7. ALTERNATIVE TRANSMISSION SYSTEMS

7.1 General

This part of the report is concerned with developing a proposed future transmission system that meets the aims and goals of the study, taking into consideration the concerns and observations noted during the study period.

To arrive at the optimal future transmission system for the northern governorates, it was found useful to develop three different alternatives for comparison purposes. To achieve this, a separate set of guidelines were assigned for each as a basis for its design.

The following sections describe the development stages of the three alternatives and their guidelines. A layout and brief description of each alternative is given, followed by a cost comparison of the alternatives. The basic rationale for each alternative has been as follows:

- Alternative 1 incorporates the best judgment of the investigators, and the results from the detailed field investigations. The general objective has been to minimize total pipe length, and to minimize pipe size by satisfying the demands close to the water source first, before carrying the balance available from that source to the next demand location. Pumping has been minimized by creating pressure zones in which new pipes are routed along ground elevation contours.
- Alternative 2 incorporates certain alternative routings for the flow, where it seemed possible that the number of pump stations might be reduced, or the total pumping costs might be reduced, but the most economical solution could only be determined by a detailed cost comparison.
- Alternative 3 incorporates the basic layout from previous studies, primarily those of SAFEGE and SOGREAH; the planning and design criteria have been updated to provide a consistent basis of comparison with Alternatives 1 and 2.

7.2 Development of the Three Alternative Systems for Year 2030

7.2.1 General Methodology

The general steps followed during the development of the three alternatives were as follows:

- To acquire a sense of the future system under consideration and the distribution zones and related reservoirs that will need direct supply from the transmission system, a preliminary research of the existing previous studies prepared by the French consulting firms of SOGREAH and SAFEGE in 1998 and the on-going WLRP project was conducted.
- Preliminary office-generated designs were suggested for connecting the reservoirs to the transmission systems using the GIS and in accordance with the general guidelines for the given alternative. Site visits and meetings with ROU staff were conducted to verify the routes and reservoir locations and to check the condition of the existing facilities – pipelines, reservoirs and pump stations - that might be used in the future system.
- An agreement on the total amount of water allocated for the study area was reached with the concerned parties – WAJ and NWMP – and the alternatives were prepared accordingly.

- Regular meetings were held with WAJ/NGWA staff to discuss the results and note any concerns or suggestions to be taken into consideration during the development of the alternatives.
- GIS shape files were prepared and relevant attributes assigned for modeling purposes.
- At this stage, the modeling of the components and the water distribution and management of the system was carried out using the H_2OMAP hydraulic modeling software.

7.2.2 General Guidelines for the Three Alternatives

The general guidelines that formed the basis for the designs were as follows:

- Make best use of the existing facilities - pipelines, pump stations and reservoirs.
- In coordination of this study with the on-going WLRP project, the reservoir locations taken under consideration in this report on the transmission system are based on the proposals suggested in the WLRP Final Conceptual Design Report, January, 2005.
- Capacities of existing wells and springs are assumed to stay as they are in the year 2004. Over-drafting of aquifers is to cease by virtue of the control of irrigation water use discussed in Section 5.
- The alternatives are designed and modeled according to the peak production and maximum-daily demand values of 1.2 × average daily demand. For the preferred alternative only, the design has been modified as necessary to carry average daily demands under emergency conditions, when the largest local wells are out of service.
- Small sub-systems were developed to rationalize the design and operation for distribution of water.
- The planning horizon was taken to be the year 2030; this corresponds to the WLRP average daily flow in 2025. In effect, we have chosen a set of design delivery requirements that match the forecast of demand as it increases over the years.

The three alternatives are described separately below, including any unique guidelines used in their formulation, followed by a layout and a brief description.

7.3 Transmission Alternative 1

7.3.1 Guidelines

- Distribute water from sources to nearby demand points, rather than pumping to a distant high point and back-feeding to the demand points.
- Make the most out of the hydraulic head or static energy available in some sources or reservoirs due to their elevations.
- Minimize pipe lengths. Where feasible, choose the shortest possible route where new pipes are suggested.
- Develop the sub-systems in a way that takes into account the elevations and the pressure zones of the distribution reservoirs as defined in the WLRP.
- In selecting alignments of new pipelines, follow the routes of existing or planned roads to avoid right-of-way land costs.

7.3.2 Description

Figures 7-3-1 and 7-3-2 show: a layout of the suggested Alternative 1 transmission system; and a layout of the locations of the existing and new pipelines, respectively.

East Transmission

The eastern transmission system (both now and in the future) starts from the Aqeb Well K114 on the far east and runs all the way to Hofa PS on the border of the western transmission system, passing by Zatary and Um El-Lulu pumping stations. The main water sources in the east are Aqeb wells, Zatary wells, Sumaya wells and the Corridor wells which will be introduced in 2018.

The eastern transmission system is divided into 5 sub-systems as follows:

Zatary Sub-System: (See plan and schematic profile on **Figures 7-3-3b and 7-3-4b** respectively). The sub-system starts off from Zatary PS on the Mafraq-Badia governorates boundary by collecting its water from the Aqeb, Corridor, Zatary, Sumaya and some other small wells. Zatary Pump Station (PS) at an elevation of 655m pumps a small amount towards Baij Reservoir in the Mafraq governorate. Most of the water is pumped in a new 1100mm-diameter pipeline and the latter section of the existing 600mm pipeline, to Um El-Lulu (at Elevation 800m) and Hofa PSs, both of which start off their own sub-Systems as described subsequently. On its way to Hofa, the already pressurized pipeline, which at this stage has been divided into two pipelines, (the existing 600mm and a new 700mm pipeline) also serves Bwaydah-Ramtha and Ramtha-JUST reservoirs.

Khaldiyeh Sub-System: (See plan and schematic profile on **Figures 7-3-3a and 7-3-4a** respectively). To stay in line with the guidelines of this alternative, a small sub-system serving Khaldiyeh and Thughrat Al Jubb reservoirs was produced. The demand projected even for the year 2030 is less than the production of the Zatary wells, so this system will be fed directly from Zatary Wells (source serving closest demand point). The wells pump water into the existing 600mm pipe; at the proposed New Khaldiyeh PS, water is re-pumped to Khaldiyeh Reservoir (at 700m), where a small pump station boosts the relatively small amount of water required to serve the demand of Thughrat Al Jubb Reservoir (at 750m).

Sumaya Sub-System: (See plan and schematic profile on **Figures 7-3-3a and 7-3-4a** respectively). This sub-system lies in the northern part of the Mafraq Governorate. As its name implies, it depends on Sumaya wells and its existing PS to serve its surrounding areas as can be seen in the layout. Sumaya wells and P.S. are the centre of those areas; it serves to the north Jabir and Swaylima reservoirs (in case of emergencies in the local sources), to the west Hamra reservoir, and to the east the Sarhan Reservoir, subsequently sending the remaining amounts of water to Zatary PS. This sub-system reduces the pipe length in comparison to the existing system where the water is pumped from Zatary PS to Um-El-Lulu, discharging on its way some water to these areas under consideration.

