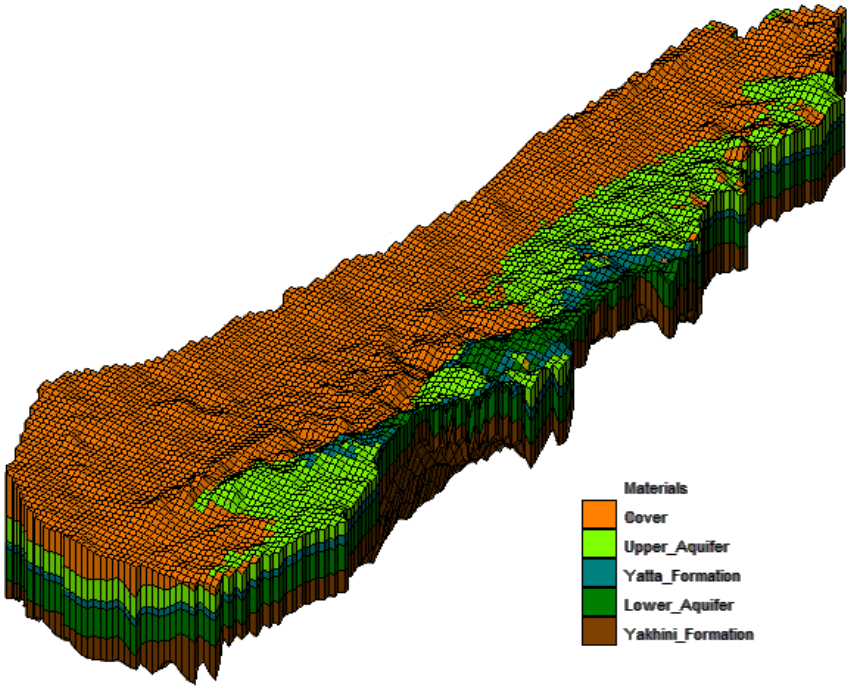
Palestinian National Authority
Palestinian Water Authority

السلطة الوطنية الفلسطينية
سلطة المياه الفلسطينية

Sustainable Management of the West Bank and Gaza Aquifers

Steady State and Transient Flow Models of the Western Aquifer Basin



Final Report
SUSMAQ - MOD # 49 V0.1

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The SUSMAQ Project

The aim of the project is to increase understanding of the sustainable yield of the West Bank and Gaza aquifers under a range of future economic, demographic and land use scenarios, and evaluate alternative groundwater management options. The project is interdisciplinary, bringing together hydrogeologists and groundwater modellers with economists and policy experts. In this way, hydrogeological understanding can inform, and be informed by, insights from the social sciences. The results of the study will provide support to decision-making at all levels in relation to the sustainable yield of the West Bank and Gaza aquifers.

The project runs from November 1999 to October 2004, and is a partnership between the Palestinian Water Authority, University of Newcastle and the British Geological Survey. The project is funded by the United Kingdom's Department for International Development (DFID).

The Flow Modelling and Hydrogeology Component is part of the SUSMAQ project

The development of a Steady State and Transient Flow Models for WAB will help approximate the actual physical situation of the aquifer system; provide an understanding and analysis of the complex ground water system of WAB; assess the groundwater flow characteristics of WAB and interpret the spatial distribution of the related parameters. After all, the development of the steady state model provides information about the water budget of the basin as a whole. This budget will provide details about the water balance between the aquifer units as well and between the basins as its boundaries.

The development of the transient model is essential to estimate the sustainable yield of WAB and to test the impacts of future development and abstraction scenarios on current pumping in the Western Aquifer Basin.

Bibliographical Reference

Steady State and Transient Flow Models of the Western Aquifer Basin. Report No.: SUSMAQ-MOD #49 V0.1. Sustainable Management for the West Bank and Gaza Aquifers, Palestinian Water Authority (Palestine) and University of Newcastle upon Tyne (UK).

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Feedback

The SUSMAQ and PWA teams will appreciate any feedback on this report. Feedback should be sent to the above contacts.

