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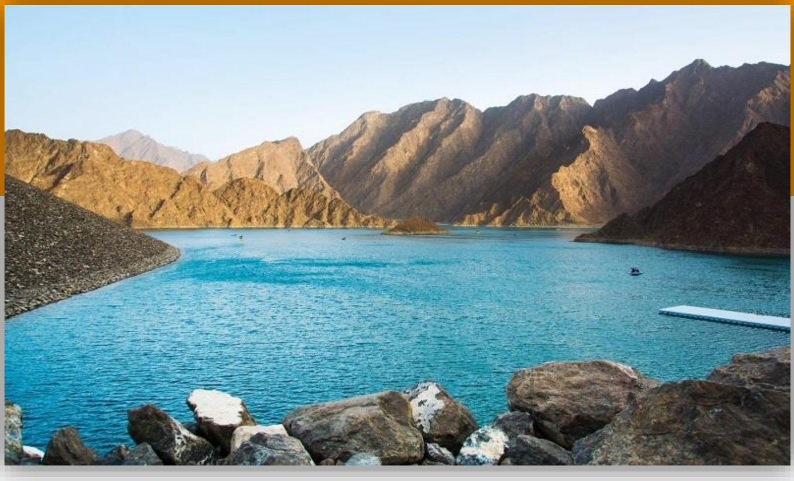
DUBAI MUNICIPALITY

TECHNICAL GUIDANCE FOR GROUNDWATER PROTECTED AREAS IN EMIRATE OF DUBAI 2020



Natural Resources Conservation Section

Environment Department

Dubai Municipality

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Definitions

Project Any activity, process or developmental plan leading to change the natural existing features, environmental conditions etc.

Project description is a document that describes the extent, limit and scale of a project. It also provides data of project location, area coverage, and details of its components, activities and processes involved. It also provides the information of waste generation and discharges expected from the project implementation.

Hydrogeological environment

This term is used in this document refers to aspects of groundwater, soil, surface water and geological environments found in the Emirate of Dubai.

EIA Report (EIA) is the methodical appraisal of the environmental aspects and impacts of a proposed project. The EIA process also review options and determines appropriate mitigation and enhancement measures that are needed to minimize, if not to eliminate, any adverse impacts due to project development.

Project Area Any activity, process, premises or development regardless of scale or magnitude, which has impact, whether significant or not, on the environment

Area of influence possible influence from project during construction & post construction phase

Consultant, Contractor & Subcontractor

Companies employed by the client to perform construction or decommissioning activities at the project site. The main contractor and sub-contractors and responsible for adhering to the requirements in approved environmental management plans and all applicable environment regulations.

Groundwater Water occupying all voids within a geologic stratum, which can be extracted, through a Groundwater well.

Vadose zone is the unsaturated horizon starting from earth surface till first appearance of water level.

Water level	Level of groundwater within a dug/open well is termed as water level.
Aquifer	Geological formation with significant extents, which can hold and transmit water to the groundwater wells.
Perched aquifer	Geological formation of limited extents usually at shallower depth underlain (or separated) by impervious layer.
Groundwater protected basins	Protected area demarcated by government for the protection and conservation of groundwater resources
Dewatering	Groundwater extraction to drain and dry the land till certain depth for construction works.
Drawdown	Water level decline during pumping is termed as drawdown.
Landfill	is the site to be allocated and the approval of its area and limits by the specialized department for the final disposal of non-hazardous and hazardous waste according to Dubai Municipality approved standards.
Leachate	Means any liquid and suspended materials which it contains, which has percolated through or drained from municipal solid waste disposal facility..
Leachate plume	Means contaminated soil or groundwater, beyond the limits of the deposit waste, which has been contaminated by leachate from the landfill site.
Contaminant	Means a chemical compound, element, or physical/biological parameter, resulting from human activity, or found at elevated concentrations, that may have harmful effects on human health or the environment.
Infiltration	is the entry into soil or solid waste of water at the soil or solid waste surface

Abbreviations

GPAs	Groundwater Protected Areas
DCL	Dubai Central Lab.
EIAC	Emirates International Accreditation Centre
NRCS	Natural Resources Conservation Section.
WHO	World Health Organization
DIV	Ditch Intervention values
APHA	American Public Health Association
US EPA	US Environmental Protection Agency
DSCE	Dubai Supreme Council of Energy
IWRM	Integrated Water Resources Management

Introduction

Groundwater is an important resource for irrigation, industrial development & selected ecosystem. Groundwater constitutes approximately between 20-30% of the total water balance of entire Emirate of Dubai. Increasing demand and high aridity of the region pose pressure on limited groundwater resources. Hence, the Protection of groundwater quality is imperative to ensure the protection of healthy ecosystems and maintenance of environmental values as well as for future economic and population growth. The guidelines document is intended to support protection of the Environmental media (mainly groundwater & soil) from any undesirable impact borne out of human activities e.g. recreational, commercial and developmental activities. Hereinafter, project developers, consultants, contractors, sub-contractors and establishment shall be called as the project.

The main objective of this document is to provide a regulatory framework and technical basis for, and a description of, the minimum requirements for Groundwater Protected Area (herein after called as GPA) in the Emirate of Dubai. Most of the developed and developing countries have developed Wellhead Protection Programs and regulations or guidelines for delineation of wellhead protection areas.

GPAs are the lands necessary for protecting drinking water sources wells and recharge areas. The term “wellhead protection area” is used to describe the area needed to protect groundwater supplies. It is utmost important to know how much of an aquifer is affected by a well, because in addition to drawing water to the well, pumping will also pull any contaminants to the well that might be leaching from the land surface. Therefore, by defining the wellhead protection area as precisely as possible, one can focus your protection program on the land that is most critical and that affects the groundwater quality meant for drinking water supply. Fine-tuning of delineation program for areas that have a direct impact on a resource would strengthen the policy. The process of wellhead delineation is extremely important, but it can also be difficult and expensive, depending on the needs of the community. Accuracy becomes important if management tools, such as land-use restrictions, are adopted to protect the water supply. In such cases, it is important to have a delineated wellhead protection area that can stand up to potential legal challenges by landowners. In the light of available legislations, DM develop Wellhead Protection Programs to enhance protection of the Emirate’s drinking water supplies during emergency times.

1.1 Regulatory framework

The groundwater law No 15 (2008) provides a sound legal framework and comprises a description of policies, principles and guidelines for the end users and water sources. As part of the groundwater management policies, the Guidelines for Groundwater Protection in Dubai Emirate were developed. The importance of groundwater, the higher risk of water quality impacts and the improved understanding of groundwater management in recent years has provided the impetus for having specific guidelines for the protected area. The Groundwater water law No. 15 of 2008 supports the implementation of the various initiatives; demarcation of the protected areas being one of them. Article 04 of local law no. 15 (2008) provides the legal basis to delineate groundwater-protected basin within Emirate of Dubai. The article clearly empower DM to allow or restrict groundwater withdrawal. Dubai Groundwater policy (2015) placed this initiative within the list of strategic programs. DM strategic plan (2016-2021) defines City Environment sustainability as one of the 5 pillars for developing a happy & sustainable city. Environment protection and the sustainability of natural resources is one of such main initiative under this pillar, which drives & strengthen existing groundwater management programs.

- Law No (15) of 2008 concerning Groundwater resources protection and management in Emirate of Dubai
- Law No (11) of 2003 on Nature Reserves within the Emirate of Dubai.
- Federal Law No. (24) of 1999 on the Protection and Development of the Environment.
- Local Order No (61) of 1991 on the Environment Protection Regulations in the Emirate of Dubai.