Upper-Aqeb – Mafraq Sub-System: (See plan and schematic profile on **Figures 7-3-3a and 7-3-4a** respectively). This sub-system, in the southern part of Mafraq governorate, depends on the Upper-Aqeb wells for its supply. "Upper-Aqeb" wells refer to Aqeb wells K114 to K101, which are the wells furthest east with the highest elevations, ranging between 760m and 797m above sea level. The well pumps deliver the water with enough head to reach Mafraq Reservoir (750m) -half way between Zatary and Um El-Lulu PS- thereby fulfilling the large

demand of 512m^3/hr of Mafraq city by making use of the static energy stored in the water coming out of these wells due to their high elevations.

The sub-system goes further to serve the lower parts of Mafraq (at elevations less than 820m) by pumping from the new suggested Mafraq PS (at the Mafraq Reservoir location). The reservoirs being served from Mafraq PS include Hayan, Moammariyyeh, Balama and Humaid reservoirs in addition to an emergency connection serving Zniyya and Mazraa reservoirs in case of failure of their local source, Zniyya Wells. By this sub-system we have avoided raising the water all the way up to Bwaydah PS (at 915m) and then releasing it as is the case in the existing system.

Um El-Lulu Sub-System: (See plan and schematic profile on **Figures 7-3-3c and 7-3-4c** respectively).Um El-Lulu PS (at Elevation 800m) pumps water to Um Naam reservoir in an existing 200mm pipeline. A new pipeline replacing the damaged existing 300mm pipeline is suggested to pump the water to the existing Bwaydah PS (915m), serving on the way the Bani Hasan reservoir. Bwaydah reservoir, though it does not have a demand of its own, is responsible for distributing water to areas in Mafraq, Bani Obaid and Jerash ROUs. Three separate branches to these areas come out of Bwaydah PS.

The first is a pressurized pipe making use of the existing 300mm pipeline. It serves the Qadam Reservoir and the Bwaydah and Rhab water towers.

The second branch is a pressurized 300mm pipeline serving Dajanyeh (at 942m), Musherfeh (at 950m) and parts of Bani Obaid ROU low reservoirs such as Balila (920m), No'aymeh Up (910m), No'aymeh Down (790m) and Kitim (865m). This reduces the total pipe length and friction losses compared to the existing system, where water is sent to Huson PS (680m) and then pumped back up.

The third branch coming out of the Bwaydah PS is a gravity pipeline, which branches out in two directions, both aiming to serve parts of Jerash at their ends. The first serves Hamama (at 880m) and then carries on to the new proposed Midawar PS and its associated reservoir (at 860m). This PS pumps the water to Nadira Reservoir at an elevation of 960m, which itself becomes responsible for serving by gravity the 'medium pressure zones' or the reservoirs of Jerash that are at elevations ranging between 810m and 890m. These include Majar, Deir Al-Liyyat, Ketta and Nahleh reservoirs. A couple of low but distant reservoirs - Burma Up (750m) and Burma Down (650m) - are also served by this branch. The other branch goes by gravity all the way from Bwaydah PS to the 'lower pressure zones' or lower elevations of Jerash ranging between 645m and 750m. These reservoirs include Jerash Up, Jerash Down and Souf Refugee Camp.

West Transmission

The main water sources in the west are:

- Tabaqat Fahel wells (Wells 1, 3, 6, 8, and spring 9) (675 m^3/h)
- Wadi Al Arab Wells (Wells 1, 2, 3, 4, 5, 7) (1525 m^3/h)
- Wehdeh Dam (4110 m^3/h)

Major local sources within the west transmission system include:

- Oyoon Al Hammam wells (325 m^3/h)

- Juhfiyya wells (171 m^3/h)
- Jaber wells (360 m^3/h)
- Hakama wells (199 m^3/h)
- Ain Al Tanour (112 m^3/h
- Zuqaq wells (172 m^3/h)

Schematic profiles in **Figures 7-3-4d, 7-3-4e, and 7-3-4f** show the new water subsystems considered in Alternative 1, consisting of three subsystems called Deir As Sina, Zubdat, and Wehdeh. The existing Tabaqat Fahel and Wadi Al Arab systems are included in **Figure 7-3-4d.** The Wadi Al Arab system receives water from the Tabaqat Fahel wells, which currently discharge at Elevation -72m and deliver 675 m^3/h by gravity to Wadi Al Arab PS0 at -190m through a 600mm existing pipe. A new set of booster pumps at PS0 is proposed to boost the Tabaqat Fahel water into the force main from PS0 to PS1; this will save about 100m in pumping head, compared to the existing system. The 600m3/h of water coming from the KAC is stored at the existing PS0 and then pumped to PS1 with Tabaqat Fahel water boosted at PS0 through the existing 600mm pipeline to PS1, where it is mixed with the water from the Wadi Al Arab Water Treatment Plant. The 100 m3/h of water currently taken from Manshiyeh wells is of poor quality, and is therefore directed to the KAC as a trade for an additional 100 m3/h of treated water from the new KAC WTP.

The Wadi Al Arab water treated in the existing treatment plant of PS1, and that by-passing it coming from PS0, are pumped together in the existing 800mm pipeline to Wadi Al-Arab PS2 and then to PS3, thereby making use of the existing pump stations and pipelines.

The proposed western sub-systems include the following:

Deir As Sina Subsystem: (See plan and schematic profile on **Figures 7-3-3d and 7-3-4d** respectively). This sub-system is fed from several new sets of pumps located at the existing Wadi Al Arab PS3. It serves regions in Al Koura and the western parts of Ajloun having elevations less than 870m. At present, Al Koura mainly depends on local sources such as Oyoon Al Hamam, whilst Ajloun is served by local wells and Ras Muneef Reservoir.

Four new branches will exit from Wadi Al Arab PS3, three of which are pumped; the fourth is a gravity line which will carry water to Mindeh reservoir which also has its own local source (Al Taybeh Wells).

The first pressurized line is directed towards Al Taybeh and Qumaym reservoir where a new PS is suggested to pump the water to Jamha, Soum and Jijin reservoirs. The second serves Deir As Sina reservoir. The third branch is directed towards the south of Al Koura to feed Jinnin which itself pumps to Ezimal, then repumped at Ezimal to Kufr Kifya Reservoir. The branch by-passes Jinnin and continues onward to serve Kufr Alma reservoir where a new pump station is suggested. Kufr Alma pump station also gets the remaining water from Oyoon Al Hamam local source through the Kufr Alma line (after feeding Tubneh and Deir Abi Said reservoirs) to feed Ashrafiyya and Kufr Awan reservoirs in Al Koura and then carries on to serve the western parts of Ajloun by two boosters, the first located at the Judyta PS – Al Wahadneh crossing, and the second at the Zuqaq PS3 location, thereby serving Al Hashimiyya, Deir Smadiyyeh and Kofranjeh Down reservoirs. A booster is responsible for serving Kofranjeh Up reservoir by taking water before it enters Kofranjeh Down.

