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Domestic Water Vulnerability Mapping in the West Bank /Occupied Palestinian Territory

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Abstract

Due to its average annual rainfall, coupled with regional water resources from the Jordan River and groundwater from its Aquifer System, the West Bank is generally not considered to be a water-poor region. However, since the Israeli occupation of the West Bank in 1967, Palestinians have been routinely denied their rights to utilize their own water resources from the Jordan River. Moreover, presently more than 80% of the annual safe yield of the Palestinian water from the West Bank's Aquifer systems is used by Israel to meet 25% of Israel's water needs. This has culminated in a constant prevention of access to their own water resources.

A combination of physical, political and socio-economic factors threaten Palestinian access to a clean and reliable groundwater supply. These include inconsistent rainfall, water table lowering and increase in salinity levels due to over-abstraction, pollution from agrochemicals, solid waste and wastewater dumping (including from the Israeli settlers, illegally living in the Occupied Palestinian Territory (OPT). An unstable socio-economic situation also threatens the affordability of water. Israeli practices such as road blocks, checkpoints, and the segregation wall have severely affected Palestinians access and control over their own water resources'. While there is ample physical, economic, social and political data available on water issues and problems in the (OPT), there still exist a lack of a detailed assessment of the combined effects of different factors on the accessibility of water in the region. Also, as all of these factors are constantly evolving, it is vital to develop an ongoing monitoring system of the Palestinian water situation.

The state of Domestic Water Vulnerability in the West Bank is assessed through the calculation and mapping of a Water Poverty Index (WPI). The WPI uses an index structure to combine data on physical availability of water, socio-economic, and political factors that limit its access. This provides not only an overall synopsis of the effects of these different factors but also a detailed analysis of each individual factors role in the accessibility of water. The maps have the following fundamental aims: (1) to identify the most 'Water Vulnerable' areas in relation to the current deteriorating water supply and existing sanitation services; (2) to analyze the factors which are particularly relevant in determining the accessibility of water in different areas in the West Bank; (3) to provide a simple visual representation of the physical, political and economic factors which influence the accessibility of water; and (4) to highlight specific elements related to the

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availability and integrity of water resources, including the location of water resources or the origins of point-pollution sources, by plotting them onto the map as additional layers.

The results provided by the index produce a simple, reliable, and progressive tool for comparison between different regions over a specific timescale. Thus, the WPI can serve as a monitoring tool or as a model to calculate water scenarios by altering the value of the single indicators based on future environmental, political, social or economic projections. Our work draws on the work of the WPI initiated by Catherine Sullivan at the Wallingford Centre for Ecology and Hydrology. It will endeavor to refine the tool of water poverty mapping, by combining an overall assessment with a detailed analysis of the different factors and their respective importance in creating Water Vulnerability.

Keywords: water rights, water resource management, access to reliable water, Water Poverty Index.

1. Introduction

The 1995 Oslo Interim Agreement recognised the Palestinian's right to water, and accorded some degree of control over access to resources to the Palestinian Authority. The specific definition of rights to water resources, however, was left to the Permanent Status Agreement negotiation, never carried out. Meanwhile, recognition of "existing patterns of utilization" of Aquifer Water was agreed upon, which accorded 483 MCM to the Israelis and 118 MCM to the Palestinians, and an additional 28.6 MCM to be made available to the Palestinians in the interim period. Even this transfer, however, was never put into practice. Also, in practice the Palestinian Authority had very little effective control. Any major development of water and sewage systems and even routine network maintenance activities in area B and C was subject to the approval of the Joint Water Committee (JWC), a joint body established to coordinate water development over which the Water Office of the Israeli Civil Administration has veto power. This has largely limited infrastructure development, creating a condition of lack of proper network maintenance and development. This situation was exacerbated following the Second Intifada. Persistent curfew, closure and roadblocks prevented tankers from distributing water to un-served communities (Wash MP 2004, p.44), while incursion caused damage to water infrastructure in over 100 different communities (Wash MP 2004, p.55). Furthermore, the construction of the segregation wall cut off users from their water sources: *"Being built significantly inside the West Bank, the Wall's path clearly targets control over the region's aquifer systems, a major source of water that Israel already lays extensive claim to, denying Palestinians their rights to water."* (Wash MP 2004, p.8). Finally, the deterioration of economic conditions following the second intifada such

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that currently 56.8% of households in the West Bank are living under the poverty line placed increasing economic constraints on households' access to water.

This study provides an overall assessment of the outcome of the factors mentioned above, in order to determine which of the areas of the West Bank are the most water vulnerable in the Domestic sector. Since the late nineteen eighties, a series of attempts have been made at measuring water scarcity by combining physical and social factors. Many of these, however, for instance the Falkenmark Water Stress Index and the Water Availability Index, only provide a measure of first-order water scarcity, i.e. physical shortage of water in relation to consumption. However, often the main factors influencing water poverty are not so much scarcity of the resource but rather lack of access. The (WPI) is precisely an attempt to assess second-order scarcity (i.e. the lack of capability to access water). It uses an index structure to combine data on physical availability of water and socio-economic factors limiting access to it. More specifically, the WPI is a composite index which combines a series of components, each of which is calculated by combining different indicators (Sullivan 2002). Table 1 summarises the key components and the indicators chosen for this study.

Table 1 Indicators Used

Component	Scope	Indicators
Resources	*physical availability of water resources, quality and variability*	• Per capita water Resources • Own water resources • Domestic water quality
Access	*access to resources for human use, for instance presence of water and sanitation infrastructure*	• Connection to Water Network • Connection to Wastewater Network • State of Water Network • Regularity of supply
Capacity and Use	*economic capacity to access water and institutional capacity to manage the resource*	• Poverty level • Percentage of income spent on water • Incidence of water born diseases • Domestic water use per capita
Environment	*environmental integrity of water resources*	• Pollution of water sources

Water Poverty Mapping underlines the general problem of scale of assessment, as at different scales of mapping there is a considerable difference in the areas is identified as water-vulnerable. It is a generally known, and further demonstrated by the work of Cullis (2004), that there are large socio/economic differences and disparities in access to natural resources over a very low spatial scale, thus large-scale evaluation of water resources may serve to hide considerable differences in access to water. This is particularly true in the West Bank, not only for considerable differences in infrastructure provision and income between urban, rural and refugee camp areas, but also for the localized effects of

some of the major physical limitations on access to water (these include physical barriers such as road blocks preventing tankers from delivering water, maintenance teams from carrying out maintenance work on the network, isolation of wells from their owners by the segregation wall, pollution of springs from settlement wastewater sources).

2. Methodology

2.1 Index Calculation

The Water Vulnerability Maps used the (WPI) to assign a numerical value representing vulnerability to each area. The (WPI) is a *Composite Index*, in which four components (resources, access, capacity and use, environment) are averaged to produce the final Water Poverty Index. Each of these components is an index itself, which combines a variable number of indicators (Table 1).

The (WPI) for the West Bank was calculated according to the methodology described by Sullivan[1]. The four components that make up the index were combined using an equally weighted average to produce a single Index score**.** The mathematical structure of the index can thus be summarised as:

$$WPI = w_r R + w_a A + w_c C + w_e E \qquad \text{....(1)}$$

Where the:
$w_r R$: resources component
$w_a A$: access component
$w_c C$: capacity component
$w_e E$: environment component

Each component was calculated by averaging the values of individual indicators. The score of each indicator was calculated in the following way.

- Where the indicators were expressed in the percentage form (such as the percentage of population with access to piped water), the percentage itself was taken.