Dubai Supreme council of Energy (DSCE) is working towards Implementation of Integrated Water Resource Management (IWRM) strategy 2030 to achieve maximum overall cycle efficiency for all uses of water in Dubai. One of main objective is to bring clarity & accuracy in city's overall water budget estimates. Based on high percentage share in total water budget of Dubai Emirate, Integrated Water Resources Management Strategy 2030 advocates effective groundwater monitoring via up to date techniques vis-à-vis classification of groundwater as a strategic reserve.

A prior knowledge of legal framework and existing groundwater conditions would enable the stakeholders i.e. Project, planners or individuals to work in better coordination with Emirate policy concerning protection of groundwater resources. To align with Emirate Groundwater policy, the stakeholders anticipated to be well informed of existing groundwater legislation, guidelines, baseline groundwater status and various policy within Emirate of Dubai. The primary focus of Emirate Groundwater policy is to achieve management and sustainability in continuously decreasing groundwater resources.

1.2 Groundwater Management

According to local Law No. 15 (2008), DM is mandated with the responsibility of groundwater resources management and protection within Dubai Emirate. Environment Department of Dubai Municipality is primarily responsible for groundwater management within Dubai Emirate. The groundwater resources managed by NRCS-ED through the following activities;

- Periodic Groundwater Monitoring Programs
- Groundwater Permitting System-Issuing drilling permit for Groundwater well/test-monitoring well/License of groundwater use
- Registration of existing (unlicensed) wells
- Registration of Groundwater well drilling companies
- Emergency complains related to groundwater issues
- Groundwater Inventory, Research & Developmental Projects
- Technical review of Environmental Impact Assessment (EIA) studies, Hydrogeological studies

Data gathered from groundwater monitoring & research programs, enables NRCS-ED to demarcate Wellhead protection boundaries through the integration of hydrogeological information.

The intent of Delineation of protected groundwater basin or the wellhead protection program is to prevent contamination of fresh groundwater resources that have potential to be use as potable water, thus protecting the health of people using groundwater for potable purpose. A wellhead protection area is defined as the surface and subsurface area surrounding a well or well field that contaminants are likely to pass through and eventually reach the water well(s).

1.3 Need to Protect Groundwater resources

With the growing need to sustainably manage our natural resources, increased emphasis has been placed on holistically managing water resources. This includes consideration of the significant role of groundwater in maintaining growing demands due to manmade environment and climate variability. High aridity and low rainfall can be stated as main reason for groundwater scarcity in Dubai Emirate. Groundwater quality requires careful management due to our increasing reliance on the resource, the high risk of contamination from uncontrolled sources, and for management of groundwater-dependent ecosystems (GDE). The typically slow-moving nature of groundwater presents a key management challenge, as impacts can be difficult to predict and may occur over a long timescale. Key hazardous events or activities include uncontrolled urban and industrial discharges, the cross-contamination of aquifers, and seawater intrusion caused by excessive use in coastal areas. Sand dunes and sandy veneers facilitates pollution attenuation if introduced, due to high permeability of sand.

1.4 Groundwater Protected Areas (GPAs)

GPA can be defined as the protected area demarcated by competent government authority for groundwater protection and conservation of fresh quality groundwater based on scientific study where stringent regulations are applicable. Construction Projects or other anthropogenic activities like farming, recreational, or any other intrusive activity in close proximity with groundwater-protected area should be in accordance to the provisions given in this document.

Groundwater resources protected areas have been demarcated using calculated fixed radius technique. Groundwater within the protected area is considered strategic reserves protected by law no. 15 (2008) and hence to be protected from any deterioration, pollution, over exploitation etc. Groundwater permits, allocation limits, number of wells is restricted and based upon strict adherence to permissible limits.

Any proposed activity/project/establishment irrespective of its physical scale, should analyze possible impact on groundwater resources with the help of hydrogeological study including calibrated mathematical models. Project proponents, the consultants and the contractors are required to undertake pre-consultation with NRCS to confirm the scope of the required technical study for assessment of the impact. The groundwater-protected zones are described below and presented in Appendix-1.

(1) The Inner Protection Zone (Zone A) is drawn to protect existing DEWA supply well fields and provides protection against contamination. Fixed radius criteria has been employed with 5-year travel time from potable supply wells, together with other hydrogeological parameters like hydraulic conductivity, hydraulic gradient, effective porosity etc. This constitute a wellfield or part of sub-basin i.e. relatively smaller in comparison to the entire wellhead basin. It is very significant in terms of public health and since it is relatively small, implementation and enforcement are more readily achieved. Its extent is usually defined by groundwater travel time, whereby a 5-10 year radius is most commonly applied. In the present study, 5-year radius has been adopted. This zone is more or less characterized by Fresh groundwater water with some exceptions like west of the Lahbab well field where

salinity increases most probably due to upcoming from deeper aquifer. The general water level in this zone is 30 to 60 m below ground level. Groundwater abstraction through pumping wells influence the water levels.

(2) The intermediate Protection Zone (Zone B) (or total source capture area) encompasses the entire recharge zone of the groundwater catchment area. It provides protection against persistent contaminants. In situations of intensive groundwater exploitation, it is also significant in terms of resource conservation for potable water supply. In some cases, the zone is further sub-divided to allow gradational land-use controls beyond the microbiological protection zone. The selection of travel-time criteria for this subdivision is somewhat arbitrary and the 10-50 year iso-chrone is most common, to provide attenuation of slowly degrading contaminants or give time for remedial action to control the spread of pollutants. This zone is more or less characterized by groundwater water having TDS 2000 mg/L with some exceptions. The general water level in this zone is 30 to 60 m below ground level. Groundwater abstraction through pumping wells has influenced the water levels and quality.

The groundwater protection zones restrict and manage different landuse activity with respect to its likelihood to contamination or deteriorate the prevailing groundwater environment. The review of existing landuse pattern reveals that the agriculture farms are the main landuse type within the protected area that poses threat to groundwater sustainability. While, unregulated groundwater-pumping, lack of wellhead protection and traditional irrigation methods are the main groundwater stresses, closely spaced farms add to the state of over-abstraction. City environmental sustainability advocated in DM strategy 2021 requires that the landuse planning should consider restriction laid for groundwater-protected area while allocating lands within Zone A & B.

2-Underlying principles for guideline

The main objective of this section is to discuss importance of groundwater as natural resource and provide a technical basis for, and a description of, the minimum requirements for working within defined groundwater protected basin in the Emirate of Dubai, in a manner without posing any threat for the Groundwater resources. The understanding and management of groundwater has improved considerably in recent decades. Using this improved knowledge and approach, the challenge is to adequately address the assessment of potential water quality impacts at local and regional scales. Management of potential water quality impacts to groundwater can be achieved by the application of underlying principles:

- Understanding of existing environmental condition
- Sustainable development goals (SDG's)
- Use of a risk-based approach
- the polluter pays principle
- the precautionary principle

These principles combine fundamental economic and social rationales for the protection of groundwater resources, incorporating consideration of the current and future value of the groundwater, management or prevention that is proportional to contamination risk, and responsibilities of the current generation to provide equitable access to resources for future generations. The Project scope of works shall contain groundwater & soil study including baseline status and addressing to the effects that are anticipated from said activity. The scope or the objectives should be framed employing best environmental ethics.