Table of Contents

List of Figures

List of Tables

1. Introduction and background

1.1 Scope and objectives

After a number of discussions in the fourth multidisciplinary workshop of SUSMAQ (see project report, **SUSMAQ-MAN#19 V0.1**) and a specialised technical meeting on flow and recharge models (see project report, **SUSMAQ-MAN#21 V0.1**), it was realised that the conceptual model presented in the report **SUSMAQ-MOD#06 V0.3** needed upgrading and updating since more data were available between the time the report was produced and now. This updated conceptual flow model is presented in this report. This report represents also the steady state and transient models of the Western Aquifer Basin (WAB) which are the main subject of this project, "Sustainable Management of the West Bank and Gaza Aquifers".

This project started under conditions of an almost complete absence of information about the aquifer system of the Western Basin. It was only possible to construct a flow model of the WAB when the database was completed to a reasonable level, although some more data are still needed to upgrade the models. The development of a steady state flow model for WAB will help approximate the actual physical situation of the aquifer system; provide an understanding and analysis of the complex groundwater system of WAB; assess the groundwater flow characteristics of WAB and interpret the spatial distribution of the related parameters. After all, the development of the steady state model provides an idea about the water budget of the basin as a whole. This budget will provide details about water balance between the aquifer units as well and between the basin and its boundaries.

Then the next step was to develop the transient flow model with the objective to be used as a tool for planning and management of the water resources of the WAB.

The transient model developed in this project aims at checking that the water levels in observation wells correlate well with the computed levels of the model, and hence the calibration process, and to test the impact of future development and abstraction scenarios on current pumping in the four management zones of WAB including impacts on Israeli current abstractions.

1.2 Area

The Western Aquifer Basin is the largest of all groundwater basins in historical Palestine and a shared basin between Palestinians, Israelis and Egyptians (see **Table1.1**, **Figure 1.1**). The model area is around 6000 km^2 large, with roughly 30% inside the West Bank.

Table 1.1 Size of the Western Aquifer Basin and model areas

	Total area	**Model area**
West Bank	1720 km^2	1720 km^2
Israel	7438 km^2	4315 km^2