1 Sullivan, C.A. (2002) Method to develop and describe community level Water Poverty Index scores. *Oxford University Centre for the Environment.*

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- Where the values were not expressed in the percentage form (such as average water supply per capita), the value of each indicator is based on the following formula,

$$\frac{(x_i - x_{\min})}{(x_{\max} - x_{\min})} \quad \text{.....(2)}$$

where x_i, $x_{\max}$ and $x_{\min}$ are the original value for each governorate, the highest value between the governorates and the lowest value between the governorates respectively. In order to avoid values of 0 and 1, in each sub-index the values of $x_{\max}$ and of $x_{\min}$ were adjusted to 10% above and below the actual maximum or minimum. In this way the range of values for each component lies between 0.08 and 0.92. These values were then multiplied by 100, in order to provide a number in the same order of magnitude as the percentages.

2.2 Choice of Indicators

According to Sullivan's (2002) idea, each component of the (WPI) should remain constant at different spatial scales and between different places. However the single indicators chosen should be adapted to the scale of mapping and to the appropriateness of different indicators for different situations of access to water.

The **resource component** of the (WPI) represents the level of availability of water resources for domestic use in the West Bank. Three sub-indicators were chosen to calculate the index.

a. Per/capita water resources: This calculates the total available piped water resources, in other words the available water from sources internal and external to the West Bank, accessed through the water network. It does not take into account the resources accessed independently, for instance through rainwater collection, or distributed by tankers **[Appendix 1, Map1]**.

b. Own water resources: The percentage of domestic water supply deriving from own-water resources (municipal and agricultural wells, and springs) in relation to all resources distributed through the network is used as a proxy for the variability of piped resources. Israeli water company (Mekorot) supplies about 53% of the West Bank's drinking water, drawing roughly 40% of its resources from wells inside the West Bank (PWA 2005) and the rest from wells located outside the Green Line, but largely tapping into the western aquifer .

c. Water quality: The quality of water actually reaching the communities was taken, as opposed to water at the source. This takes into account the various processes which can influence water quality both positively. The governorate value is the percentage of communities reporting good water quality in relation to the total number of communities in each governorate **[Appendix 1, Map 2]**.

The **access component** of the Water Poverty was calculated from four sub-components. One of these relates to the coverage the waste-water network, three to the water network. Three indicators were chosen for the water network, as statistics on connection alone do not provide a representative measure of access. The state of the network was taken into account, as leakage is a considerable problem in the West Bank, to the extent that only 45% of water entering the network actually reaches the population (PWA in Wash report 2005, p. 31). Also, the presence of a network does not automatically mean that the network is regularly filled with water. The index was thus calculated from the following sub-components:

a. Percentage of population connected to the Water Network: This figure was taken as an indicator of the population with access to piped water **[Appendix 1, Map 3]**.

b. Percentage of population connected to the Wastewater Network: **[Appendix 1, Map4]**.

c. Percentage of communities with a good state of Water Network: The 2004-2007 Wash report classifies communities according to the state of their water network as Good, Leaking or Bad. The percentage of communities with a Good state of water network on total number of communities was calculated for each governorate.

d. Irregularities of water distribution: The number of communities connected to the water network with 24 hour access as a percentage of all communities was calculated for each governorate.

The **capacity component** "…tries to capture those socio-economic variables which can impact on access to water or are a reflection of water access and quality..", independently from the physical availability of water. Two sub-indexes relate to the economic capacity to command access to water (poverty level, percentage of income spent on water). The incidence of water born diseases was also included in the index, as an indicator on quality of accessed water. This measures a different factor from the water quality indicators included in the resources component of the index, as it is an indicator not only of water quality, but also of capacity to treat it and overall water availability. The capacity and use index was thus calculated from the following sub-indexes:

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a. Poverty level: The Palestinian Central Bureau of Statistics defines Deep Poverty as a condition in which the basic needs of food, clothing and housing are met with difficulty. Thus, the percentage of population in deep poverty for each governorate was taken to indicate the amount of population having difficulty to access basic services. The data was derived from the PCBS 2006 Poverty Report. As data was not available on the governorate level, but only by geographical area (North, Centre and South West Bank) the figure for each governorate was chosen according to its geographical location in each of these areas.

b. Percentage of income spent on water: The percentage of income spent on water was calculated by averaging the percentage spent in each community in the governorate **[Appendix 1, Map 5]**.

c. Water born diseases: The percentage of communities experiencing water born diseases in relation to the total number of communities was calculated by averaging the percentage of population affected by water born disease in each community **[Appendix 1, Map 6]**. The figures were taken form WaSH Database, accessed January 200).

d. Use: Figures for domestic water use by governorate were taken from the 2004 Wash Report.

The **Environment component:** Based on the 2007 ARIJ Report on the *Status of the Environment in the Occupied Palestinian Territory*, three main sources of pollution were identified as potential threats to the environmental integrity of the West Bank's water resources: pollution from agrochemicals, waste-water and solid waste dumping. All of these refer to groundwater, which constitutes the main water reserve of the West Bank.

a. Environment. The actual numerical value for the index was taken from the figures for contamination of the sources of water themselves. More specifically, water quality was calculated as a percentage of domestic water with chemical concentration (mainly Nitrates) over the drinking water limits, as a part of all spring- and ground-water used for domestic provision. Contamination from wastewater identified by the presence of faecal bacteria and high nitrate levels in the water sources is widespread throughout the West Bank. Most solid waste dumps are unplanned sites for which no environmental protection measures were planned.

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3. Results and Discussion

3.1 Overall Resource Index

The combination of the three lowly-correlated components rank the Qalquiliya and Tulkarm governorates first, as these areas are water rich and maintain control over the majority of their water resources **[Appendix 2, Map 7]**. At the opposite end of the spectrum, Hebron, Salfit and Jenin are highly dependent on external water resources, have many un-served localities relying on tankers and consequently poor quality of water reaching the users. Jerusalem and Ramallah have few internal resources, but they are generally well connected and well served areas, with an acceptable quality of water reaching the majority of the users. Both Bethlehem and Jericho are self sufficient for about half of their water consumption generally have high resource availability and have no localities reporting poor water quality

3.2 Overall Access Index

Overall the central West Bank is the best connected to water and wastewater and – despite the mediocre condition of the network, largely due to its age – generally has a more regular water supply. Also, particularly in the Jerusalem and Ramallah governorates, mapping at a lower spatial scale (village boundary) shows a relatively homogenous pattern with less marked differences between rural and urban areas than in the north and south of the West Bank. The Bethlehem governorate scores very high on all of the access components, however mapping at the village boundary level highlights a divide between the urban areas in the West of the Governorate and much poorer areas to the East, which are also subject to frequent water cuts. The complete lack of a wastewater network coupled with the mediocre state of the water network (only 25% of connected communities report a good state) assign Jericho a particularly low score on the access component of the WPI. The governorate-level score for Nablus is misleadingly high, thanks mainly to its good state of the water network and relatively good service of the connected communities. However, a lower spatial scale of mapping shows a very un-homogenous situation, in which the Nablus urban area (which holds roughly 50% of the governorate's population) scores extremely well, while large stretches of the south of the governorate are extremely poorly served **[Appendix 2, Map 8]**. Salfit and Qalquilya are relatively homogenous on all of the components, which situate them in the mid-range of the access component, while the worse scoring governorates are in the South (Hebron) and in the North (Jenin and Tubas).

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3.3 Overall Capacity and Use Index

Overall, the values of the Capacity component of the (WPI) show a fairy rigid divide according to the locality type. Water price, water use and incidence of water born diseases are all strongly interlinked and depend widely on the division between served and un-served areas. Some of the most dramatic consequences involve both cost of water and its quality, thus the incidence of water born diseases. Furthermore, as the Capacity component of the (WPI) also takes into account the population's poverty levels and this tends to be divided along a rural-urban-refugee camp divide, this allows us to conclude that location is an extremely important element in determining communities' capacity to access water, and that the overall governorate level of access is strongly dependent on the demographic and topographic factors of its terrain. As would be expected from these considerations, the central West Bank is thus the best scoring area on the Capacity Component, while the South and North are worse off **[Appendix 2, Map 9]**. Intuitively, the use component is highly linked to water supply, thus the main differences in water use occur once again on a divide between served and un-served areas, and areas with a fairly high level of socio-economic capacity and ones without. Overall, water use tends to be a central factor related to other components of the index.

