4.2.6 WATER QUALITY

The Determination of Protection Zones of Aquifer and Resource for Drinking Water (2012) regulation bans discharge of waste water into groundwater that is used or planned to abstract for drinking water. Meanwhile DSI Groundwater Technical Regulation (1972) determines that operated all wells would be taken samples for chemical analyses every year in determined time and will be sent to DSI laboratory.

Participants believe that water quality is considering in the implementations:

I believe that there is no contaminating into water resources. This issue is controlled by Environment Ministry with strict rules (DSI01)

Water quality is protected with regulations and in the implementations stage any problem is not monitoring according to informants.

4.2.7 ECOLOGICAL LIFE

Old groundwater regulation does not include the protection and improving of ecological life in detail. Social and economical issues are emphasised. For instance, DSI Groundwater Regulation (1961) - Article 15 defines ‘beneficial requirements for abstraction from aquifer respectively as drinking, cleaning, municipal services, livestock and agricultural irrigation, mine and industrial water, sporting and similar facilities for local water user or industrial consumers.’. The ecological life is not mentioned in this regulation. Environmental Law (1983) mentions basically that ‘it is essential to protect the biodiversity and the ecosystem.’

There has been improvement about protection of ecological life and environment since Environmental Impact Assessment (EIA) regulation that was legislated in 2014. This regulation aims to protect and improve environment in Turkey. There are two issues about groundwater management in the regulation. First, EIA has to be implemented in the groundwater abstraction and groundwater storage projects that are higher than 300,000m3 / year. Second, lakes, rivers and aquifers are determined as protected areas.

Second important regulation for ecological life is the Protection of Wetlands (2014). Article 6 of this regulation includes mandatory principles for the protection of wetlands. Only related to groundwater management part is ‘wetlands must not be polluted, and their natural structures and ecological characteristics must be protected. In all kinds of land and water use planning, protection of the functions and values of wetlands is considered.’

DSI aims to design environmentally most suitable projects after 2014. The aims of DSI are defined about water management in the Strategic Plan 2017 – 2021. In the light of these aims, DSI develops technically, economically and environmentally most suitable projects and prepares planning reports (DSI, 2015).

DSI01 believes that the awareness of ecological life has increased. There is more consideration of ecological life. Meanwhile there are some gaps:

All of our projects have ecological values after EIA. While water amounts are determined for consumptions, ecological life is considered. However there are two *problems. First, sometimes implementations are different because of social and political reasons. Second, ecological damages are noticed lately. I believe that there is lack of forecasting. That is why abstraction and recharge are not controlled sufficiently. Only after droughts in wells and ecology, problems are understood (DSI01).*

As result, Environmental Impact Assessment (2014) and The Protection of Wetlands (2014) regulations have been implemented since 2014 for new projects. Informants reported rising protections in the water management implementations since 2014. Results of these projects showed that the protection of ecological life increased. However two issues reduce effectiveness of EIA in the projects. First are social and political reasons, second is lack of forecasting of ecological damages.

4.2.8 CLIMATE CHANGE

There is no regulation about climate change impacts on groundwater resources in Turkey. However climate change has been studied by Climate Change Adaptation Working Group in the SYGM. Tasks are determined as determining goals and improving strategy and policy about climate change, preparing researches about the effects of climate change on water resources, floods, drought, and monitoring the implementation of the determined measures (SYGM, 2020a).

There are two important projects by SYGM. First, The Climate Changes Impact on Water Resources Project aims to describe the effects of climate change scenarios on the surface and ground waters and to determine adaptation actions in the catchments of Turkey. Climate change projections are modelled between 2015-2100. Project includes (SYGM, 2014):

- Preparing climate change projections for all catchments according to 3 global climate models with RCP4.5 and RCP8.5 emission scenarios. Temperature, precipitation, evaporation and flow projections are being constituted with the model outputs for each basin.
- A hydrological model is run with climate projections' outcomes, and surface water currents are determined in catchments. Budgets of surface water are described along significant water reaches and side reaches. Also, groundwater

storage amounts were determined according to groundwater data and climate projections' results for each catchment.

Second important study is preparing drought management plans. Data by SYGM shows that drought anaylyse plans of 15 basin of 25 main basins had finished in Turkey to analyse climate change impacts (SYGM, 2020b). Completed plans include measures to be taken before, during and after the drought. Secondly, water budget, analyses of change of water resources by GRACE Satellite and hydrological models are studied.

Konya Basin Drought Management Plan suggests measures to reduce possible impacts of climate change (Dolsar Engineering, 2015):

- generally reducing greenhouse gas emissions and deforestation
- determining the potential damages various sectors in the future because of climate changes
- evaluation of how water resources will change due to climate change

SYGM01 reported that *'Basin Drought Management Plan have been prepared for 25 main basins as climate change models by SYGM. I believe that we have effective studies about climate change issues.'*

Projects show that climate change has been modelled, and measures are planned in Turkey by SYGM. Future climates in basins are estimated by climate change projections. The changes of groundwater and surface water are evaluated. After that, possible damages are described. These research projects help to understand size of climate impacts. Answers of informants supported that existing research projects will be sufficient to protect and improve water resources if they are implemented. There is no information about implementations of these plan and projects.

4.2.9 TIME SCALE FOR GOALS

Time scale is mentioned only as 6 years in the regulations to define measures and goals program.

According to the Protection of Groundwater against Pollution and Deterioration - Article 12, ‘The measures program includes basic measures, as well as special measures determined according to the characterization, pressures, effects, and monitoring results of groundwater masses. This measurement program is prepared by SYGM for six-year terms. In the second half of this period, the measures program is reviewed and updated. New or revised measures are added in the next 6-year program’.

6 years was confirmed by participants: *6 year was selected due to EU Water Frame Directive.*

In addition to this, DSI Strategic Plans were prepared for next 4 years (Table 1). Participants said that 6 year term was determined according to EU WFD. Long term groundwater management plans were not met while researching. Results show that there is gap about long term groundwater management plans.

4.2.10 SYSTEM RISKS IN GROUNDWATER MANAGEMENT PLANS

Strategic Plans and Basin Drought Management Plans include risk assessments that have possible system mistakes and their possible solutions. Some examples are examined.

Some threats that affected and can affect the implementations of Strategic Plan 2010 - 2014 are analysed. Risks and Uncertainty Analyse determine risks as natural disasters, sufficient budget and political choice. Sources of uncertainty include insufficient and late payments, lack of personal and uncertainties of law (DSI, 2009).

Risks are detailed in the Strategic Plan 2019-2023. Estimated risks and control actions are determined step by step.

Table 3 demonstrates some examples (DSI, 2018).

Table 3. Determined Risks and Solution Suggestions for Strategic Plan 2019-2023

Estimated Risks	**Control Actions**
Projects can be finished lately because of	First, the importance of projects will be told to citizens. Second, initially projects

field problems by citizens.	without problems will be started.
Enough water may not be in the dam because of drought	Affected areas will be determined, and the effectiveness of irrigation will be increased.
Monitoring of water quality can failure	Data by other institutions can be procured

Konya Basin Drought Management Plan has drought risk estimation and risk management (Dolsar Engineering, 2015).

All participants reported that management plans comprise risk factors:

Water management plans consider possible risks. This is really effective for all water managers and decision makers. Before starting implementations, water managers understand possible risks (DSI03).

Management plan and Strategic plan cover estimated risk for the delay of implementations. Control actions are explained to reduce estimated risks. Interviews believe that these risk assessments are helpful tools for decision makers to predict risks before implementation state.

