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Optimising the management of the Gozo Mean Sea Level Aquifer (Malta)

EIP Water Online Market Place
Matchmaking for water Innovation
MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)

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Taken from: http://travessa-pirineus.blogspot.com.es/2014/08/dia-15-de-lospitalet-al-refugi-de-juclar.html

Introduction

The Gozo Mean Sea Level Aquifer

Underlies almost the whole island, except in the south-eastern region of the island;

Sustained primarily in the Lower Coralline Limestone and the Globigerina Limestone where this occurs at sea-level;

Is in direct lateral and vertical contact with sea-water, and the bulk of its storage capacity occurs below sea-level; and

Has significant importance for the water supply of the island (municipal and agricultural sectors)

Gozo:

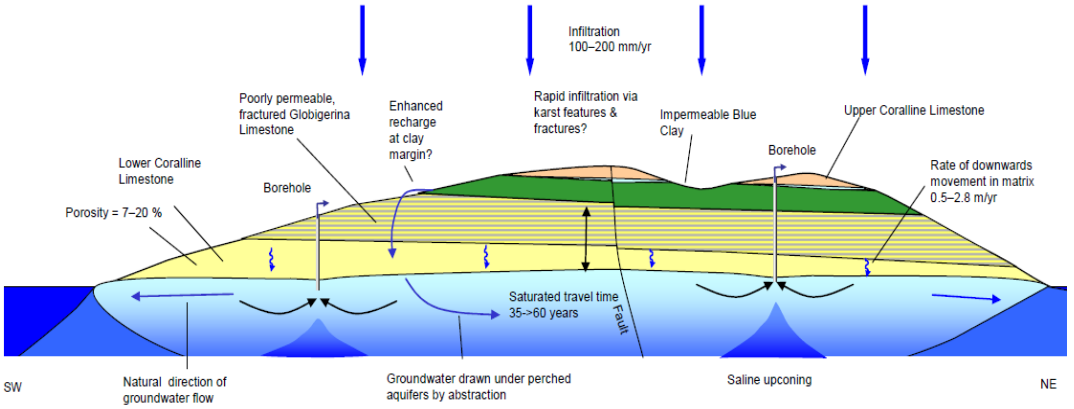
Elongated Carbonate Island

14km - length

7.25km - width

67km² - surface area

60km² - gw body extent



Model Development Framework

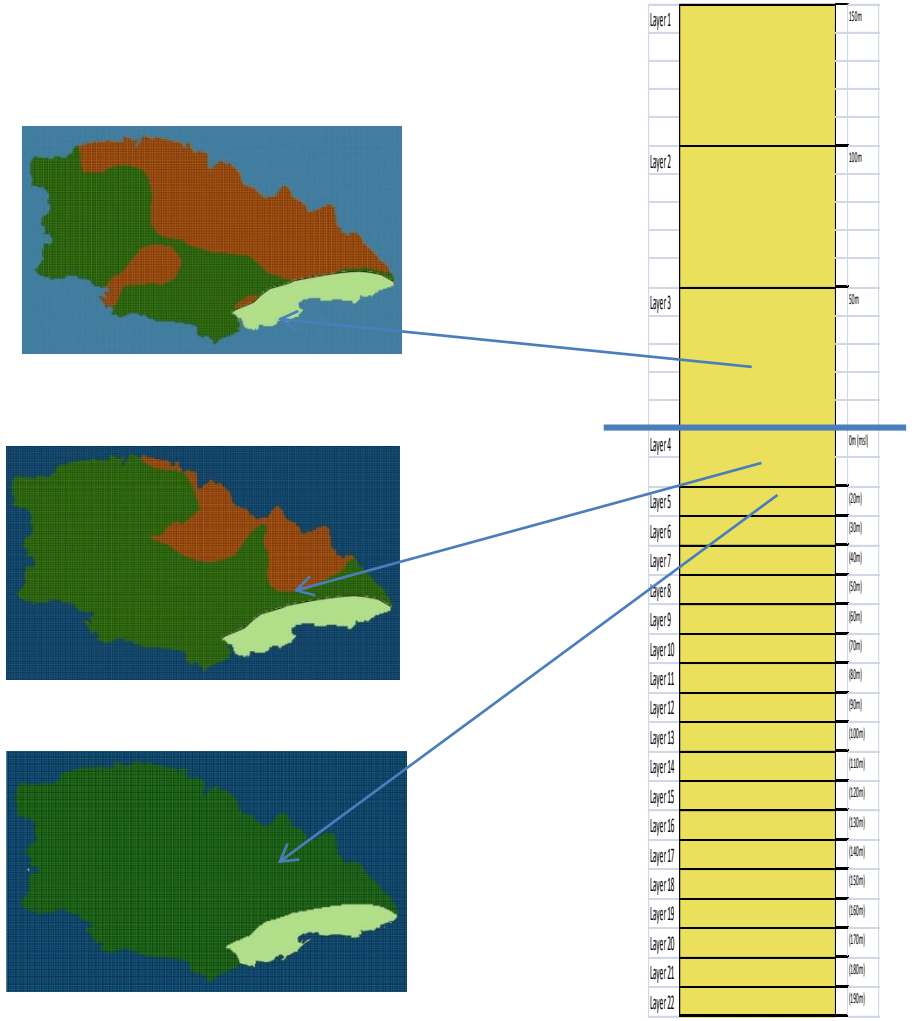
Horizontal Dimension:
173 rows by 288 columns square cells each of size 50 by 50 m.