3.4 Overall Environment Index

Groundwater pollution is a considerable environmental threat in the West Bank. This depends both on the Karsic nature of the aquifer, which renders it particularly susceptible to pollution from seepage, and to the many sources of pollution. The contamination of domestic water sources were taken as the indicator for the Governorate as a whole. Water quality was calculated as a percentage of domestic water with chemical concentration (mainly Nitrates) over the drinking water limits, as a part of all ground-water used for domestic provision. While, as in most other WPI components, the Hebron governorate scores low, it is the North-Western governorates of Tulkarm and Qalquilia who score worse on the Environment Index, while Bethlehem, Jerusalem and Salfit are relatively free from Pollution of domestic water sources. **[Appendix 2, Map 10].**

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4. Conclusions: Water Vulnerability Mapping

At the governorate level, the WPI illustrates that the central West Bank has considerably better access to water than the North and South **[Appendix 3, Map 11]**. The best-off governorate is Jericho, which scores highly on all components except access. This governorate, in fact, is the best endowed with water resources and is the least populated. However, it is also the governorate in which the struggle over water resources is acute (the governorate is largely occupied by the Jordan Valley which was declared as closed military area by the Israeli's, thus off bounds for all Palestinians but its inhabitants) and where the majority of Mekerot wells are located. Jerusalem and Bethlehem governorates are less well endowed with natural resources; however they are the governorates with the better socio-economic condition, and score very high on the access and capacity components. Nablus governorate, on the other hand, is considerably well endowed with natural resources, but shows a lower capacity. Hebron governorate scores low on all levels: on one hand, it is the most arid part of the West Bank, and indeed natural aridity plays a large part in the governorates water problem. Also, particularly in the South of the Governorate there are many rural communities with very unstable socio-economic condition and a general lack of infrastructural development. The other low-scoring governorates (Tubas, Qalquilia, Jenin, Salfit), on the other hand, are generally richer in quantity of water resources, but are both the location of major struggles over accessing the resources, have a less stable economic situation and show considerable problems with water pollution and associated health and environmental problems. This is particularly the case in the worst scoring governorate – Tulkarm – in which only 26% of local resources used for domestic water provision are free from pollution**.**

When the WPI is applied at the Village Boundary level, a more complex pattern of water vulnerability emerges. In general, in all governorates there are large differences between rural and urban areas, and as we have seen the presence or not of piped water was a central element conditioning water use, price and quality. To this respect, the Jerusalem and Ramallah governorates show the lowest variability between different areas. Over the whole of the West Bank, the most water-poor areas are the rural south and south-west of the Hebron governorate, the rural areas to the east of Nablus, the north of Jericho governorate and some parts of Jenin. Apart from the city, the Salfit governorate also suffers from a high rate of water vulnerability. The Tubas governorate also is host to some of the communities suffering from the worse levels of water vulnerability. The majority of these are Beduin communities **[Appendix 3, Map 12]**.

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5. Recommendations

This study had two main purposes. Firstly, we aimed to provide an analysis of the current state of Water Vulnerability in the West Bank, and of its causes. We did so by calculating and mapping the (WPI). In the more detailed maps in particular, we analysed the single indicators in each Component of the Index and the relation between them. The second purpose of our work was to elaborate a synthetic visual tool for on-going monitoring of Water Vulnerability, which is indeed one of Sullivan's (2002) scopes in the development of the WPI, and which has been attempted – albeit purely in the index form, without maps and for the West Bank as a whole – by the Palestinian Hydrology Group, who used projections of economic growth, population growth or resource enhancement to estimate future scenarios of access to water (Tamimi et al. 2005). There is scope for developments of both the analytical and the synthetic function of the WPI. In particular, the following three points are:

1. Broaden the scope of the study: *include an assessment of water for non-domestic use (agricultural and industrial water).*
2. Integrate hydrological monitoring with socio-economic data: *strengthen the analysis of the Environmental component of the index, with modelling of aquifer over-abstraction and pollution, as well as precipitation data.*
3. Develop an on-going monitoring system: *develop capacity for provision of updated information.*

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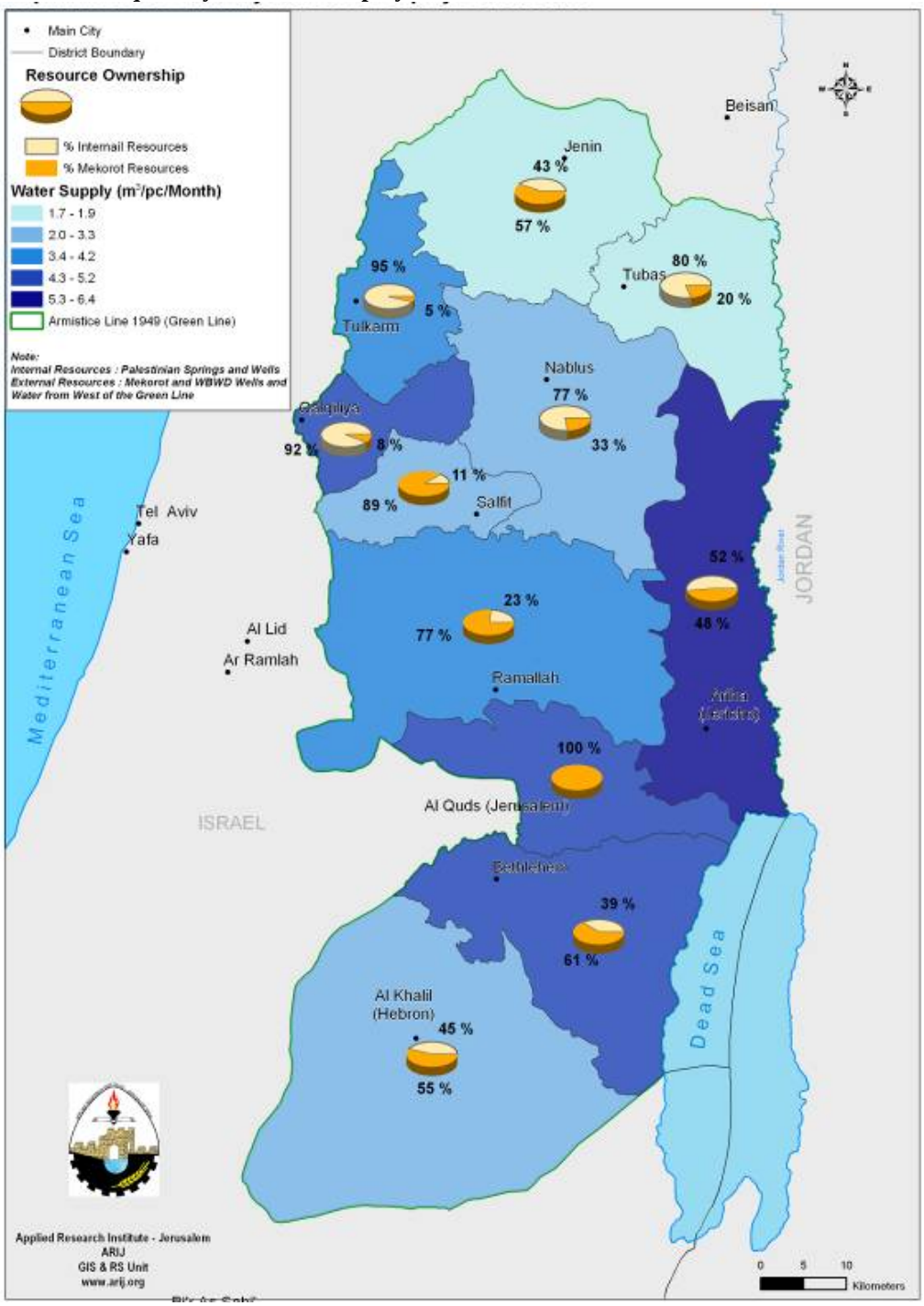
Appendix 1