4.3 IMPLEMENTATION

4.3.1 SUSTAINABLE YIELD

Initially, DSI controls and limits abstraction amounts in aquifer systems with sustainable yield in the regulations. Meanwhile sustainable yield is a discussed topic for groundwater management in Turkey. There are three discussion issues of sustainable yield implementations. First, in the regulations some terms cause confusion of sustainable yield implementation. Second, announced value is lower than real safe yield value in views of informants. Third, unlicensed wells are main problem for exceeding of sustainable yield.

Participant believes that there is a need to renew regulations related to sustainable yield. Old regulations have juridical and technical confusions. Some old articles in the regulations are not understood by some DSI workers:

Actually we have studied about safe yield (sustainable yield) topic because there was a requirement to renew groundwater law. Our groundwater regulation was legislated 60 years ago. Old law descriptions have gaps. Hydrological conditions have changed. These cause different implementations of safe yield between DSI regions because DSI workers in regions do not understand and implement old law descriptions (DSI01).

When analysing regulations, there are differences to calculate yearly groundwater abstraction in the two different regulations as mentioned by informant. That is why regulations describe groundwater abstraction differently.

Groundwater abstraction depends on beneficial requirement amount (lower than safe yield) according to DSI Groundwater Regulation- Article 15:

‘Beneficial requirement value is determined by DSI to calculate allowed consumption from aquifer, which is never higher than safe yield. Beneficial requirements are defined respectively as drinking, cleaning, municipal services, livestock and agricultural irrigation, mine and industrial water, sportive and similar facilities for local water user or industrial consumers’.

DSI Groundwater Technical Regulation does not mention beneficial requirement, and it says that yearly abstraction from aquifer should be equal to recharge:

‘Generally, yearly abstraction from aquifer should be equal to recharge. To provide this equality, DSI Local Directorships would record the changing of groundwater level. To block the exceeding of safe yield, all wells will be licensed by DSI Local Directorships. Water users will not abstract much water than allowed amount. According to precipitations and recharge, safe yield can be declined or increased. This changing will be informed to water users’.

As result, there is confusion that abstraction from aquifer will be lower than safe yield or equal to recharge.

Additionally DSI Groundwater Technical Regulation (1972) aims to block the exceeding of safe yield. Measures are described as increasing monitoring and licensing of wells. Lastly, DSI has opportunity to change determined safe yield value according to changes of precipitations and recharge.

Second discussion issue is that participant believes that announced value is lower than real safe yield value:

Safe yield value was calculated for all basins. Some decision makers believed that safe yield value was so higher therefore they reduced calculated safe yield randomly, which was about 70% or %80 of initial calculated safe yield I believe that safe yield was higher than we announced (DSI02).

Informants believe that unlicensed wells are main problem for implementation of safe yield as last discussion point. Water users prefer unlicensed wells in basins where groundwater using is limited:

After the overflow of safe yield value, abstraction was limited in Konya Basin. We do not accept new demands. Therefore water users prefer unlicensed wells. The numbers of unlicensed wells have increased in basin (DSI03).

Abstraction amount is not known certainly by unlicensed wells. There are social and economical pressures to determine and close unlicensed wells:

We do not determine how much there are unlicensed well and total abstractions by these wells. If we determine unlicensed wells, we have to close these wells. This is big social and economical problem. Much people will be affected by close decision (DSI02).

For instance, groundwater is main need of Konya for irrigation socially and economically. Konya has much more unlicensed wells, and is also the first city of agriculture and animal husbandry. 10% of wheat, 62% of carrot, 99% of tulip and 5.5% of livestock of Turkey were produced in Konya in 2017 (Konya Agriculture and Forestry Directorate, 2018). Closing of these unlicensed wells is higher problem in Konya.

Fines are not large enough and are not being applied by local authorities to prevent unlicensed wells:

There are minimum and maximum fine limits in the regulation. Local authorities are responsible to decide fine amounts. They decide generally minimum limit that is not enough and is paid easily (DSI01).

As result, there are three main problems of sustainable yield. First, there is confusion in the regulations about terms of beneficial requirement, yearly abstraction and safe yield. Second, announced safe yield does not show reality. Lastly, unlicensed wells are not determined and closed because of social and political issues, and water fine is not sufficient.

4.3.2 AWARENESS AND WATER-SAVING APPROACHES

Water saving is supported with regulation in Turkey. Control of Water Use in Irrigation Systems and Reducing Water Losses (2017) regulation aims using of irrigation systems effectively, providing water saving, reducing water loses and prohibiting unauthorized water using.

Raising awareness is important to save water and promote productive agriculture. There are projects to increase awareness.

"Water Messengers" is the project that DSI initiated and developed in 2014. Project was improved by EU economic resources in 2017. It was named as “Water Messengers Training and Raising of Awareness Technical Support Project". It was spread throughout the country with the partnership of the Ministry of National Education and the General Directorate of TRT (a TV channel) (Turkey Republic Environment and Urban Ministry, 2017).

Participants believed that there was increasing of awareness and water saving for educated people. These conferences, educations and projects were helpful tools:

To show importance of water, there were educations in schools, social projects such as "water messengers" and meetings with water users. Water messengers project aimed to improve water saving and awareness. Many students *and teachers were informed about using water effectively. I believe that water save was understood (DSI01).*

However all participants added that awareness is not sufficient between farmers. The main aim of farmers is higher income. They do not consider environment and agronomy:

Farmers firstly aim to increase productivity and income. Awareness is lower between farmers. So water saving is not important for them. They do not know modern agriculture (agronomy). For instance, much of them do not know water needs of planted products. They believe that over water increases product efficiency (DSI03).

Meanwhile informants believe that free water for irrigation causes overconsumption by these farmers who have lower awareness to save water:

There are some effective irrigation systems to reduce water consumption. Especially automatic irrigation system provides water saving but they are not preferred by farmers. That is because automatic irrigation system will need cost but there is no water charge in Turkey. Therefore farmers do not need water saving and a new investment. They consume water freely (DSI01).

Water users access freely for irrigation how much water they want in Turkey. Control of Water Use in Irrigation Systems and Reducing Water Losses (2017) has only one article about water fee that irrigation cooperatives collect fees for maintenance, repair and management of irrigation systems (irrigation canal and water pump).

Participants emphasised that this regulation does not allow water sales and water charges for irrigation. Only a little repair cost has been collected from all farmers:

Sometimes some foreign investments such as World Bank indicates that water consumption costs should depend on water consumption amount. However in Turkey law does not allow water sales for irrigation (DSI02).

A report shows that there is political pressure about water charges in Turkey. Water charges were discussed in the parliament in 2018. Government claimed that water was not limitless and water charges would reduce overconsumption. However farmers did not accept and said that if water for irrigation would be sold, farmers would not plant and would sell their fields. Therefore regulation was not accepted in parliament (Hurriyet, 2018).

Consequently, awareness projects are not successful for relevant stakeholders (farmers). Water consuming is becoming higher by farmers because of free water, and old irrigation systems. Farmers challenge water charges. Therefore water charges are not used as dissuasive of over consumption of water resources.

4.3.3 BROAD PARTICIPATION

In the Establishment, Tasks, Working Procedures and Principles of Basin Management Committees (2015), the missions of Basin Management Committees (BMC) were defined as preparing, implementing and monitoring the basin flood and drought managements and basin protection and action plans. Meetings of committees are done as 2 times a year. As a result of this regulation, basins are managed by BMC.