2.1 Sustainable Landuse planning

Groundwater protected zone A & B restrict some landuse types, which can pose hazard for the health of groundwater resources. While some of landuse categories, allocation shall base upon feasibility studies. A general landuse allocation criterion within groundwater-protected zones is presented in Appendix-2. The feasibility study or pre-EIA study shall examine the appropriateness of the proposed landuse in a logical manner. More specific landuse allocation should base on in-situ groundwater dynamics or vulnerability models. The appropriateness of specific landuse should validated through groundwater modeling studies. Vulnerability models often provide more insight approach for appropriate landuse classification based on the response of the area for a specific landuse type. A detailed categorization of the projects subjected to Environmental Impact Assessment (EIA) is given in DM-ED "Guidance of the Environmental Clearance (EC) Requirements for development and Infrastructure Projects in the Emirate of Dubai". For projects within GPA's, Hydrogeological study serve as additional requirement of the EIA for Projects with potential effect on soil and groundwater environment. The purpose of the EIA or Hydrogeological study is that if an activity is permitted within the Groundwater Protected Area, it must be carried out in such a manner that it will not release contaminants into the groundwater or aquifer, or adversely affect public groundwater to uphold article 13 & 14 of Dubai law No. 15 (2008) concerning Groundwater protection. In addition, it must comply with applicable federal, provincial and municipal regulations, orders.

Protected areas contain good quality groundwater resources in the Emirate of Dubai. These groundwater resources are strategic importance for a variety of reason. The main stress on the Dubai's groundwater resources can be categorized as;

- Climatologically driven impacts, with scanty rainfall and high aridity.
- Geogenic or Lithogenic impact
- Extensive irrigated agriculture farms– the major consumer (and sometimes an important polluter) of groundwater resources.
- Unplanned Landuse – a major user (and polluting user) of groundwater resources.

The results of rapid urbanization on groundwater quality and quantity are now fairly well documented and include complex relationships between land cover, runoff and aquifer recharge, contaminant type and load and unsustainable over-abstraction. Foster et al (1998) also show that rapid urban expansion can result in the loss of groundwater resources as the upper aquifer suffers from over-abstraction; becomes too polluted for use and is therefore lost as a resource. Changes in groundwater level, because of urbanization, can also affect the existing building stock in terms of subsidence and waterlogging of foundations – this problem may become more acute with climate change. There is increasing recognition of the importance of landuse planning and sustainability of natural environment. Landuse planning has long been the means through which public infrastructure and services have been delivered in both the developed and developing world. Relating the landuse development that causes groundwater degradation and the need to provide sustainable groundwater resources for the people who live and work in that development is where integrated environmental management is required. In this context, integrated environmental management of groundwater would require the integration of groundwater protection policies, waste management policies, pollution prevention policies, and land use planning. Sustainable landuse planning with respect to Wellfield protected areas has been documented in many developed countries.

2.2-Environmental Quality Standard for Groundwater

The protected groundwater areas management provide safeguard for the strategic groundwater resources. These areas (especially Zone A) reserved to use as storage and supply of groundwater for potable use during emergency time. DEWA is harnessing possibilities to enhance strategic groundwater storage through desalination water injection. Both the Margham and the Al Maha site were evaluated with regard to their suitability for Aquifer Storage Recovery (ASR). The criteria for evaluating both sites include aquifer geometry (available storage volume, lithology, etc.), geo-hydraulic parameters (hydraulic conductivity, transmissivity, storativity and yield), aquifer hydraulics (groundwater levels, flow direction and flow velocity), well performance, requirements for well field infrastructure (wells, pipelines), existing landuse (limiting ASR size and storage capacity) and operational aspects during emergencies.

This probably makes management of protected areas extremely important for the Emirate where sustainable landuse allocation have to be followed strictly. Owing to the anticipated use of groundwater drinking water standards should be used for the assessment of groundwater quality. In absence of national guidelines for drinking water values, standards from WHO, USEPA and European legislation have been applied to the characterization list of parameters.

2.3-Planning for the protection of Groundwater resources

The protection of the groundwater resources should be based on recent data collected from the area of interest sufficiently covering the project boundary and outside (preferably). The report should address possible impacts of construction activities as well as future scenario in relation to groundwater quality and quantity. Specifically, the baseline study should ensures that the basic components sufficient to address groundwater environment and its response be taken into consideration. The main components of hydrogeological study are as follows;

- Walkover survey & updating land use pattern
- Geological, Geotechnical investigation,
- Groundwater & Soils investigation (water quality, depth to water level, local & regional Groundwater flow direction, water balance, dewatering related issues)
- Conceptual groundwater model
- Likelihood of groundwater impact (contamination/depletion etc)
- Groundwater trend (rise) current, during construction & post project
- Proximity with Groundwater protected basin
- Groundwater flow modeling

- Handling hazardous materials
- Impact assessment, Mitigation plan & Environmental enhancement (solutions)
- Use of modeling results in Impact assessment, Mitigation plan & Environmental enhancement (solutions) Reporting
- Follow up and monitoring
- Interpretative cross sections through the proposed development site should be constructed, at right angles to one another and at a vertical scale that places the proposed development site in the context of the local geological and hydrogeological regimes. This cross section should describe the geology and indicate the position of the water table at the proposed development site. The cross sections should include available borehole information. Where a conservation site, a groundwater abstraction, or a
- groundwater discharge location is located within 2 km of the proposed development site at least one cross section will pass through these features.
- The project location should be identified in relation to protected groundwater areas. Risk Assessment should be carried out identifying all possible component expected during initiation, construction and operational phase.
- Impact Assessment should be carried out identifying all possible project activities and expected threats during initiation, construction and post completion phase.
- The groundwater monitoring/tests requirement for the project will be required from the time of initial project plan, constructional phase, following an environmental incident etc.
- The project nearing a surface water body and other sources of pollution should include in their impacts assessment. The project should give expected water requirements of the project. Also water consumption statistics should be added in periodic or monitoring reports.
- The project should consider the likelihood of groundwater rise in futuristic scenario and adopt permanent solution to alleviate groundwater rise within the area of interest.
- Relevant person having educational/professional background in the field of groundwater hydrology should carry the groundwater study/EIA reporting /EMP. For groundwater sampling, standard techniques viz. US-EPA should be adopted while for chemical analysis American Public Health Association (APHA) guidelines should be adopted.
- The Standard content of a Hydrogeological report is given in Appendix-3.

- The project should not undertake any activity that directly causes or induce chances of groundwater pollution; and project should ensure this by having a groundwater-monitoring program.
- Projects should consider vertical and horizontal movement of groundwater and consider monitoring the impact of project related activities accordingly.
- The project's groundwater program should consist of periodic monitoring of water quality and water levels.
- NRSC reserves the right for additional information from project, amend or update this document as deemed necessary.
- The project should consider impact assessment if any surface water is present or has a plan for lake, pond, and water recreational activities within the project boundary.

2.4-Modeling Groundwater Environment

Modeling studies often require seeing complex environment behavior in totality of course with applied threats (stresses). Base this specific requirement upon project components like geographical extents, intrusive character, distance from groundwater-protected basin, impact on groundwater environment etc. Consultant may add groundwater-modeling study considering the project impact of the hydrogeological environment.

2.4.1-Conceptual modeling

Preparation of conceptual model involves identification of the study area, identifying nature of boundary conditions, estimate groundwater budget, hydraulic properties of vadose zone, aquifer parameters with the consideration of all sources and sinks. One of the important sources, especially for phreatic aquifer, is groundwater recharge. Unconfined sandy aquifers are more vulnerable to surficial activities. Model should consider impacts of all possible component of to imitate expected impacts borne out of any activity/project etc.

2.4.2-Flow & solute transport modeling

A suitable modelling technique employing Numerical or analytical methods should be adopted with proper rationale. The model should be validated and calibrated with known data set and realistic scenarios be adopted to show case the problem domain. MODFLOW is the most popular groundwater/transport code based on block-centered Finite Difference Method. Modeling study requires that the conceptual model be detailed with all input data.