Map 1: Resources quantity and ownership by Governorate



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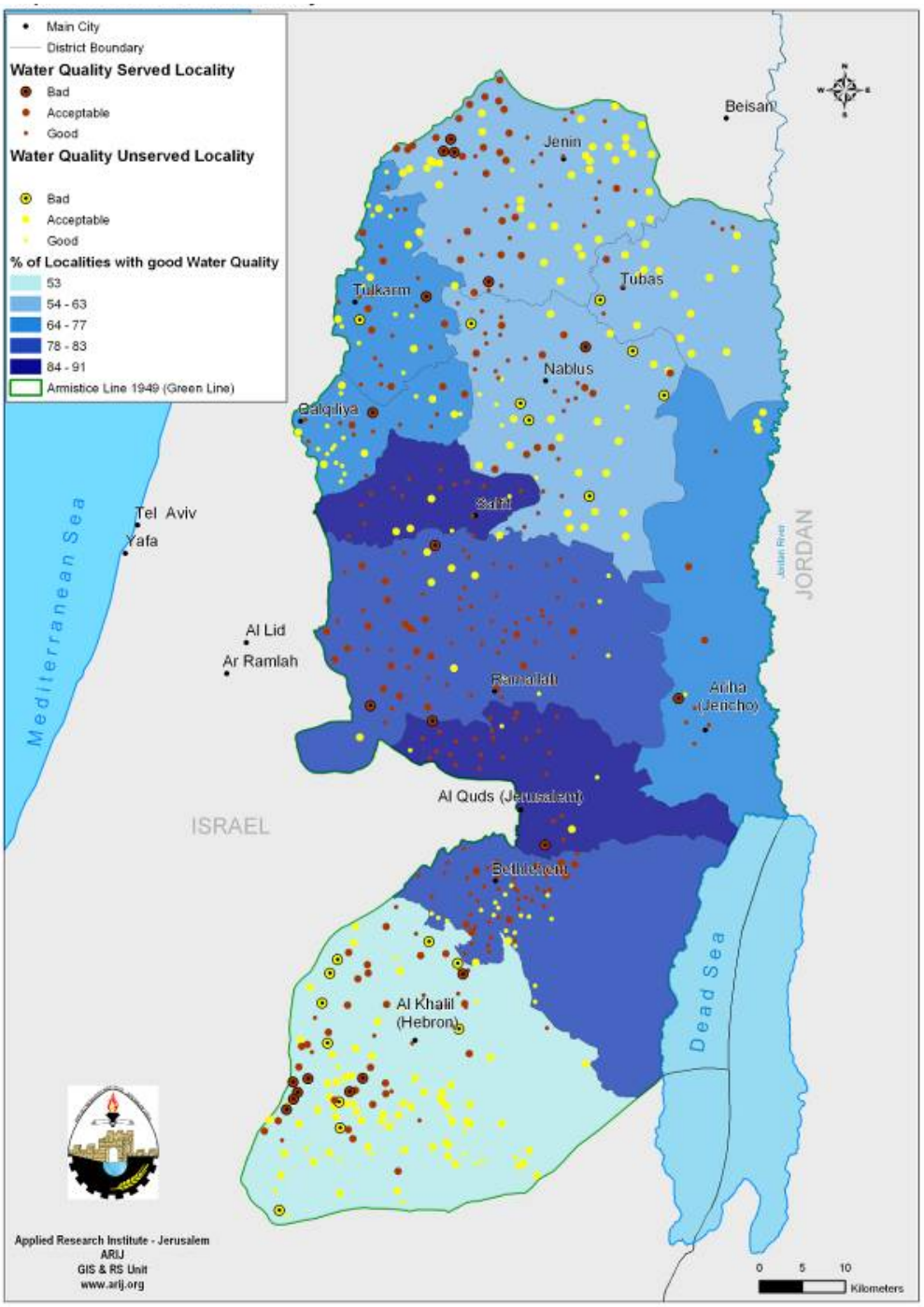
Map 2: Domestic Water Quality



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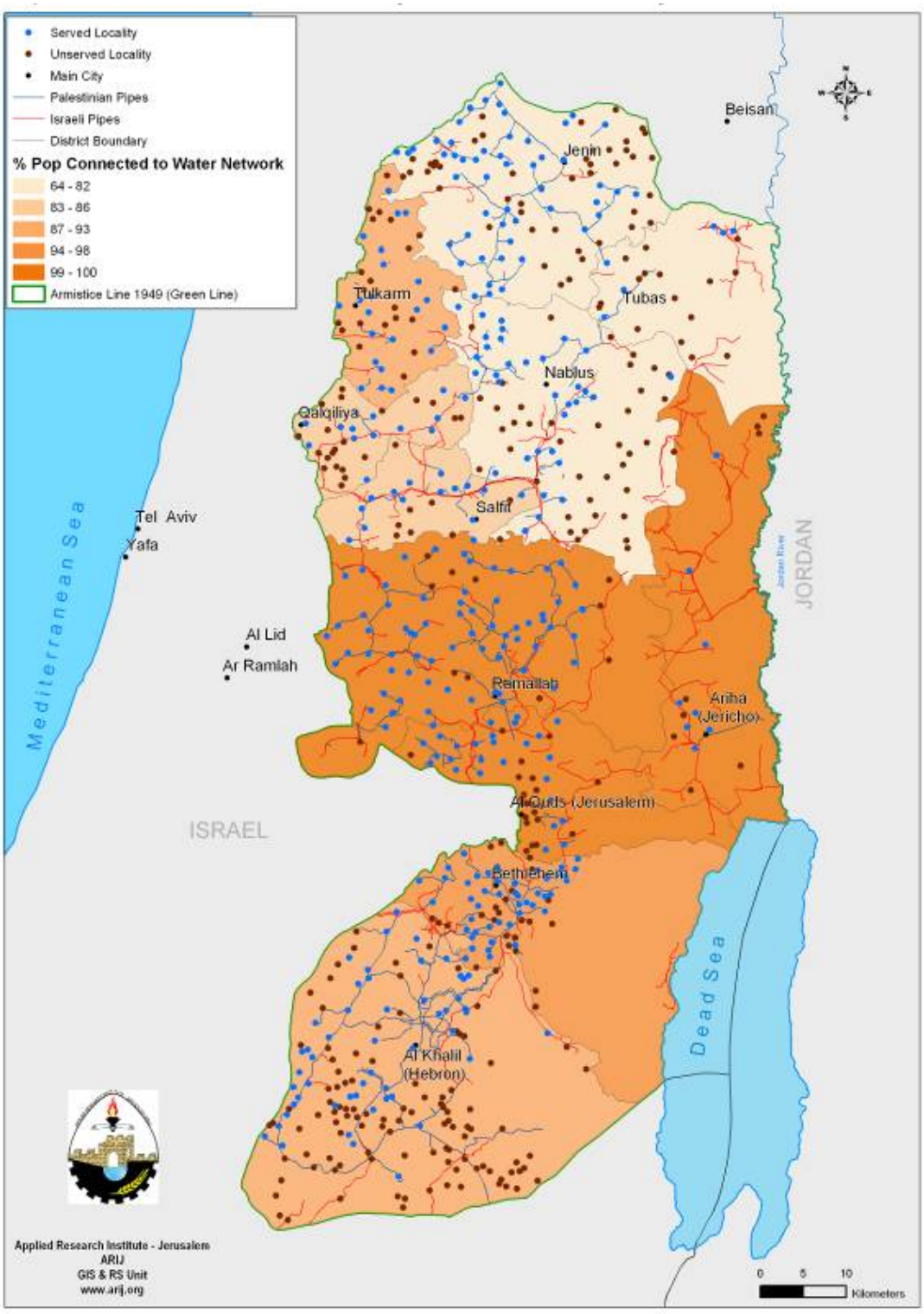
Map 3: Connection to water Network by Governorate



