Aquifer Management and Sustainability

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Why Groundwater Management is needed?

Management of a groundwater system, means making such decisions as:

- The total volume that may be withdrawn annually from the aquifer.
- The location of pumping wells, and their rates.
- Decisions related to groundwater quality (Groundwater contamination) as a result from:
  - Hazardous industrial wastes
  - Leachate from landfills
  - Agricultural activities such as the use of fertilizers and pesticides

How can Aquifer Management be a achieved?

- MANAGEMENT means making decisions to achieve goals without violating specified constraints.
- Good management requires information on the response of the managed system to the proposed activities.
- This information enables the decision-maker, to compare alternative actions and to ensure that constraints are not violated.
- Example: once contamination has been detected in the saturated or unsaturated zones. The decision maker requires to predict the path and the fate of the contaminants in order to plan activities to protect the aquifer.

Aquifer Flow Models

- A tool is needed to provide information concerning the response of aquifer as results of human, political and natural stresses.

- The tool for understanding the aquifer system and its behavior under stresses as well as for predicting this response is called **model**.

- Usually, the model takes the form of a set of mathematical equations, involving one or more partial differential equations. We refer to such model as a mathematical model.

Ground Water Modeling

- **Why do we use Model?**
  - To make predictions about a ground-water system's response to a stress.
  - To understand the system.
  - To design field studies.
  - Use as a thinking tool

Use of Groundwater models

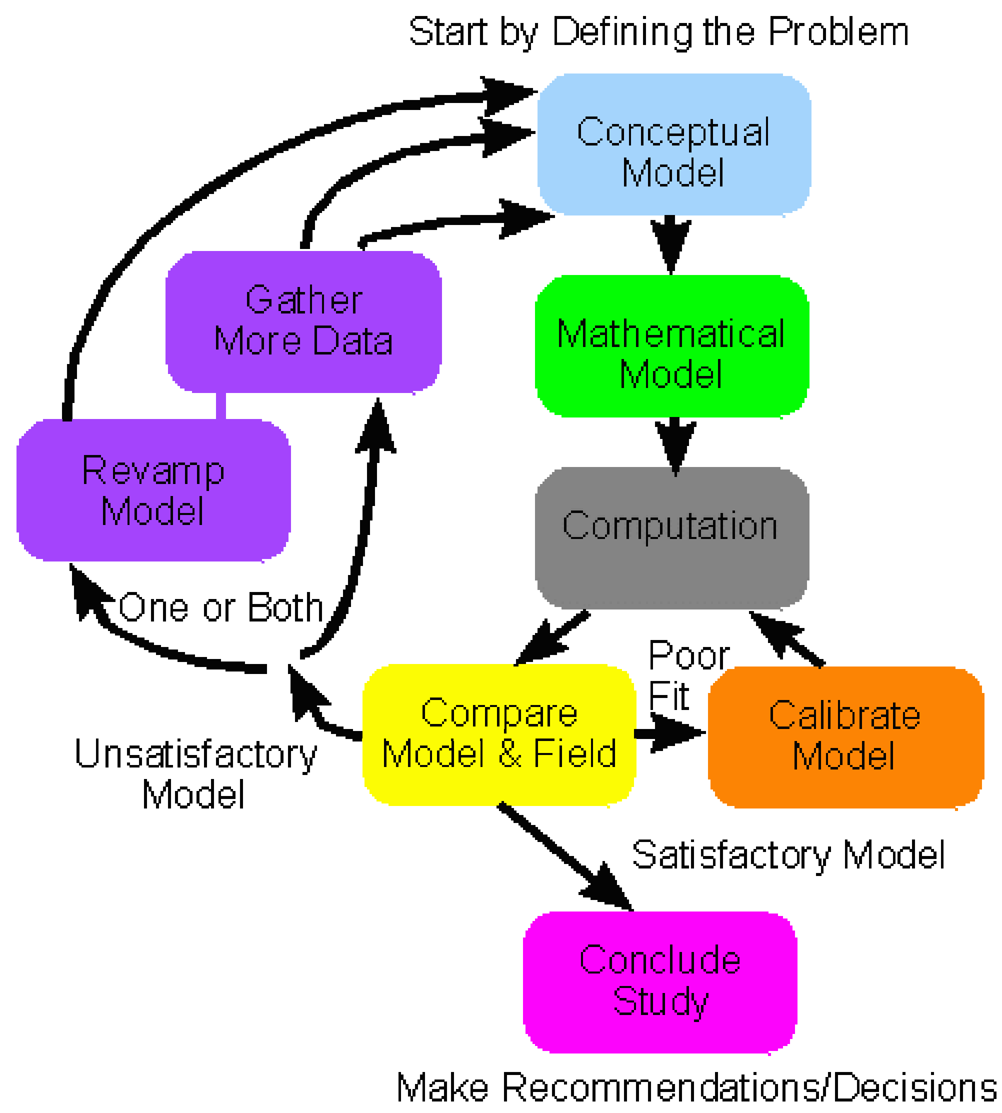
Can be used for three general purposes:

- ***To predict or forecast*** *expected artificial or natural changes in the system.*

- *To* ***describe*** *the system in order to analyse various assumptions*

- *To* ***generate*** *a hypothetical system that will be used to study principles of groundwater flow associated with various general or specific problems.*

Developing Groundwater model



Developing Groundwater model

Conceptual Model:

A descriptive representation of a groundwater system that incorporates an interpretation of the geological & hydrological conditions. Generally includes information about the water budget. May include information on water chemistry.

Developing Groundwater model

Components of a Mathematical Model:

- Governing Equation: (Darcy’s law + water balance equation) with head (h) as the dependent variable
- Boundary Conditions
- Initial conditions (for transient problems)

Case study: Developing Model for Western Aquifer Basin.

Model Coverages:

- **Sources\Sinks Coverage:** geographical representation of the aquifer, aquifer layers, layers geometry, wells locations and abstractions, springs locations and heads
- **Recharge Coverage:** spatial distribution of recharge over recharged areas within the aquifer.
- **Observation (Target) Points:** water level time series for selected wells distributed over the modeled area.
- **Hydraulic Properties Coverage:** Storativity, Specific yield, vertical and horizontal conductivities.
- **Initial Heads:** point or more with known water level to let the model start with.
- **Boundary Conditions:** types of boundary (e.g. flow boundary or no flow boundary)

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Sources/Sinks Coverage

Layer 1: all formations above the Upper Aquifer (Quaternary, Oligocene, Miocene, Pliocene, Eocene, Senonian)

Layer 2: Upper Aquifer (Turonian and Upper Cenomanian)

Layer 3: Yatta Formation (Lower Cenomanian)

Layer 4: Lower Aquifer (Albian)

Layer 5: Yakhini Formation (Lower Cretaceous)

Model Layers

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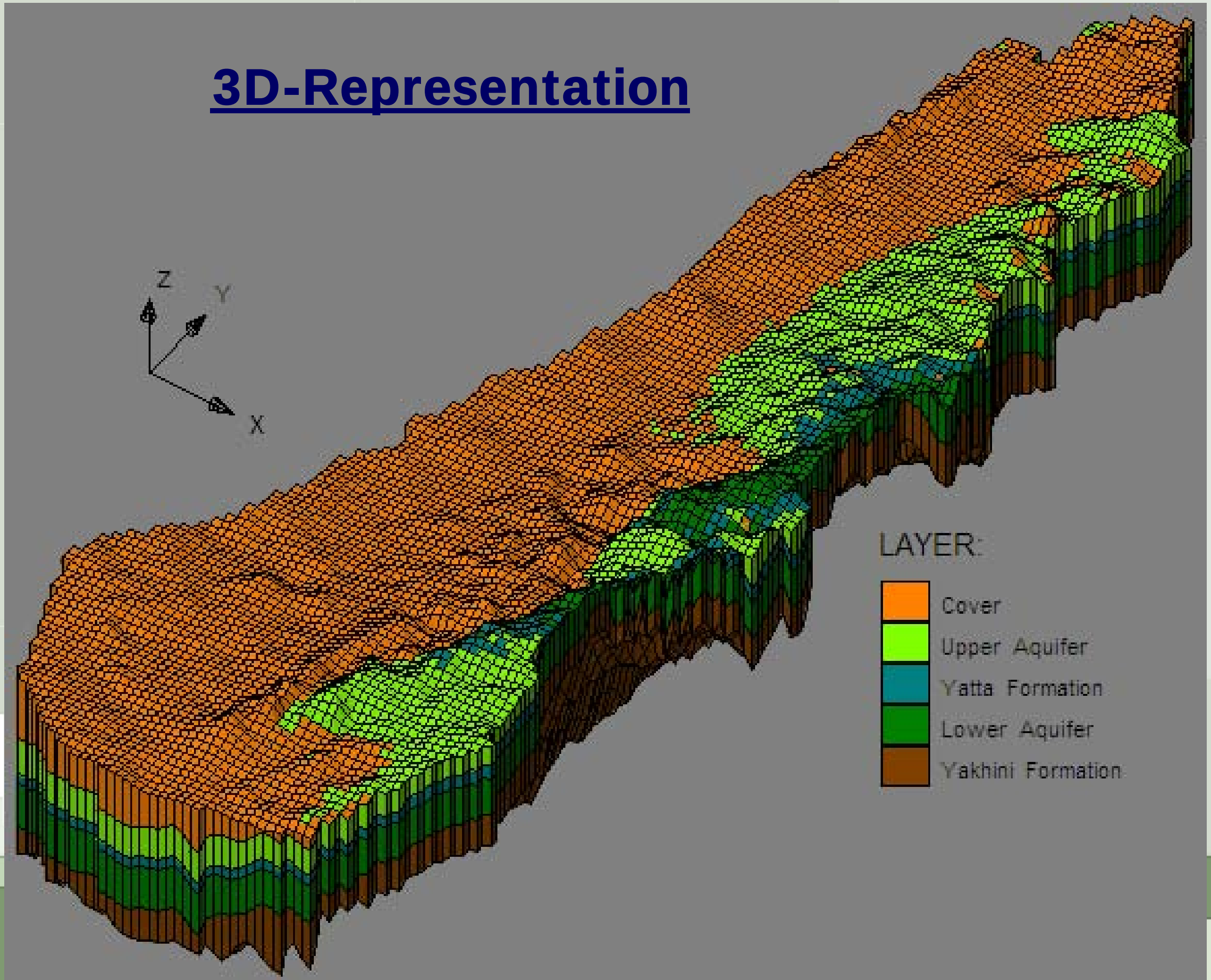
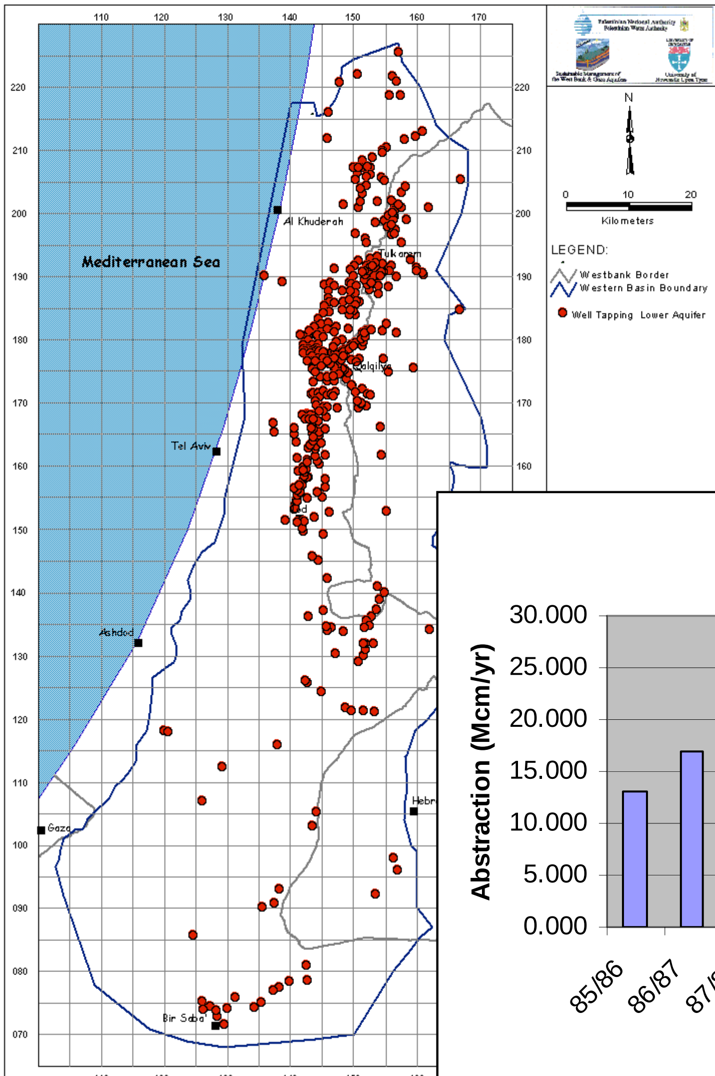
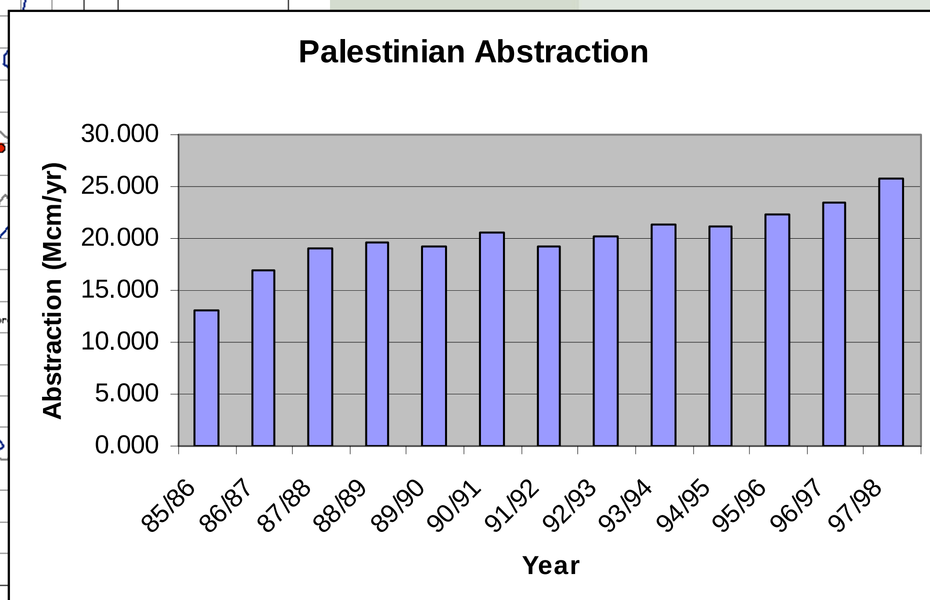