Sinai	4990 km^2	-
SUM	**14148 km^2**	**6035 km^2**

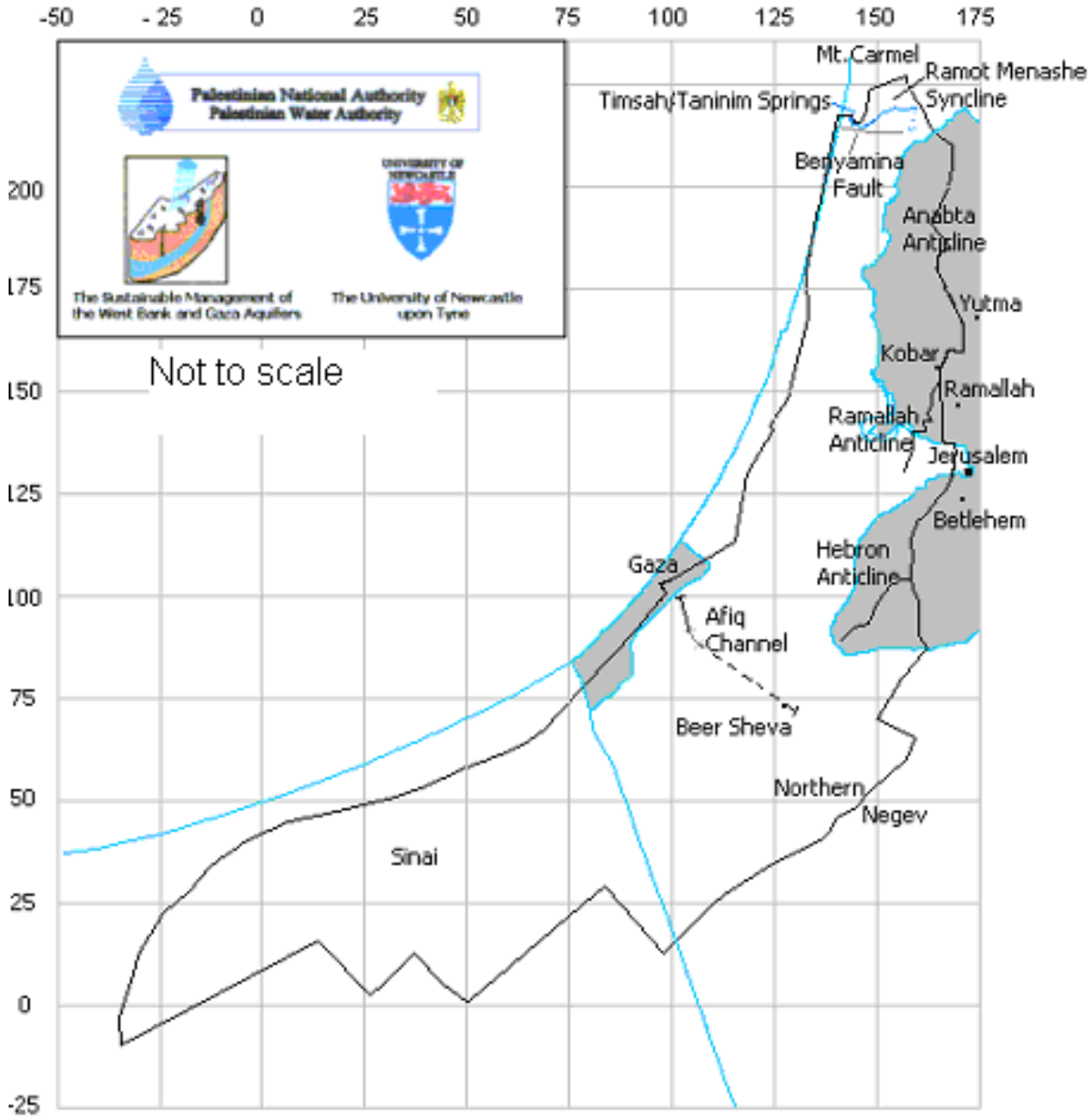

Figure 1.1 Location map of the Western Aquifer Basin

Almost 5000 km^2 lie in the Egyptian side, however with both little recharge and outflows. The total abstractions in Northern Sinai sum up to 9 MCM/yr only (personal correspondence with the Egyptian Institute of Groundwater). This amount comprises of the Western Basin and other aquifers. However, the exact recharge and discharge within the political borders of Egypt is beyond the scope of the Sustainable Management of the West Bank and Gaza Aquifers, SUSMAQ, Project.

The basin extends around 235 km from Mount Carmel in the North to Northern Sinai in the South and between 70 and 30 km from the Mediterranean coast in the West to the heights

of the West Bank in the East (see **Figure 1.1**). In the following, if not stated otherwise, the term WAB will refer to the model area of the Western Aquifer Basin.

1.3 Climate

The climatic zones range from sub-humid Mediterranean climate conditions (more than 700 mm annual rainfall) to arid desert conditions in the Sinai. The ground elevation lies between sea level and 1000 m above sea level in the Hebron area.

1.4 Geography

The Western Aquifer Basin covers a wide range of different landscapes and topographic environments. It reaches from sea level at the Mediterranean coast in the west up to 983 m near Hebron.

Most of the area of the Western Aquifer Basin is located in Israel; the fourteen regions of the WAB are fully or partly covered by the western aquifer basin, (see **Figure 1.3**). Three of these regions lie in the West Bank. Therefore, here the Palestinian names will be used.

Starting in the west, there are three regions along the Mediterranean coast:

The Negev coastal plain
The Southern coastal plain and
The Central coastal plain (or in some texts: Northern coastal plain)

Adjacent to the east follow the six regions (from north to south):

The Ramot - Menashe region
The Um El-Fahm region
The Nablus region
The Northwestern West Bank
The Shefela (or Hashephela) region in the central and southern foothills and
The Negev western foothills

Three more regions partly reach beyond the eastern border of the basin:

The Central and Southern West Bank, or Jerusalem and Hebron Mountains
The Beer Sheva Valley and
The Northern Negev

The whole area of the Western aquifer can be divided into three longitudinal strips of different elevations that match incompletely with the above- mentioned regions: The coastal plain area, the foothill and lower slopes area and the upper slopes and mountain area. The coastal plain has a width range of 15-20 km with elevations between 0-100 meters above sea level. The foothills area has a width range between 3 and 15 km (see **Figure 1.2**).