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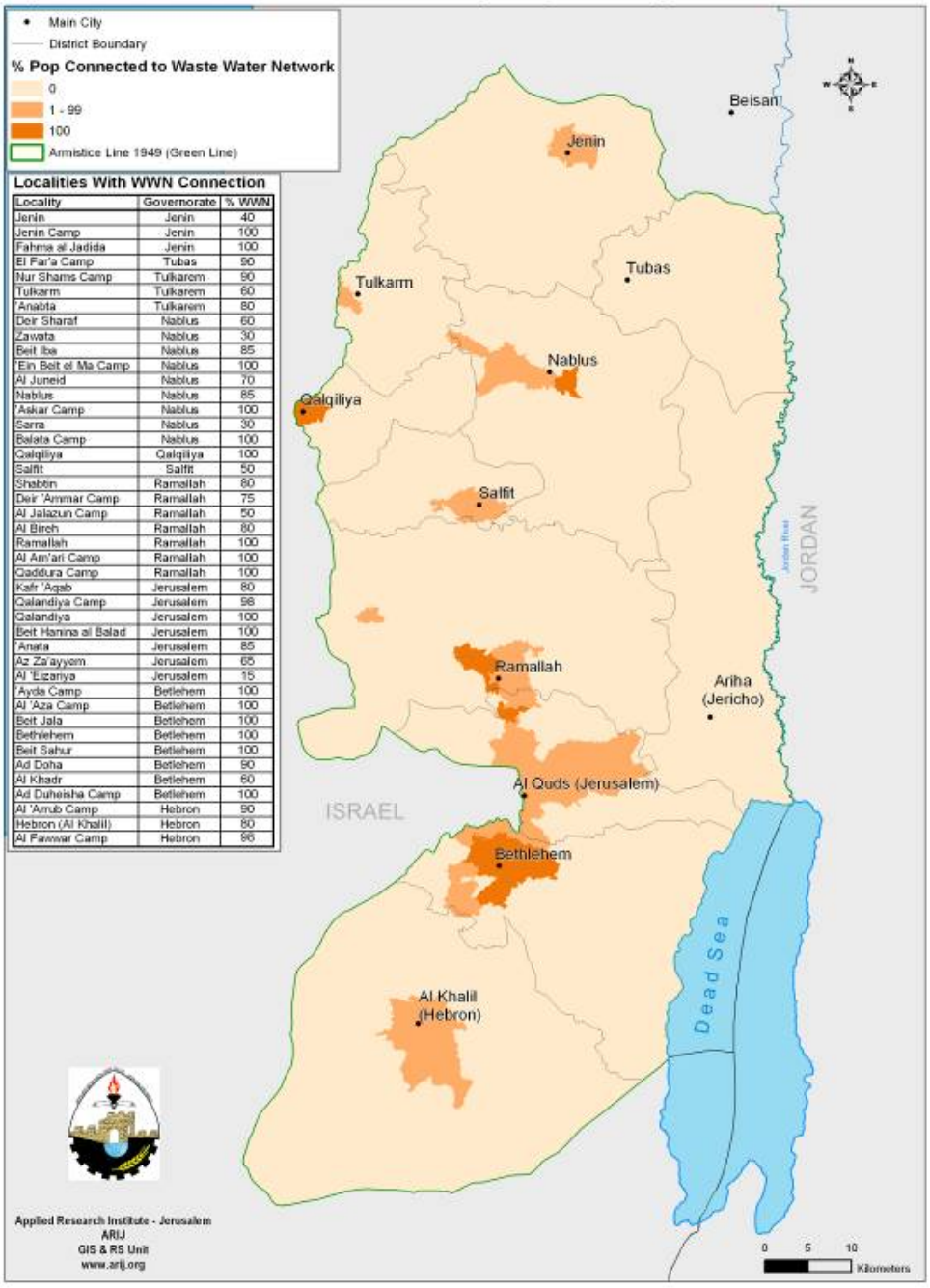
Map 4: Connection to wastewater Network



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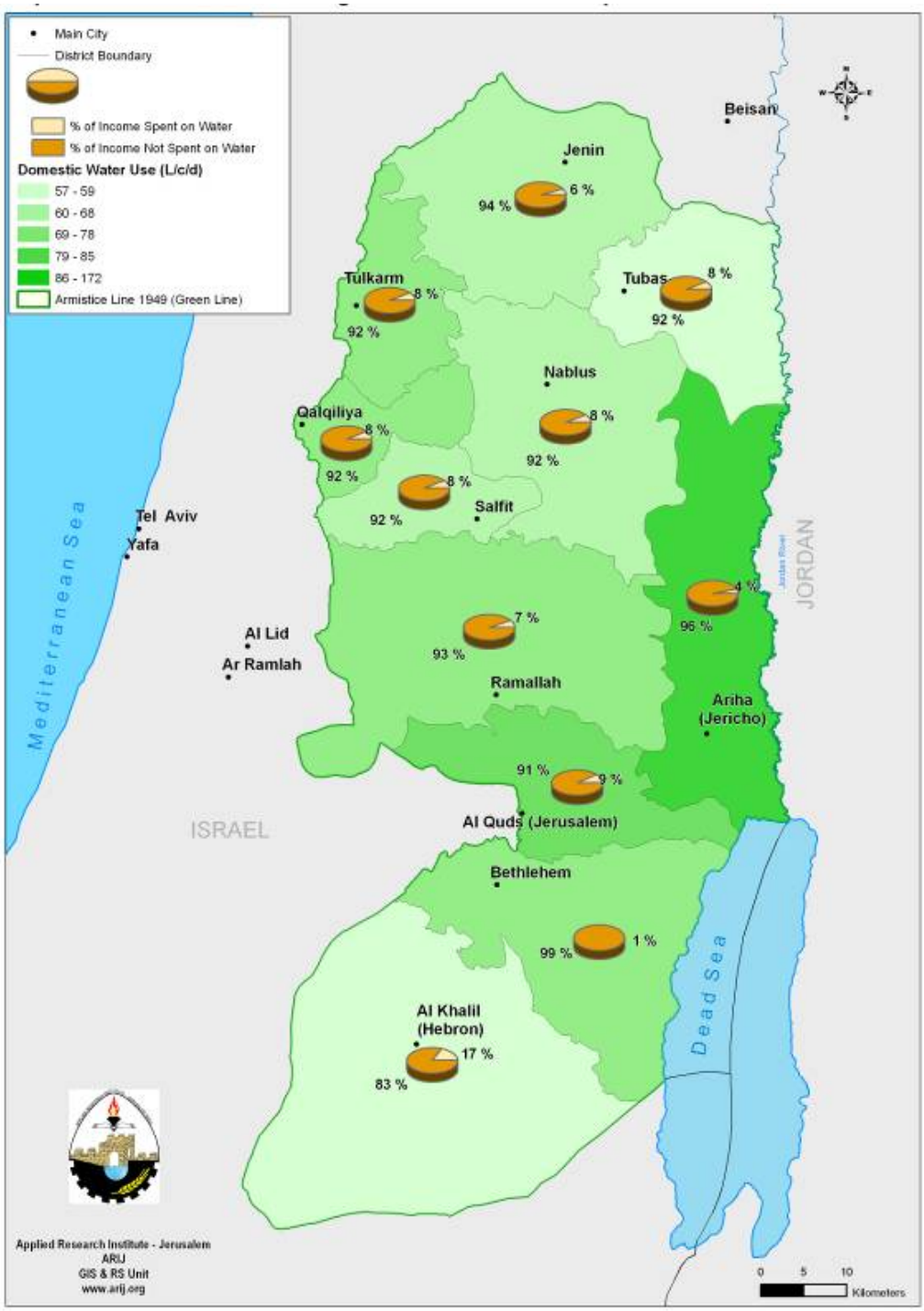
Map 5: Water Use and % Income spent on water