Local sources that feed the Deir As Sina subsystem include:
Dougara well feeds Jijin reservoirs, Zuqaq spring (Zuqaq PS1) feeds Al Hashimiyya reservoir, Halawa well feeds Deir As Sina transmission pipeline, and Al Qantara spring feeds Kofranjeh Down reservoir.

The advantages of this sub-system are to make sure that Al Koura is receiving its total demand in 2030 from the transmission system, when the local sources are expected not to be sufficient. The water will no longer have to be pumped up to Ras Muneef (at 1190m) and then passed to lower elevations by gravity flow; the Deir As Sina system will save energy and reduce pipe length. Wadi Al Arab PS3 was selected as the water source for this subsystem, instead of Zubdat or Ras Muneef PS, for the same reasons: to reduce energy consumption and pipe length.

Zubdat Subsystem: (See plan and schematic profile on **Figures 7-3-3e, 7-3-4d and 7-3-4e** respectively). This sub-system includes the main pumping stations of Zubdat, Hofa and Samad. Zubdat PS and Zubdat reservoir are fed from three different directions. The first is from Wadi Al Arab PS3 which feeds on the way Kufr Youba reservoir. The second is the proposed PS2 of Wehdeh system, and the third comes from Hofa PS which is originally served by Zatary PS in the East. Zubdat PS itself in this alternative is only responsible for meeting the demands of its own distribution zone and that of Beit Yafa reservoir which it serves by pumping.

Hofa PS, which lies on the boundary between the eastern and western systems, feeds areas in Irbid Governorate as follows:

- By gravity, it serves three reservoirs: Ham, Aydun and Sarih in three different lines.
- Two pressurized pipelines feed the Juhfiyya, Habka and Huson reservoirs.
- Another pressurized main serves Samad PS.

Samad PS starts off its own network as follows:

- Two lines by gravity serve Al Mazar and Shatana reservoirs.
- Three pressurized lines serve Deir Al Birak, A'seem and Ras Muneef reservoirs.

A'seem reservoir receives 495m3/h flow from Samad PS, and sends by gravity to the Ajloun reservoirs: E'rhaba, Sina'ar, Rasoun, Ishtafina, Ajloun, Ain Jana, Anjarah Down, Mazraat Eshkarah, Jabal Al Akhdar and Hooneh reservoirs, some of which are also partly served by local sources.

A few reservoirs in the area are fed totally from local sources. These include E'nba, Ibya and Deir Yousef reservoirs, which are fed by the Juhfiyya local source. Similarly, Arjan and Ba'oon are served from Ain Al Tanour spring.

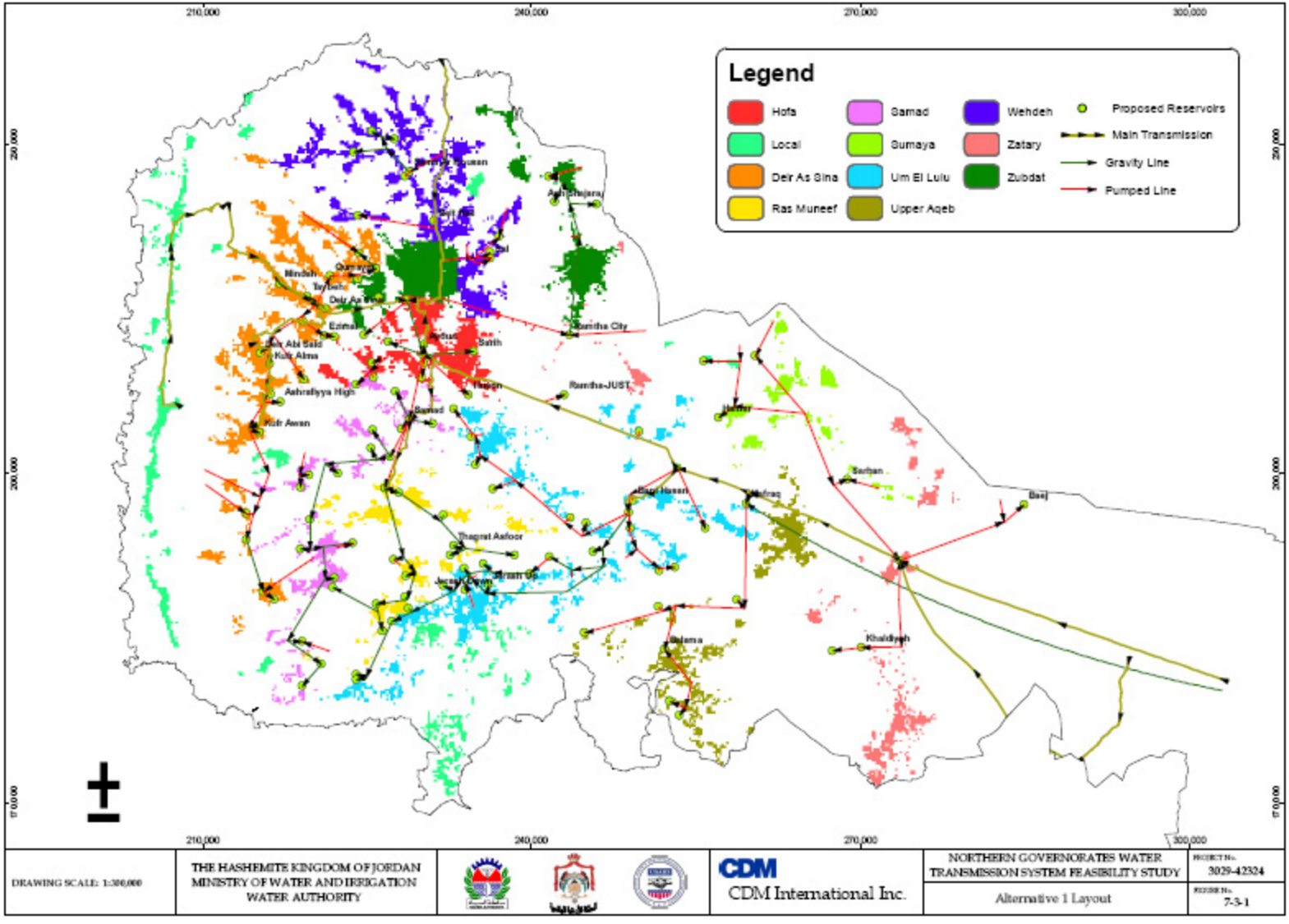
Ras Muneef reservoir, similarly, becomes responsible for its own network. It serves by gravity the high areas of Jerash through the Souf Up, Souf Down, Raymun and Sakib reservoirs. The latter reservoir serves by gravity Husayniyyat and Anjarah Up reservoirs in Ajloun.

A separate branch coming out of Ras Muneef reservoir is responsible for serving Sakhra reservoir which itself feeds Kufr Khal, Muqbla, Thagrat Asfoor and Qafqafa reservoirs in Jerash governorate.