Article 8 of same regulation describes members of BMC:

Governor, general director of water and sewerage administration, mayor, the highest level representatives of the Ministry of Forestry and Water Affairs, Ministry of Energy and Natural Resources, DSI, General Directorate of Forestry, General Directorate of Meteorology, General Directorate of Highways, Development Agency are official representatives of the basin committees.

Different community groups are represented by special sector representatives as representatives of irrigation cooperatives, one representative from the aquaculture sector, representatives of power generation plant authorities, private sector hydroelectric power plant representatives, representatives of universities and non-governmental organizations and other experts. These groups can be invited to the meetings without voting rights by decision makers if they are need in the meetings (Article 8/3).

Additionally one participant reported that Basin Management Groups do not focus on groundwater management issues technically:

I believe that groundwater is not argued in yearly meetings in these Basin Management Committees. They focus on political management decisions instead of technical. Committees do not have importance of groundwater and experts are not listened in this meeting along decision process. For instance our experts joined these meetings but they could not explain main water resource problems. They did not have voice (DSI01).

The content of regulation provides broad participation of stakeholders in basins. Regulation provides participations of society, experts and decision makers for catchment managements. This is important advantage of broad participation of stakeholders in basin scale. However there are gaps in the regulation content. First, the representation of significant community representatives in basin depends on invitation of governors according to Article 8/3. If governors do not invite representatives of community groups, these stakeholders do not join to these meetings. Second, if community representatives are invented to meetings, they have only opportunity to share their opinions without voting rights.

In addition to this, implementation demonstrates that the opinions of groundwater experts are not considered in the BMC. According to participant answer, the technical suggestions of experts are ignored by governors in these meetings. Generally social and political issues become discussion topics in these meetings. Participant believes that group directors do not know importance of groundwater. These are drawbacks of regulation.

4.3.4 INTRA- AND INTERGENERATIONAL EQUITY

DSI Groundwater Regulation Article 16 aims social (intra) equity between neighbours: ‘Anyone, who does not have enough water or no water in his land for his beneficial needs, may want the groundwater of his neighbour to meet his beneficial needs if there is groundwater in the neighbouring land and groundwater is sufficient both’.

Meanwhile all informants reported that all citizens are equal in the groundwater law in Turkey. There is one acceptance condition. DSI accepts water demands if water consumption from aquifer is less than safe yield. After that, abstraction amount is calculated according to peoples' field sizes:

Law gives same opportunities to all people. There is no exception for any groups or social status. Actually we give licenses to demanding water according to peoples' field sizes if safe yield is not exceeded in the basin (DSI03).

Participants reported that regulations and projects aim sustainable groundwater consumption for future generations:

Basin Protection Plans had been prepared for 25 main basins. Until 2023, it is aimed that these basins will have less polluted water standards. I believe that less polluted water will be used for irrigation, industry and livestock for future (SYGM01).

Regulations and plans consider inter-generational and social equity, however implementations shows that overconsumption than sustainable yield causes groundwater depletions on aquifers. For inter-generational equity, aquifers should not be abstracted more than sustainable yield. Generally there is no inter-generational and social equity.

4.4 MONITORING

Three regulations aim monitoring of surface water and groundwater.

First, National Monitoring Network is important project to observe surface and ground waters nationally. National monitoring network was established by Monitoring of Surface Water and Groundwater Regulation (2014) - Article 11:

'The National Monitoring Network is determined and established for all surface and groundwater by the working groups who are the participations of all relevant institutions and organizations that carry out monitoring activities'.

Second, results of monitoring are used to develop groundwater chemical quality. Monitoring processes and aims are explained in detail with the articles 8, 10 and 11 of the Protection of Groundwater against Pollution and Deterioration regulation explain the aims of monitoring:

‘‘Monitoring data is used to analyse the impacts of human activities on groundwater. The groundwater observation wells are determined by DSI in the number and location to represent each aquifer, and the groundwater levels are monitored enough frequency. According to the results of the monitoring, risks of groundwater bodies are determined by DSI and reported to SYGM regularly’’ (Article 8) and monitoring period as 6 years.

‘‘According to the monitoring results, groundwater chemical status are evaluated by SYGM with taking the opinion of DSI and published as a report every six years. This report includes groundwater quality standards of groundwater mass, threshold values and monitoring results values and comments of results by experts’’ (Article 10).

‘To start improving of chemical quality of groundwater, the concentrations of contaminants at risk groundwater masses are determined by SYGM according to results of monitoring program’ (Article 11).

Third, DSI Groundwater Measurement Systems regulation aims to control abstraction amounts and monitor aquifer automatically.

‘The maximum abstraction value yearly is described for water users by DSI with the license number of water user. After maximum abstraction value for water user, abstraction is finished automatically.’

Regulations aim to monitor aquifers and improve groundwater quality and quantity. However informants emphasised that the effectiveness of monitoring data is not higher.

First, manual monitoring systems have many disadvantages such as measuring errors:

Surface water monitoring system is broad in lake, river and dam reservoir, and some of them are automatic. Observations well for groundwater (more than 1000) provide monthly and seasonally data. However I believe that observation wells do not represent aquifer systems and much of them are manual. Therefore result *quality depends on measurers. We need to improve manual measurement systems (DSI01).*

Second, measurement system is not implemented for all basins in Turkey:

In groundwater monitoring studies, rainfall flow data, long time groundwater level changes, the pollution material and water quality are monitoring and reported yearly some river basins in Turkey (SYGM01).

Regulation aimed that all wells would have measurements systems. But it was not implemented. Only there are two obligated basins such as Meriç-Ergene and Konya Basin for all wells that must have measurement systems (DSI01).

Third, system installation cost, consumption limitation and expectation of water fee in future are main disadvantages for water users:

Water users do not want measurement systems. First, installation cost is important. Second, water consumers do not want to use measurement system in their well because of limitation of water abstraction. Third, there is no water charge in Turkey for irrigation. Water consumers believe that the measurement system is a bad thing that will cause water charge in future (DSI03).

In conclusion, there are regulations to monitor aquifers and surface waters and improve quality and quantity of water resources. However informants emphasised that implementations of regulations were not successful. Three reasons were emphasised as measuring errors of manual monitoring systems, only monitoring of some basins and oppositions of water users.

4.4.1 ACCESSIBLE AND CURRENT DATA

Data collection methods are described by DSI Groundwater Regulation as hydro geological research reports, research wells, geophysics, and water chemistry.

There are data systems by DSI and SYGM. For example, DSI started to establish the World-Class Water Data system that the transfer of groundwater and surface water values to water database. With the Water Database Project, data can be accessed and monitored from anywhere in the Turkey via Geographic Information Systems (GIS) (DSI, 2009). Additionally, Climate-Water Database was constituted in order to store all produced data and outputs of the project (SYGM, 2014).

Informants believe that data system is not common for all basins. There are enough data for critical groundwater systems only. Collecting data is sharing between DSI and SYGM. Much of these data can be accessed online:

DSI can access immediate data from some wells that have automatic measurement systems for important basins (Meriç-Ergene and Konya Basins). Data results have been analysed by DSI and SYGM both (DSI01).

Generally regulations and project were prepared to increase groundwater data. However implementation was limited for significant two basins where there was high groundwater depletion. Groundwater data is not collected for all basins in Turkey. Therefore data system needs improvement.

4.4.2 MODERN TECHNOLOGY

Basin Drought Management Plans, which were prepared for SYGM by Dolsar Engineering (2015), use satellite images and statistics maps to determine surface topography and land cover.

Participants in DSI complained that technological equipments are not used for groundwater management and producing data in DSI:

Actually we have department of geographic information systems. Unfortunately this department does not work effectively. Technological infrastructure is not enough. We discussed about using satellite data however this was not accept. Some people are not innovative in DSI (DSI01).