Vertical Dimension:
22 horizontal layers of constant thickness

Hydrogeological properties:
Variation in geology in the horizontal and vertical dimension to represent presence of Lower Coralline and Globigerina Limestone formations

Hydrological properties:
Recharge varies according to outcropping formations

Boundary Conditions:
0m fixed head at coast
No flow boundary condition - fault



Steady State

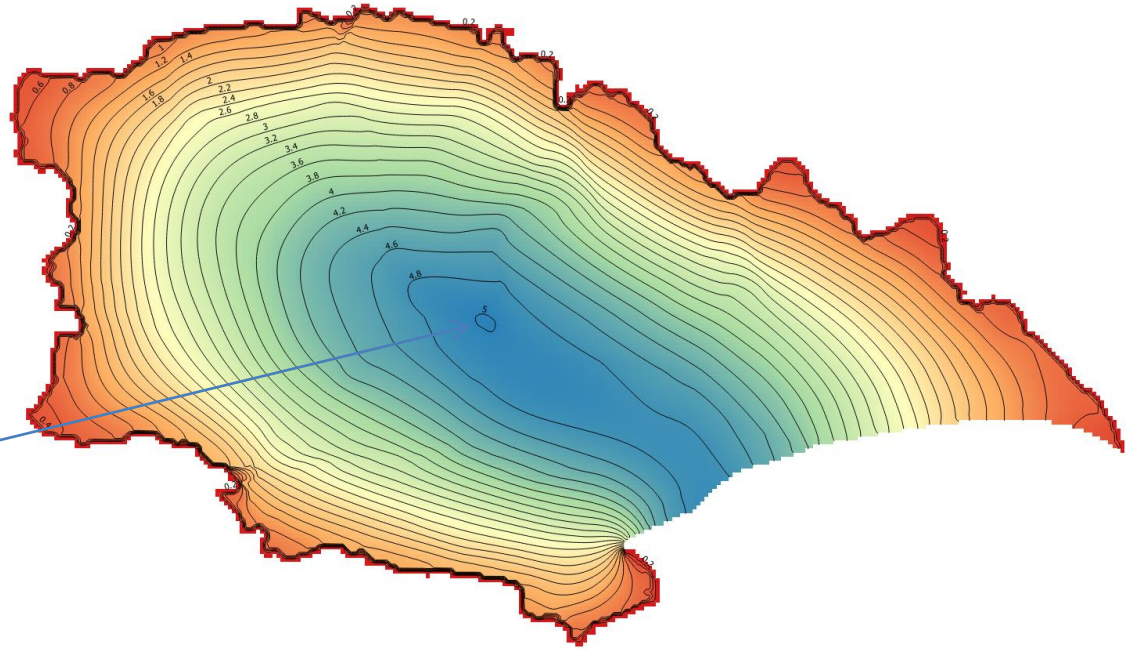
The first run of the model was under steady-state conditions, representing the island's aquifer under conditions of no abstraction enabling the freshwater lens to achieve its maximum dimensions.

RESULTS:

Maximum head of +5m amsl in central region of the island.

Values of the same order of those registered in drilling logs in the 1970s – when aquifer was still relatively unexploited.

Mild impact in hydraulic head due to the presence of Globigerina Limestone at/below sea-level.