2.4.3-Aquifer Vulnerability modeling

For specialized project, where, landuse allocation appropriateness for specific project/activity is in question, Aquifer vulnerability model should be prepared to logical analysis of the likelihood of contamination with special reference to the area and regional scale too. DRATIC is the most popular aquifer vulnerability model.

2.4.4-Artificial Recharge Study

Artificial recharge is defined as the practice of artificially increasing the amount of water that enters a groundwater reservoir. An artificial recharge installation may serve more than one purpose. In certain areas, for example, artificial recharge not only adds water to the available groundwater supply, but also is a means of disposing of storm water runoff. In another instance, artificial recharge to control salt-water intrusion from deeper aquifer is

also increasing the available supply of fresh water and alleviating a ground subsidence condition that has been in progress for years. Some of relevant purposes for which artificial recharge is practiced are given below;

- Conserve and dispose of runoff and flood waters
- Supplement the quantity of groundwater available
- Reduce or eliminate decline in the water level of groundwater reservoirs
- Store water in off-seasons for use during the growing seasons

This requires a detailed hydrogeological and groundwater modeling study to discuss appropriateness, suitability, effectiveness and impact assessment associated with artificial groundwater recharge.

2.4.5-Groundwater Budget Study

Everything that influence groundwater storage quantity form a part of groundwater budget. The evaluation of groundwater budget employing widely applicable techniques is mandatory is large-scale project/activity (by size or by impact). A precise budget is a prerequisite of hydrogeological and groundwater modeling study.

3- Risk Assessment, Mitigation and Environmental enhancement

Integrate information given in Section 2 to generate an effective risk impact assessment for the project/activity. The objectives of the impact assessment exercise may differ, as may the intended end user of the information. This summary provides a simple overview of key issues and approaches. The purpose of mitigation measures is to avoid, reduce or minimize undesirable impacts and enhance beneficial impacts on the environmental media. Environmental scientists are required to utilize high professional ethics to select, gather and execute information concerning relevant impacts, mitigation and enhancement. The list of possible activities should not be considered as comprehensive and the practitioner must use professional judgment to identify other hazards associated with the activities present with their framework and where there is any doubt, should adopt the precautionary principle. The generic Activities identified are outlined below

- Earthworks
- Dewatering Works
- Storage / Transmission of leachable or hazardous materials
- Excavations of materials above & below the water table
- Infiltration from surface water features & utilities (all types of water use)
- Change in area physiography, abutting Storm water flow
- Pre & post construction water usage & possible impact

The process for managing the protection of groundwater quality is one of risk assessment that identifies where action is required, followed by implementation of management measures to protect groundwater quality so that it continues to meet all its identified environmental value categories. These risk assessment techniques can be easily translated into a land use policy approach that draws on the traditions of zonal planning, can be used in development control, is pragmatic and flexible while providing for safeguards for groundwater resources. This is the 'suitable for use' approach. In many respects, the suitable for use approach to land use planning has its origins in Environmental Impact Assessment whereby the impacts of a development project are assessed against existing and potential environmental conditions of a site. The principles underlying this

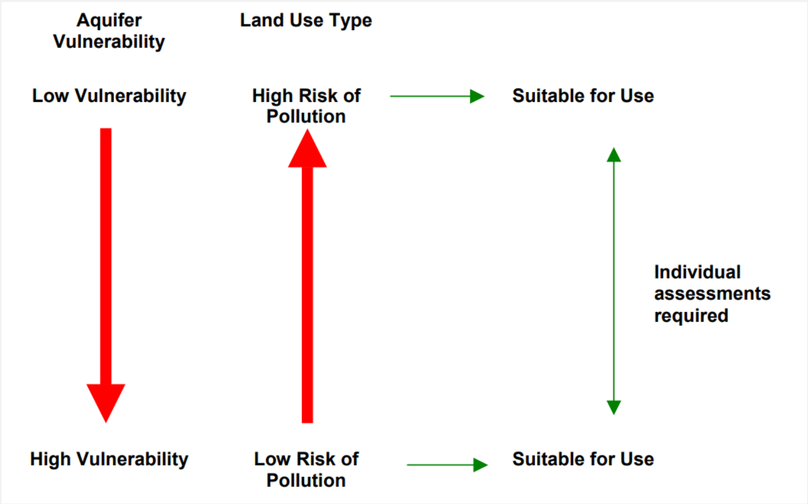


Fig.1 Risk assessment model

3.1-Impact Assessment

The proponent must provide an assessment of potential impacts. The impact assessment will vary depending on the trigger of the hydrogeological assessment (e.g. a significant recharge area may require a water balance). The assessment of potential development impacts may include, but is not limited to, a description of the following potential impacts;

- Changes to water table elevation (including seasonal fluctuations)
- Changes in groundwater flow direction
- Alterations to infiltration/recharge/discharge rates and volumes on varying time scales (i.e., daily monthly or annual depending upon proximal environmental features)
- Impacts on water quality and quantity
- Impacts to nearby receiving surface waters (wetlands, watercourses or other significant features)
- Impacts to environmental features
- Change in local storm water flow

Effective risk management will enable protection of the groundwater as well as minimizing the costs of corrective measures. A risk-based approach could include a fully quantified risk assessment or it could consist of a more qualitative approach to estimating risk with a lower reliance on detailed baseline data. The key objective of adopting a risk-based approach is to guide investment in groundwater quality protection that is commensurate with the level of risk to the assigned environmental value for the groundwater system. It allows governments, service providers, industries and communities to prioritize investment in the areas that face the greatest risk.

Gather all information given in Section 2 to integrate hydrogeological characteristic and project activities to identify potential impacts. Identify the environmental receptors within the estimated Zone Of Influence or downstream of the discharge, which may be affected through the project dewatering. Identify data gaps in the baseline information and potential mechanisms of impact. Undertake an analysis of the likelihood and significance of impacts to each environmental receptor to determine EMP decision matrix. The likelihood of impact is based on probability where low is unlikely (less than 10%), medium is possible (10% to less than 50%) and high is more likely than not (50% or greater). Identify and report relevant project specific factors that could be considered when evaluating the significance of impact. Potential Environmental Impacts can be divided into the following parts.

3.1.1-Impacts during construction Phase

This should include given below impacts (but not limited to) during the construction phase e.g.

- Change in elevation profile,
- Natural drainage pattern,
- Impact on/of storm water runoff,
- Loss of agriculture land/soil,
- Impact on groundwater environment including groundwater rise/decline,
- Dewatering impact,
- Induce infiltration
- Exposing groundwater level or aquifer interface
- Waste handling
- Handling of Hazardous material
- Groundwater contamination,
- Soil contamination
- Natural groundwater flow pattern
- Accidental oil spillage
- Pollution through poor groundwater well construction

3.1.2-Impacts during Operational (Post project Phase)

This section should cover (and not limited to) post project impacts;

- Impact of different types of waste disposals
- Total water use and resultant leakages
- Likelihood of groundwater level rise
- Impact of groundwater level rise
- Impact of recreational water/irrigation features
- Storm water generated

3.1.3-Methodology for Impact assessment

A suitable methodology should be employed for the selection of relevant risk parameters and their relative importance (weight) should be defined using an appropriate weight criteria. Standard risk-based approaches involve the identification of a hazard and the assessment of risk for that hazard. In terms of groundwater contamination, risk is generally a qualitative (or sometimes semi-quantitative) measure that considers the likelihood of the hazard occurring and the consequences if the hazard occurs. The requirement for preventative or management measures should be evaluated using two levels of risk;

- Maximum risk (sometimes called pre-mitigation or initial risk), which is the risk in the absence of preventative or management measures
- Residual risk, which is the remaining risk after preventative and management measures have been applied