Case study: Developing Model for Western Aquifer Basin.

Sources\Sinks Coverage

e.g. Wells distribution in WAB





Year	Abstraction Mcm/Yr
85/86	13.023
86/87	16.886
87/88	19.053
88/89	19.687
89/90	19.174
90/91	20.673
91/92	19.321
92/93	20.234
93/94	21.374
94/95	21.233
95/96	22.270
96/97	23.482
97/98	25.848

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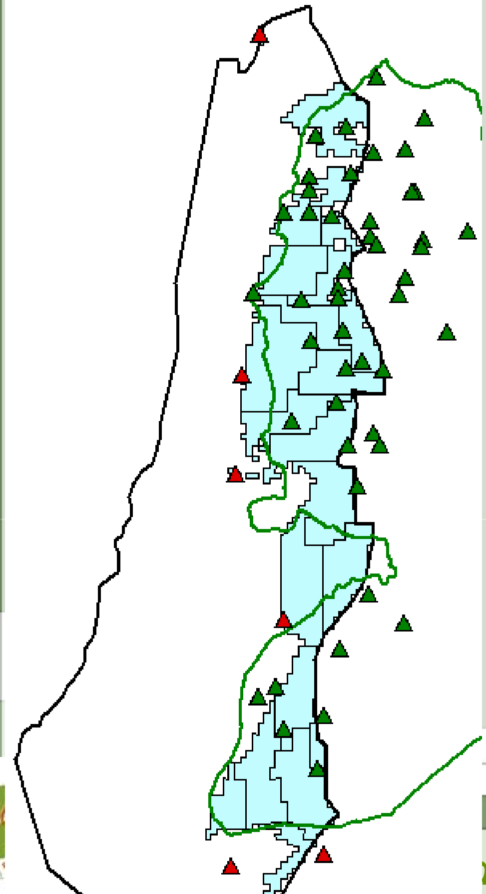
Preparing Recharge Coverage :

Collect the Rainfall Data



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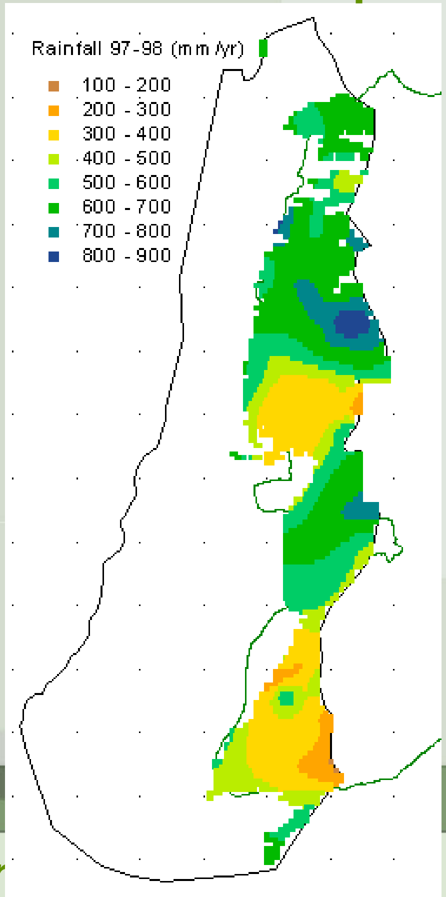
Prepare Rainfall Distribution Map



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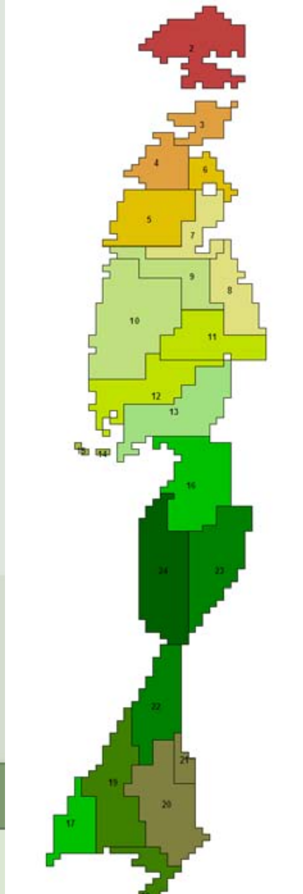
Estimate the Recharge Distribution Map



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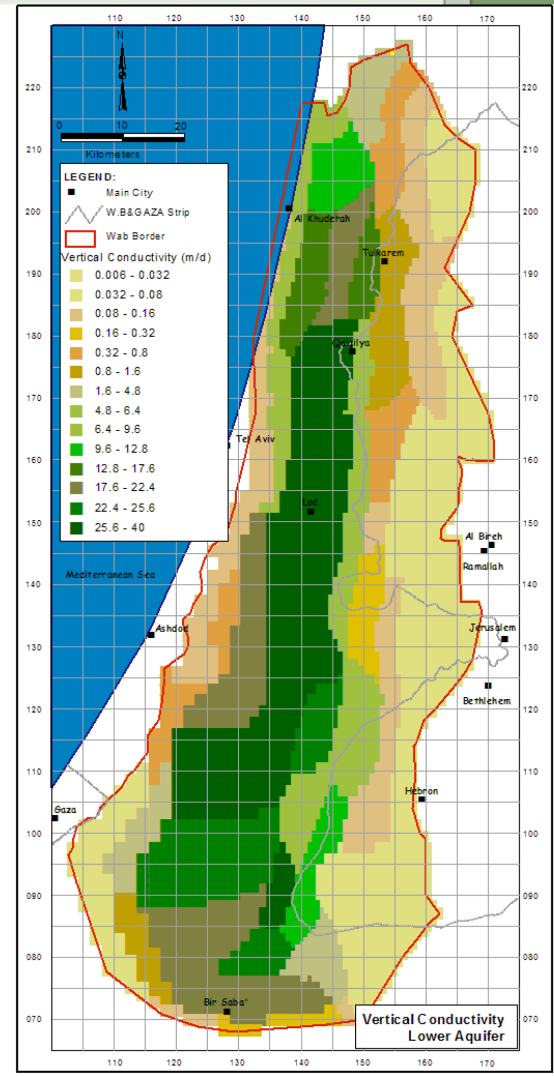
Hydraulic Properties Coverages :

- Horizontal and vertical conductivities (Kh and Kv) for each layer in the model
- Storativity and specific yield for each layer in the model