The coastal plain lies at elevations between 0 and 100m asl., except for the Negev coastal plain that reaches up to 200m asl, (see **Figure 1.2**). The foothills rise from 100 m asl to around 300 m asl, and are followed to the east by the upper hills and mountain regions that reach up the highest point of 983m asl at the coordinates 158.3/110.55, near the spring Ein Ad-Deekeh, 2 km west northwest of Halhul.

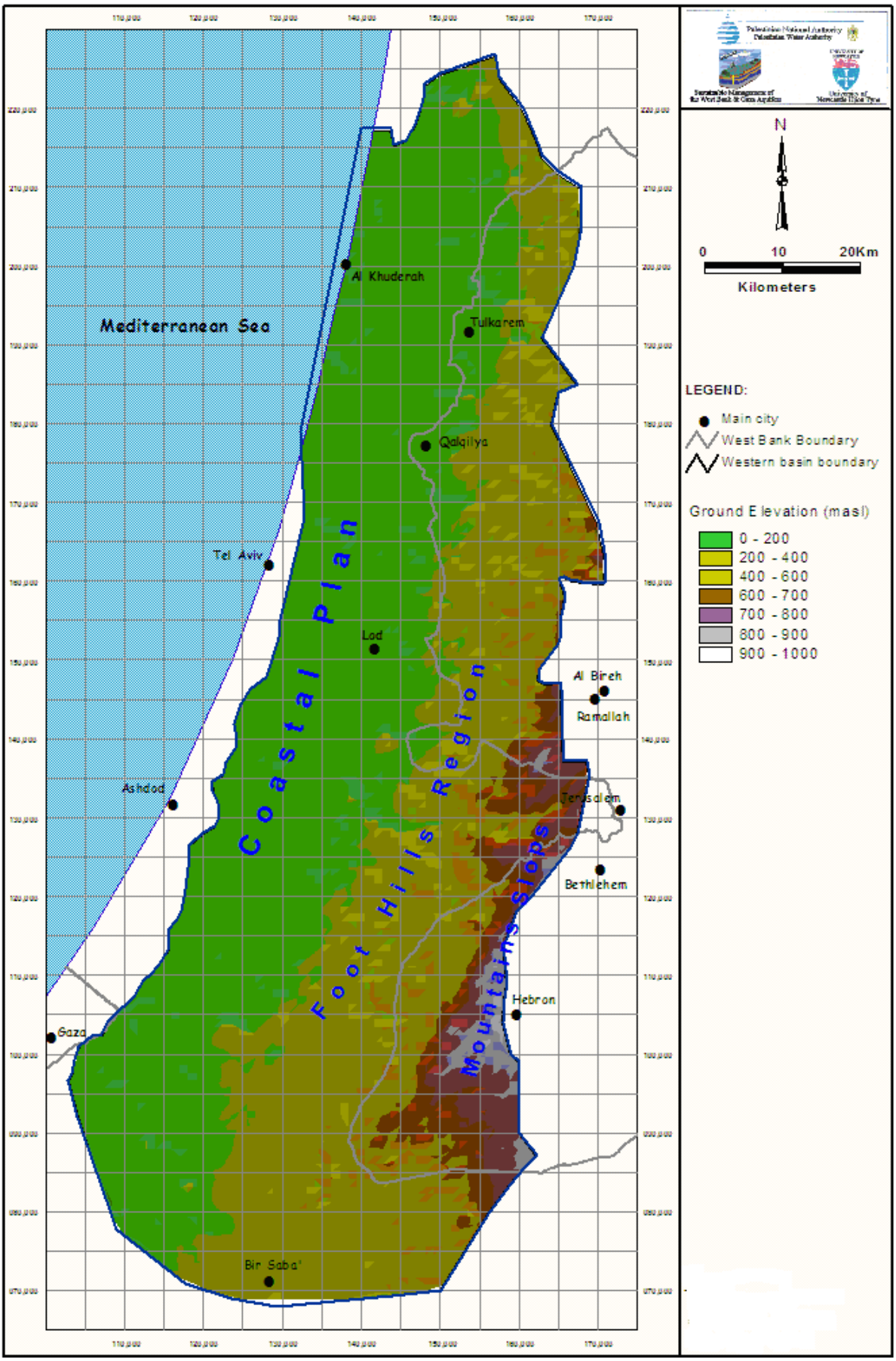

Figure 1.2 Ground elevations in the WAB

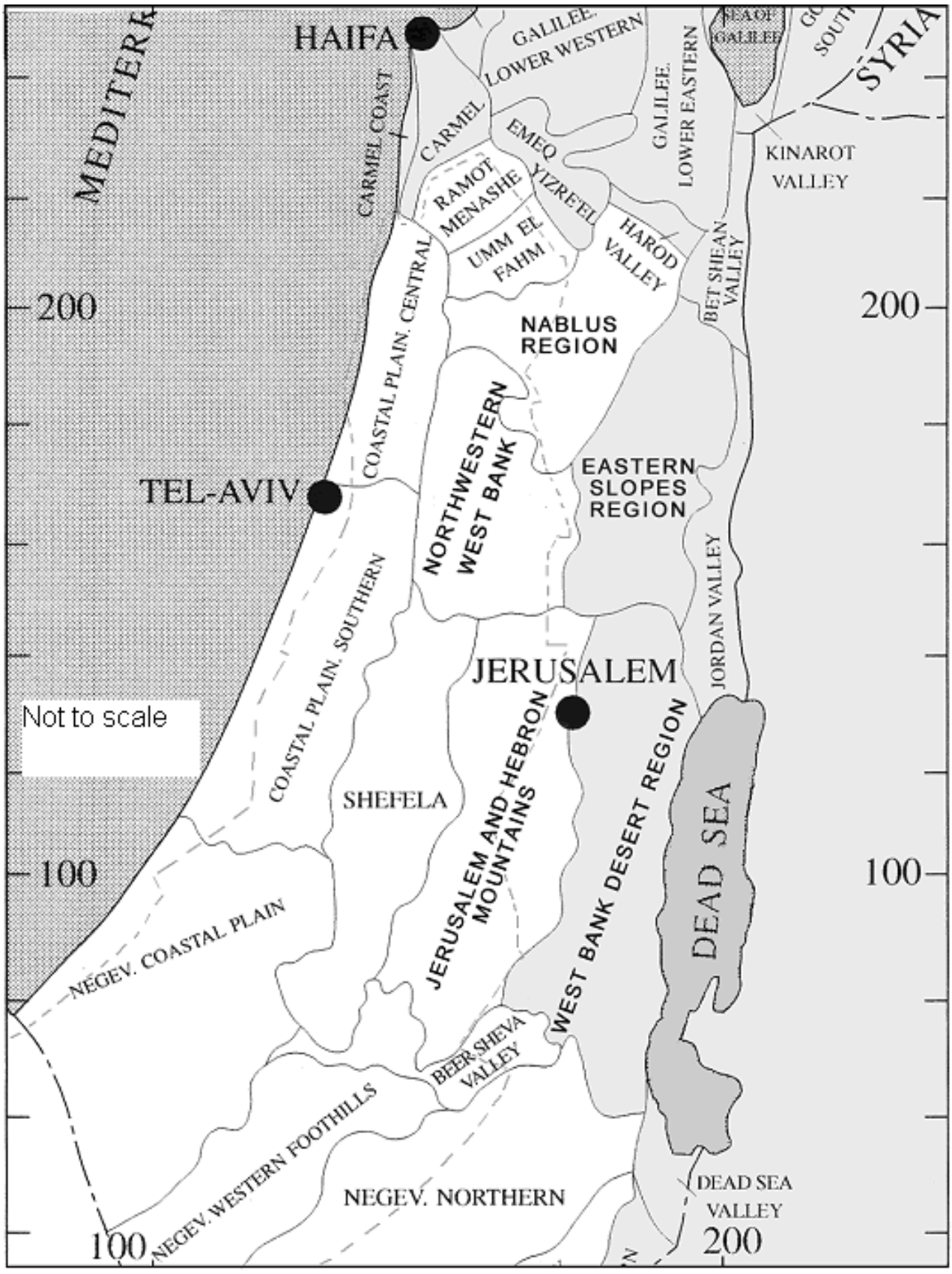

Figure 1.3 Geographic regions of the Western Aquifer Basins (The thin dotted line delineates the geographical borders of the WAB.)