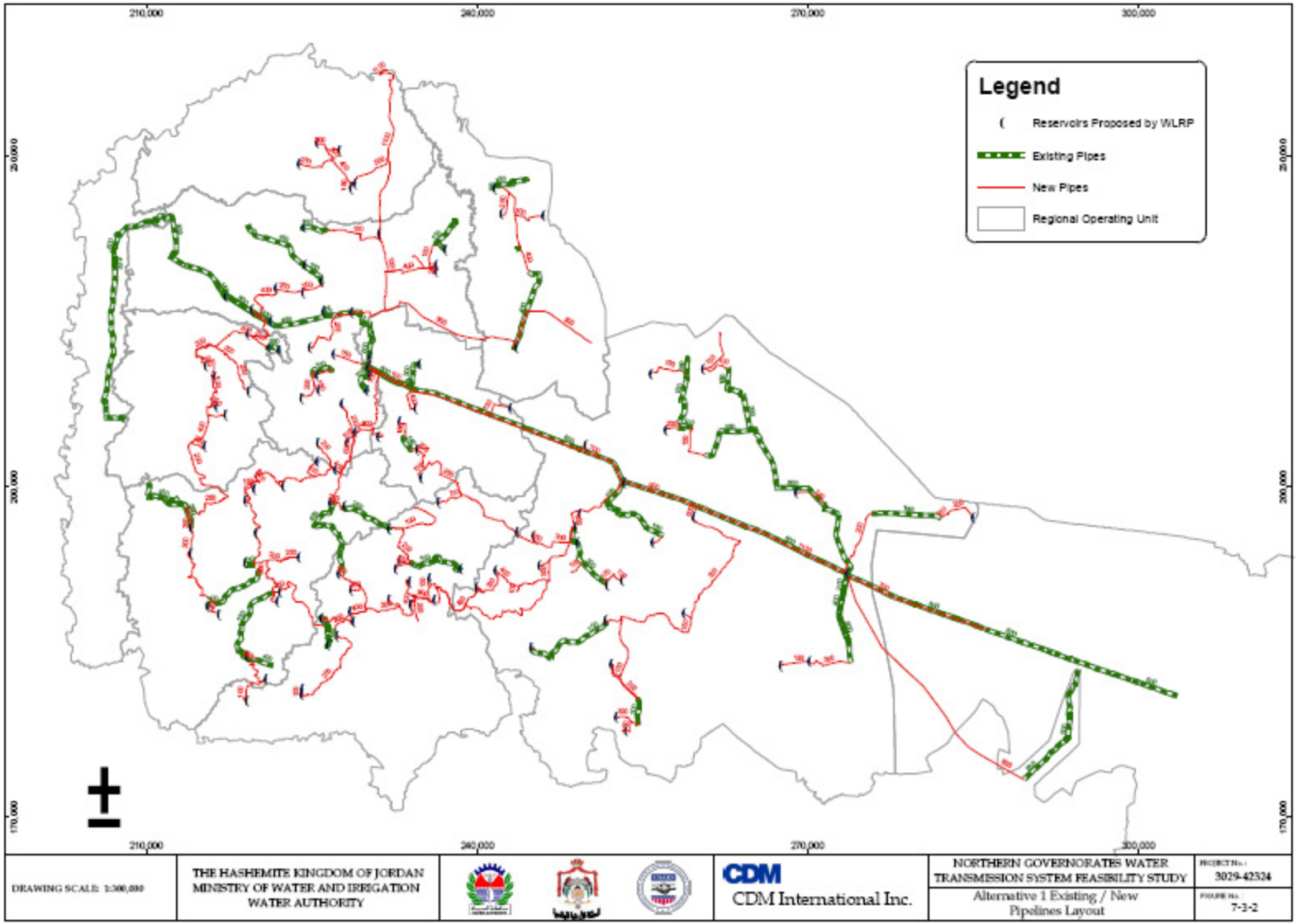
Wehdeh Subsystem: (See plan and schematic profile on **Figures 7-3-3f and 7-3-4f** respectively). This sub-system is dependent on the flow expected from the Wehdeh Dam. A pipeline for conveying this flow from the Dam, a treatment plant, and three pump stations (named Wehdeh PS0, PS1 and PS2) are to be constructed. For a detailed description of the Wehdeh Dam proposed pipelines and pumping stations refer to Appendix K.

Wehdeh PS2 pumps the water in two directions, to Zubdat Reservoir and to Bani Kinana. The pipeline to Zubdat reservoir branches out in three directions: The first towards Beit Ras and Foua'ra; the second to Sal, Sal WT, and Al Mughayyir reservoir (which is also served by the Rahoub and Hakama wells); and the third branch (before the pipeline reaches its destination at Zubdat reservoir) supplies Ramtha City and the Al Toura, Ash Shajara, and Amrawa/Thunayba reservoirs. Local sources also feed this area such as Jabir wells, Al Mahasi and Al Toura wells.

Wehdeh PS2 also pumps water in the direction of Bani Kinana. It reaches Sama Ar Rousan reservoir, where water is pumped to Safouk tower in one pipeline, and sent by gravity to the reservoirs of Durama, Hartha and Saham in another pipeline.



DRAWING SCALE: 1:300,000	THE HASHEMITE KINGDOM OF JORDAN MINISTRY OF WATER AND IRRIGATION WATER AUTHORITY		CDM CDM International Inc.	NORTHERN GOVERNORATES WATER TRANSMISSION SYSTEM FEASIBILITY STUDY	PROJECT No. 3029-42324
				Alternative 1 Layout	REVISION No. 7-3-1