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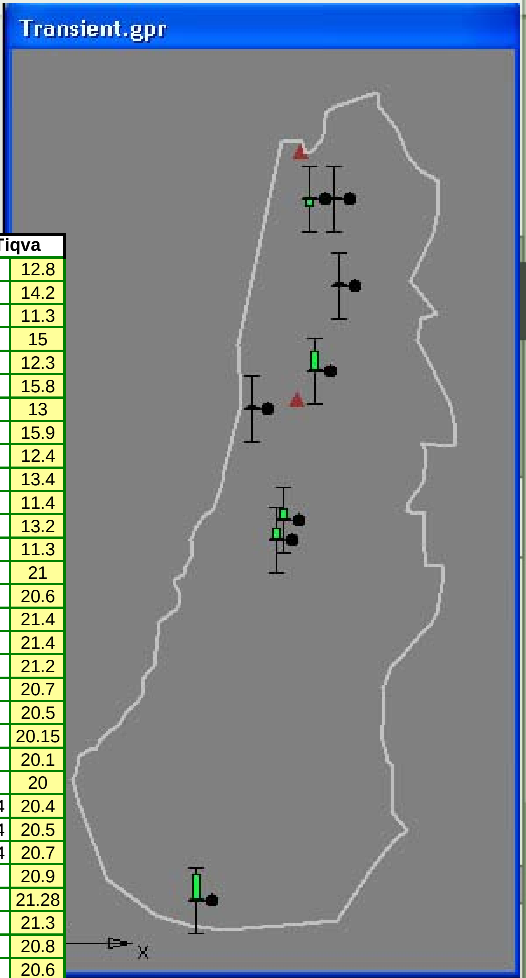
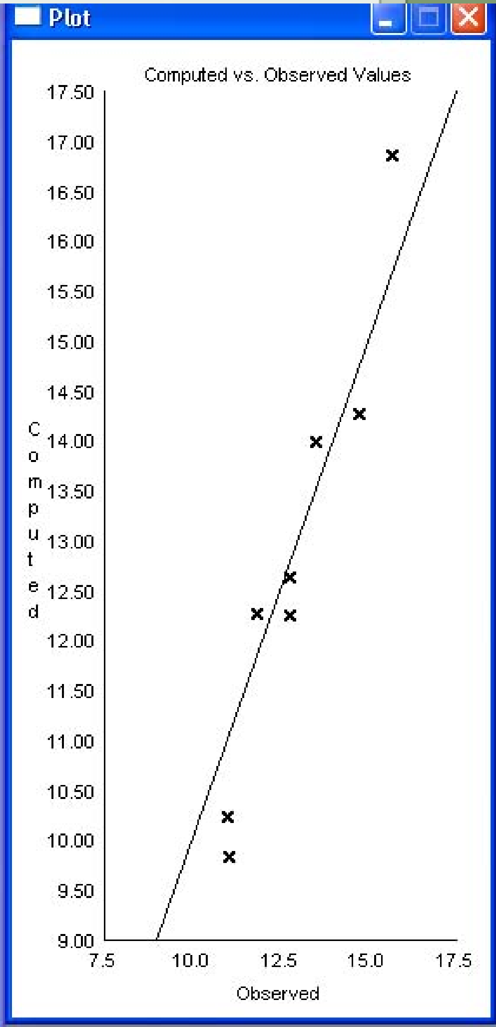
Observation coverage (water levels)

14-17-005		15-19-45		Ayalon1		Beir_Shava		Gezer1		Manisheh_1		Manisheh_2		Petah_Tiqva	
1/13/1986	11.7	1/7/1986	13.6	3/30/1986	14.9	3/30/1986	15.4	3/30/1986	15	3/30/1986	12.9	3/30/1986	12.7	9/29/1985	12.8
3/16/1986	12.2	3/3/1986	14.2	9/29/1986	12	9/29/1986	14	9/29/1986	12.3	9/29/1986	9.4	9/29/1986	9.3	3/30/1986	14.2
4/1/1986	12.3	4/1/1986	14.2	3/30/1987	15.6	3/30/1987	14.9	3/30/1987	15.2	3/30/1987	14	3/30/1987	13.8	9/29/1986	11.3
4/5/1986	12.4	4/5/1986	14.3	9/29/1987	12.9	9/29/1987	14	9/29/1987	13	9/29/1987	9.7	9/29/1987	10.2	3/30/1987	15
5/10/1986	11.4	5/6/1986	13.3	3/30/1988	16.2	3/30/1988	15.2	3/30/1988	16	3/30/1988	13.7	3/30/1988	14.8	9/29/1987	12.3
7/10/1986	9.7	7/7/1986	11.7	9/29/1988	13.7	9/29/1988	14.5	9/29/1988	13.5	9/29/1988	10.3	9/29/1988	10.6	3/30/1988	15.8
11/17/1986	10	9/4/1986	10.9	3/30/1989	16.2	3/30/1989	15.6	3/30/1989	15.9	3/30/1989	13.5	3/30/1989	14.4	9/29/1988	13
1/26/1987	11.5	11/7/1986	11.7	9/29/1989	13.1	9/29/1989	14.3	9/29/1989	13	9/29/1989	9.8	9/29/1989	10.3	3/30/1989	15.9
3/20/1987	12.8	1/12/1987	13.2	3/30/1990	14	3/30/1990	14.5	3/30/1990	13.7	3/30/1990	11.8	3/30/1990	12.3	9/29/1989	12.4
5/15/1987	12.2	3/16/1987	14.8	9/29/1990	12	9/29/1990	13.6	9/29/1990	12	9/29/1990	9.3	9/29/1990	9.8	3/30/1990	13.4
11/15/1987	10.7	5/4/1987	14.5	3/30/1991	13	3/30/1991	14.8	3/30/1991	13.2	3/30/1991	11	3/30/1991	11.6	9/29/1990	11.4
1/18/1988	12	7/4/1987	13.0	9/29/1991	12	9/29/1991	13.2	9/29/1991	12	9/29/1991	9.4	9/29/1991	9.8	3/30/1991	13.2
4/8/1988	13.4	9/5/1987	11.8	3/30/1992	21.2	3/30/1992	21	3/30/1992	21	3/30/1992	18.8	3/30/1992	19.7	9/29/1991	11.3
6/11/1988	12.3	11/7/1987	12.8	9/29/1992	21	9/29/1992	21.5	9/29/1992	20.7	9/29/1992	17.4	9/29/1992	18.3	3/30/1992	21
8/9/1988	11.1	1/12/1988	13.9	3/30/1993	23.5	3/30/1993	21	3/30/1993	22	3/30/1993	19.8	3/30/1993	20.9	9/29/1992	20.6
9/26/1988	10.8	3/15/1988	15.6	9/29/1993	21.6	9/29/1993	21.3	9/29/1993	21.78	9/29/1993	17.6	9/29/1993	18.4	3/30/1993	21.4
12/9/1988	11.8	8/14/1988	12.6	4/13/1994	22.2	4/13/1994	21.5	4/13/1994	21.7	4/13/1994	18.9	4/13/1994	19.4	9/29/1993	21.4
2/12/1989	13.1	10/16/1988	12.6	5/13/1994	22.2	5/13/1994	21.5	5/13/1994	21.2	5/13/1994	18	5/13/1994	19	4/13/1994	21.2
4/11/1989	13.6	2/4/1989	15.0	6/13/1994	22	6/13/1994	21.5	6/13/1994	21	6/13/1994	17.5	6/13/1994	18.5	5/13/1994	20.7
6/16/1989	12	4/4/1989	15.6	7/13/1994	21.75	7/13/1994	21.5	7/13/1994	20.7	7/13/1994	17	7/13/1994	18	6/13/1994	20.5
8/24/1989	10.4	6/12/1989	13.8	8/13/1994	21.3	8/13/1994	21.4	8/13/1994	20.6	8/13/1994	16.7	8/13/1994	17.6	7/13/1994	20.15
10/20/1989	10.3	8/10/1989	12.0	9/13/1994	21.1	9/13/1994	21.3	9/13/1994	20.9	9/13/1994	16.3	9/13/1994	17.3	8/13/1994	20.1
12/12/1989	10.8	10/2/1989	11.6	10/13/1994	20.88	10/13/1994	21.1	10/13/1994	20.7	10/13/1994	16.2	10/13/1994	17.2	9/13/1994	20
2/9/1990	11.1	12/11/1989	12.8	11/13/1994	20.78	11/13/1994	20.99	11/13/1994	21	11/13/1994	16.2	11/13/1994	18	10/13/1994	20.4
4/8/1990	11.4	2/4/1990	13.3	12/13/1994	20.6	12/13/1994	21.15	12/13/1994	21.2	12/13/1994	17.1	12/13/1994	17.1	11/13/1994	20.5
6/14/1990	10.4	4/5/1990	13.7	1/13/1995	20.85	1/13/1995	21.2	1/13/1995	21.4	1/13/1995	17.8	1/13/1995	18.7	12/13/1994	20.7
8/17/1990	9.4	6/11/1990	12.3	2/13/1995	21	2/13/1995	21.3	2/13/1995	21.7	2/13/1995	17.9	2/13/1995	18.8	1/13/1995	20.9
12/14/1990	9.3	8/11/1990	11.3	3/13/1995	21.2	3/13/1995	21.39	3/13/1995	21.8	3/13/1995	18.4	3/13/1995	19.4	2/13/1995	21.28
3/23/1991	10.4	10/19/1990	11.2	4/13/1995	21.4	4/13/1995	21.4	4/13/1995	21.5	4/13/1995	18.3	4/13/1995	19.3	3/13/1995	21.3
5/20/1991	10.2	12/10/1990	11.4	5/13/1995	21.7	5/13/1995	21.5	5/13/1995	21.1	5/13/1995	18	5/13/1995	19	4/13/1995	20.8
7/15/1991	9.7	3/19/1991	12.7	6/13/1995	21.9	6/13/1995	21.5	6/13/1995	20.6	6/13/1995	17.5	6/13/1995	18.5	5/13/1995	20.6
9/14/1991	9.3	5/18/1991	12.4	7/13/1995	21.6	7/13/1995	21.6	7/13/1995	20.3	7/13/1995	16.9	7/13/1995	17.9	6/13/1995	20.2
1/23/1992	12.2	7/12/1991	11.8	8/13/1995	21.2	8/13/1995	21.3	8/13/1995	20.2	8/13/1995	16.3	8/13/1995	17.4	7/13/1995	19.8
3/19/1992	17.7	9/12/1991	11.0	9/13/1995	20.8	9/13/1995	21.19	9/13/1995	20.2	9/13/1995	16	9/13/1995	17	8/13/1995	19.7
5/12/1992	18.7	11/14/1991	11.5	10/13/1995	20.5	10/13/1995	21	10/13/1995	20.5	10/13/1995	15.9	10/13/1995	16.9	9/13/1995	19.6
7/11/1992	18.7	1/19/1992	15.3	11/13/1995	20.6	11/13/1995	20.9	11/13/1995	20.7	11/13/1995	15.8	11/13/1995	16.8	10/13/1995	19.9
9/19/1992	18.3	3/15/1992	20.8	12/13/1995	20.6	12/13/1995	20.89	12/13/1995	20.9	12/13/1995	16.5	12/13/1995	17.5	11/13/1995	20.4



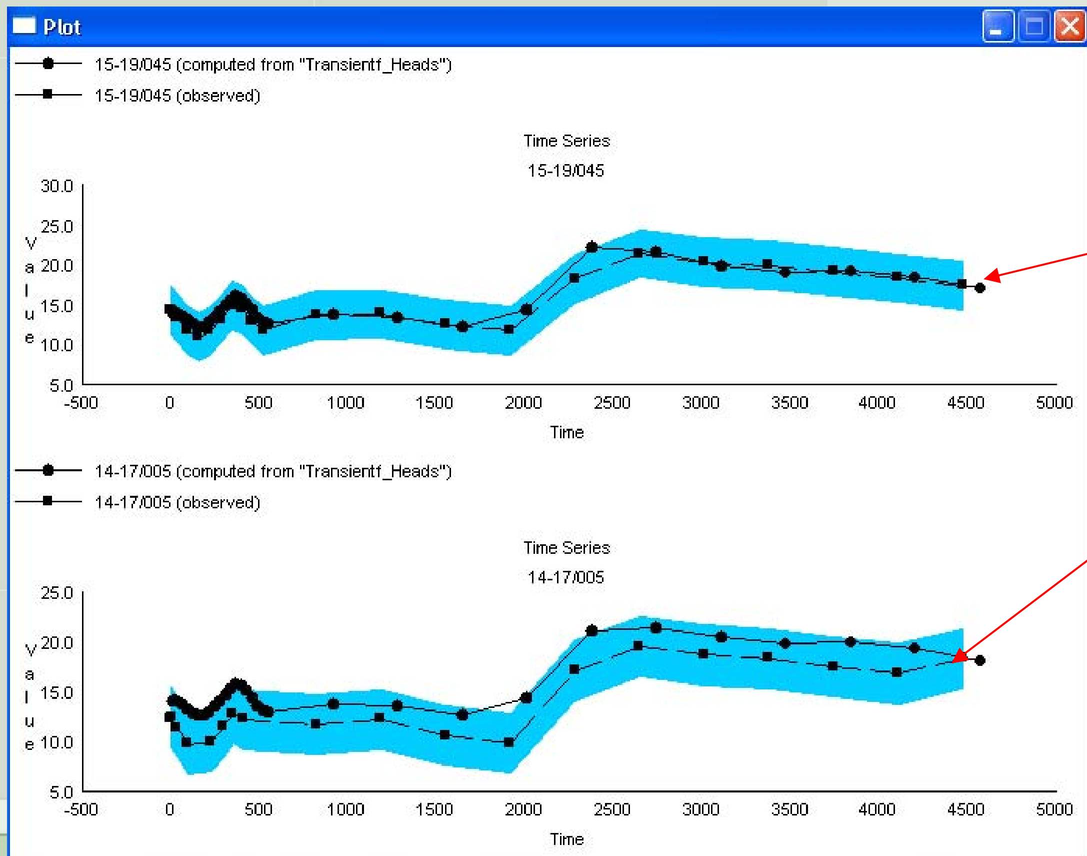
Case study: Developing Model for Western Aquifer Basin.