Piezometric peak of 5.0m amsl

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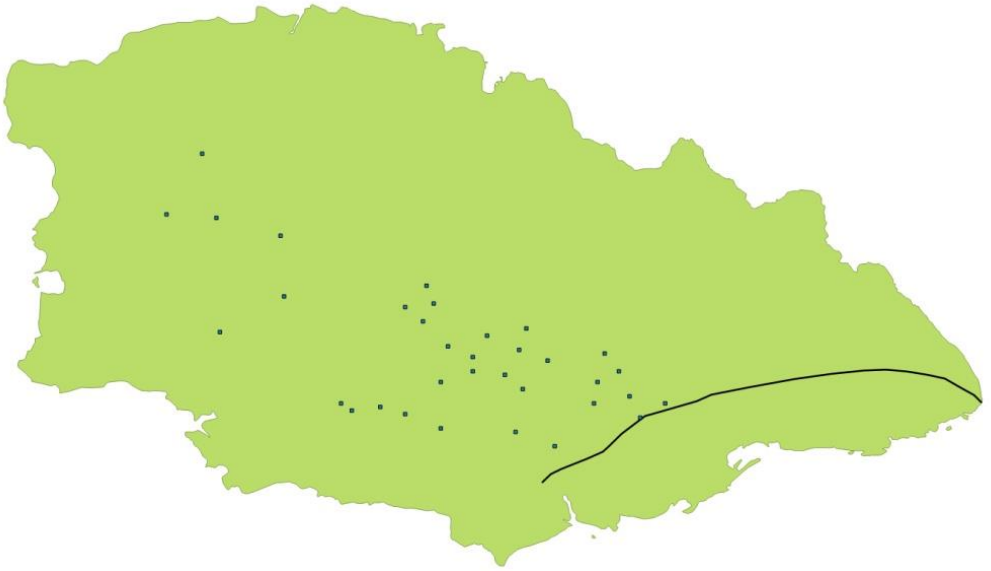
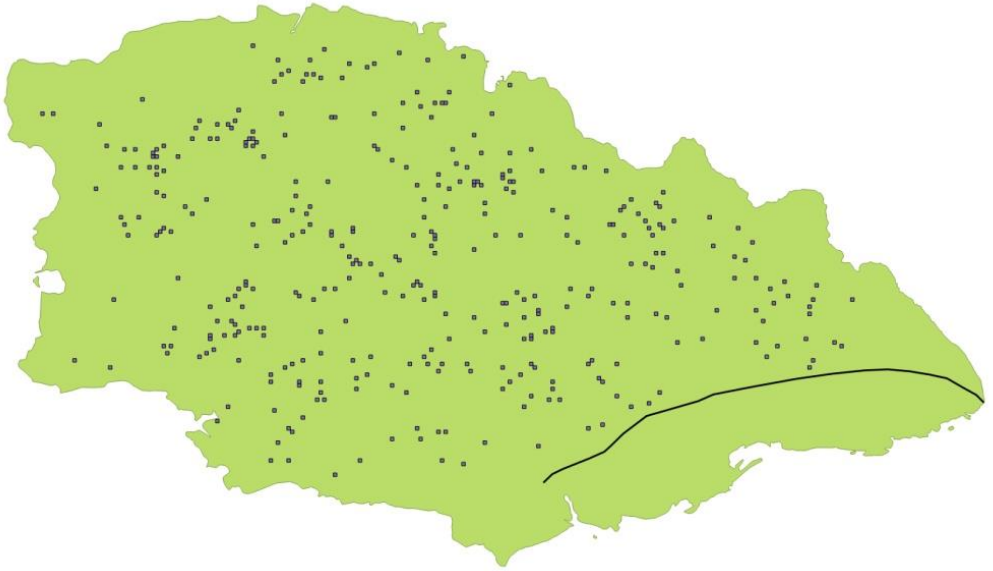
Transient State

Groundwater Abstraction

Public Abstraction Stations
Number: 37
Range : 60m³/d – 300m³/d
Annual Volume: 1.9 million m³



Private Abstraction Stations
Number: 382
Mean Abstraction: 5m³/d
Annual Volume: 0.7 million m³ (metered data)