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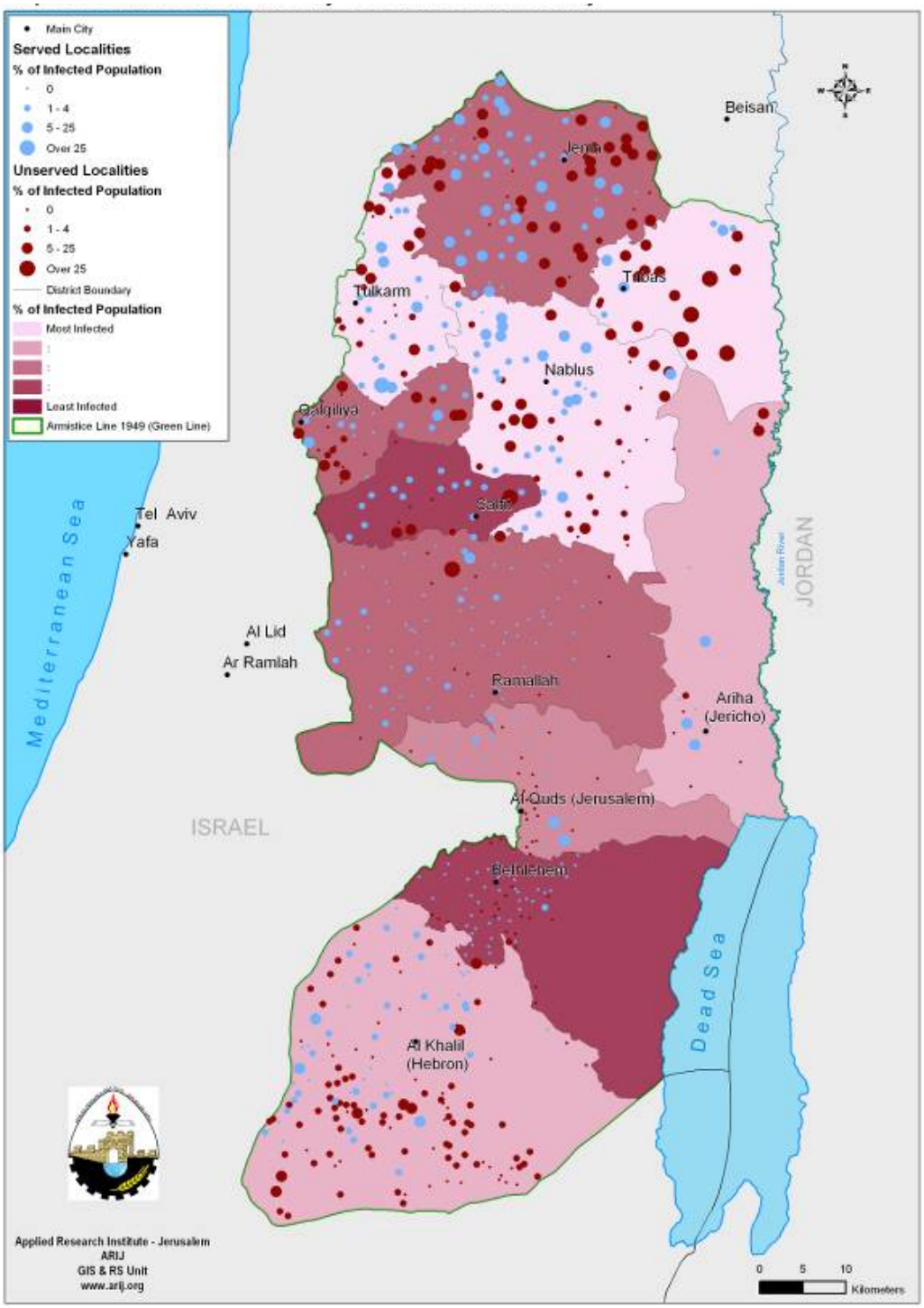
Map 6: Water Born Diseases by Governorate and Locality



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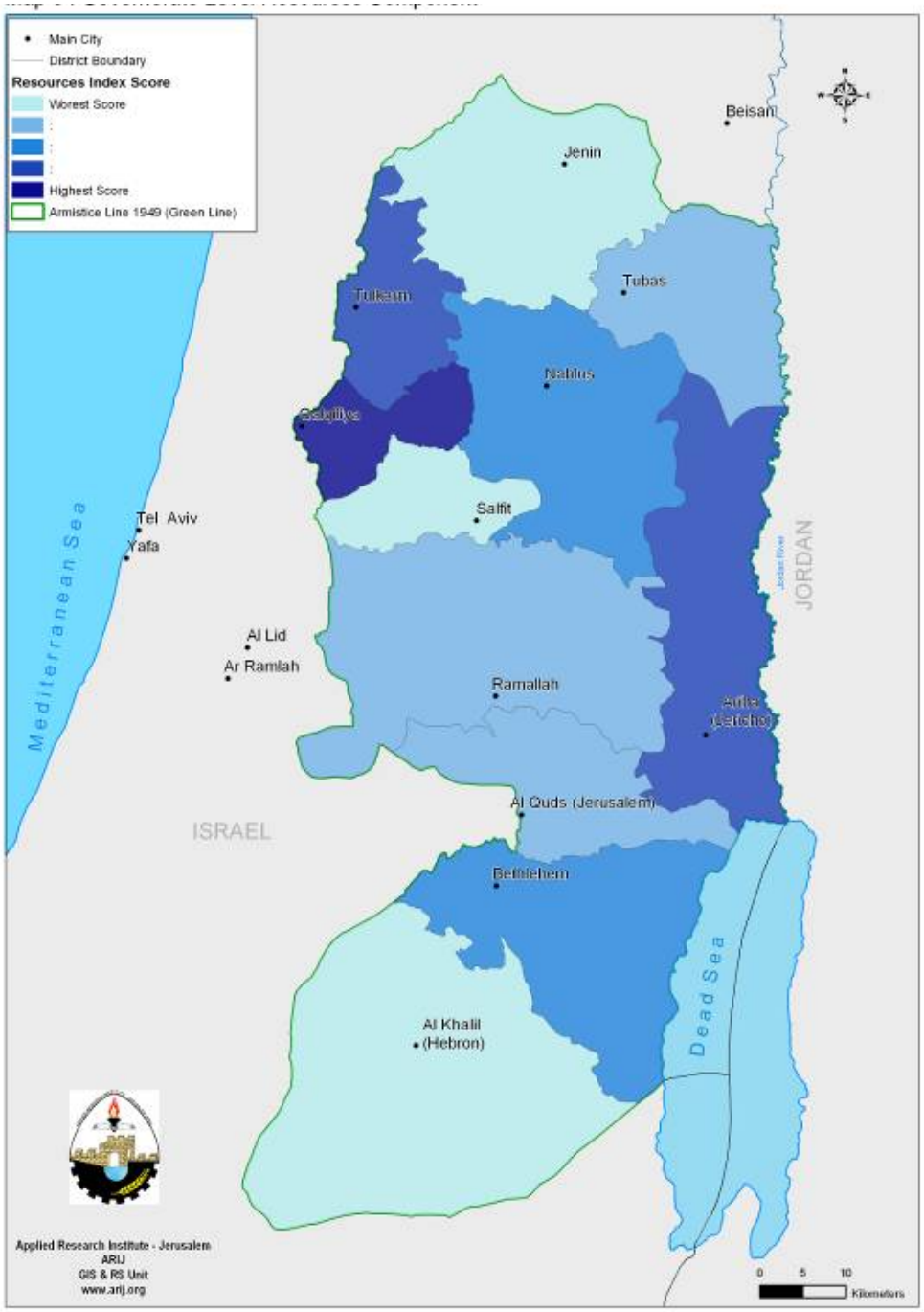
Appendix 2