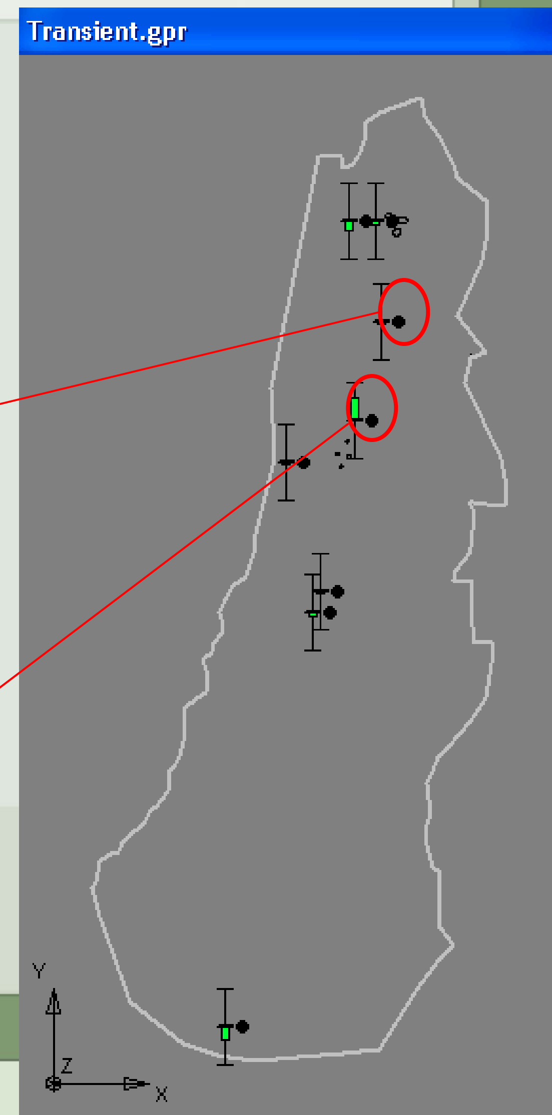
Starting Head Values (Initial Condition):



Case study: Developing Model for Western Aquifer Basin.

Model Calibration



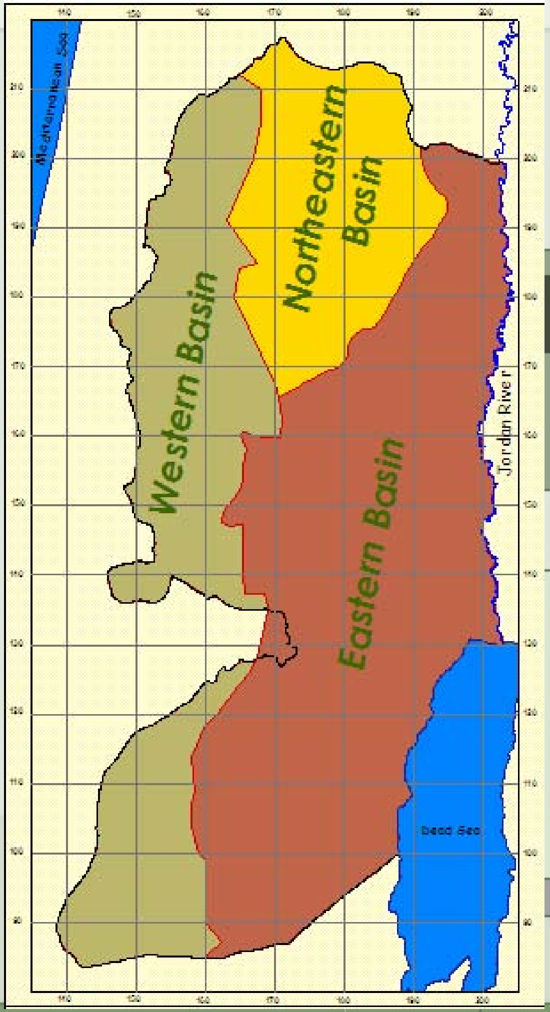


Case study: Developing Model for Western Aquifer Basin.

Run the Model

Background

- Located in a semi-arid area.
- Shortage of water resources
- Supply << Demand
- Groundwater is the main water resource in Palestine.



Development of an Integrated Management Tool for Western Aquifer Basin (IMT)

(Case Study)

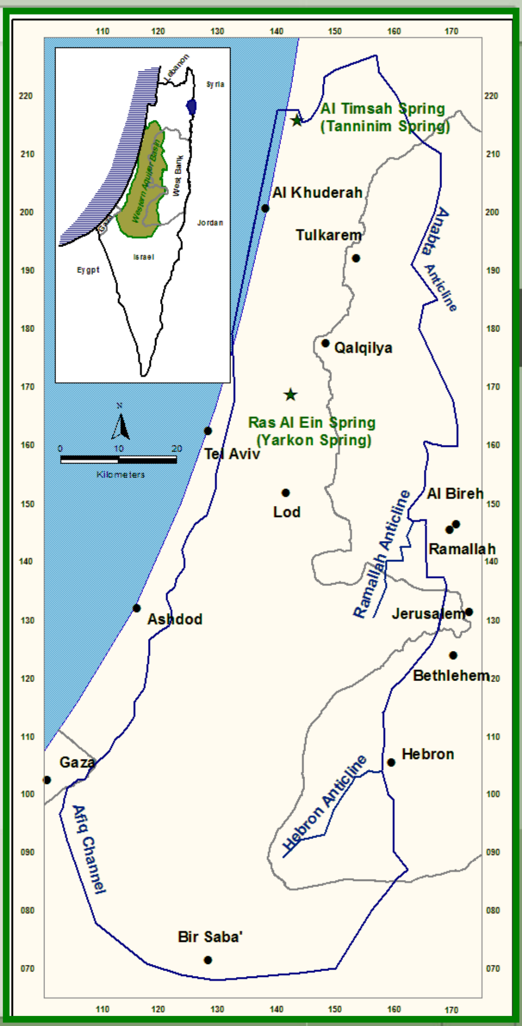
Importance of WAB Management

- Largest sustainable yield. Therefore, the aquifer has the potential to decrease the Supply-Demand Gap. *(equity use of aquifer)*

- The aquifer is very sensitive to hydro-political and climate change scenarios.

  (Separation wall, over pumping, pollution, Rainfall, etc)

- Decision Makers and Negotiators need fast, accurate and reliable answers.



The IMT comes to answer the following questions:

- What are the impacts on the aquifer if the two coming years are dry/wet?
- What are the impacts on the aquifer if the Israelis/Palestinians increase their abstraction by 50 Mcm/yr?
- How much the sustainable yield of the aquifer/Zone?
- What are the spatial distribution of the available water within the aquifer? (Productive areas)
- Etc.

Before Developing the IMT:

- Is it possible to answer without IMT?
- Who?
- How much time?
- What are the shapes of answers?

Remember!

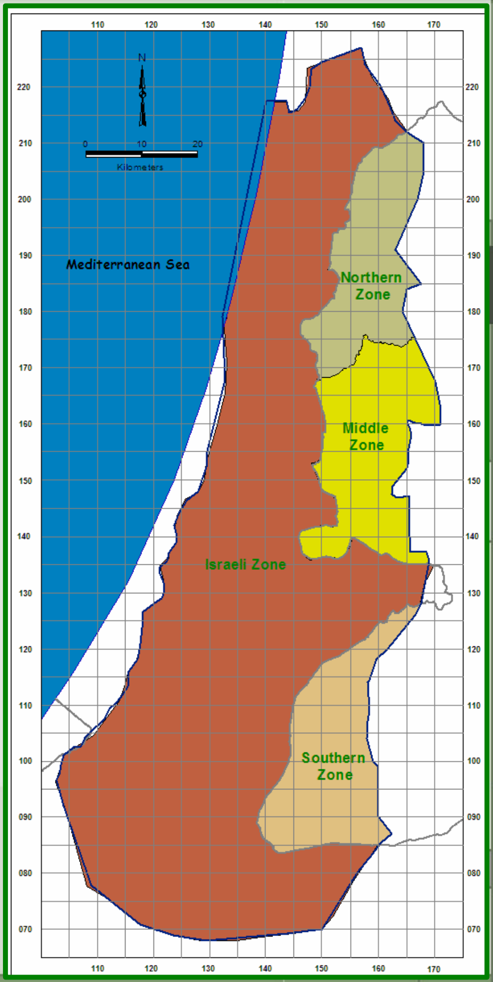
- You have:
  - Databases
  - Models
  - Expertise

Integrated Management Tool (IMT)

Multi-purpose software designed to manage Western Aquifer Basin by integrating all available information (models and databases) in order to be used by high level decision makers.