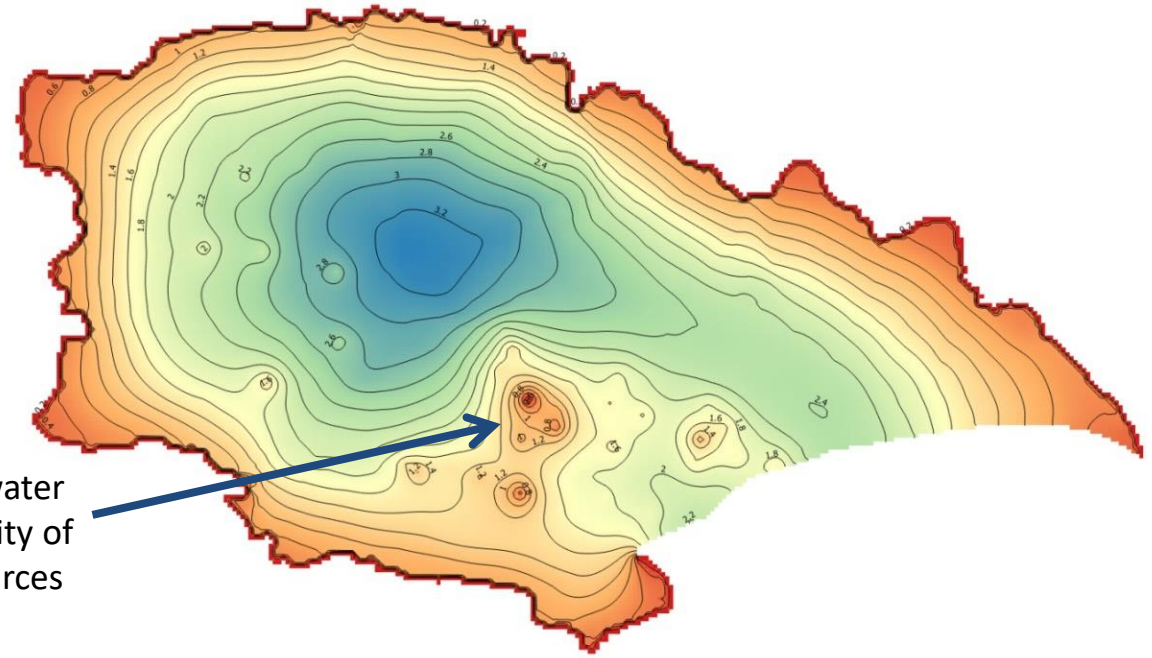
Transient State

RESULTS

Groundwater abstraction results in the overall lowering of the piezometric head - new peak of 3.2m amsl – displaced to the western side of the island.

Regional impact of groundwater abstraction, head lowered to below 1.5m amsl in region of high groundwater abstraction (high density of public wells)

Piezometric levels in accordance with measurements in groundwater gauging wells.



Region of high groundwater abstraction – high density of public groundwater sources

Water Balance

Transient State

Uptake from groundwater storage in lens is occurring and hence the groundwater body is in an unsteady state.

As abstraction (outputs) is greater than recharge (inputs) the groundwater body is classified as being in poor quantitative status.

INPUT	
Recharge (total)	12.5Mm^3
OUTPUT	
Abstraction (total)	2.6Mm^3
Natural Discharge	10.6Mm^3
BALANCE	
Uptake from Storage	0.7Mm^3

Natural coastal groundwater discharge estimated to account for 80% .of all outputs from the groundwater body.

The main envisaged (conventional) management measure applicable under such conditions is the reduction of groundwater abstraction; to address the negative groundwater balance and hence reduce uptake from storage.

Achieving Good Status

Addressing over-abstraction

A management scenario wherein all private abstraction is prohibited was tested under the model.

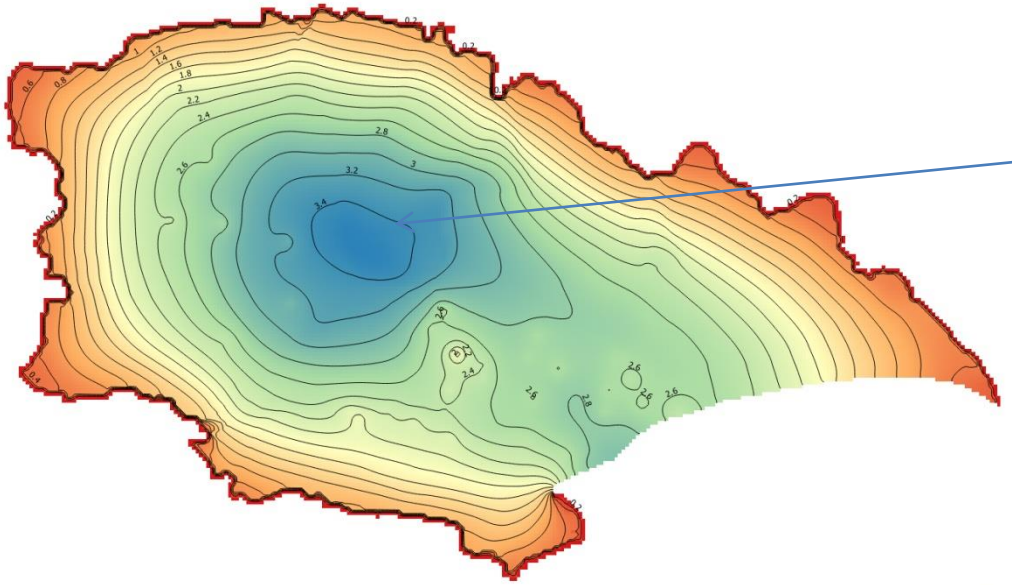
Under this scenario gw abstraction is reduced by 0.7Mm^3, and should thus be sufficient to ensure the achievement of good quantitative status.