Map 7: Governorate Level Resources Component



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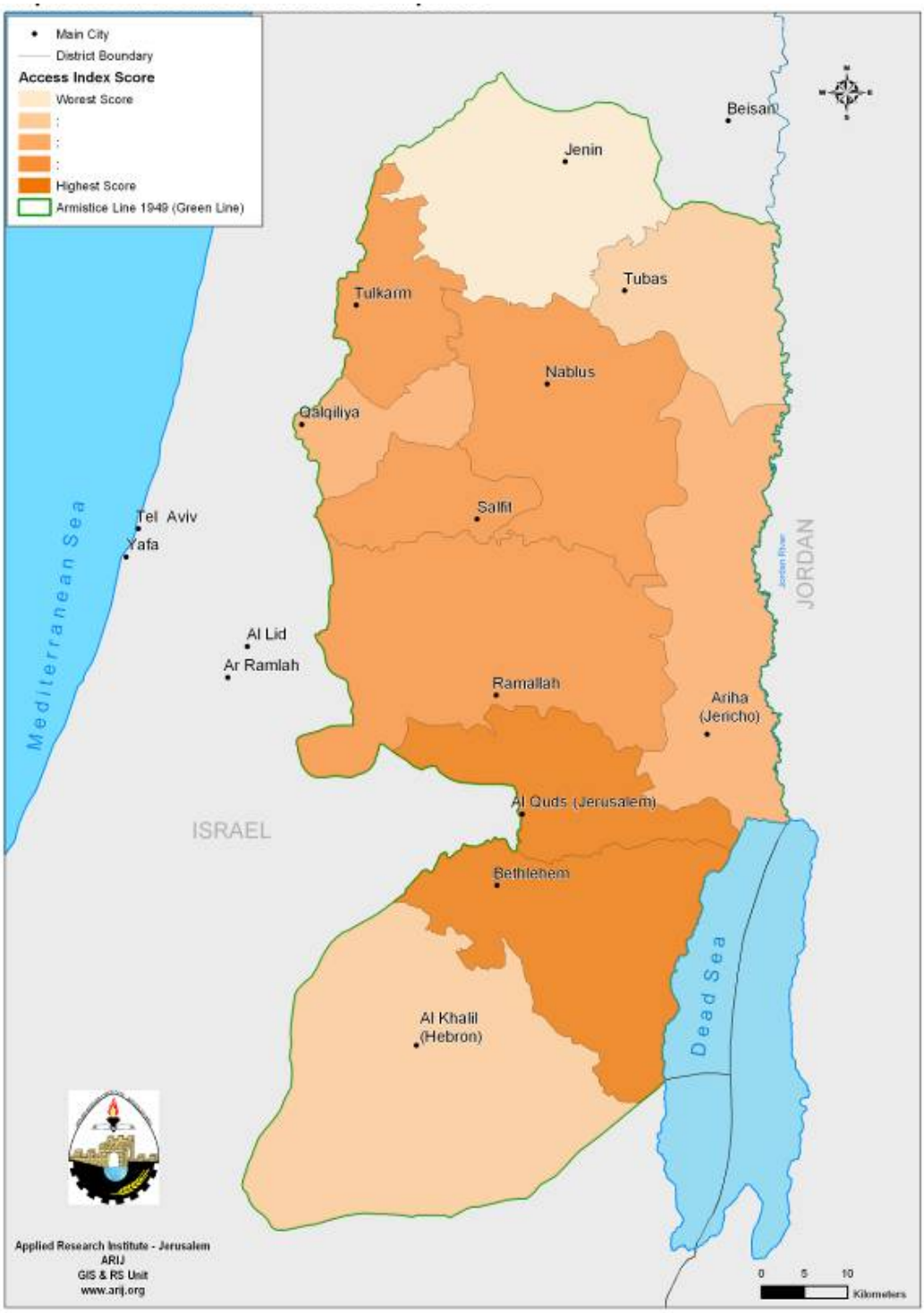
Map 8: Governorate Level Access



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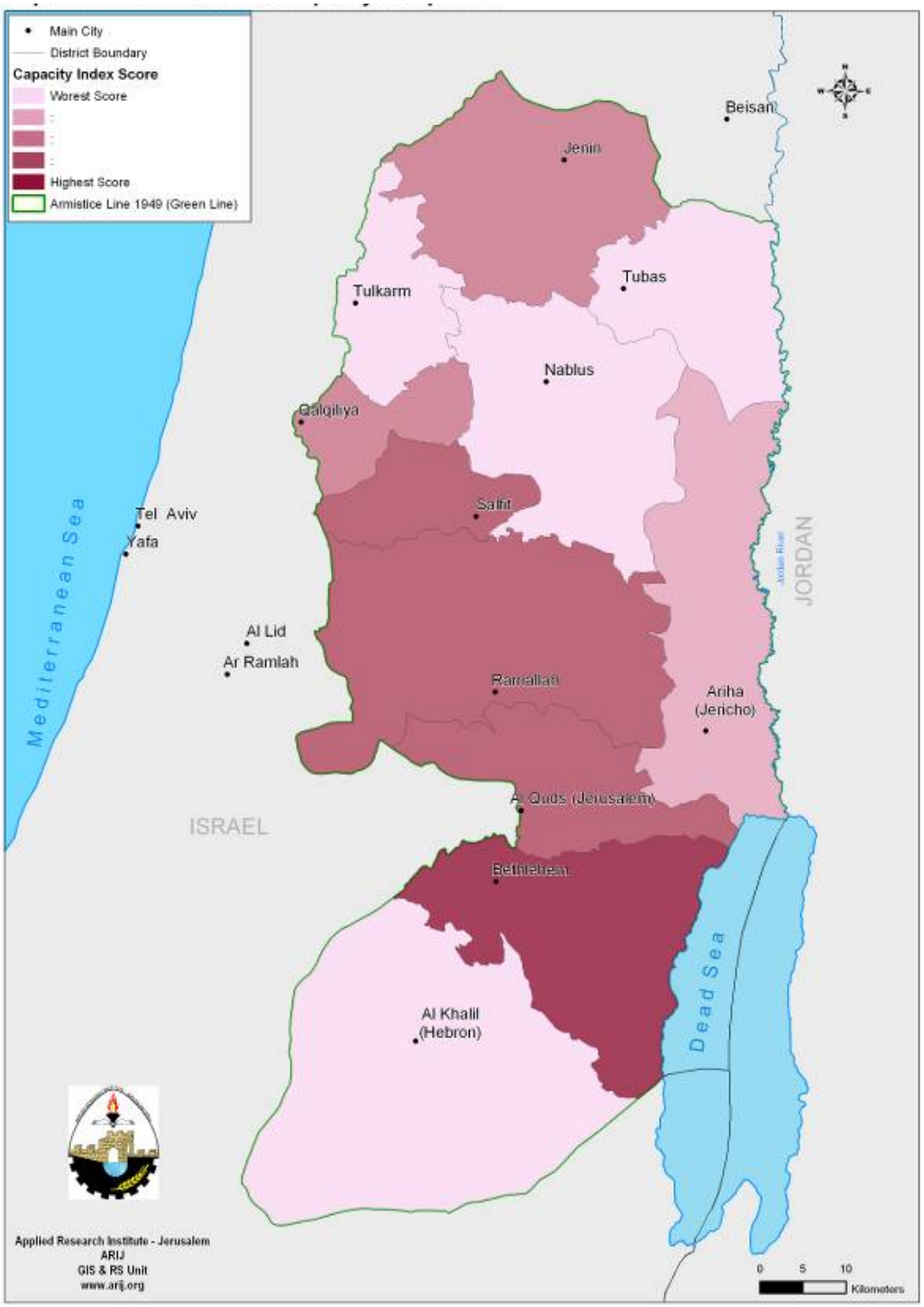
Map 9 : Governorate Level Capacity and Use Component