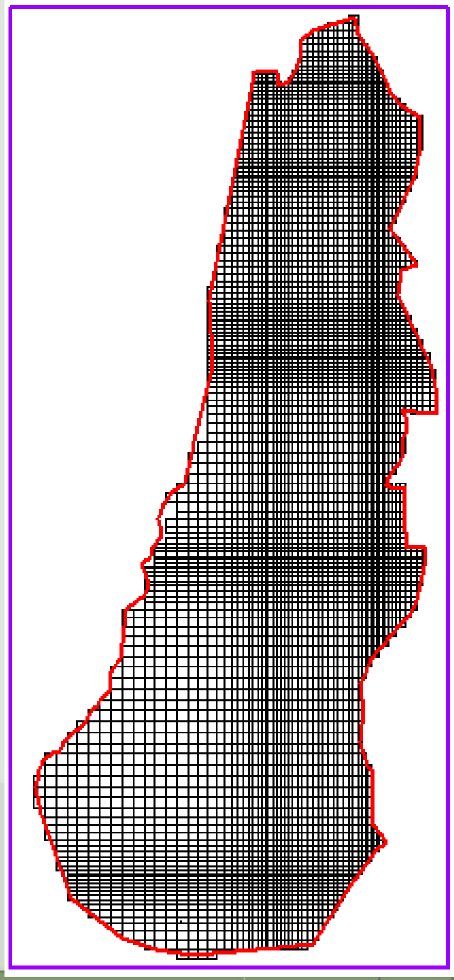
Definitions

- The WAB is divided into four management zones

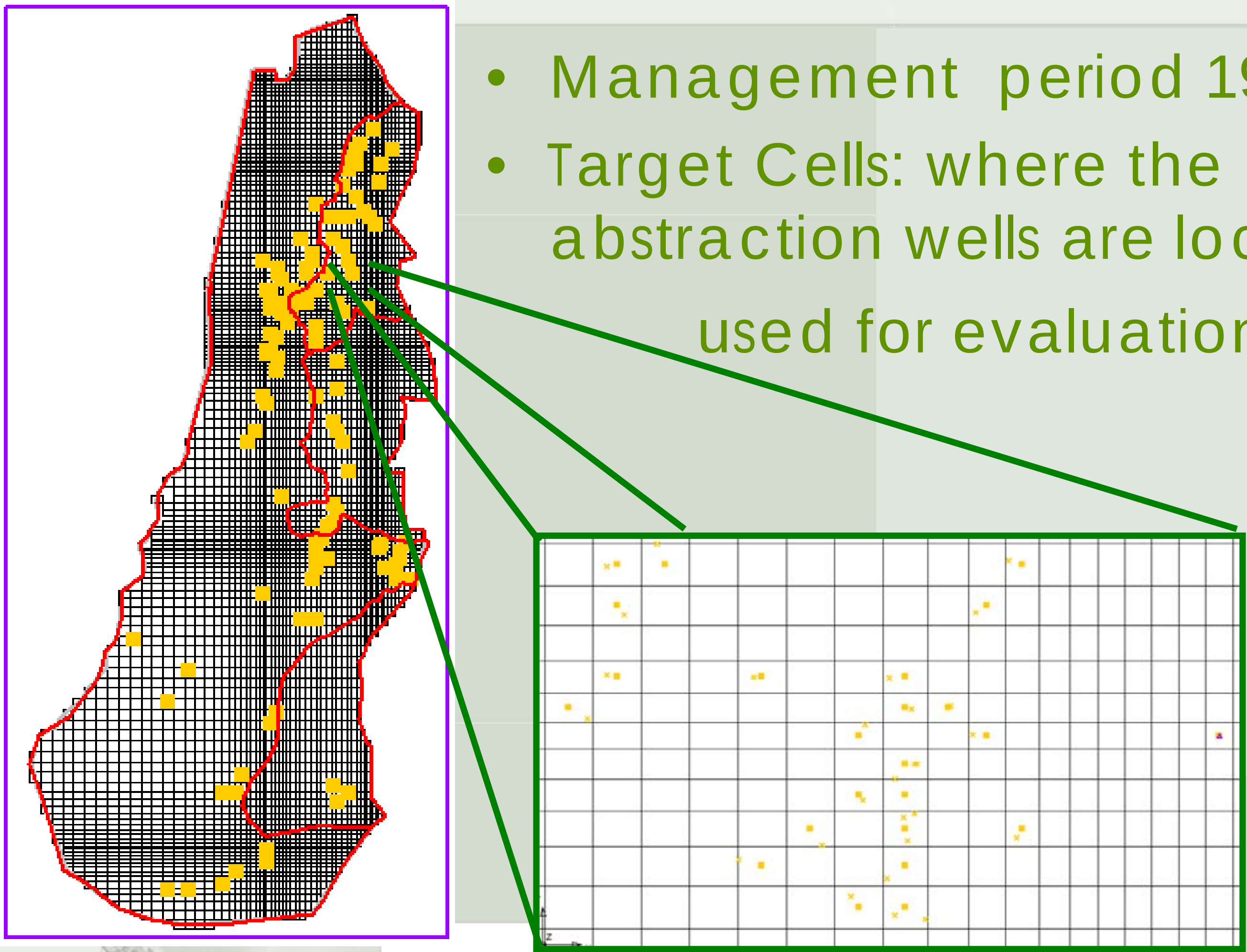


Definitions

- The WAB is discretized into small cells to facilitate calculations, then the results are aggregated for each management zone



Definitions



- Management period 1999-2025
- Target Cells: where the abstraction wells are located, used for evaluation process.

Definitions

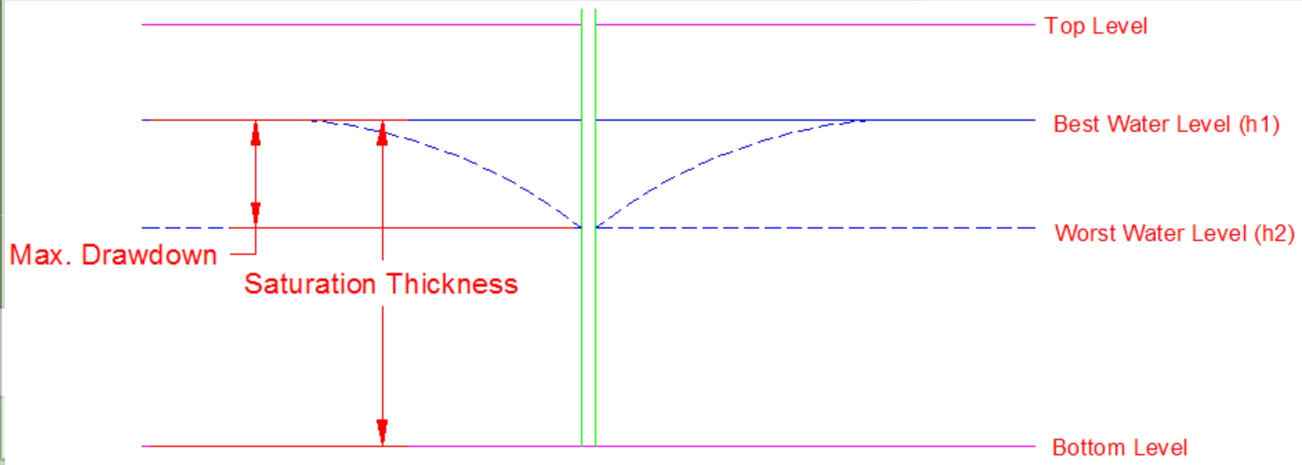
- Two basic indicators were introduced:
  1. **Water level Indicator (EN01):** Evaluate the impact of scenario on water levels.

$$[EN01]_{i,j} = \frac{(Historical\ Water\ Level)_i - (Water\ Level)_{i,j}}{(Historical\ Water\ Level)_i - (Worst\ Water\ Level)_i}$$

Where i : *management cell*

j : *year*

[EN01]i,j = Minimum(*[EN01]i,j,U* , *[EN01]i,j,L*)

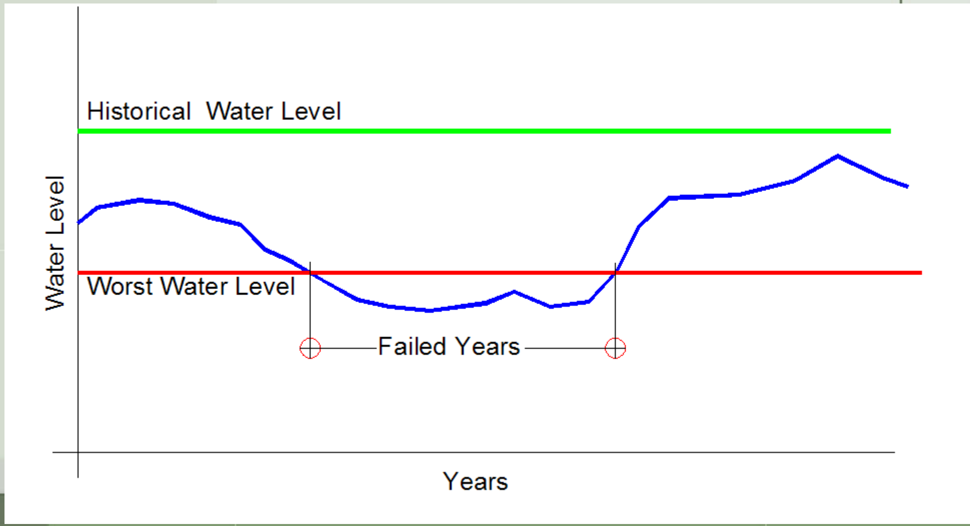


Definitions

- Two basic indicators were introduced:

  2. Reliability Indicator (EN02) : Measure the ability of the aquifer to discharge the needed amount of water within the management period without any failure.

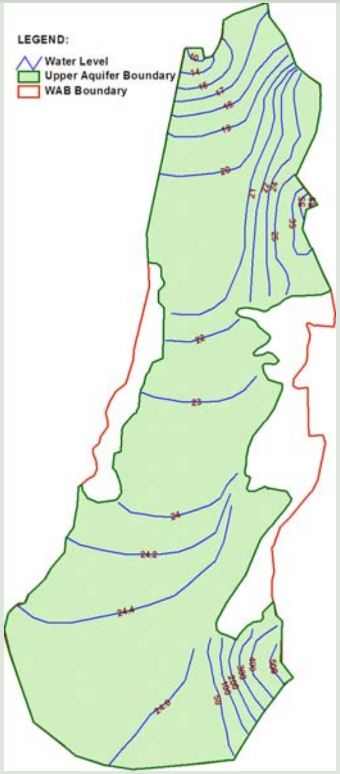
$$[EN02] = \left(\frac{Failed\ Years}{Management\ Period} \right)$$

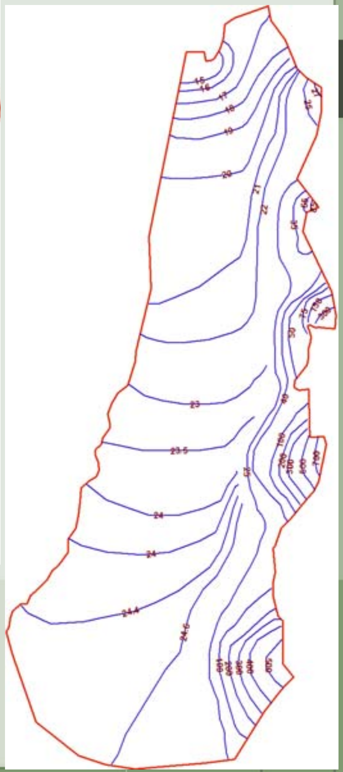


Tool Components:

- Steady state model before utilization.