INPUT	
Recharge (total)	12.5Mm^3
OUTPUT	
Abstraction (total)	1.9Mm^3
Natural Discharge	11.2Mm^3
BALANCE	
Uptake from Storage	0.6Mm^3

Model results show that the measure still does not lead to the achievement of good quantitative status. Reduced abstraction results in higher piezometric heads, increasing natural discharge

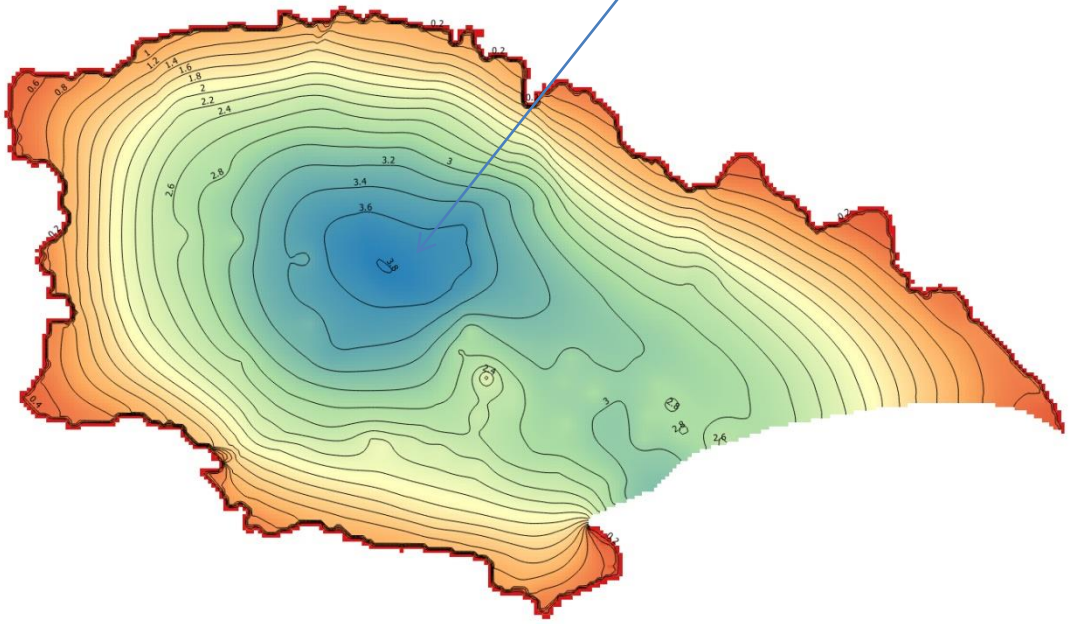
Groundwater management under coastal conditions requires more than a simple water balance approach.

Achieving Good Status



Maximum Head:
3.4m amsl

Maximum Head:
3.8m amsl



Decreased Abstraction
Increase in Piezometric Level
Increased Natural Discharge
Uptake from storage persists
No change in Quantitative Status conditions