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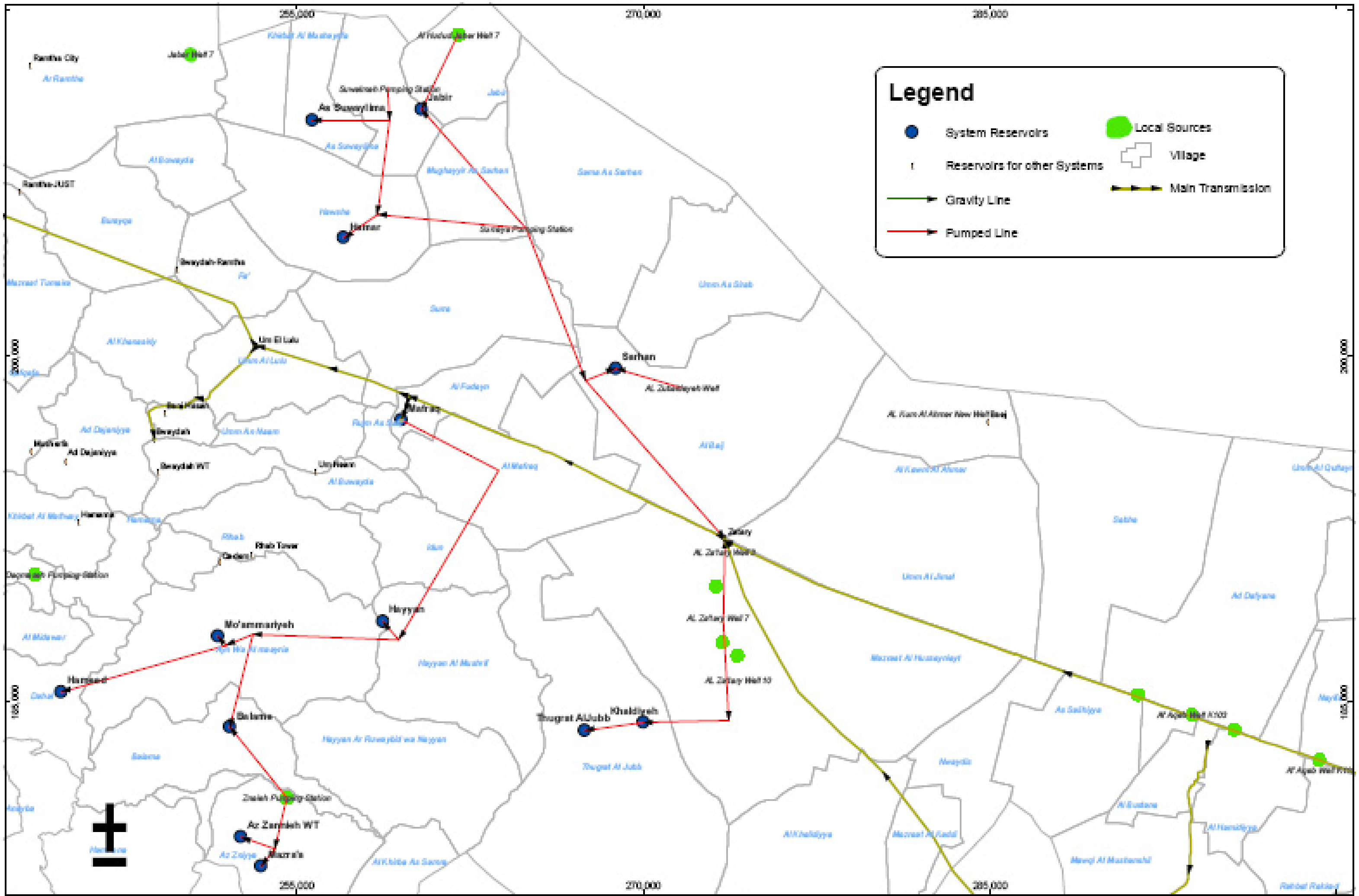

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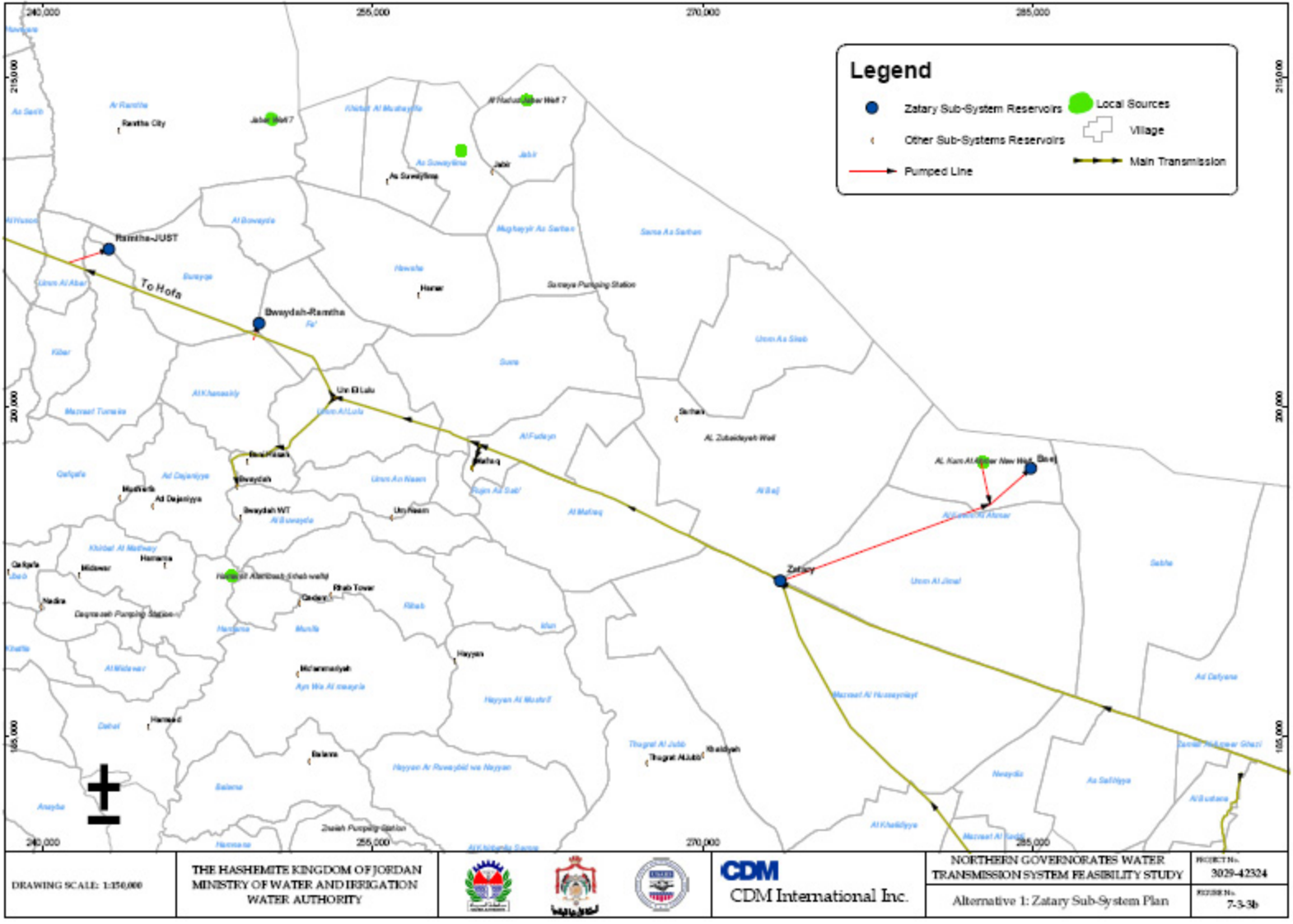