3.2-Mitigation measures

Preventative measures to mitigate risks need to be identified for all hazards for which the risk is medium or high. If the residual risk is not acceptable, further mitigating measures are considered in a multi-barrier approach until the residual risk is low. Uncertainty is managed through monitoring, review and adaptation of groundwater protection measures where necessary, recognising that the costs of remedial measures are generally many times the costs of prevention. The section should include recommendation(s) for actions to mitigate potential impacts identified through the hydrogeological studies. Specific measures should be described to mitigate the potential impacts identified in Section 3.1. Mitigation recommendations shall address both the anticipated long-term and short-term impacts. To this end, a monitoring program to address potential impacts prior to, during and post-development may be requested by the Conservation Authority at its discretion. In this case, a contingency plan may also be required (see contingency plans). Mitigation measures are case variant therefore should include but are not limited to;

- Recharge or infiltration basins for urban runoff

- Preservation of protected groundwater areas from undesirable recharge/discharge areas
- Sedimentation control plans to prevent siltation of recharge/discharge areas
- Re-orientation of local surface water drainage
- Provisions for land use and site control plans (e.g., tree cutting restrictions, soil use related conditions, prohibition of use or storage of specified contaminants, access restrictions, etc.)
- Safe handling of waste and chemicals and Contingency plan

3.3-Plan for Environmental Improvements

EIA should provide detailed plan for the Environmental improvement in addition to the immediate mitigation measures and in connection to the impacts anticipated from the Project. This may include but not limited to;

- Groundwater monitoring plan
- Groundwater dewatering plan (Pumping/Gravity drainage)
- Rainfall recharge

3 Construction Environment Management Plan

The Environmental Management Plan is an action-oriented document for environmental safeguard from project activities. It summarizes the results of the studies undertaken in section 2 and section 3. The CEMP provides detailed mitigation, monitoring, and contingency plans, and provides a detailed plan for reporting and communications for implementing the CEMP based on adaptive management principles.

3-1 Develop the Mitigation Program

Develop a detailed mitigation program based on the preliminary impacts analysis completed in section 3. The intent of this program is to minimize or avoid construction impacts to each environmental receptor from water extraction or discharge. For each environmental receptor, specify mitigation measures and their implementation sequence. The mitigation program should be designed to be flexible to adapt to updated information through monitoring. Examples include the selection of construction technologies, or the selection of discharge locations.

3-2 Soil and Groundwater Contamination Control Plan

The Soil and Groundwater Contamination Control Plan should outline measures to manage and minimize the impact of the project on soil and groundwater. This plan should include, but not be limited to, the following information;

- Documentation of the measures used to ensure that oil and other hazardous materials are properly contained to prevent contamination of soil and groundwater. As necessary, a listing of the measures needed to remove or remediate previously identified contaminated soil onsite from prior industrial activities.
- Proper handling of soils during excavation works and stock piling, transportation etc.

3-3 Emergency Management Plan

The Emergency Management Plan should outline the procedures established to respond to emergencies pertaining to groundwater and soil during construction activities. This plan should include, but not be limited to, a list of emergency procedures, incident reporting and emergency coordinators following the standard procedures for corrective actions.

3-4 Reporting Requirements

The CEMP should outline procedures for reporting requirements, including the frequency and content of required reports, such as the following:

- Pre-operation compliance reports
- Incident/Emergency reports
- Periodic or annual performance reports

A standard table of contents of the monitoring report is given in Appendix 4.

4 Sampling, Monitoring & Well drilling Requirements

Monitoring reports should consist of the summary of continuous or periodic monitoring of planned groundwater monitoring program. The sampling and monitoring is required in the Environmental reports and later required to be submitted periodically (as approved) for review and approval as outlined in a permit during Construction Environmental Management Plan (CEMP), Operation Environmental Management Plan (OEMP) or as stated otherwise by NRCS-ED.

4-1 Sampling and monitoring requirements

- Groundwater Sampling phase including sample collection, preservation, transportation, lab assessment, parameters to be analyzed should be carried out following standard sampling (USEPA) & analytical protocol (APHA) under proper chain of custody and qualified supervision.
- Certain chemical parameters (pH, Electrical Conductivity, temperature, and dissolved oxygen (DO) should be measured at the wellhead, as laboratory results may not be representative of groundwater conditions. The baseline groundwater quality parameters are given in Appendix-5.
- To establish data efficient base, sampling (control) points should fairly cover and represent the prevailing conditions within the project limits. Groundwater Quality at the control points (monitoring wells) should be established for the project site.
- Groundwater level should be measured at the control points with respect to surface level and DMD which should be further used for infer groundwater flow direction.
- Groundwater monitoring wells (piezometers) should be constructed to a depth of maximum influence of the Project. In case, overlying an important aquifer, full aquifer depth should be tapped. Test pits or boreholes should be advanced to a depth to correspond with the engineering plans associated with planned Project. Piezometers should be wellhead protected and fenced to avoid contamination. Test pit or borehole locations and well design should be provided for DM-ED approval
- Based on evaluation of initial groundwater data and the nature of the project, a Monitoring Program should be prepared detailing frequency and sampling parameters.

- Representative soil sampling should be done following standard techniques. The baseline soil tests are given in Appendix-6.
- Representative soil & groundwater sampling means that it should cover important influence from or to the project activities.
- Sampling frequency should sufficient account environmental/climatic response and validation of proposed/ongoing/future activities.
- The Lower detection limit (LDL) of parameters should be less than standard guidelines limit of World Health Organization (WHO) and DIV 2000 as applicable for groundwater quality criteria.
- The laboratory conducting required tests should have Emirates International Accreditation Centre (EIAC) approval to carry out requested parameters.

4-2 Groundwater permitting system

Groundwater use within emirate of Dubai is a subject of prior permission (Drilling permit & use License) from the ED-NRCS. Well drilling permit should be obtained from NRCS to drill and construct groundwater well. License of groundwater use is required to use the water from the well. For construction projects, use of groundwater is permitted for sand settling and road compaction works only. The handling of groundwater environment should adhere to local & federal laws. Groundwater use should comply with the terms and conditions, right from obtaining permit for well drilling to well construction criteria and later to its fair use policy.

5.2.1 Groundwater use

Article 6 of Dubai's law no (15) 2008 includes groundwater use restrictions and well specifications.

- Groundwater allocation is defined by DM-ED, which is based on "safe yield" concept and is subject to be revised as and when required by groundwater balance study at the Emirate level.
- In order to save groundwater overexploitation, law bans Flood irrigation. Flood irrigation is replaced by more advance irrigation methods like drip, bubbler, sprinkler etc.
- Water consumptive crops like those of Rhodes grass is also prohibited. Similarly, Farms are not encouraged to grow Fodder and to adopt fit to use policy to accommodate TSE water supply.

- DM reserves the right to suspend the drilling permit/license of groundwater use temporarily or permanently based on violations of general terms and conditions or any other specific reason deemed appropriate to permitting authority.

Appendix-7 present groundwater use related allocation limits within Groundwater protection zones. Well permits/licenses issues by DM-ED manage the groundwater allocation criteria.

4-3 Basic Requirements for Groundwater well drilling

The main objective of this section is to provide a technical basis for, and a description of, the minimum requirements for drilling activities in the Emirate of Dubai. It also describes the shared responsibilities of drilling companies by providing legal basis, unified standard across the Emirate of Dubai.