Achieving Good Status

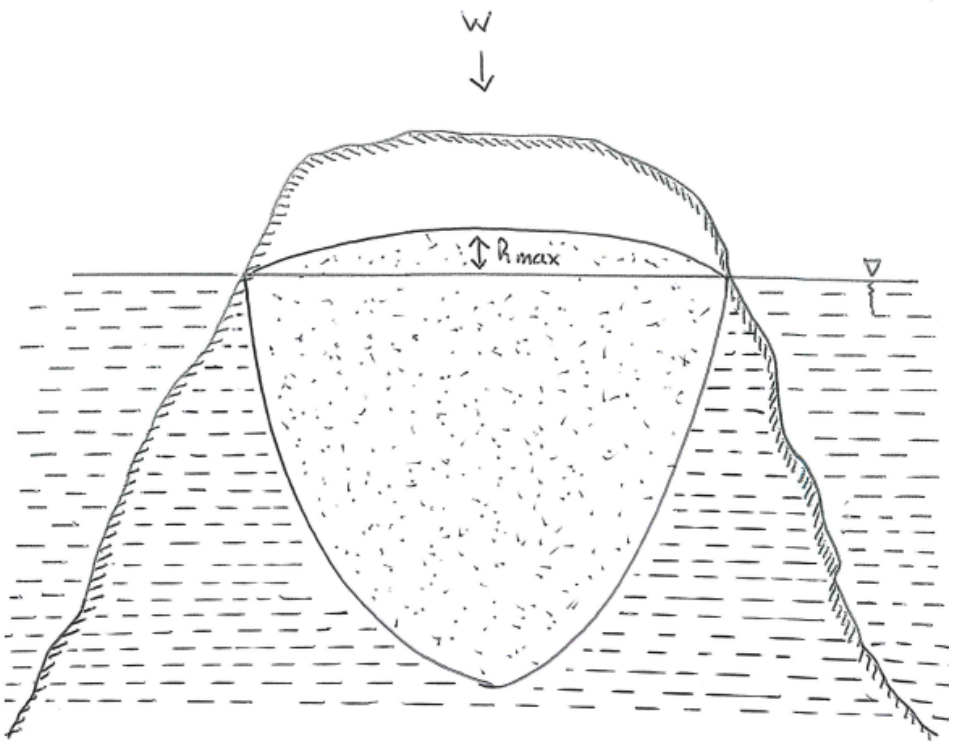
Achieving balance conditions (inflow = outflow) is viewed as achieving steady state conditions – water levels in the groundwater body are stable.

Two end scenarios:

(i) unexploited conditions: the groundwater body achieves its maximum extension, and all inflowing volume is lost as natural discharge: **Recharge = Discharge**

(ii) no groundwater body: the groundwater body needs to establish itself, and all inflowing recharge is stored in the aquifer system to sustain the groundwater body: **Recharge = Storage**

Recharge = Storage + Discharge



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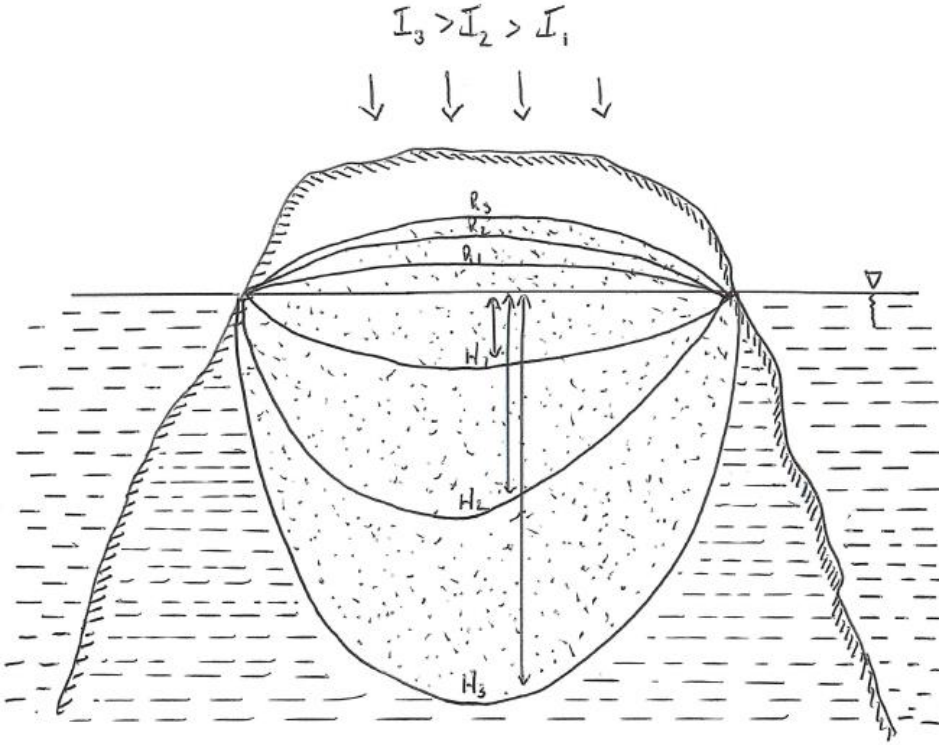
Achieving Good Status

In between these two end-steady states, varying inflows (due to abstraction) will result in intermediary steady states.

Shifting from one steady state to another is expected to take a relatively long time due to the volume of water which needs to be displaced (with sea-water) from the lower part of the aquifer system

Each steady state however represents good status conditions – as outputs from the groundwater body are equal to inputs, and there is no uptake from storage to balance flows.