SYGM uses the satellite data and statistics about groundwater management but DSI does not. Participants in DSI emphasised two important issues that technological infrastructure was not sufficient while having experts, and improvement of using new technology was not accepted in institution. This shows that importance of technological innovations was not understood in DSI. Therefore technological infrastructure was not improved by decision makers who did not accept to use new technology in DSI.

4.5 EVALUATION

4.5.1 EFFECTIVENESS OF GROUNDWATER MANAGEMENT PLANS

Surface and groundwater management plans and projects are evaluated yearly. DSI has published annual evaluation reports since 2005, which explains the realization of the targets, impediments and reasons of impediments. For example, annual report by DSI (2009) shows the results of water projects, economic conditions and coordination of stakeholders, analysis and evaluations. This report is important example to show effectiveness of management plans yearly.

Meanwhile participants reported that all groundwater management plans have evaluation processes before publication:

Groundwater management plans and policies are prepared by experts of planning department. After that, all plan and reports are controlled by experts of control department for DSI and SYGM. If there is mistake, this is reported by experts. I believe that this control process increase the effectiveness of management plans (SYGM01).

The structures of DSI and SYGM provide an effective control mechanism. Any mistakes or gaps are determined step by step before publication of plans and policies. Along implementations of plans and policies, annual evaluation reports show the successes and failures of targets, and reasons of failures. Effectiveness of groundwater management plans and policies are controlled along all process.

4.5.2 ADAPTIVE MANAGEMENT

Participants reported that existing groundwater management plans and policies in Turkey generally were renewed after EU WFD to improve the existing gaps. Lots of groundwater regulations from EU were adopted:

Groundwater management policies were renewed after EU directive since 2012. EU regulations were translated and adopted. In addition, SYGM has prepared *basin action plans, basin drought plans. Results have been evaluated by SYGM, and plans are improved according to results of monitoring (DSI01).*

Adaptive management is emphasised in the regulation, and this regulation provides opportunity to renew monitoring programs:

‘Despite the measures taken, if monitoring results cannot meet groundwater quality standards and threshold values, monitoring programs are reviewed with taking the opinions of the relevant institutions and organizations by SYGM.’’ The Protection of Groundwater against Pollution and Deterioration (2012)

However the implementation of regulation is not achieved. For instance, failing objectives and targets were determined in the DSI Annual Report (2019), but there were no suggestion or implementation to fix:

According to monitoring results, some impediments were determined and evaluated thoroughly as increasing damages of surface and ground water, increasing flood risks by climate change, water using ineffectually, and insufficient research studies (DSI, 2009).

Regulations and answers of participants show that adaptive management was aimed to improve the gaps of implementations in Turkey. However results show that implementations are not successful.

5. DISCUSSION

The findings of analysing of regulations and implementations are summarised in Table 4. Generally speaking, there have been new regulations, projects and action plans to improve existing groundwater management sustainably. Planning and preparing of new regulations are successful. However implementations of regulations and plans are not successful in Turkey. They need to be improved.

Table 4 The Findings of Evaluations of Regulations and Interviews in Turkey for Sustainable Groundwater Management

	Impediments	
	Context of Law - Regulation	**Execution of Law - Regulation**
PLANNING		
The Preparing of Multidisciplinary Groundwater Management Plan	-	-
Appropriate Scale Management Plan	++	++
Different Management Approaches For Aquifer Types	+	+
The Interrelation of Groundwater and Surface Water	-	-
Models	++	++
Water Quality	+	+
Ecological Life	+	-
Climate Change	-	-
Time Scale for Goals	-	-
System Risks In Groundwater Management Plans	++	+
IMPLEMENTATION		
Sustainable Yield	-	-
Awareness and Water-Saving Approaches	++	-
Broad Participation	+	-
Intra- and Intergenerational Equity	+	-
MONITORING	+	-
Accessible and Current Data	+	-

Modern Technology	+	-
EVALUATION		
Effectiveness of Groundwater Management Plans	+	+
Adaptive Management Plan	+	-

Sustainable groundwater principles are not met	-
Sustainable groundwater principles are met partly	+
Sustainable groundwater principles are met successfully	++

The findings are grouped into five categories.

1- The positive impacts of new organizational structure and EU WFD
2- The importance of multi-disciplinary approach
3- Social and political issues dominate ecological life implementations
4- Climate change implementation plans have not yet been developed
5- Implementation issues

These findings will be detailed and discussed respectively.

5.1 THE POSITIVE IMPACTS OF NEW ORGANIZATIONAL STRUCTURE AND EU WATER FRAMEWORK DIRECTIVE

Two of the most important management tools of groundwater governance are institutional arrangements and published procedures and policies (Foster & Garduño, 2013). Results show that groundwater governance of Turkey has these two management tools.

First, as a candidate country of EU, Turkey has renewed its water management regulations via EU Water Framework Directive (WFD). Table 4 shows the evaluation of these new regulations. Generally contexts of law and regulation are available for sustainable groundwater management. When the EU Directives were checked, the name of the regulation and many contents were similar. WFD were adopted into new regulations of Turkey to improve water management (section 4.5.2).

Second, informants reported that SYGM was established to improve the existing gaps of groundwater management as a second water management institution in 2011 (section 4.2.1). The one assignment of SYGM was defined as ‘following of processes of international conventions and legislations on the protection and management of water resources’ (Turkish Republic The Assignment of The Ministiry of Forestry and Waterworks, 2011). Therefore SYGM follows and adapts international regulations as EU WFD into policies in Turkey.

The positive improving groundwater management in Turkey emphasises the benefits of international guidance and organisations like the EU which set standards for its members. EU WFD helps to improve water status for Member Countries (European Union, 2020). Complex water management issues need a deep knowledge of the groundwater bodies, but generally EU Member States have insufficient knowledge of groundwater at Community level, and main technical tools are supported by EU (Onorati et al., 2006). As result, international guidance and organisations provide many advantages for countries.

5.2 THE IMPORTANCE OF MULTI-DISCIPLINARY APPROACH

Loucks (1992) believes that perspective of a single-discipline is not sufficient to manage water resource systems and this issue is apparent in Turkey. Groundwater management plans should be supported by lawyers, contractors, agronomists, environmentalists, economists, chemical and biological experts, social scientists, political and regional scientists (Stout, 1998; Loucks, 1992).

First, Basin Management Committee (BMC) is significant tool to implement multidisciplinary groundwater management in Turkey as it includes representatives of a range of disciplines as well as other stakeholders. However it is common for different stakeholders have different agendas in multidisciplinary research (Cuevas et al., 2012). This issue is one problem of implementation of multidisciplinary management in Turkey. Informants believed that political and social issues are main agenda than technical suggestions of experts in the BMC (section 4.3.3).

Second, groundwater management is criticised as being much fragmented, including many organizations with uncertain roles and responsibilities (Jakeman et al., 2016). This causes some problems along planning and implementation of multi-disciplinary groundwater management in Turkey. For instance, some prepared plans (as single-disciplinary) by SYGM without the opinions of DS caused ignorance of hydrological relationship between surface water and groundwater (section 4.2.4).

Third, the sustainable management of water resources is technically difficult (Jacobs et al., 2016). Lack of different professions (environmental and agriculture engineers) drops effectiveness of implementation of groundwater management in DSI, and cause technical challenges in groundwater management (section 4.2.1). However the implementation of sustainable groundwater management needs professional multi-discipliner management teams (Jakeman et al., 2016).