- Drilling company should be registered with DM-NRCS.
- The drilling equipment must be in good condition and appropriate for the local geological formations, soils, and rocks. The drilling equipment must be clean and free from contaminants, which would otherwise be introduced into the aquifer.
- Drilling fluids must be free of harmful chemicals. As far as practicable, drilling fluids should be limited to clean water, air, and approved foaming agents. Water used for mixing drilling fluid must be clean (of potable quality).
- Returned drilling fluid, which is not re-circulated, must be disposed of in a satisfactory manner, i.e. using (a) a sediment trap, and (b) a soak-pit.
- Fuel should not be stored on the drilling site nor within 50 meters of the well. If repairs or re-fueling on site are necessary, every care must be taken to ensure that no leakages or spillages occur.

5.3.1. Casing types and Material

- Plastic casing may be of several types: Polyvinyl chloride (PVC), Acrylonitrile butadiene styrene (ABS), rubber-modified polystyrene (SR), High Density Polyethylene (HDPE), polyolefin, polypropylene.
- Plastic casing must have sufficient strength to withstand the pressure and setting temperature of the cement grout that will be placed in the annulus outside the casing.
- The conductor casing should be installed and grouted to a depth sufficient to stop collapse from sidewalls. Surface end of casing should be 0.5 to 1 meters above surface level.

5.3.2-Well depth, casing diameter, Pump capacity and abstraction volume

- The well depth is assigned by the Environment Department based on the location of requested well; location and depth shall not be changed once approved from the department.

- Casing diameter (conductor and screen) shall not exceed by the limit criteria set by Environment Department, Dubai Municipality.
- The abstraction volume per day per well is defined for its maximum limit, this shall not exceed in any case. Further, the allocation of abstraction volume will be based on specific requirement of user and general groundwater conditions in that region.
- Keeping high power pump capacity un-necessarily is waste of money and energy. For sustainability issue, Pump capacity should be in accordance with daily abstraction volume and should withstand future groundwater decline.
- The high power pumps will put negative impact on groundwater resources. Whilst high capacity pumps are unhealthy for the groundwater environment, same time they are violating the rights of rest of the users mainly in the neighborhood.

5.3.3 Piezometer, Well head protection & Well Abandoning

Groundwater monitoring well, also known as piezometer, should be constructed to a depth of maximum influence of Project, excavation works or dewatering depth whichever is greater. The depth of piezometer should be representative of the aquifer formation. Minimum drilling depth of a piezometer should be 5-10 meter below the water level. In case, overlying an important aquifer, sufficient aquifer depth should be tapped. Boreholes should be advanced to a depth to correspond with the engineering plans associated with planned Project. Test pit or borehole locations and all related information should be provided as appendix. Each borehole record should show the date of excavation, geological description, water level, drilling technique, well/casing diameter and data collection. Coordinates and Ground elevation (in meters above sea level) must be provided for each pit. The water level data should be utilized to address key issues like dewatering, anticipated change in water level, water quality and quantitative status. The location of monitoring wells should also consider up-stream and downstream approach of proposed Project area. Well drilling permit should be obtained from the Natural Resources Conservation Section (NRCS) to drill and construct groundwater well or permanent piezometer.

Temporary piezometer (for >6 months of monitoring) and geotechnical boreholes are not required to obtain this permit. However, all types of borehole drilling i.e. for testing, pumping, dewatering and monitoring should follow DM standard well design layout

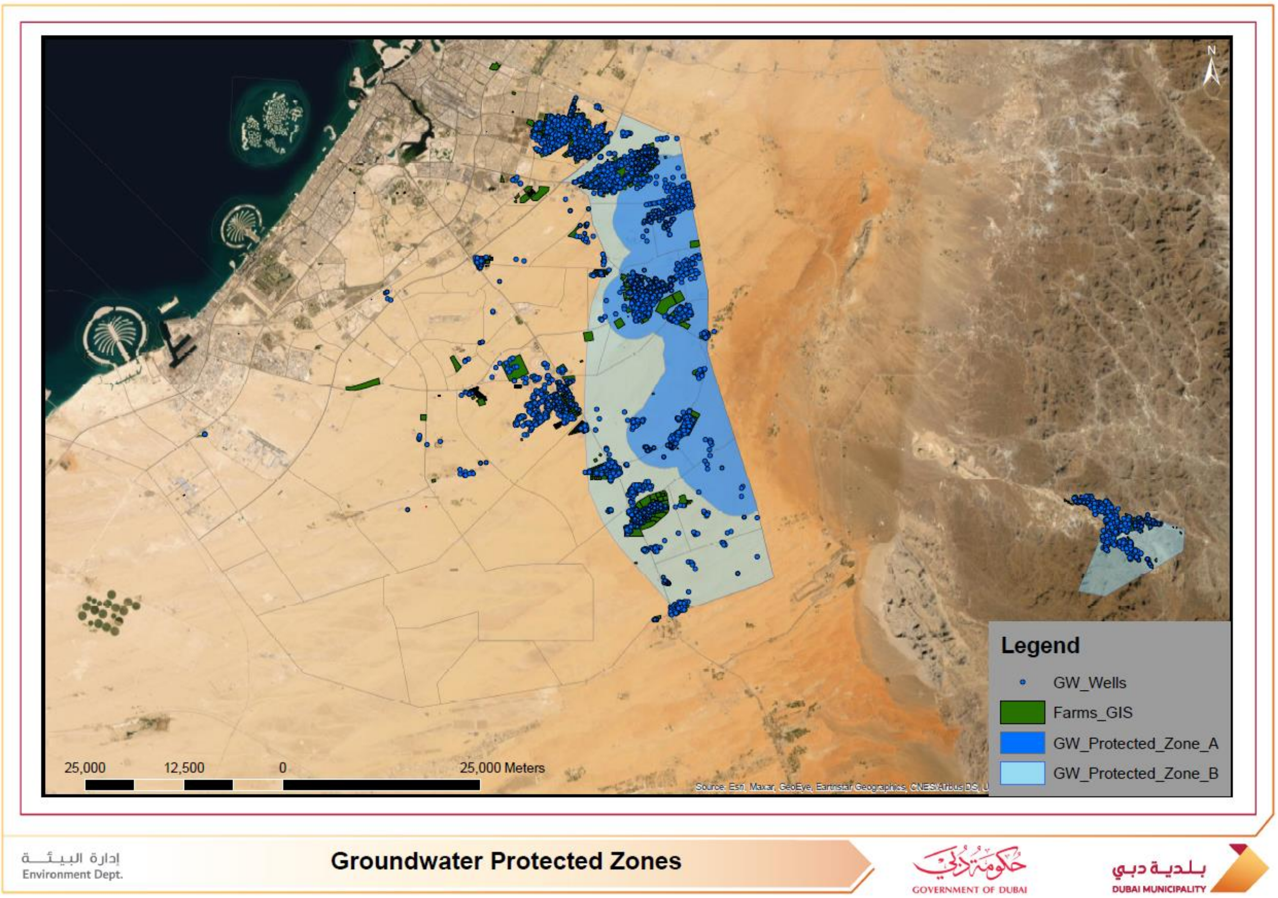
- Groundwater wells should be properly designed to disallow any pollution from the surface. The wellhead protection should be done as per the DM standard layout (Appendix-8). The wellhead protection consists of concrete foundation, and the top well cap or metal cover box. The metal cover box is fixable through four (04) screw at the corners and can be removed easily at the time of well repairing.