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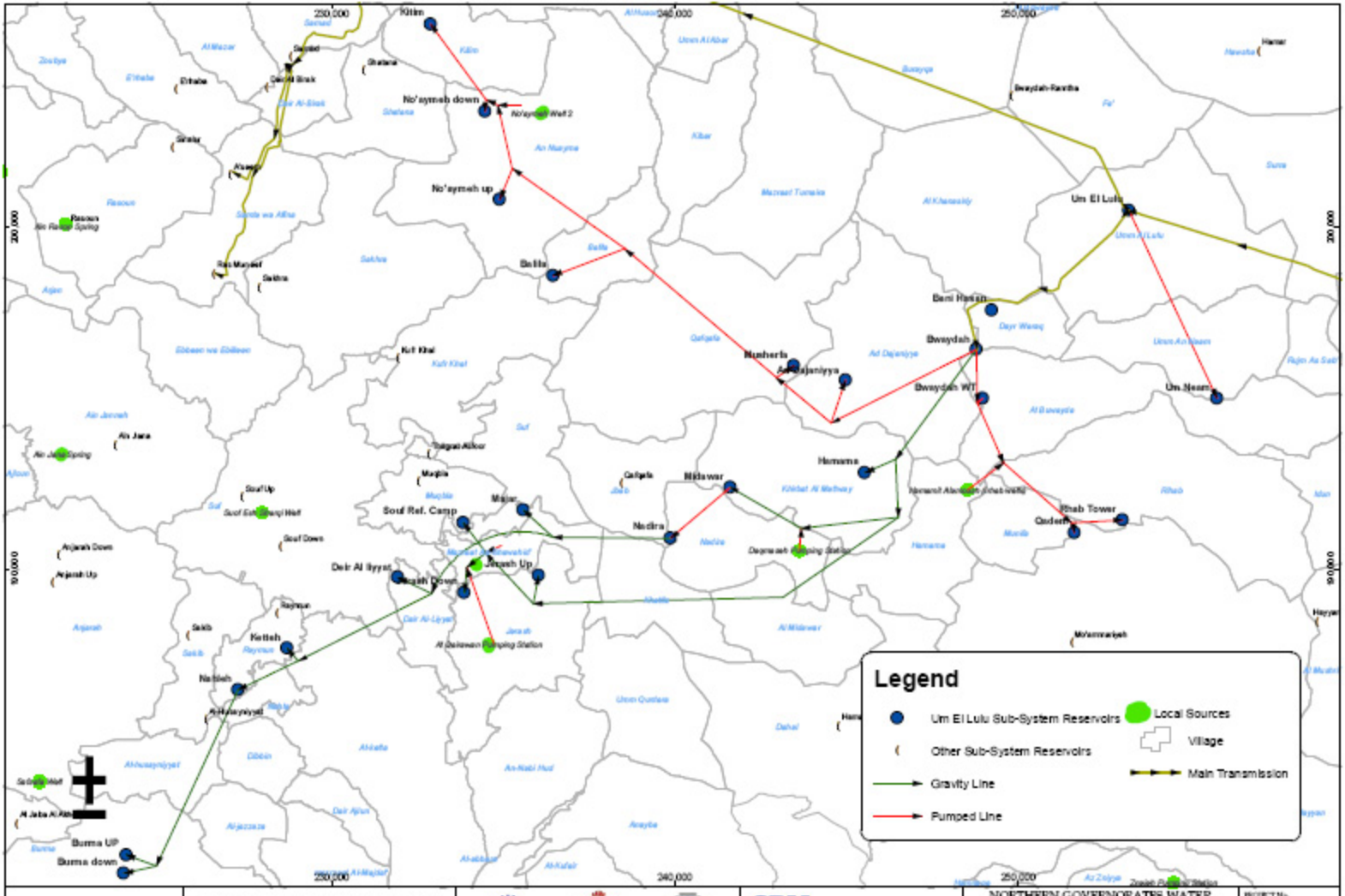
			Alternative 1: Zatary Sub-System Plan	FIGURE No. 7-3-3b