Different agendas of stakeholders in Basin Management Committees, lack of coordination and collaboration between different governments departments (DSI and SYGM) and insufficient experts (agricultural or environmental engineers) in institution are main impediments of multi-disciplinary groundwater management in Turkey.

Firstly water resources management needs strong engineering with technical suggestions (Pahl-Wostl et al., 2008). Therefore social and political issues should not dominate decisions of BMC. Engaging experts (such as hydro geologists) would certainly help to solve many problems (Sophocleous, 2007). Therefore the increasing voice of experts in BMC is required as multi-disciplinary.

Secondly there are requirements of coordination and collaboration of different departments for implementation of groundwater management (Gupta & Onta, 1997). The effective coordination and collaboration of DSI and SYGM should be provided. Lastly lots of disciplines are required for sustainable water management from hydrology, engineering, hydraulics, ecology, chemistry, soil sciences, and technology to economics (EU Commission, 2019). Existing technical gaps of groundwater management should be reviewed by mentioned experts and scientists for Turkey.

5.3 SOCIAL AND POLITICAL ISSUES DOMINATE ECOLOGICAL LIFE IMPLEMENTATIONS

Results show that implementations of ecological life protection in Turkey are affected by social and political issues.

First, there have been improvements legally about protection of ecologic life with Environmental Impact Assessment (2014) in Turkey. Only there are some gaps in the implementation of EIA. Durán-Sánchez et al. (2018) emphasise that sustainable water management should have balance economically, socially and environmentally. Informants reported that social and political reasons reduce effectiveness of EIA. Social and political issues are in the front of protection of ecologic life in the implementing state (section 4.2.7).

Walker et al. (2015) believe that social and political problems are common problems, and solutions are not easy. There are some possible social and political reasons in Turkey. Initially, the higher income expectation of farmers causes the ignorance of ecological protection requirements (Section 4.3.2). Secondly groundwater is primary consumption in many basins for agriculture. The reducing of irrigation water for the protection of ecological life may not be accepted by farmers (section 4.3.1). This is important pressure for decision makers in the implementation. For instance, groundwater abstraction charge was not accepted in the parliament because of opposition opinions of farmers. Power of farmers affects decision makers in Turkey (Section 4.3.2). Finally old regulations did not cover ecological life values until 2014. This caused the ignorance of these values for many years. The legislation of EIA increased ecologically most suitable projects for the protection of ecological life however the behaviour changing of water users is difficult (Section 4.2.7).

Another key issue is that early warning system of damages of ecological life is not effective technically. Margat et al. (2006) believe that monitoring is the important alert for showing changes of groundwater systems. Informants emphasised that there is lack of forecasting of ecological damages (section 4.2.7). There are some monitoring studies for data collection in some basins of Turkey, but informants believe that these systems should be improved from manual to automatic for all basins (Section 4.4). Groundwater resources may be managed with improved monitoring (Jakeman et al., 2016).

In the UK, only small proportions of wetlands and less than 1% of the UK's entire river length are part of formal protection networks. However protection or management of ecological life has started to influence policy and decision-making since 2010. There is a growing research of implementations and experience throughout the UK (Matlby et al., 2011).

Generally freshwater ecosystem of England is affected negatively by urbanisation, wetland drainage, flood defence (over 42% of all floodplains in England and Wales were separated from their rivers), the purposeful and accidental use of water resources, pollution (increasing nutrient concentrations), and climate change (increased water demand and lower resource availability, saline intrusion on freshwater coastal areas, water temperature increases of 1.5–3°C over the past two decades) (Matlby et al., 2011).

In conclusion, Turkey and England have effective plans for ecological life. Investigations of ecological life protection have increased similarly for two countries at planning state. They face problems socially and politically about implementations of ecological life. For instance, EIA (section 4.2.7) and UK National Ecosystem Assessment have effective regulation and plans. However implementations of ecological life for Turkey and England have similar mentioned problems socially and economically such as urbanisation, construction and pollution.

Monitoring studies of Turkey are regional (in some basins) and much of them are manual. There is potential for Turkey to consider England monitoring system. Lots of hydrological and environmental data are provided by Met Office (2020) automatically and online in England for all regions. Turkey may adopt monitoring system of England to predict ecological damages early. This data system may be helpful to provide broad data for all basins in Turkey and to estimate potential ecological problems.

Finally, changes in water management require new methodological approaches from the social sciences (Pahl-Wostl et al., 2008). To remove social and political problems in the implementation of ecological life protection, Walker et al. (2015) suggest supports of natural and social scientists, who may help to change water users attitude. Groundwater resources management may be successful if stakeholders are collaborating fully. Therefore the aim of groundwater management is influencing or changing people’s attitude. (Van der Gun, 2012). Natural and social scientists may be appointed into management groups to change water user's behaviour in groundwater management in Turkey.

5.4 CLIMATE CHANGE IMPLEMENTATION PLANS HAVE NOT YET BEEN DEVELOPED

Climate change is significant issue in the hydrological cycle (Famiglietti, 2014). Groundwater management is affected by climate change such as increasing water demand (Alley et al., 1999), changing groundwater recharge (Van der Gun, 2012), increasing floods and droughts (Konikow & Kendy, 2005), and damages of ecological life (Alley et al., 1999). This changing should be estimated and evaluated for sustainable water management (Sandoval-Solis et al., 2011). Therefore Turkey has studied climate change that is modelled, and management plans are prepared. Climate Change Adaptation Working Group is working effectively in SYGM (Section 4.2.8).

Climate change projections and drought management plans were prepared in Turkey (section 4.2.8). Risk estimation and risk management were detailed in the plans (section 4.2.10). However there is no information about implementation of prepared plans and projects. Therefore the implementations of climate change plans and projects are uncertainty. It is possible that climate change implementations can meet problems politically or socially as ecological protection implementations.

Turkey and England have similar plans about climate change. 'Adapting to a changing climate' (second adaptation report under the Climate Change Act) was published by The Environment Agency in 2016. River basin and flood risk management plans are updated every 6 years. Risks and adaptation strategies of climate change impacts were determined for water resources in England. This improves to manage climate change impacts in water management (Environment Agency, 2016a).

There are many uncertainties about short-term climate impacts therefore Mertz et al. (2009) recommend more climate resilient improvements and robust risk management strategies that promote climate change adaptation. They believe that rising climate adaptive capacity and several adaptation options would be effective to reduce uncertainties. Additionally people can be better ready adaptation of climate change impacts if they know groundwater’s potential that is helpful for climate change impacts (Van der Gun, 2012). As result, Turkey should focus on increasing climate change adaptation and risk management strategies, and rising awareness of climate change impacts and importance of groundwater resources among water users.

5.5 IMPLEMENTATION ISSUES

Groundwater management implementations are important for sustainable groundwater resources (Pandey et al., 2011). Environmental, social and economic benefits depend on effectiveness of policy implementations (Bruce et al., 2009). Results show that management decisions of decision makers, unregulated groundwater abstraction, lower awareness of farmers and free groundwater abstraction affect success of sustainable groundwater management implementations in Turkey.

There is need of collaboration between water managers, local communities, and hydro geologists for applicable and achievable sustainable groundwater management (Alley et al., 1999; Gleeson et al., 2012). These stakeholders are represented in the Basin Management Committees in Turkey. However representation of experts (hydro geologists) and water users are superficial in the committees (section 4.3.3).

The technical suggestions of groundwater management experts are ignored by governors as chairmen because of social and political issues as mentioned above in detail. Additionally representation of significant stakeholders depends on invitation of governors. That is why in the regulation decision makers invite representatives who would join meetings (section 4.3.3). However De Stefano et al. (2015) believe that decisions of water users affect the achievement or failure of any groundwater policy in groundwater management.