- The flow meter should be installed on production well as per the design outlay.
- Groundwater wells which are no longer in use or have left half way during drilling exercise should be abandon in a manner that prevent any kind of contamination from these wells. The proper abandoning of such wells is crucial as they may act as a pathway for the groundwater contamination.
- Article (4 & 14) of Dubai law number (15), 2008, concerning protection of Groundwater in the Emirate of Dubai, exposing groundwater resources to any kind of pollution is considered as violation of groundwater use policy and subject to penalty. A groundwater well will qualify for abandonment if
    - Dry
    - temporary wells after requested time duration
    - cancellation of well permit due to any reason
    - yield reduced to a level not acceptable for users
    - Physico-chemical water quality criteria makes it unsuitable for use
    - presence or indication of any material other than water
    - well with unknown status
- All obstructions in the well shall be removed prior to commencing to seal the well. Remove all material from the water well, such as the pump, pipe, pump cylinder, and electric cable. Approved sealing materials consisting of neat cement, sand cement, concrete, or bentonite should be used for sealing the well. Other approved sealing material well-proportioned mixes of silts, sands, and clays (or cement), and native soils.
- Place fill disinfected material (pea gravel, impervious clay material, or limestone chips) from the bottom of the well to below the point where the casing is to be removed. In the upper part of the well, place the sealing material—bentonite approved for water-well sealing, clean clay, or neat cement grout. Concrete or cement may be used if the upper part of the well is dry.

- Using proper equipment and safety devices, remove at least the top 2 meters of the well casing. The casing will be either brick, stone, concrete block, porous tile, or other material. The remaining 1-meter deep hole is to be filled with topsoil (Appendix 9).

List of Appendices

Appendix 1 : Groundwater Protected Zones



Groundwater Protected Zones Map

Appendix 2 : Land uses/Activities allocation status within Groundwater protected zones

<table>
<tr><th rowspan="2">S.No.</th><th rowspan="2">Items</th><th colspan="2">Protected Basins</th></tr>
<tr><th>Zone A</th><th>Zone B</th></tr>
<tr><td>1</td><td>Petrol Station</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>2</td><td>Sewage Treatment Plant (STP's)</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>3</td><td>Landfills</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>4</td><td>Abattoir</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>5</td><td>Food processing facilities</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>6</td><td>Dairy & Poultry Farm</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>7</td><td>Manure stockpiling</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>8</td><td>Commercial groundwater use</td><td>Not permitted</td><td>Not permitted</td></tr>
<tr><td>9</td><td>Cemetery</td><td>Not permitted</td><td rowspan="7">Allowed with conditions: According to the environmental requirements and the approval of other competent authorities</td></tr>
<tr><td>10</td><td>New Agriculture Farms</td><td>Not permitted</td></tr>
<tr><td>11</td><td>Livestock/Animal grazing/Izbat</td><td>Not permitted</td></tr>
<tr><td>12</td><td>Forestry</td><td>Groundwater dependent forestry is not permitted</td></tr>
<tr><td>13</td><td>Water treatment (RO facility)</td><td>Not permitted</td></tr>
<tr><td>14</td><td>Recreational activities (Swimming pools, Golf course, water features, sports fields, camping, sand bashing, lagoons)</td><td>Not permitted</td></tr>
<tr><td>15</td><td>Construction Projects</td><td>Not permitted.
Project for Environmental enhancement, protection and management are allowed.</td></tr>
</table>

Appendix 3 : Standard Table of content for Hydrogeological study for EIAR

Section	Contents	EIAS/EIAR	Hydrogeological Study
Introduction	Regional-Geology, Hydrogeology	✓	✓
	Hydrology (Rainfall, Runoff, flood-scenario, Infiltration, Surface water flows, ponds, drainage & sewerage)	✓	✓
	Identification of direct & indirect threats from existing & proposed landuse	✓	✓
	Local-Geology, Hydrogeology & Storm water handling	✓	✓
Baselines	Establish baseline Groundwater & Soil conditions	✓	✓
	Sampling maps (Location coordinates, sampling photos)	✓	✓
	Representative Groundwater levels & Quality	✓	✓
	Depth to groundwater, Groundwater elevation maps	✓	✓
	Integration of Geotechnical finding (Lithology, structure, permeability, water level, SPT etc) and conclusion drawn	✓	✓
	Additional aquifer tests to understand aquifer behaviors	✓	✓
	Environmental soil testing & quantitative assessment	✓	✓
	Quantify different water use types	✓	✓

	Groundwater budget integrating all influential components	✓	✓
Conceptual model	Develop conceptual Gw model integrating all In & OUT components (in text & as schematic diagram)	✓	✓
Numerical Modeling	Develop initial conditions with site specific aquifer parameters and steady state model		✓
	Transient stage-Calibration & Validation		✓
	Relevant stress futuristic Scenarios		✓
Impact assess (during project & post project) on Soil & groundwater	Quantify different water types and discuss impact on groundwater level rise, decline, change in flow pattern	✓	✓
	Impact of activities and landuse on Groundwater quality	✓	✓
	Short & long term impact	✓	✓
	Identify risks on Soil & Groundwater resources	✓	✓
	Impact/Risk Assessments	✓	✓
	Discuss worst case impact & preparedness	✓	✓
Management & monitoring control plans	Description of Project specific impact & mitigation measures	✓	✓
	Develop & prioritize categories of impacts/Risks based on their severity	✓	✓
	Environmental monitoring Report	✓	✓
	Environmental improvement plan	✓	✓

Appendix 4 : Standard Table of content for Environmental Monitoring Report

Executive Summary	Project Name Project Description Reporting Requirements Summary of EIA
Monitoring Protocols and Standards	Monitoring Protocols Monitoring Standards Instruments & Test methods
Monitoring Programs	Methods Monitoring time & Frequency Monitoring locations Quality assurance/Errors Monitoring results
Non Compliance	General description Exceedance comparing to applicable standard/background conc. (DIV 2000)
Conclusions & Recommendations	

Appendix 5 : Groundwater quality parameters

S. No.	Parameter	Unit of measurement	WHO	Dutch Target value (µg/l)	
			Drinking water standard	Target	Intervention
1	pH		6.5-8.5		
2	Temp	Degree Celsius			
3	Color		<5 Hazen unit		
4	Turbidity	NTU	1		
5	E Conductivity	microS/cm	1500*		
6	TDS	mg/L	1000**		
7	Total Hardness	mg/L as CaCO3			
8	Chlorine	mg/L	5**		
9	Sodium	mg/L	200**		
10	Potassium	mg/L	10**		
11	Calcium	mg/L	75**		
12	Magnesium	mg/L	30**		
13	Sulphate	mg/L	500**		
14	Nitrate	mg/L	50		
15	Phosphate	mg/L			
16	Total Nitrogen	mg/L			
17	Chloride	mg/L	250**		
18	Aluminium	mg/L	0.1		
19	Arsenic	mg/l	0.01	7.2	60
20	Cadmium	mg/L	0.005***	0.06	6
21	Chromium	mg/L	0.05	2.5	30
22	Cobalt	mg/L		0.7	100
23	Copper	mg/L	2	1.3	75
24	Iron	mg/L	1.5		
25	Lead	mg/L	0.01	1.7	75
26	Molybdenum	mg/L	0.07**	3.6	300
27	Boron	mg/L	2.4		
28	Barium	mg/l	0.7	200	625
29	Berylleum	mg/l	0.0012**	0.05	15
30	Manganese	mg/L	0.4		