Legend
Um El Lulu Sub-System Reservoirs
Other Sub-System Reservoirs
Gravity Line
Pumped Line
Local Sources
Village
Main Transmission
Kilim
No'aymeh down
No'aymeh up
Balila
Um El Lulu
Beni Hasan
Bwaydah
Bwaydah WT
Um Neam
Numeria
Hamama
Nidawar
Nadira
Khab Tower
Soul Ref. Camp
Jeyash Up
Jeyash Down
Deir Al Ayyat
Ketteh
Nabieh
Burma UP
Burma down
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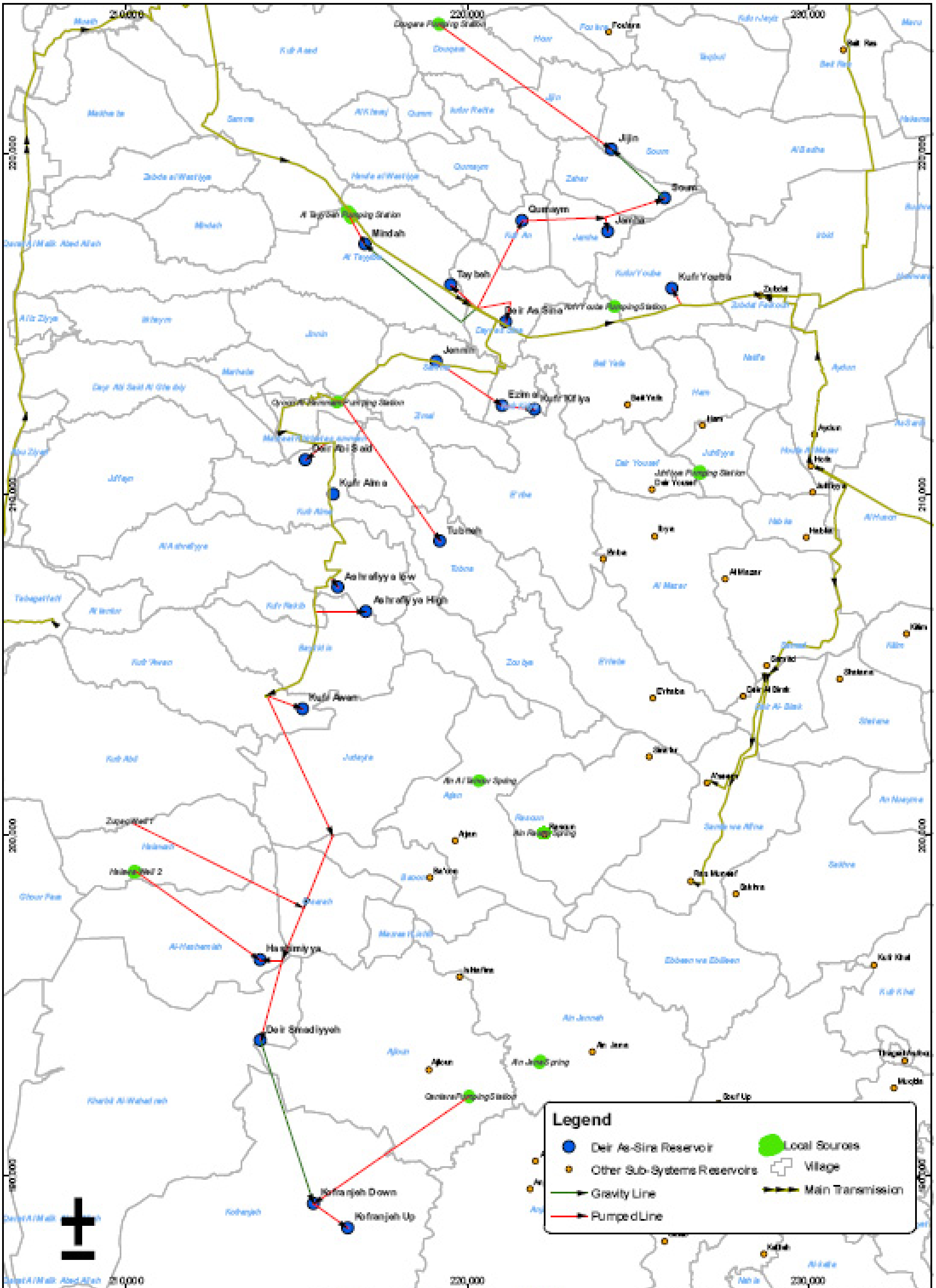
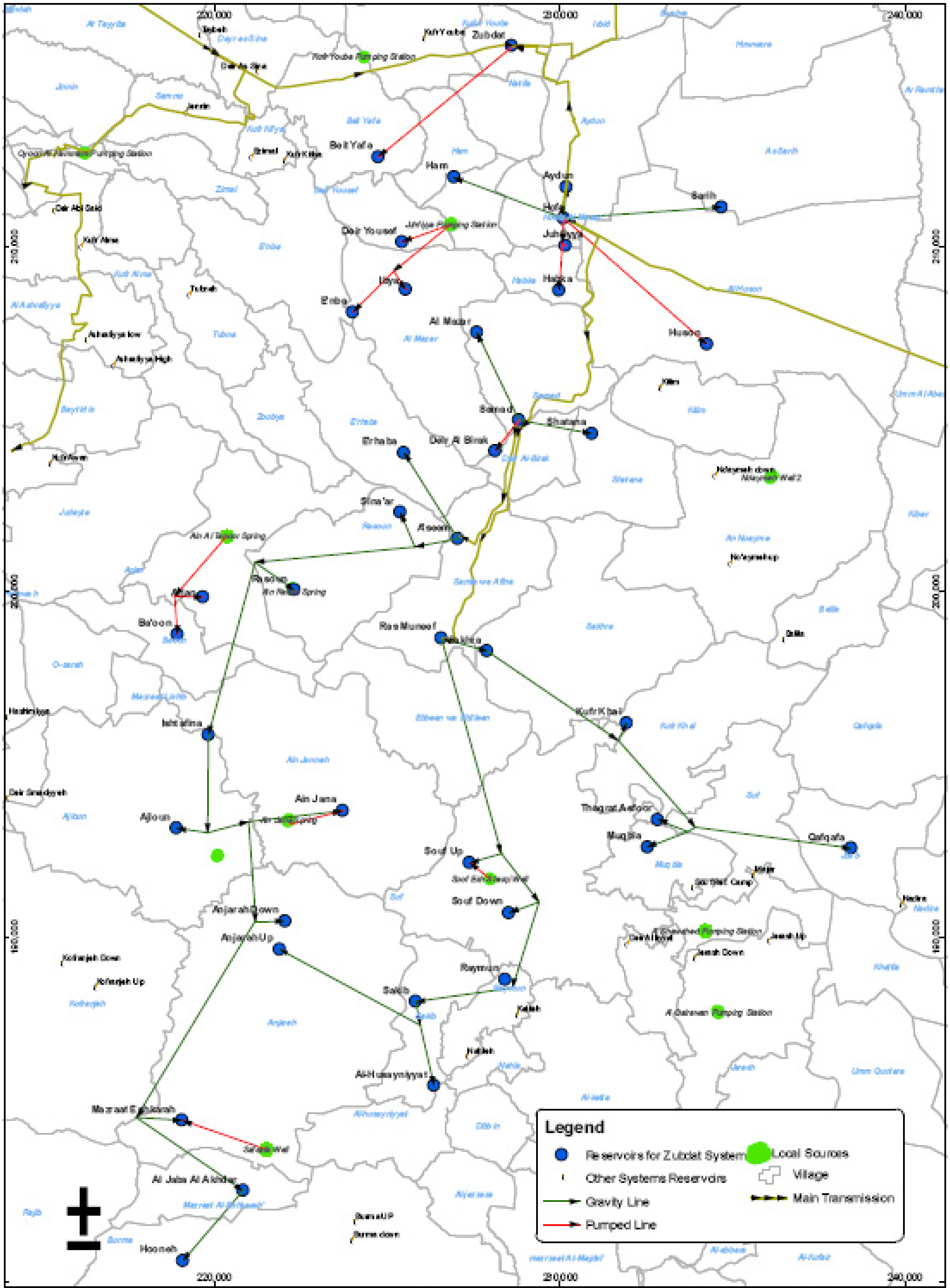
WATER AUTHORITY
CDM International Inc.
NORTHERN GOVERNORATES WATER TRANSMISSION SYSTEM FEASIBILITY STUDY
PROJECT No. 3029-42324
Alternative 1: Um El-Lulu Sub-System Plan
FIGURE No. 7-3-3c



DRAWING SCALE 1:[illegible]	THE HASHEMITE KINGDOM OF JORDAN MINISTRY OF WATER AND IRRIGATION WATER AUTHORITY	CDM International Inc.	NORTHERN GOVERNORATES WATER TRANSMISSION SYSTEM FEASIBILITY STUDY Alternative 1: Deir As Sina Sub-System Plan