By comparison, in the Severn River Basin Management Plan in England, the partnership is currently made up of 129 organisations and stakeholders covering the sectors of agriculture, forestry, tourism, recreation, mining, business, water companies, statutory bodies and both local and national government. The partnership exemplifies what can be achieved by thinking for the long term, taking an integrated approach (considering economic, social, environmental and cultural outcomes), collaborating and involving others in finding sustainable solutions (Environment

Agency, 2016b). The management plans of Turkey and England provide broad participation for many stakeholders similarly. However there is gap of implementation in Turkey.

Groundwater abstraction should not be higher the natural recharge of groundwater for sustainable yield (M. Sophocleous, 2000). Sustainable yield values are calculated by DSI in Turkey, but are not followed in the field (section 4.3.1). This has some reasons such as differences in the old regulations, unlicensed wells, lower awareness level about groundwater saving and free groundwater abstraction cause overconsumption of groundwater among farmers.

First, old regulations show differences about allowed consumption from aquifer such as allowed groundwater amount is equal to recharge or is lower than safe yield. This is not clear (section 4.3.1). As mentioned by Kalf & Woolley (2005), there is certainly a requirement to review the definition and methodology of determining sustainable yield. That is why some yield calculations do not cover evapotranspiration, flow streams, infiltration, and springs from the aquifer in some plans (Sakiyan & Yazicigil, 2004).

Second, Bruce et al. (2009) believe that certain and timely reporting of all licensed groundwater abstractions are required for the enforcement of sustainable groundwater management. However all informants reported that unlicensed wells are main problems for unregulated groundwater abstraction (section 4.3.1), and measurement systems is not implemented for all basins of Turkey (section 4.4). That is why there are social and economical pressures to determine and close unlicensed wells in Turkey. Much water users will be affected dramatically when unlicensed wells are determined and closed (section 4.3.1). Groundwater abstraction rights system (including permission, licenses or concessions) should be highly priority (Margat et al., 2006).

In England, enforcement and sanction penalty principles aim to alter the behaviour of the offender, remove any financial benefit from the breach and deter future breaches of offender and others (Environment Agency Enforcement and Sanctions Policy, 2020).

While fine appears to deter breaches in England, informants believe that fine is not deterrent for unlicensed wells in Turkey (section 4.3.1). ‘When breached licence conditions or committed an offence, the Environment Agency may take enforcement action including criminal sanctions (warnings, formal cautions and prosecution, with fines up to £20,000) and civil sanctions.’ (Apply for a Water Abstraction or Impoundment Licence, 2020).

Third, sustainable groundwater management needs the supports of water consumers. New groundwater legislation and related regulatory frameworks aim to increase awareness of groundwater issues among stakeholders (Van der Gun, 2012). There is increasing awareness to save water among educated people by some conferences, educations and projects such as ‘Water Messengers’ in Turkey, however awareness is not sufficient among farmers who do not know the importance of agronomy, and higher income expectation and lower education level (section 4.3.2). However education and increasing awareness are main principles for adaptive and sustainable groundwater management (Knüppe, 2011).

In England, Defra (2008) emphasises:

- Government and other stakeholders should have stronger and more consistent water saving messages to increase awareness and encourage behaviour changing
- The Government should have collaboration with members of the Water Saving Group and wider stakeholders to increase customer awareness of saving water.
- Awareness of effective water using in industry should be told
- Connection of water use in their homes and greenhouse gas emissions should be told to householders to minimise water wastage and maximising water efficiency

Generally speaking, suggestions of DEFRA are implemented in Turkey. However effectiveness is lower among farmers. Awareness implementation should be increased for farmers in Turkey.

Forth, informants report that there is connection between overconsumption of groundwater and unpaid water for irrigation. In the law water users access freely for irrigation how much groundwater they want in Turkey (Section 4.3.2). For behavioural change, economic instruments (prices and charges) may be used, which have incentive function to reduce overconsumption by water users (Finney, 2013).

EU WFD Article 9 emphasises water charges. Water-pricing policies are purposed to supply sufficient encouragement for users to consume water resources efficiently and thereby contribution to the environmental objectives. Recovery of the prices of water services, including environmental and resource costs are recommended to Member States. Significantly while implementing water pricing policies, Member States may consider the social, environmental and economic impacts of the recovery as well as the geographic and climatic conditions of the region (THE Council Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy, 2000).

A better example from England, water charges have been used to improve environment. The charge prices and investments are determined every five years. These are influenced by what water consumers want and by what environmental obligations must be met (Environment Agency, 2019).

Finney (2013) describes practical challenges and constraints of water charge:

- Institutional and administrative challenges: an insufficient legal framework, ineffective legal means of punishment non-payers and late payers, insufficient integration and cooperation between different management institutions
- Human resource constraints: shortages of the skilled human resource to implement the system
- Financial challenges: lack of funds for the required monitoring of water consumption
- Shortage of data about hydrology, meteorology, water quality, and water consumption
- Social challenges: possible adverse impacts to poor people

As result, decision makers should consider all components of sustainable management socially, economically and environmentally for equal management decisions (Durán-Sánchez et al., 2018). Additionally there are certainly requirements to clarify definition of sustainable yield (Kalf & Woolley, 2005) and to adopt water pricing (Finney, 2013) into Turkish groundwater regulations. In Turkey water charges can be used to develop ecological life or water resources systems (modern irrigation system). But there are a lot of issues with water pricing as mentioned by Finney (2013). The opposed attitude of water users, lack of legal framework and human resource will be main problems. Still adaptation of water charge into groundwater management should be discussed as soon as to protect water resources.

6. CONCLUSION AND SUGGESTIONS

This research aimed to analyse firstly whether existing groundwater management policies and plans in Turkey have impediments to implement sustainable groundwater management. To answer this question, regulations, strategic plan, annual reports, drought management plans and projects were investigated (Table 1), and interviews with four informants were done (Table 2).

Results show that lots of regulations were renewed to improve groundwater management in Turkey by the positive impacts of EU WFD and new organizational structure (SYGM). These are positive effects. Nevertheless there are some impediments respectively because of social and political pressures (ignored ecological life, overconsumption of aquifers, and inadequate participation of stakeholders) and technical issues such as single disciplinary groundwater management, insufficient experts, monitoring problems, and confusions in the some old regulations about groundwater management.

Regulations and implementations of UK and EU were analysed to reduce existing impediments in Turkey. There are some potentials for Turkey to consider some of the things that England implements. Some improvements from UK may be adopted into groundwater management of Turkey.

First, the monitoring principles of MET Office will provide data to forecast and improve groundwater system. Meanwhile water abstraction charges may reduce overconsumption in Turkey. These collection charges may be invested to improve ecological life as mentioned EU WFD. Establishment of monitoring system and water charge implementations have many economical and social challenges. Nevertheless these issues should be argued resolutely in Turkey.

Second, social and political pressures affect many implementations of sustainable groundwater management in Turkey as all countries. Collaboration of natural and social scientists and other experts is suggested as solution of social and political problems. Social scientists play a key role to understand and change behaviour of water users. This is a need of improving many impediments. Moreover multi-disciplinary management approach suggests social scientists as important component. Additionally the opinions of lawyers, contractors, agronomists, environmentalists, economists, chemical and biological experts, political and regional scientists will improve existing groundwater management system in Turkey. Certainly educated human resources and some robust regulations to collect all these people working together are needs to implement multi-disciplinary management in Turkey.

