INNOVATIVE SOLUTIONS FOR WATER WARS IN ISRAEL, JORDAN AND THE PALESTINIAN AUTHORITY

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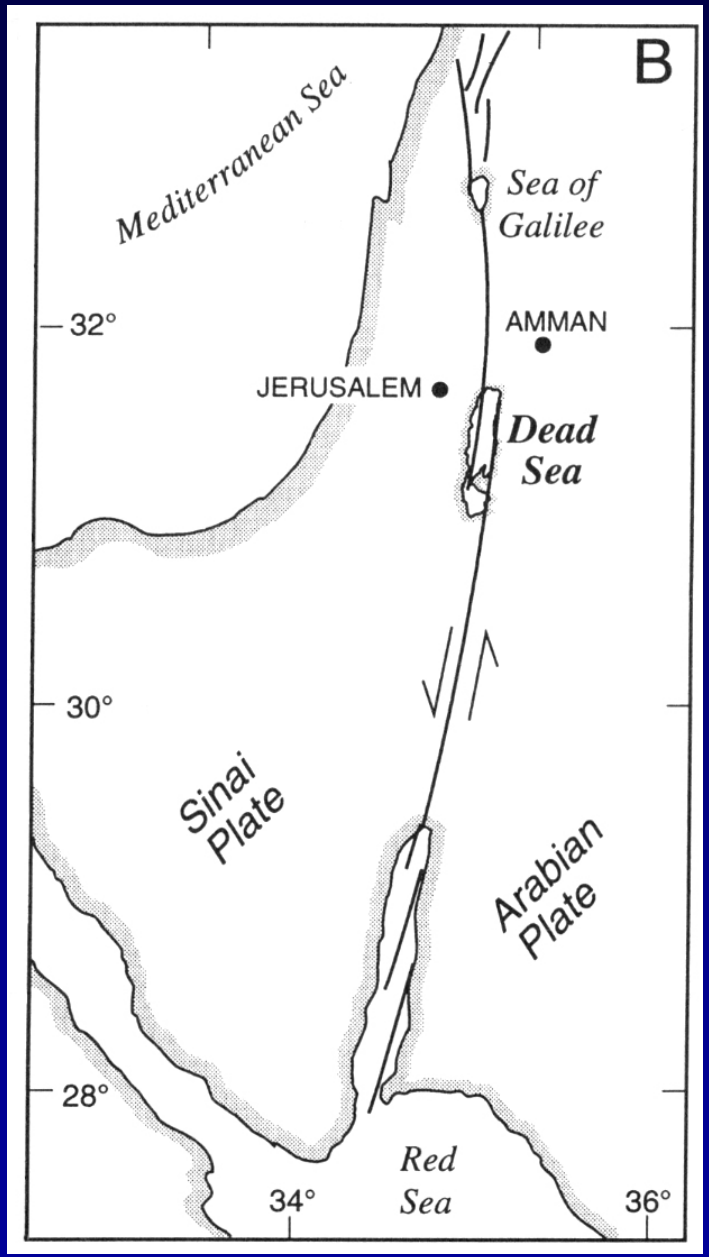
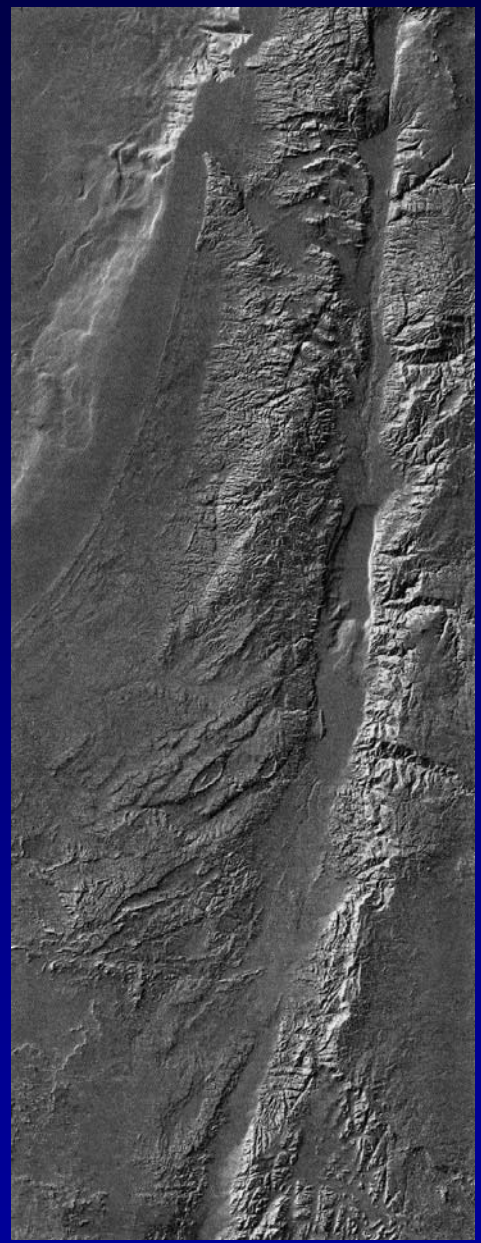