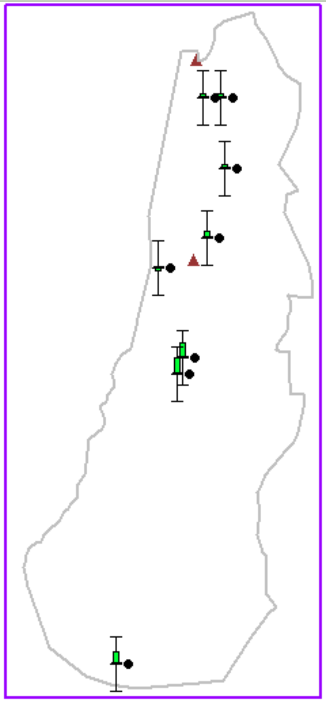
  (Historical water levels)

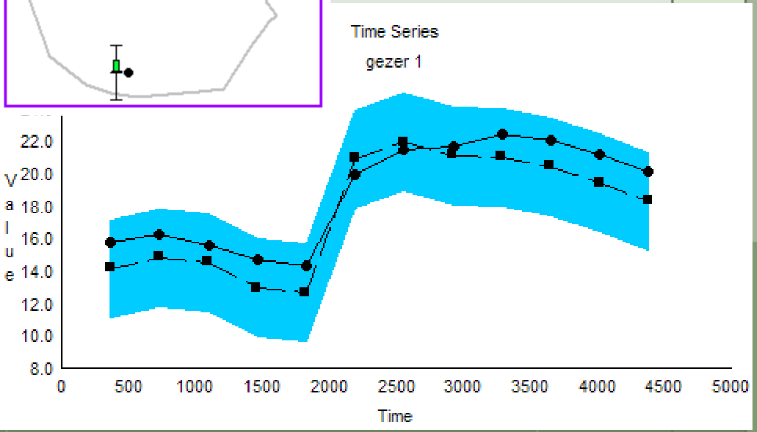




Tool Components:

- Transient flow model (1986/87 to 1997/98).
  - Calibrated water levels.
  - Calibrated recharge values.
  - Calibrated Aquifer properties (specific storativity (Ss), storativity (S), specific yield (Sy), Aquifer geometry, hydraulic conductivities and transmissivity).





Tool Components:

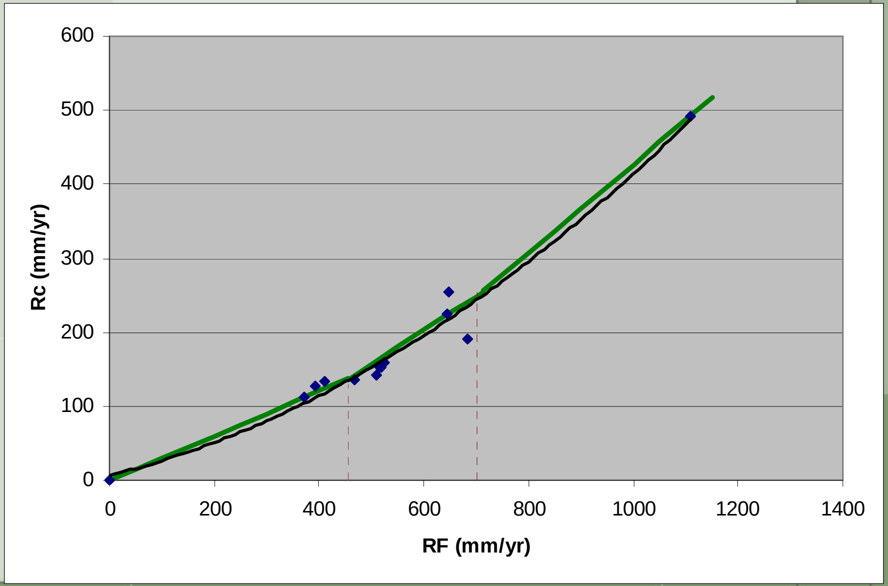
- Recharge Model: Rainfall/recharge regression equations were derived from calibrated transient flow model (1986-1998).

R=0.6 (P – 285)	P > 700 mm
R=0.46 (P - 159)	700 mm > P >456 mm
R=0.3 (P)	P < 456 mm

where:

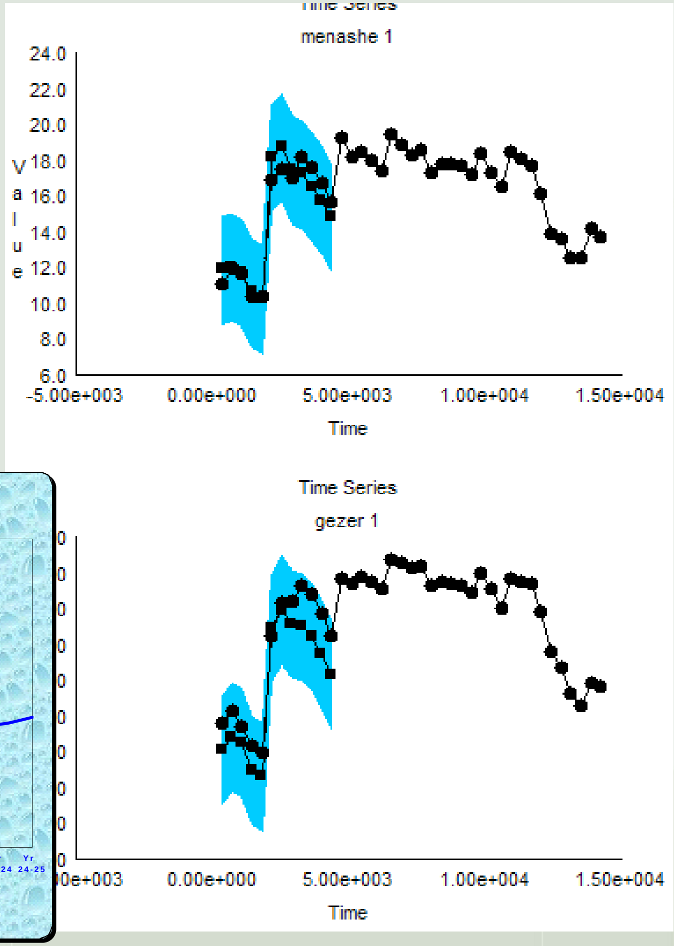
R = Recharge from rainfall in mm/yr

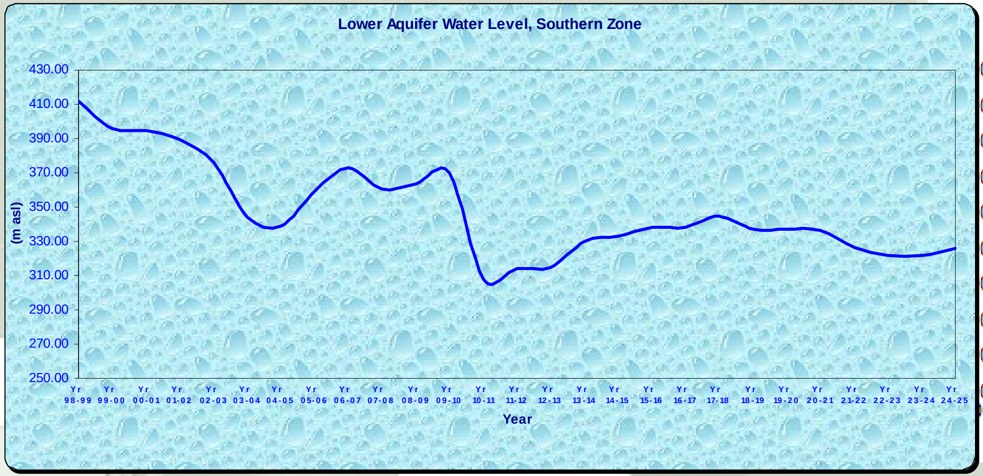
P = Annual rainfall in mm/yr.



Tool Components:

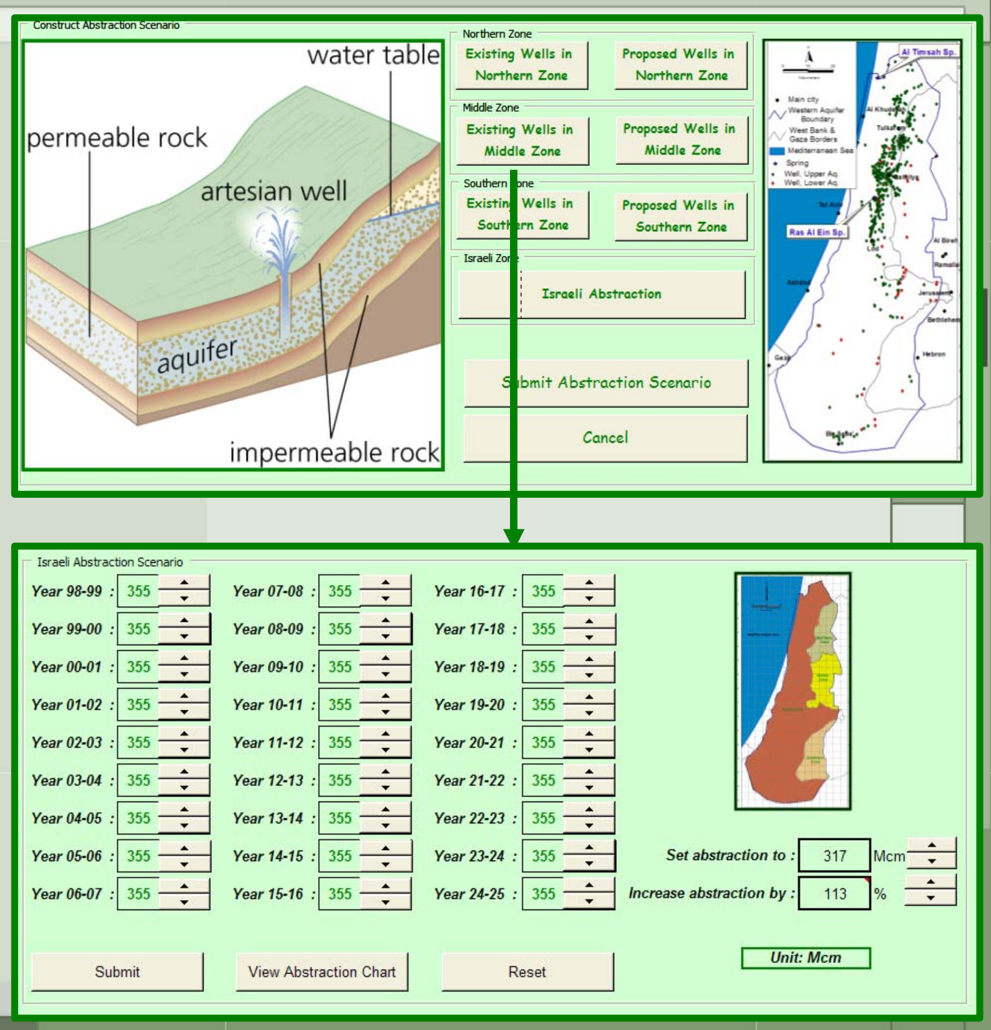
The Transient flow model was extended to cover the management period (i.e. from 1986/87 to 2024/2025)





Tool Input: Abstraction Scenario

Abstraction scenario: define abstraction scenario for the four management zones.



Tool Input: Abstraction Scenario

*Preparing **Abstraction File**:* IMT distribute the total amount of abstraction in each zone to wells.