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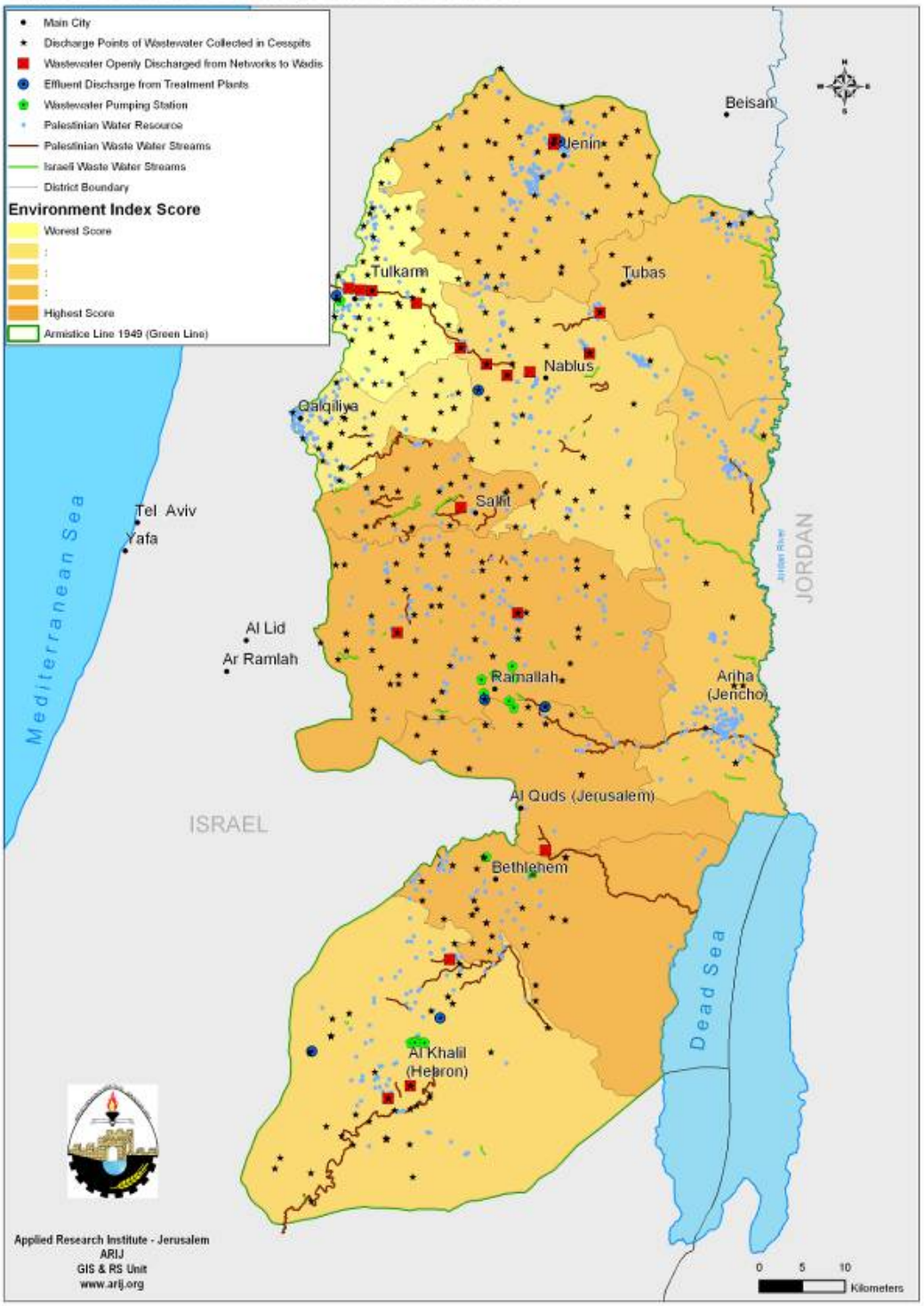
Map 10 : Governorate Level Environment Component



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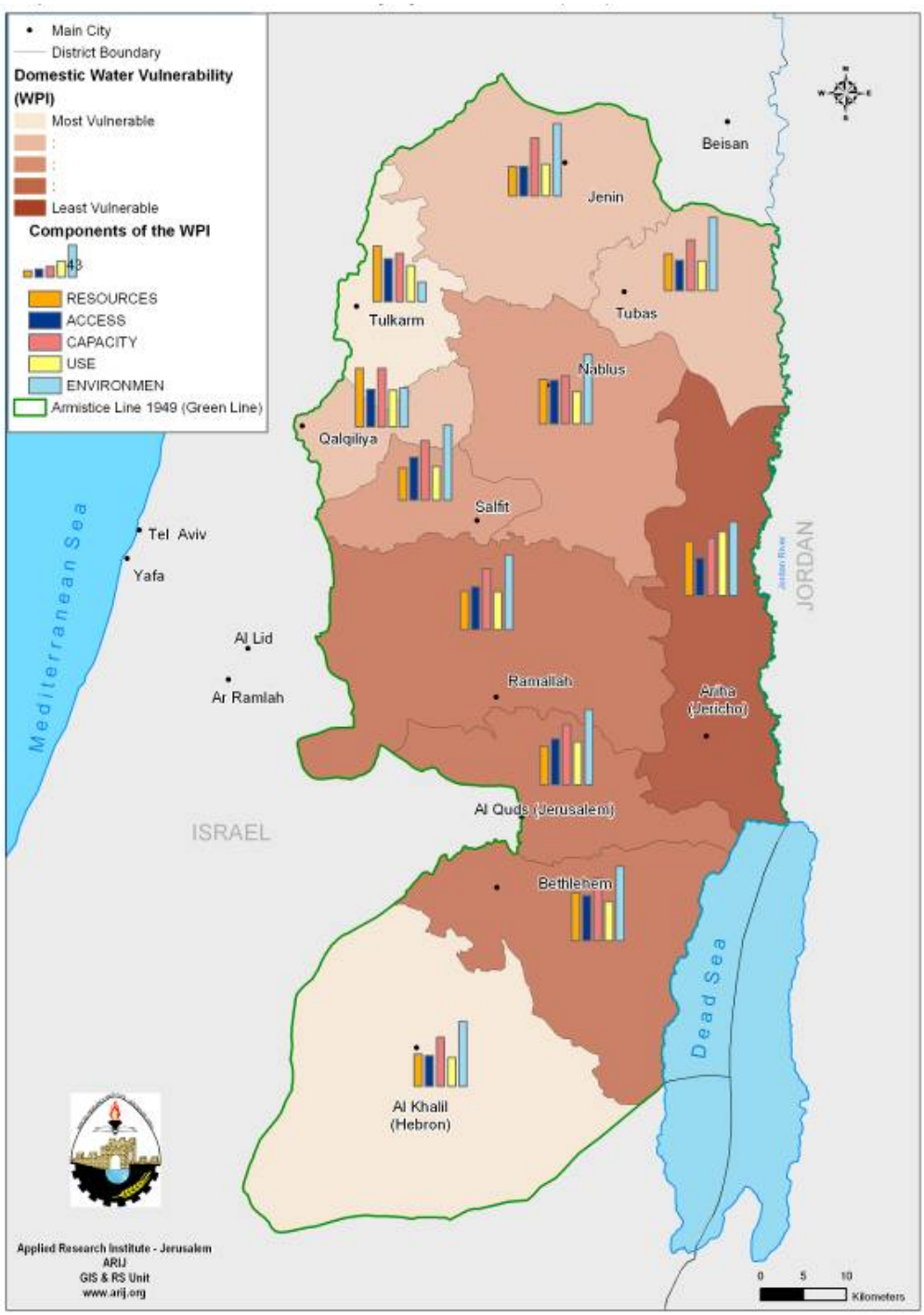
Appendix 3

Map 11: Governorate Level WPI



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Map 12: Locality Level WPI