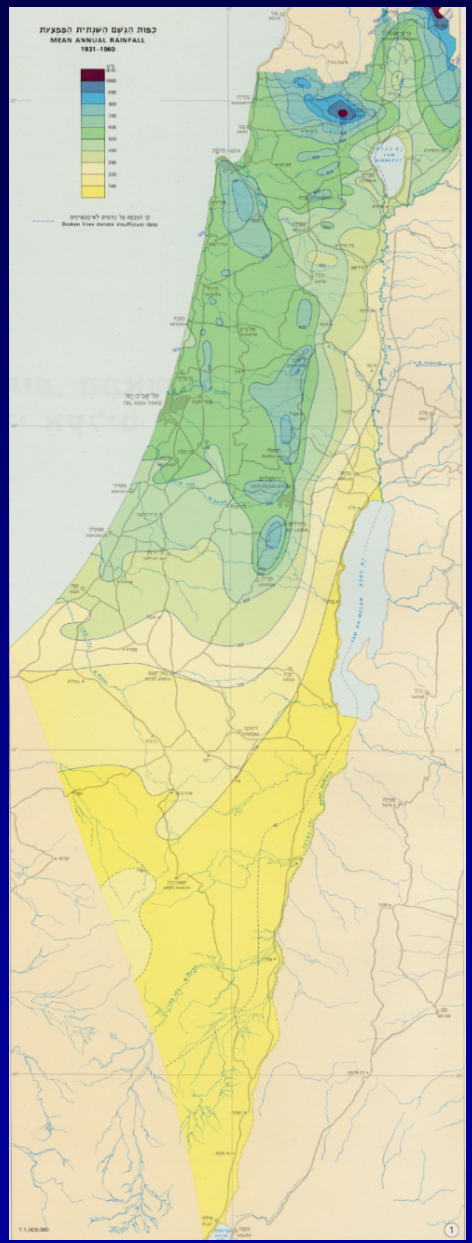
CROSSROADS BETWEEN TWO CONTINENTS

The Jordan River Valley/Dead Sea Transform lies between the Arabian and Sinai tectonic plates, at the north end of the East African-Syrian rift