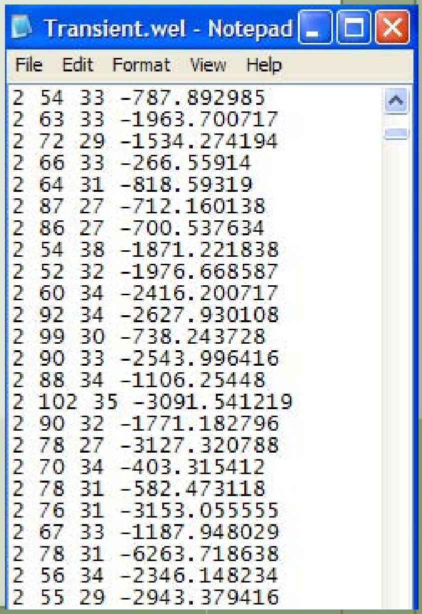
$$(Abstraction\ Index)_i = \frac{(Average\ \ Abstarction\ 1986-1998)_i}{Average\ \ abstraction\ of\ \ the\ \ zone\ 1986-1998}$$

$$where \quad i = specific\ \ well$$

$$therefore, \qquad (Abstraction)_{i,j} = (Abstraction\ \ Index)_i \times (Abstraction)_j$$

$$where \qquad i = Specific\ \ well$$

$$j = Specific\ \ year\ (1998/99 - 2024/25)$$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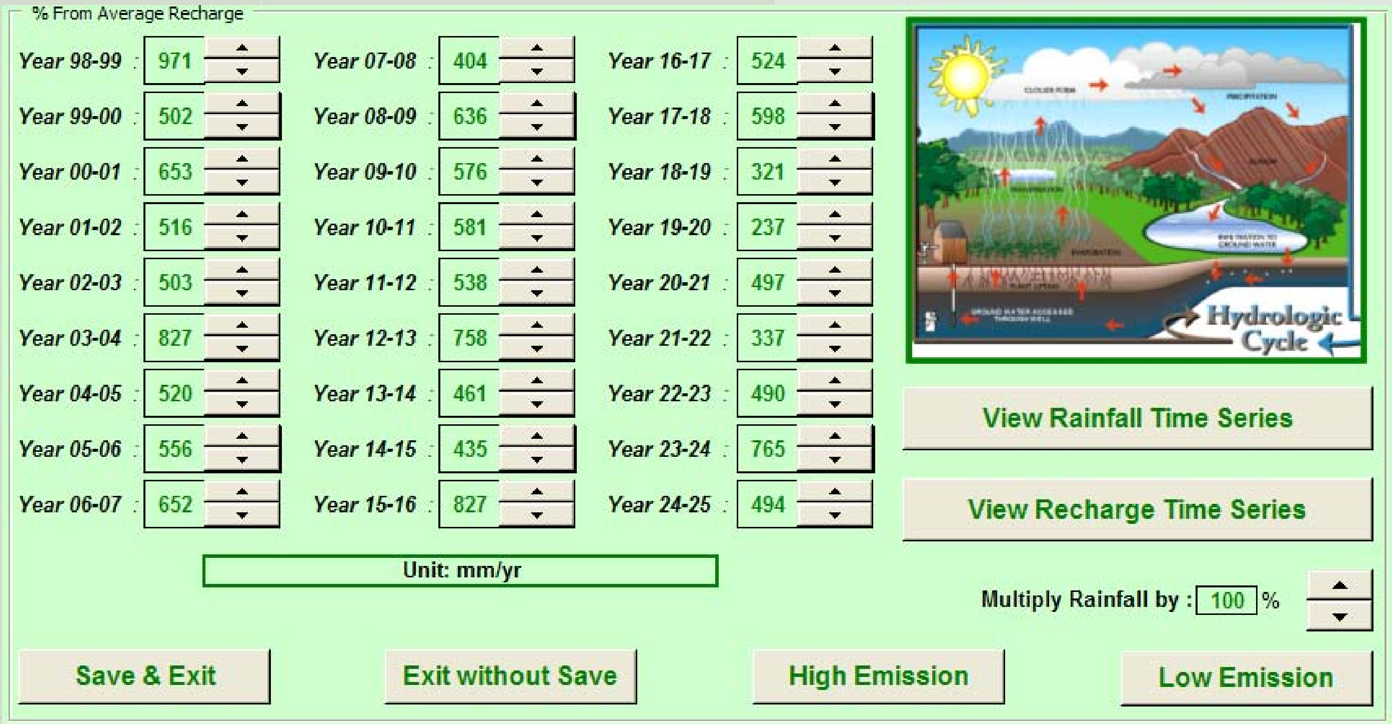
```
2 54 33 -787.892985
2 63 33 -1963.700717
2 72 29 -1534.274194
2 66 33 -266.55914
2 64 31 -818.59319
2 87 27 -712.160138
2 86 27 -700.537634
2 54 38 -1871.221838
2 52 32 -1976.668587
2 60 34 -2416.200717
2 92 34 -2627.930108
2 99 30 -738.243728
2 90 33 -2543.996416
2 88 34 -1106.25448
2 102 35 -3091.541219
2 90 32 -1771.182796
2 78 27 -3127.320788
2 70 34 -403.315412
2 78 31 -582.473118
2 76 31 -3153.055555
2 67 33 -1187.948029
2 78 31 -6263.718638
2 56 34 -2346.148234
2 55 29 -2943.379416
```

Tool Input: Rainfall Scenario

Rainfall Scenario: Construct/import rainfall scenario (annual, mm)



Tool Input: Rainfall Scenario

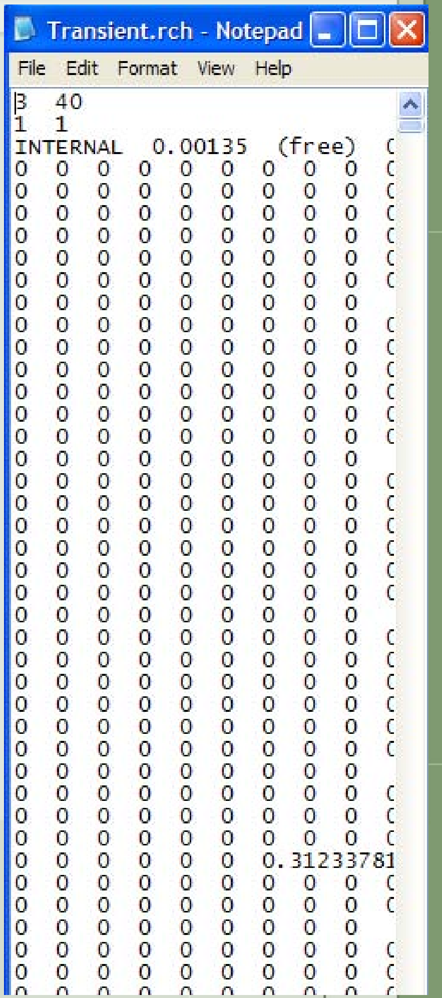
Preparing **Recharge File:** Estimate recharge from rainfall scenario based on rainfall/recharge equations, then distribute recharge over the recharge cells.

$$(Recharge)_{i,j} = (Recharge\ Index)_i \times (Recharge)_j$$

where $i = Recharge\ cell$

$j = Specific\ \ year\ (1998/99 - 2024/25)$

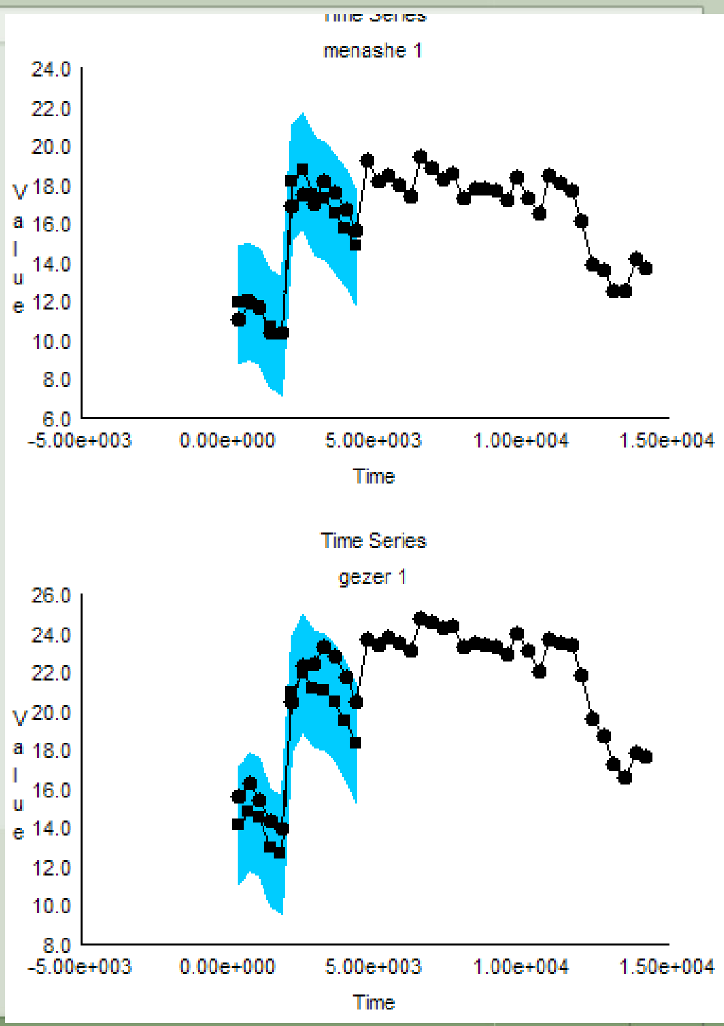
$$(Recharge\ Index)_i = \frac{(Average\ \ Recharge\ 1986-1998)_i}{Average\ \ Recharge\ \ 1986-1998}$$



Running the Tool

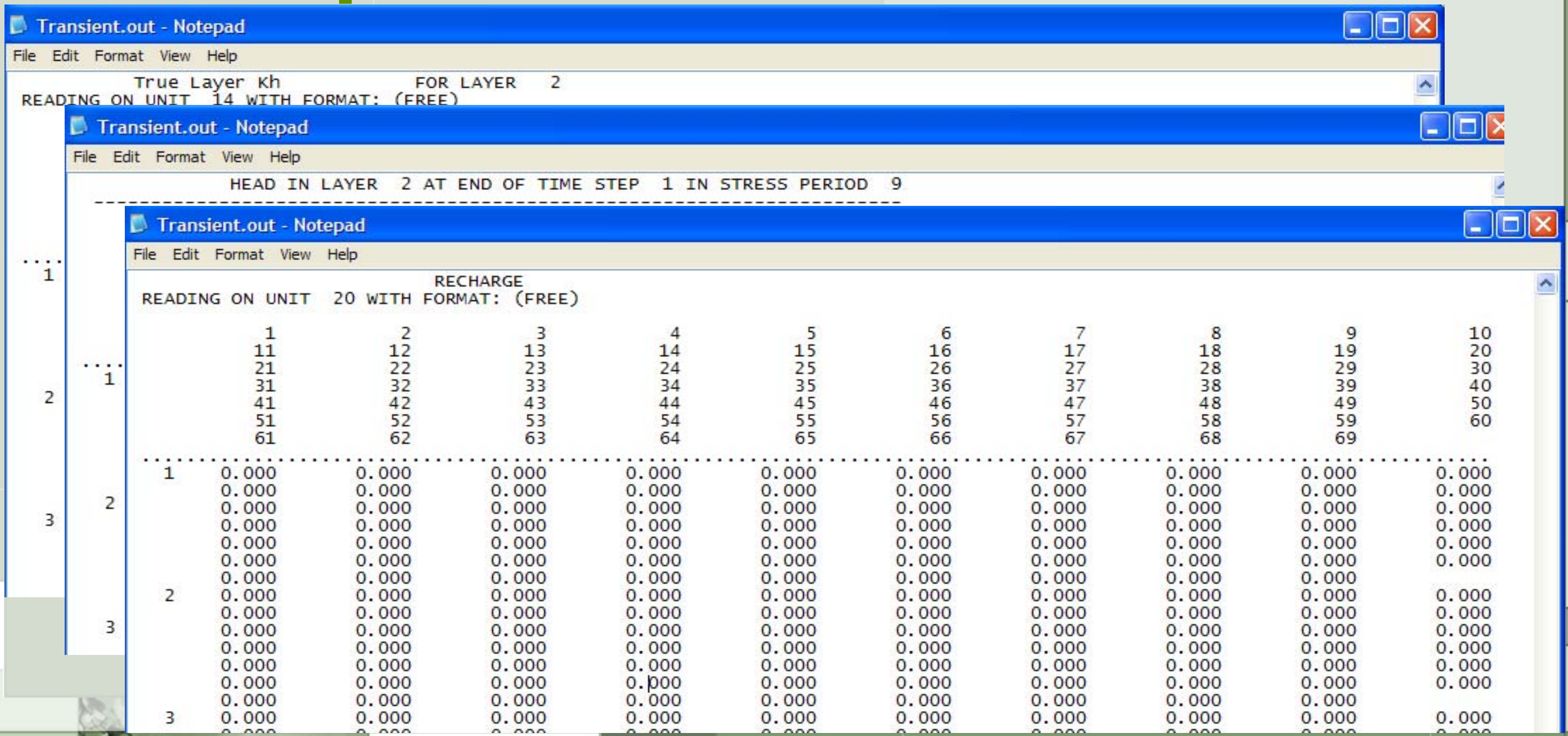
Run the Extended transient flow model for tested scenario.