The different regions have been introduced and described in further detail in the Compiled Base Data Report of SUSMAQ.
The following **Table 1.2** summarizes the regions with the range of elevations.

Table 1.2 Regions and range of elevations (in m asl)

West		Middle		East	
Region	Elevation	Region	Elevation	Region	Elevation
Central Coastal Plain	0-100			Ramot Menashe	100-300
				Um El Fahm	100-<500
				Nablus	100-400
Southern Coastal Plain	0-100	Hashephela foothills	100-450	Northwestern West Bank	100-700
		Beer Sheva Valley	200-500	Jerusalem and Hebron Mountains	450-800
Negev Coastal Plain	0-200	Negev Western Foothills	20-400	Northern Negev	300-600

1.5 Geology

The range of age of the outcropping formations reaches from Lower Cretaceous to Holocene. The Lower Cretaceous formations of the Kurnub group are exposed as Aptian shale (Tammun) at the anticline axes and as Kurnub sandstone in the Negev. The aquifers of the Western Aquifer Basin (WAB) consist mainly of karstified limestone and dolomite of Upper Albian to Turonian. The two aquifers are separated by a Lower Cenomanian sequence of aquitard to aquiclude formations, known as Yatta formation in Palestinian terms and as Moza and Beit Meir formations in Israeli terms. Although Beit Meir contains portions of limestone and thus builds locally restricted perched aquifers, Yatta as a whole is simplified and modelled as one aquiclude on the regional level. The Holocene and recent alluvial deposits are found in large areas in the coastal plain. The outcrops of the aquifers are distributed as follows (**Table 1.3**):

Table 1.3 Outcrop area of aquifers and aquitards

Aquifer Formations	Outcrops	Aquitard Formations	Outcrops
Upper Albian	292.4 km^2	Lower Cenomanian	165.7 km^2
Middle Cenomanian-Turonian	1366 km^2	Senonian – Quaternary	4210.5 km^2

1.6 Water use

The water use is very heterogeneous, due to both natural and political reasons. While some areas are fully developed and even overexploited (coastal plain in central Israel), other areas rarely yield sufficient water in satisfying quality (Negev and Sinai). In the West Bank foothill region, Israel, through its occupation forces, imposes restrictions on the development of the important potential of the aquifer.

1.7 Previous studies

There are a number of modelling studies about the Western Aquifer Basin carried out by the Israelis (Bachmat, 1995; Guttman and Zukerman, 1995; Zukerman, 1999), but no comprehensive model has been undertaken on the Palestinian side as yet. However, the Israeli studies lack the following:

- Some of them, as Bachmat 1995, are based on a coarse grid of 25 km^2 cell size and therefore do not reflect realistic averages of the aquifer hydraulic and physical properties.
- Recharge estimates were made on generic relationships between rainfall and outflows (wells and springs). However, Guttman & Zukerman 1995, calibrated the results of these equations.
- There is a great distrust in the geometry and hydraulic connection between aquifers developed in most of these studies. (This is the case for the 25km^2 grid size of Bachmat 1995 but also of the other models.)
- The assumption of considering the WAB to have only one aquifer unit, as in most previous models, is not very convincing.
- In addition to the above inaccuracies in most of the Israeli conceptual and numerical flow models, the SUSMAQ team was not able to have free access to all the details of the Israeli studies on the WAB.

In this study we tried to address most of the shortcoming of the previous studies. This is the first Palestinian study that develops comprehensive numerical steady and transient flow models with great details on boundaries and geometry, hydraulic properties with assessment of the sustainable yield of the aquifers of the Western Basin.

Full report/document is not available online