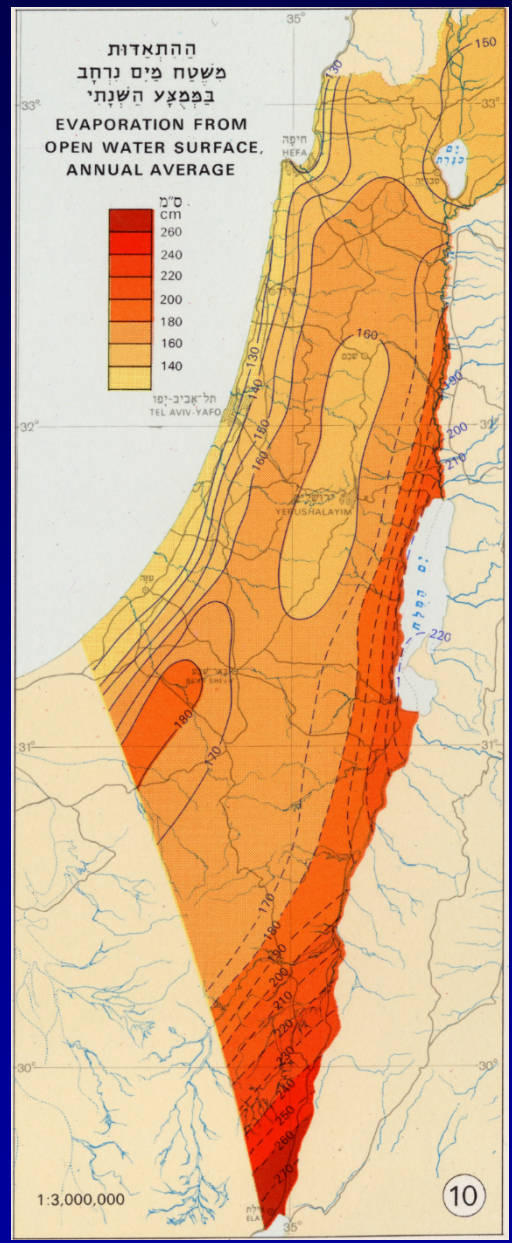
ISRAEL, JORDAN, SYRIA, LEBANON, EGYPT and the PALESTINIAN AUTHORITY are linked by <u>COMMON AQUIFERS</u> and <u>WATERSHEDS</u>