Third, some confusing in the regulations such as sustainable yield, and allowed professions except for geology and hydrology engineers in the water management should be renewed. Sustainable yield should be understandable to determine allowed groundwater abstraction sustainably. In addition, groundwater regulations should allow above mentioned other experts legally for preparing and implementation of sustainable groundwater management plans.

Forth, adequate participation of stakeholders is important issue. Representatives of social groups of water management basins should be increased in Basin Management Committees. Additionally these management groups should provide equal voice to representatives of water management experts for decisions.

Sustainable groundwater management needs implementations of effective policies, developed plans, sustainable decisions. Results of analysing regulations and interviews showed that there have been much effective groundwater management policies and plans in Turkey for sustainable groundwater management in the last decade via EU WFD. Further investigation and policy adaptations from EU WFD into groundwater management of Turkey are strongly recommended.

Last but not least, the implementations of groundwater regulations should be supported and improved to implement sustainable groundwater management patiently. Time scale of positive results may be longer in groundwater management. However it should not be forgotten that sustainable groundwater management will provide many advantages for intra- and intergenerational equities, and maintenance of water resources in Turkey.

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8. APPENDIX

APPENDIX A. EVALUATION CRITERIA FOR SUSTAINABLE GROUNDWATER MANAGEMENT			
STAGE		**Principles**	**Evaluation Criteria**
PLANNING	**1**	**Multidisciplinary Groundwater Management**	Are groundwater management plans prepared by educated personals from all related disciplines (hydro geologists, biologist, chemist, agricultural, environmental engineers and social scientists)?
	2	**Appropriate Scale Management Plans**	Does groundwater management have appropriate scale plans?
			Are the roles of central and local management authorities explained clearly to reduce chaos?
	3	**Different Management Approaches For Aquifer Types**	Are there fossil aquifers (non-renewable aquifer)? Are there different management policies for these type aquifers, for instance, reducing irrigation water consumption (effective irrigation), controlling leakage and minimizing water losses from aquifer system?
			Are fossil aquifers recharged by other water resources such as flood, desalination, wastewater reuse to improve fossil aquifer for future generation?
			Is there transboundary aquifer? If there is transboundary aquifer, is it managed with shared countries?
			Do water management plans consider international agreements, the water policies of other countries and environment in transboundary water management?
			Are groundwater levels and withdrawals in transboundary aquifer gauged and reported internationally?

			Do water management plans include any agreement with border countries or stakeholder for guaranteed water using?
	4	**The Interrelation of Groundwater and Surface Water**	Do water laws consider the physical relationship between groundwater and surface water sufficiently?
	5	**Models**	Does groundwater management plan have groundwater model for future scenario?
			Does groundwater management plan have climate change model?
			Are implementations of the plan controlled with models?
			How are model results used to prepare new groundwater management plans?
			Is model controlled and renewed with new data from field periodically?
	6	**Water Quality**	Are groundwater and surface water qualities measured such as pollution, salinity?
	7	**Ecological Life**	Are groundwater dependent ecosystems identified?
			Do water management plans include items to develop and to protect ecological values?
	8	**Climate Change**	Does groundwater management plan consider climate change impacts? Is groundwater management plan adaptive for climate change?
			Is there any new measure to reduce impacts of climate change?
	9	**Time Scale for Goals**	Is groundwater management plan prepared according to forecasting of 50-100 years?
	10	**Groundwater Management Plans Adequately Address System Risks**	Does groundwater management plan have risk assessment process?

IMPLEMENTATION	**11**	**Sustainable Yield**	Is groundwater abstraction controlled by sustainable yield? If it has been controlled, has been the amount of sustainable yield calculated periodically?
	12	**Awareness Increasing Awareness And Water-Saving**	Is there any regulation to increase awareness of stakeholders?
			Are there any regulation to increase water save and to reduce waste of water?
	13	**Broad Participation**	Does groundwater management plan consider the views of stakeholders and local society?
	14	**Intra- and Intergenerational Equity**	Does groundwater management plan provide intra- and intergenerational equity for all stakeholders?
MONITORING	**15**	**Monitoring and Accessible New Data**	Are groundwater aquifers monitored sufficiently for national and international scales?
			Is new data collected periodically to improve groundwater management plan?
	16	**Modern Technology**	Does groundwater management plan allow using modern technology?
EVALUATION	**17**	**Effectiveness Of Groundwater Management Plans**	Is there evaluation process of effectiveness of groundwater management plan?
	18	**Adaptive Management Plan**	Has been groundwater management plan renewed periodically according to results of monitoring data?
			Has been groundwater management plan checked regularly whether targets are being met? If the targets are not achieved, does groundwater management plan have action to regulate unsuccessful points?

APPENDIX B. INTERVIEW QUESTIONS

		Principles	Interview Questions
PLANNING	1	**Multidisciplinary Groundwater Management**	Why are reports prepared by only geologists, hydro geologists and engineers for groundwater management plans? Which professions can you suggest for sustainable groundwater management groups?
			How do you decide for taking the opinions of relevant institutions or organizations? Are there specific consultancy areas? Are these institutions or organizations national or international? Do not you think that DSI and SYGM are not sufficient for solutions of all groundwater issues?
	2	**Appropriate Scale Management Plans**	What are groundwater operation areas? Do you manage groundwater bodies according to determined groundwater operation areas?
			What is role of SYGM in groundwater management in Turkey?
	3	**Different Management Approaches For Aquifer Types**	Why do not policies have different management approaches for different type aquifers such as fossil aquifers (non-renewable aquifer), transboundary aquifers?
			Do you support that fossil aquifers should be recharged by other water resources such as flood, desalination, wastewater reuse to improve fossil aquifer for future generation? Are safeguards adequate?
			How do you implement international agreements in transboundary water management?
			How do you gauge and report groundwater levels and withdrawals in transboundary aquifer?
	4	**The Interrelation of Groundwater and Surface Water**	Why only do you control the physical relationship between groundwater and surface water for pollution? Why is not amount considered for relationship?
			Why do not you observe flow (amount) between groundwater and surface water to manage both sustainably?
			How is monitoring system for groundwater and surface water?
	5	**Models**	Why do you think that the regulations are not supported by a groundwater model?
			Why model studies are not priority?
	6	**Water Quality**	Where do you discharge waste water? Are you sure that waste water does not mix into groundwater in your discharge location? How do you observe and check these implementations that are made? You do not allow any discharged into groundwater that are used or planned to abstract for drinking water. Why do you allow indirect discharge of treated wastewater into other groundwater bodies? Will not they be used for drinking for future?

			Why do you think that groundwater is cleaner biologically than surface water in nature? Why do you think that 10 m is enough to protect well from surface pollutions?
			Do you have any measure to block groundwater pollution before aquifer is polluted? During the activities where dangerous substances are used, which measures do you take to protect aquifers? In open groundwater recharge areas for settlement, How do you decide that location is appropriate for settlement?
	7	**Ecological Life**	Do you think that the perverting of terrestrial ecosystems from groundwater pollution is enough to develop and to protect ecological values?
	8	**Climate Change**	How do you control implementations of adaptation activities? What are positive impacts of adaptation activities to reduce climate change impacts?
	9	**Time Scale for Goals**	Why is report published every six years? How much year do you have long term plans?
	10	**Groundwater Management Plans Adequately Address System Risks**	Why are not risks of implementations of groundwater management plans and policies determined?
IMPLEMENTATION	**11**	**Sustainable Yield**	Do you think that definition of safe (sustainable) yield is enough without defined detriments?
			Why do not beneficial requirements include environmental values? Do you think that yearly abstraction and recharge are controlled enough?
			Why does not safe yield value consider environmental values and loses (evaporation)? Why not are all wells licensed? What are well license problems in implementation? Is administrative fine enough?
			Why do not all wells have measurement systems? How do you control whether wells have measurement systems?
			How do you control any change in well by water users?
			Why are not other excavations required licenses?