Lower steady states also represent regional sea-water intrusion – uplifting of the freshwater-saltwater interface. This also has qualitative impacts on groundwater exabstraction.

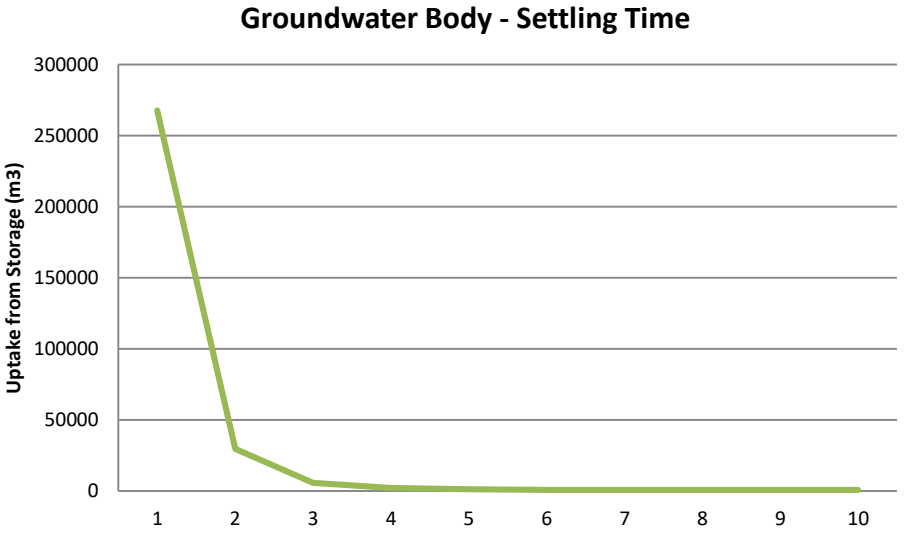


Natural Conditions

Groundwater Body Settling Curve

Movement between one steady state to another will require the loss (gain) of significant volumes of groundwater, in particular from the lower part of the freshwater lens. Hence conditions of overabstraction (and hence uptake from storage) are expected to persist for a number of years until the new piezometric levels are established.

Current research being undertaken through groundwater modelling with FREEWAT aims to establish the groundwater body settling curve for the Gozo MSLA, hence determining the expected time for the groundwater body to achieve steady state conditions (no uptake from storage) under pumping conditions.

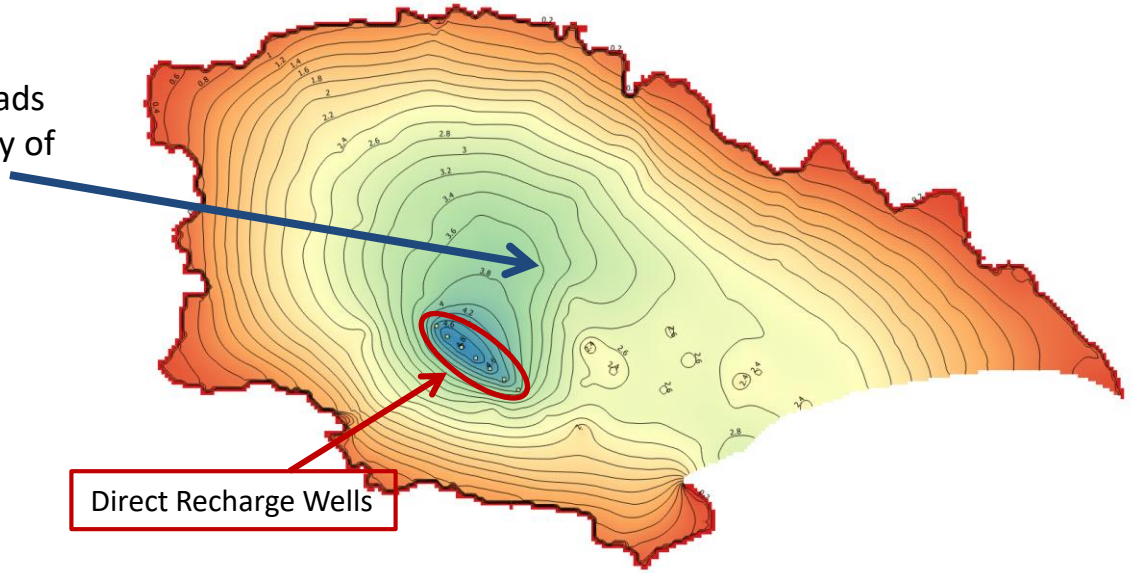


Scenario Modelling

Managed Aquifer Recharge

Installation of 7 recharge wells discharging to the aquifer a volume of 1million m^3 pa.
Simulates potential impact of diverting treated water produced in Gozo New Water Plant for MAR purposes.
Recovery of aquifer system at a local and regional level.
Movement of recharged water is towards public well fields.