31	Nickle	mg/L	0.07	2.1	75
32	Zinc	mg/L	3	24	800
33	Mercury	mg/L	0.006	0.01	0.3
34	Oil & Grease-Free oil	mg/L	0.01***		
35	Pesticides	mg/L			
	Alachor		0.02		
	Aldrine		0.00003	0.009	
	Chlordane		0.0002	0.02	0.2
	Dieldrin		0.00003	0.1	
	Endrin		0.0006	0.04	
	Lindane		0.002		
	Methoxychlor		0.02	9	
	OP-DDT		0.001		0.01
	PP-DDT		0.001		
	Pendimethaline		0.02		
	Trifluralin		0.02		
36	Phenols	mg/L		0.2	2000
37	Benzene	mg/L	0.01	0.2	30
38	Hydrogen sulphide	mg/L	0.05**		
39	Total Cyanide	mg/L	0.3	5	1500
40	Dissolved Oxygen	mg/L			
41	BOD	mg/L			
42	1, 2 dichloroethane	mg/L	0.03	7	400
43	Dichloromethane	mg/L	0.02	0.01	1000
44	E. Coli	No./100 ml	0		
45	Total Coliform	No./100 ml	0		
46	Total Bacterial Count	No./100 ml @37 Celceus	0		
*TDS= 0.65xEC, **Threshold values, ***EU standard					
Coordinates of sampling location(s)					
Date/time of Sampling					
Sampled after well purging by (Bailer/Pump)					
Total project area					
Depth (measured) to water level (m)					
Base map, Depth to water level map, Water elevation contour map, piezometer photos					

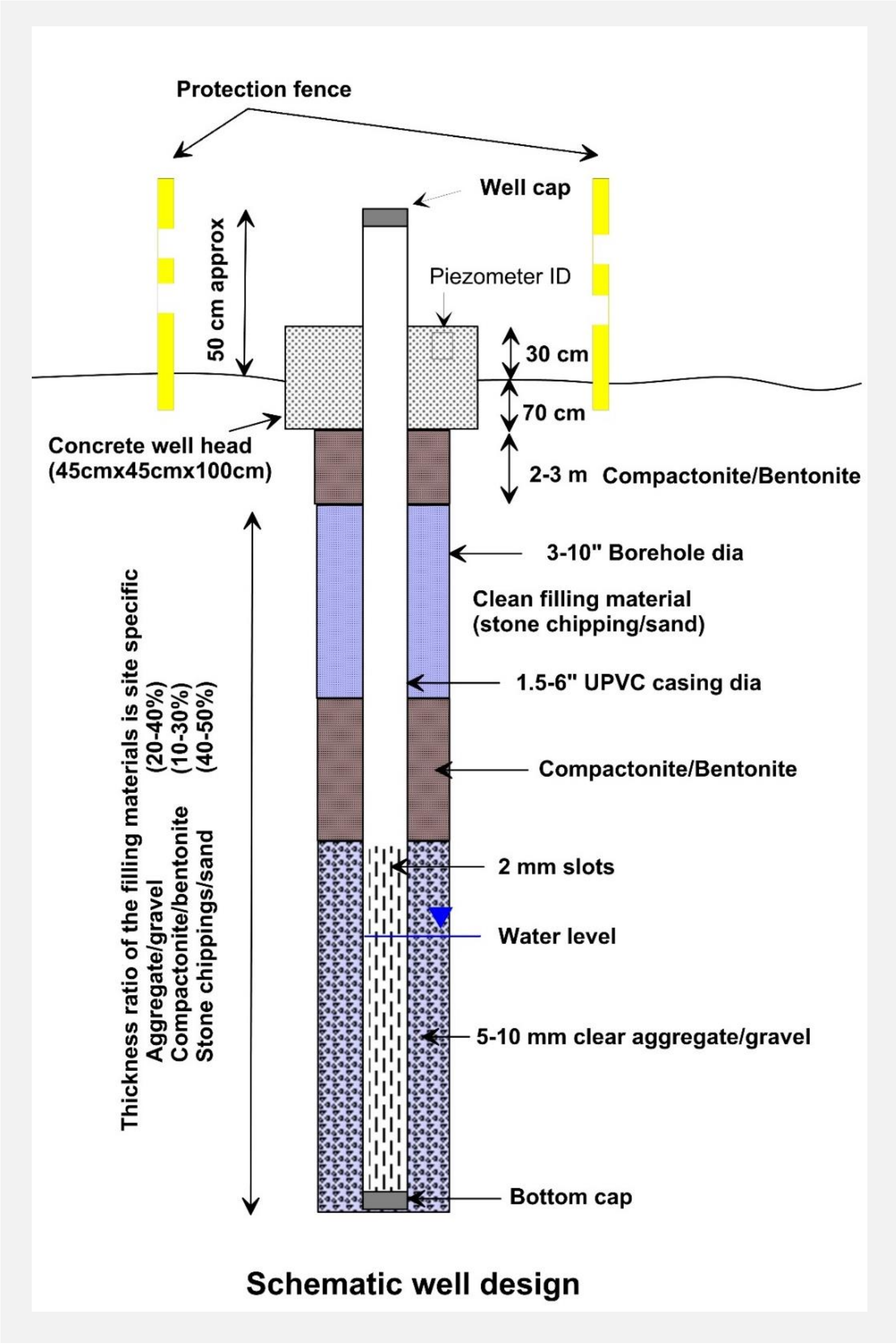
Appendix 6 : Soil quality parameters

S. No.	Parameter	Unit of measurement
Sampling date		
Soil Sample Coordinates, sampling photos		
Depth to water level (m)		
Representative Sample depth (cm)		
Physical Parameters		
1	pH	
2	E Conductivity	microS/cm
3	SAR	Ratio
4	ESP	Ratio
5	Gypsum%	%
6	Estimated Organic Matter	% OM
7	PHCs	
8	Zn, Mn, Fe, Cu, Si, Al, Co, Se, Cd, Pb, As, Cr, Ni, Hg, CN,	mg/kg
9	Soil texture	(USDA classification)
Quantitative Assessment		
1.	Cut and fill volume	Cubic meter
2.	Agricultural soil	Cubic meter
3.	Non-agricultural soil	Cubic meter

Appendix 7 : Groundwater management allocation criteria within protected area

S.No.	Items	Protected Basins		Outside PA
		Zone A	Zone B	
1	**Max. Well depth (m)**	70	80	90
2	**Max. Well casing diameter (inches)**	6	6	8
3	**Max. Discharge (l/min.)**	50	60	80
4	**Max. pump capacity (hp)**	5-7.5	5-7.5	5 to 10
5	**Casing type**	U-PVC	U-PVC	U-PVC
6	**Max. daily abstraction volume (m^3) per well**	5	10	25
7	**Minimum distance between wells (m)**	125	100	75
8	**Flowmeter type and installation technique**	DM approved	DM approved	DM approved
9	**Well Head protection**	as per DM standard	as per DM standard	as per DM standard
10	**Well ID**	Unique Well ID	Unique Well ID	Unique Well ID
11	**Well record register**	Basic well information and Daily operational record	Basic well information and Daily operational record	Basic well information and Daily operational record
12	**Well use**	Agriculture	Agriculture/Approved use types	Agriculture/Approved use types
13	**Water quality Sampling report**	Mandatory	Mandatory	Mandatory
14	**Irrigation method allowed**	Drip, Sprinkler	Drip, Sprinkler, Bubbler	Drip, Sprinkler, Bubbler
15	**Commercial groundwater use**	Not permitted	Not permitted	Permitted with allocated quantity of groundwater use.

Appendix 8: Groundwater well schematic design & head protection



Schematic Well Design

Appendix 9: Criteria for Groundwater well abandoning

1- Take photos for the existing well before closing.
2- Remove all the accessories cable, pump & whole screen (or till 3-10 feet) from the existing wells.
3- Fill the groundwater well by natural sand, Bentonite, soil and Gravel, These material should be uncontaminated (Take photos for the material/Sand).
4- The impervious layer depth slot should be filled impervious sealing material.
5- Fill the top layer 3 to 5 meters of the well by Bentonite mixed with water the impervious seal/layer, to avoid the groundwater from any type of contamination.
6- Make a report detailing method statement as describe item 1-5 above (include field activity pictures).

Schematic diagram to show depth wise sealing material.