ANNUAL RAINFALL vs EVAPORATION



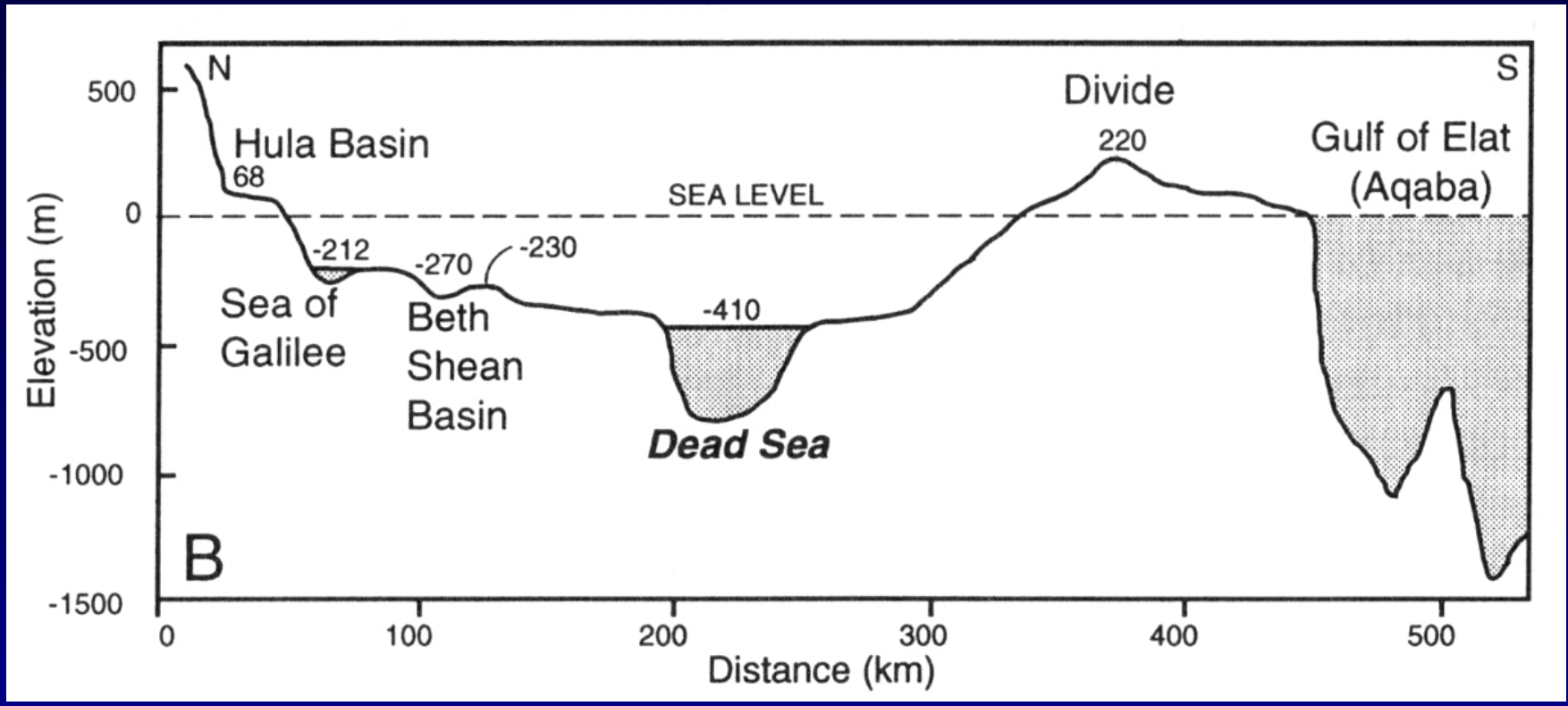
abundant water in the north

little rain and lots of heat in the south



JORDAN RIVER

- Only significant river in the Holy Land is the Jordan River, born on the slopes of Mt. Hermon (el. 9232 ft).
- Three principal tributaries meet in Hula Valley, two within the Golan Heights secured by Israel from Syria in June 1967 War
- Average annual flow of about 1.5 million acre-feet



- The **Jordan River** follows the East Africa-Syrian Rift, flowing southward into the Dead Sea transform, now 415 m (1,362 ft) below sea level
- The dry **Wadi Arava** flows to the Dead Sea from a drainage divide 220 m (722 ft) above sea level

SEA OF GALILEE

- The **Sea of Galilee** lies in a down-faulted graben, about 700 feet below sea level
- It covers an area of 64 square miles
- Less than 145 ft deep
- Contains 3,257,690 acre-feet of fresh water (about 70% capacity of California's Lake Shasta)

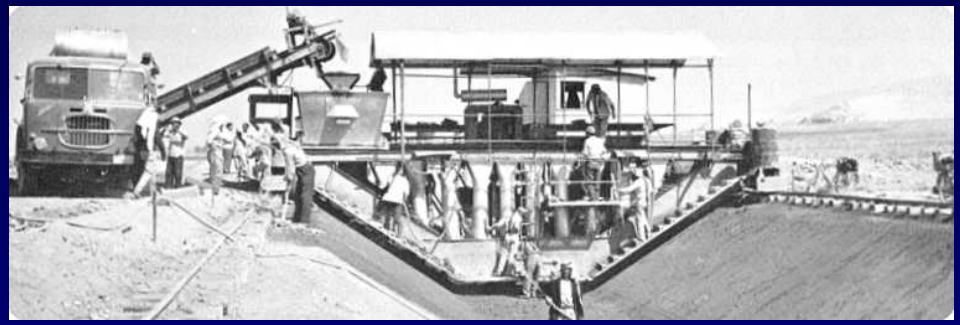
ISRAEL'S NATIONAL RESERVOIR

- The **Sea of Galilee** [Sea of Kineret] covers 64 mi^2
- The Jordan River supplies about 75% of Jordan's and 30% of Israel's annual water consumption

THE JOHNSTON WATER PLAN

- In 1953-55 U.S. Special Envoy to the Middle East Eric Johnston hammered out a cooperative agreement for sharing the Jordan River system between Jordan, Lebanon, Syria and Israel.
- The shares of each country were based on how much irrigable land it had, so Lebanon and Syria got the least, even though those two countries produce the most water.
- The agreement was honored for 12 years, from July 1955 until the June 1967 Arab-Israeli War

JORDAN'S EAST GOHR CANAL



- Between 1957-1961 the Jordanians built their 110-km long East Ghor Canal
- This brings water from the Sea of Galilee to the east side of the Jordan River Valley
- Recently renamed the King Abdullah Canal