Increased piezometric heads indicated over whole body of groundwater.



Scenario Modelling

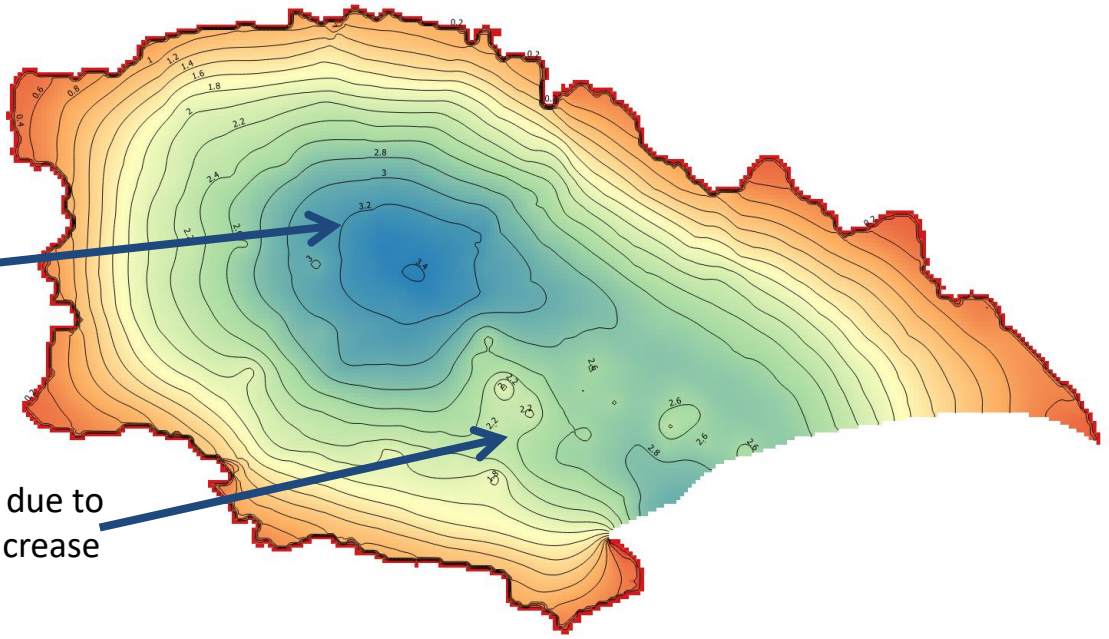
Reduction in public abstraction by 50%

Recovery of aquifer system in the south-western region – direct impact of groundwater abstraction. Piezometric levels are now in the region of 2m amsl.

Marginal increases in piezometric head over the whole groundwater body – piezometric peak rises to 3.4m amsl

Marginal impact at groundwater body level.

Recovery of aquifer system due to lower abstraction rates – increase in piezometric head.



Conclusions

Water Balance

Model confirms the high natural groundwater discharge rates (estimated at levels of 50 – 80 %) of mean annual recharge: expected in small islands due to high ratio between coast (perimeter) and island area.

Water balance calculations are not sufficient to assess good quantitative status conditions in island aquifer systems. In these cases, there is an inherent link between the water balance parameters.

Aquifer Management

Aquifer management cannot be undertaken on the basis of a simple cumulative water balance model. Spatial distribution of abstraction is an important factor.

Impact of private abstraction is not as pronounced as that from public abstraction on a regional basis. However lowering of hydraulic heads due to private abstraction increases the impact on public groundwater abstraction sources, making them more vulnerable to sea-water upconing and hence salinisation..

Conclusions

Status

Poor quantitative status conditions were still registered when total abstraction was lowered, and assessed through a short-term model.

Longer term models are required to assess the eventual achievement of a steady state under exploitation conditions – through the settling of water levels to lower heights.

Model Optimisation

Model optimisation can be undertaken through:

- *Increased knowledge on the spatial variability of hydraulic parameters in the Gozo aquifer system,*
- *Updated data on private groundwater abstraction (including increased data from metering programme), and*
- *Increasing extent of gauging network to broaden model calibration.*

3rd River Basin Management Plan

Further development of the model is envisaged to enable its use in the status assessments to be undertaken within the frame of Malta 3rd RBMP (2021).

Thank-you for your attention

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