– The results are water level distribution for upper and lower aquifers



Read Results from Model

- Read the results from the model (aquifer properties, recharge, water levels). [GMS Format]



```
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            True Layer Kh             FOR LAYER    2
 READING ON UNIT  14 WITH FORMAT: (FREE)

Transcient.out - Notepad
File  Edit  Format  View  Help
             HEAD IN LAYER   2 AT END OF TIME STEP   1 IN STRESS PERIOD   9

Transient.out - Notepad
File  Edit  Format  View  Help
                                  RECHARGE
 READING ON UNIT  20 WITH FORMAT: (FREE)

            1        2        3        4        5        6        7        8        9       10
           11       12       13       14       15       16       17       18       19       20
           21       22       23       24       25       26       27       28       29       30
           31       32       33       34       35       36       37       38       39       40
           41       42       43       44       45       46       47       48       49       50
           51       52       53       54       55       56       57       58       59       60
           61       62       63       64       65       66       67       68       69
 ..............................................................................................
   1    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
   2    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
        0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
   3    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
```

Built Database

Re-arrange outputs: from GMS format to data base format

Water level for Upper aquifer 1986-2025

X	Y	Zone	H98-99	H99-00	H00-01	H01-02	H02-03
156295	226548	IZ	14.40	16.94	18.82	19.91	19.68
157063	226548	IZ	14.40	16.94	18.82	19.91	19.68
15285							
15372							
15459							
15545							
15629							
15706							
15025							
15112							
15198							

X	Y	Zone	H98-99	H99-00	H00-01	H01-02	H02-03
156295	226548	IZ	14.4	16.8	18.7	19.9	19.7
157063	226548	IZ	14.4	16.8	18.7	19.9	19.7
152855	225341	IZ	14.3	16.8	18.7	19.8	19.6
153723	225341	IZ	14.4	16.8	18.7	19.8	19.6
15459							
15545							
15629							
15706							
15025							
15112							
15198							

H17-18	H18-19	H19-20	H20-21	H21-22	H22-23	H23-24	H24-25
17.66	18.23	18.1	19.18	18.58	17.83	18.32	17.73

H17-18	H18-19	H19-20	H20-21	H21-22	H22-23	H23-24	H24-25
17.6	18.2	18.1	19.1	18.6	17.9	18.3	17.8
				8.6	17.9	18.3	17.8
				8.5	17.8	18.2	17.7

X	Y	Zone	R98-99	R99-00	R00-01	R01-02	R02-03
154590.7	210833.3	IZ	0	0	0	0	0
155458.4	210833.3	IZ	56802				
156294.8	210833.3	IZ	53179				
157063.5	210833.3	IZ	49366				
157762.3	210833.3	IZ	45023				
158397.5	210833.3	IZ	39304				
158975	210833.3	IZ	33260				
159500	210833.3	IZ	37692				
159991.3	210833.3	IZ	31113				
160473.8	210833.3	IZ	30031				
160956.3	210833.3	IZ	33086				
161438.7	210833.3	IZ	33062				

R17-18	R18-19	R19-20	R20-21	R21-22	R22-23	R23-24	R24-25
0	0	0	0	0	0	0	0
279085	133148	98357	214371	139623	210211	397499	212629
261285	124656	92084	200698	130717	196803	372145	199067
242549	115717	85481	186307	121344	182691	345460	184793
221213	105538	77962	169918	110670	166621	315072	168537
193111	92131	68058	148332	96611	145454	275046	147127
163417	77964	57593	125524	81755	123088	232753	124504
185192	88353	65267	142249	92649	139489	263767	141094
152866	72931	53874	117420	76477	115141	217726	116466
147550	70395	52001	113337	73818	111137	210155	112415
162561	77556	57291	124866	81327	122443	231533	123851
162444	77500	57250	124777	81269	122355	231368	123763

Recharge data base 1986-2025

Calculation of Basic Indicators

Calculate the values of basic indicators

Zone	Best Value	Worst Value	EN01 98-99	EN01 99-00	EN01 00-01	EN01 01-02	EN01 02-03	EN01 03-04	EN01 04-05	EN01 05-06	EN01 06-07	EN01 07-08	EN01 08-09	EN01 09-10	EN01 10-11	EN01 11-12	EN01 12-13	EN01 13-14	EN01 14-15	EN01 15-16	EN01 16-17	EN01 17-18	EN01 18-19	EN01 19-20	EN01 20-21	EN01 21-22	EN01 22-23	EN01 23-24	EN01 24-25	EN01 Avg
Northern	0.00	1.00	0.03	0.07	0.06	0.07	0.09	0.03	0.06	0.07	0.06	0.09	0.07	0.08	0.08	0.09	0.06	0.09	0.10	0.06	0.07	0.08	0.11	0.16	0.17	0.19	0.18	0.14	0.16	0.09
Middle	0.00	1.00	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.02	0.03	0.04	0.03	0.03	0.03	0.04	0.05	0.06	0.07	0.07	0.06	0.06	0.04
Southern	0.00	1.00	0.62	0.62	0.65	0.67	0.67	0.69	0.71	0.73	0.71	0.74	0.77	0.75	0.77	0.76	0.75	0.79	0.81	0.78	0.81	0.80	0.83	0.84	0.84	0.89	0.91	0.90	0.91	0.77
Israeli	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.03	0.03	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.06	0.06	0.07	0.07	0.06	0.07	0.04

Calculate the Averages

Date	Abst-Northern zone (Mcm)	Abst-Middle zone (Mcm)	Abst-Southern zone (Mcm)	Abst-Israeli zone (Mcm)	Abst-Pal zone (Mcm)	Abst (Mcm)	Rech-Northern zone (Mcm)	Rech-Middle zone (Mcm)	Rech-Southern zone (Mcm)	Rech-Pal zones (Mcm)	Rech-Israeli zone (Mcm)	Rech (Mcm)	WL-Upper-Northern zone (masl)	WL-Upper Middle zone (masl
Yr 86/87	16.22	0.59	0.42	17.24	371.44	**388.68**	84.44	66.77	24.24	175.44	57.11	232.55	57.65	142.0
Yr 87/8														
Yr 88/8														
Yr 89/9														
Yr 90/9														
Yr 91/9														
Yr 92/9														
Yr 93/9														
Yr 94/9														
Yr 95/9														

WL-Upper-Southern zone (masl)	WL-Upper-Israeli zone (masl)	WL Upper (masl)	WL-Lower-Northern zone (masl)	WL-Lower-Middle zone (masl)	WL-Lower-Southern zone (masl)	WL-Lower-Israeli zone (masl)	WL Lower (masl)	EN01 Northern zone	EN01 Middle zone	EN01 Southern zone	En01 Israeli zone	EN02 Northern zone	EN02 Middle zone	EN02 Southern zone	En02 Israeli zone
368.38	38.10	73.94	45.83	185.57	224.13	39.27	71.72	0.06	0.03	0.65	0.03	0.00	0.00	0.00	0.00
368.28	37.84	74.29	43.51	182.96	222.66	38.91	70.86	0.07	0.03	0.67	0.03	0.00	0.00	0.00	0.00
368.20	37.43	73.91	41.63	180.41	221.20	38.39	69.95	0.09	0.03	0.67	0.04	0.00	0.00	0.00	0.00
368.55	38.96	73.46	48.23	188.36	222.67	40.20	72.72	0.03	0.02	0.69	0.02	0.00	0.00	0.00	0.00
368.48	38.77	75.17	45.40	185.56	221.39	39.90	71.86	0.06	0.03	0.71	0.03	0.00	0.00	0.00	0.00
368.44	38.50	74.78	43.99	184.14	220.17	39.56	71.25	0.07	0.03	0.73	0.03	0.00	0.00	0.00	0.00
368.47	38.65	74.47	45.15	185.70	220.00	39.79	71.64	0.06	0.02	0.71	0.03	0.00	0.00	0.00	0.00
368.27	37.65	74.68	40.96	180.49	217.76	38.57	69.69	0.09	0.03	0.74	0.04	0.00	0.00	0.00	0.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.03	0.00	0.00	0.00	0.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.03	0.00	0.00	0.00	0.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.03	0.00	0.00	0.00	0.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.04	0.00	0.00	0.00	0.00

Upper Aquifer

Zone	Area (km^2)	Top (m asl)	Bottom (m asl)	Historical WL (m asl)	Kh (m/d)	Kv (m/d)	Ss (1/m)	S/S_y	T (m^2/d)
Northern Zone	516	223	-22	63.4	34.9	3.49	0.000037	0.0084	6282
Middle Zone	330	300	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Southern Zone	429	449	2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Israeli Zone	4023	-236	-5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WAB	5298	-79	-3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Lower Aquifer

Zone	Area (km^2)	Top (m asl)	Bottom (m asl)	Historical WL (m asl)	Kh (m/d)	Kv (m/d)	Ss (1/m)	S/S_y	T (m^2/d)
Northern Zone	516	-122	-479	39.1	23.7	2.37	0.000035	0.0128	9002
Middle Zone	571	226	-101	169.3	5.4	0.55	0.000036	0.0121	1982
Southern Zone	584	300	-50	271.0	22.9	2.27	0.000023	0.0078	8344
Israeli Zone	4336	-604	-995	48.4	169.6	15.53	0.000019	0.0075	69837
WAB	6008	-396	-773	80.7	127.2	11.68	0.000022	0.0085	52177

Interface: Input, Process & Output

IMT.EXE

Applications

1. **Direct applications:** Run to check future Rainfall or/and Abstraction Scenarios.

Applications

2. **Indirect applications:** within Decision Support System (DSS)