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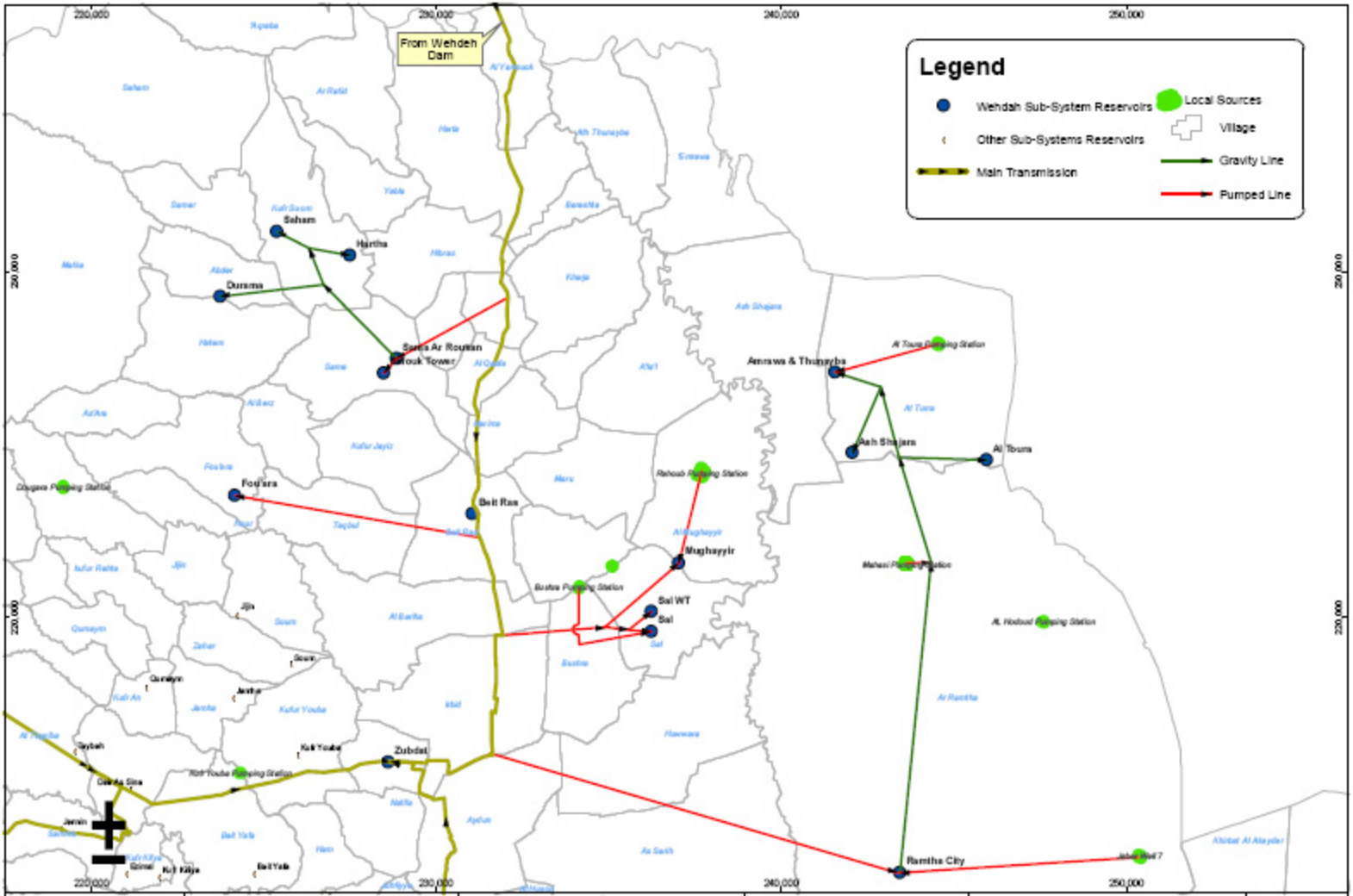
			Alternative 1: Zubdat Sub-System Plan	FIGURE No. 7.3-3a



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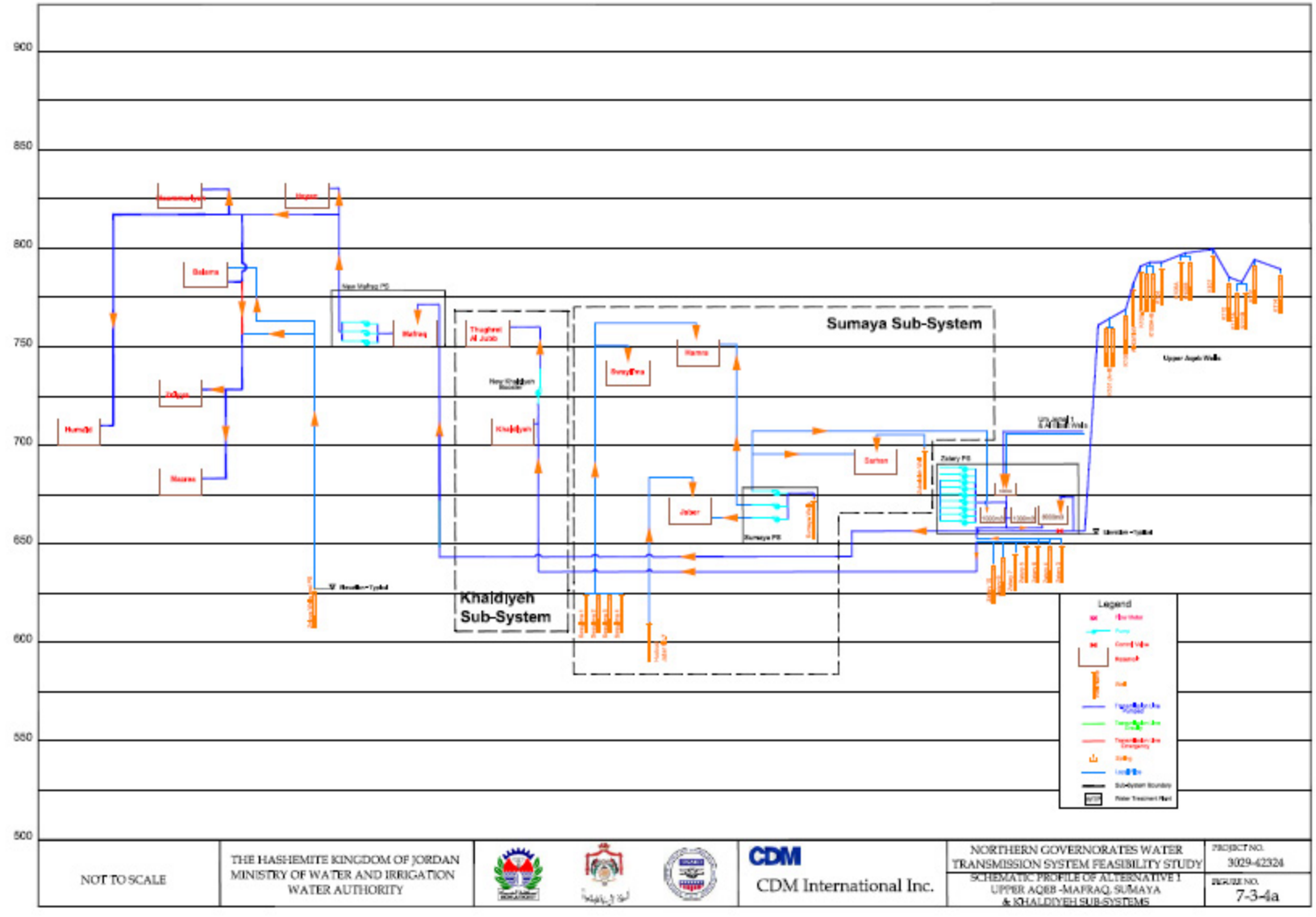
Alternative 1: Wehdeh Sub-System Plan

PROJECT No. 3029-42324

FIGURE No. 7-3-3f



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NORTHERN GOVERNORATES WATER TRANSMISSION SYSTEM FEASIBILITY STUDY

SCHEMATIC PROFILE OF ALTERNATIVE I
UPPER AQ68 -MAFRAQ, SUMAYA
& KHALDIYEH SUB-SYSTEMS

PROJECT NO. 3029-42324

FIGURE NO. 7-3-4a