	12	**Awareness Increasing Awareness And Water-Saving**	Why do not policies provide opportunity for increasing of awareness of stakeholder?
			Why do not policies consider water saving?
	13	**Broad Participation**	What do you think of the level of stakeholder participation? Do you think that the regulations allow for much stakeholder participation?
	14	**Intra- and Intergenerational Equity**	If aquifer is not enough to meet the beneficial needs of all water users, how do you decide the amount of abstractions between water users for beneficial needs?
			How much meter is the distance of neighbouring land? Do you think that the sharing of water between near water users provide equality between water user? What do you think that the sharing of water between near water users reduces or increases abstraction?
MONITORING	15	**Monitoring and Accessible New Data**	How do you control that all wells have measurement systems?
			Is there adequate support for monitoring and reporting? If not, why not?
			How do you decide about appropriate place and numbers of well and depth?
			What is frequency for enough monitoring? Why is report published every six years? Why do DSI and SYGM study both?
			Why does not much flow measurement point have data in Water Database Project? Why are results shown only one year?
			How do you decide which measurement systems will be used by water users?
			How do you analyse data to improve groundwater management plans?

	16	**Modern Technology**	Why do not policies consider using technology in groundwater management?
EVALUATION	**17**	**Effectiveness Of Groundwater Management Plans**	Why are not effectiveness of implementations of groundwater management plans and policies controlled?
	18	**Adaptive Management Plan**	How often do you get opinions? Do you think there is an adequate response when monitoring results indicate a problem?

APPENDIX C. REVIEWED LAW, REGULATIONS AND DOCUMENTS FOR TURKEY

Turkish Republic Groundwater Law No:167, (1960)

Turkish Republic DSI Groundwater Regulation, 1961)

Turkish Republic DSI Groundwater Technical Regulation, (1972)

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APPENDIX D. REVIEWED DOCUMENTS FOR UK AND EU

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Met Office. (2020). *Historic Station Data*. https://www.metoffice.gov.uk/research/climate/maps-and-data/historic-station-data

THE Council Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy, 168 THE EUROPEAN PARLIAMENT 35 (2000).

APPENDIX E. FAVOURABLE OPINION LETTER

University of BRISTOL

Faculty of Engineering Research Ethics Committee (FREC)
Queens Building
University Walk
Bristol BS8 1TR
Telephone: (0117) 331 5830

27th July 2020

Mr Nami Erdogan
Dr Claire Gronow
Department of Civil Engineering
Queens Building
University Walk
Bristol
BS8 1TR

Dear Mr Erdogan and Dr Gronow,

Ref: 102562
Title: Improvement of sustainable groundwater management in turkey

Thank you for responding to the issues raised by the Faculty of Engineering Research Ethics Committee (FREC) as outlined in our letters dated 30.06.20, 21.07.20 and 23.07.20. Your response to the issues raised by the FREC has been reviewed and the above-named study has received a favourable ethical opinion.

Please note that the FREC expects to be notified of any changes or deviations in the study.

Good luck with your research.

Yours sincerely
Chris Bennett
Research Ethics Assistant

pp
Dr Conor Houghton,
Engineering Faculty Research Ethics Officer (FREO)

APPENDIX F. ETHICS – INFORMANT FORM

Faculty of Engineering

PARTICIPANT INFORMATION SHEET

University of BRISTOL

Participant Information Sheet

PROJECT TITLE: DETERMINATION OF SUSTAINABLE GROUNDWATER MANAGEMENT PRINCIPLES AND THE IMPROVEMENT OF IMPEDIMENTS OF GROUNDWATER MANAGEMENT SYSTEM IN TURKEY VIA UK AND EU IMPLEMENTATIONS

Invitation paragraph

I would like to invite you to take part in my dissertation project. Before you decide whether or not to participate, I would like you to understand why the research is being conducted and what it would involve for you. Talk to others about the study if you wish. Please ask me questions if anything is unclear.

What is the purpose of the project?

As part of my dissertation, I investigate whether existing groundwater management plans in Turkey and England have sustainable groundwater management principles. First, this project aims to determine gaps of groundwater management. Second, how these gaps can be improved.

Why have I been invited to participate?

Groundwater policies are significant tools that regulate groundwater management in theory. However reality can be different than mentioned in law. Meanwhile some problems may be shown in implementation process. Therefore participants can provide key opinion about contextual issues, and problems with implementation. I believe that you are experts who have experience about groundwater management. Your experiences can ensure broad perspective about the past and now of groundwater policy.

Do I have to take part?

It is up to you to decide whether you wish to participate in the project. I will describe the study and go through this information sheet with you before you participate and answer any questions you might have. If you agree to take part, I will then ask you to sign a consent form. You are free to withdraw at any time, without giving a reason.

However this project will be submitted until September 2020. If you withdraw at near September, data in project can be affected. Therefore using data cannot be withdrawn.

What will happen to me if I take part and what will I have to do?

Interviews will be online. Available mobile application can be determined by participations for online interviews. It is planned about 1 hours and it is recorded as audio. (Audio will not be used in any presentation or not be added any social networks. It will be helpful for writer instead of taking notes along interview). Questions are relevant only sustainable groundwater management plans and policies. Any special question will not be asked.

What are the possible disadvantages and risks involved in taking part in the project?

It is not expected disadvantages and risks about answers of questions. That is why groundwater management is a general studied topic in Turkey and England. All policies are accessible for all people. This dissertation is supported by the General Directorate of State Hydraulic Works (DSI) in Turkey. DSI aims to improve groundwater management systems. Therefore they allow analysing the gaps of existing groundwater policies. I intend to use direct quotes from our interview in my thesis; these will be quoted anonymously and should not allow participants to be identified. However, to ensure you agree to allow the use any particular quote we will send you a transcript of the interview and you can indicate at that point, within a week of receiving the transcript, if there is anything you said which you would not like to have quoted.

What are the possible benefits of taking part?

Participants can play key role to evaluate existing groundwater management. Generally participants are chosen from different occupational groups. This can provide broad perspective about existing groundwater management.

Will my participation in this project be kept confidential?

Any data, all answers and all record will be kept confidential during and after the study. Here, the participant should be told:

- Data from interviews will be collected (research notes and sound recordings).
- Data will be stored in writer's personal laptop and personal one drive account
- Data will be protected in writer's personal laptop and personal one drive account as encrypted files. Data will not be shared with any other persons.
- Answers will be used in master dissertation. It will not used as a whole part, it will be separated according relevant parts of sustainable groundwater management principles.
- All records will be destroyed after I have graduated.

What will happen to the results of the research project?

This master dissertation will be sent to University of Bristol Library and the General Directorate of State Hydraulic Works in Turkey. Results can be accessed by Turkish Engineers and students. I hope results can be effective and can be used scientific researches. It can be a guideline for decision makers in Turkey.

Who is organising and funding the research?

My master programme is funded by The General Directorate of State Hydraulic Works in Turkey Water and Environmental Management Programme in University of Bristol.

Who has reviewed the study?

Dr Claire Gronow

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If participants have any concerns related to your participation in this study, please direct them to the Faculty of Engineering Research Ethics Committee, via the Research Governance Team, research-governance@bristol.ac.uk