ISRAEL'S NATIONAL WATER CARRIER

- National Water Carrier canal built by Israelis, beginning in 1958.
- Water lifted 372 m from Sea of Galilee and conveyed southward, into populous areas along the coast and the Negev Desert
- Extended and connected to numerous pipelines since 1964, using intermediary pump stations
- 80% of conveyed water is used for agriculture

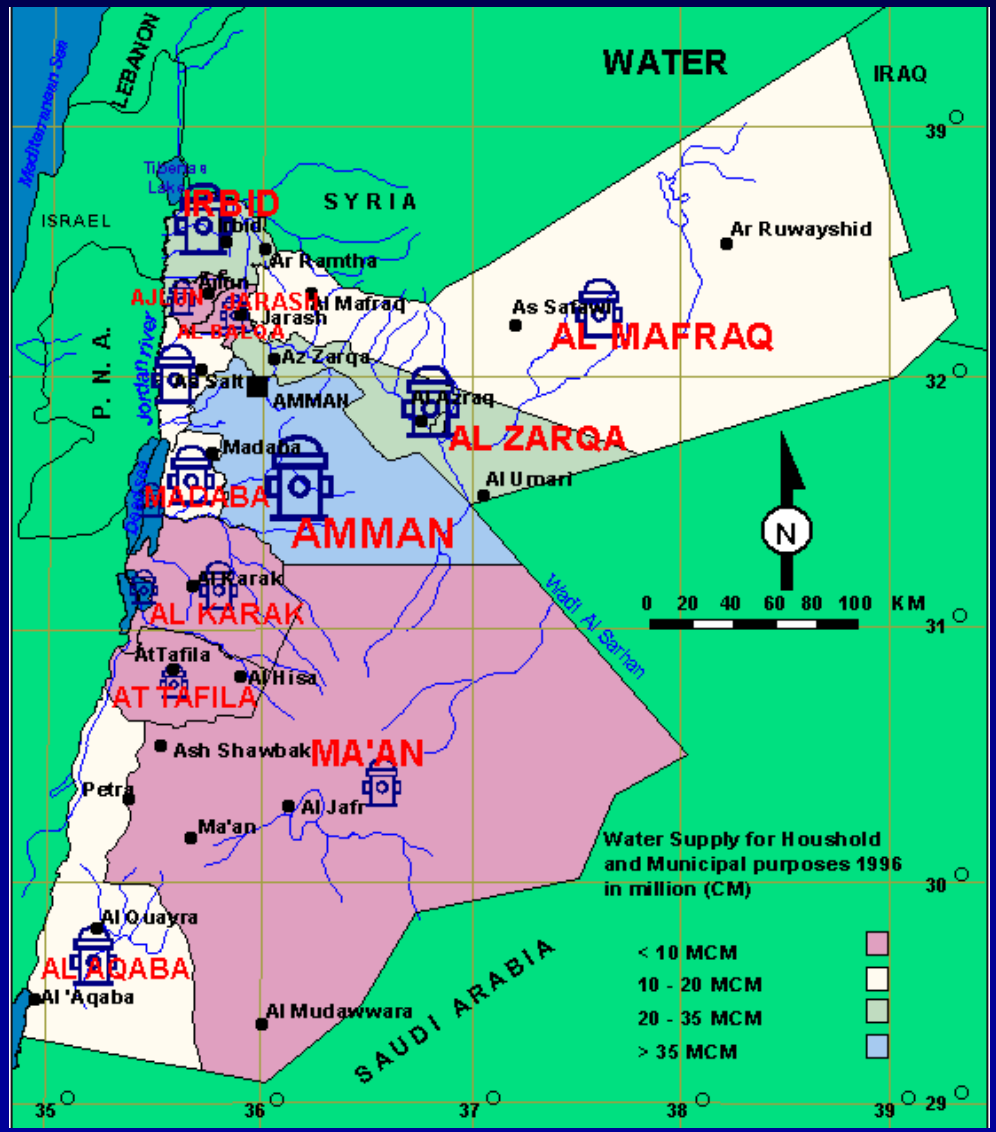
MIDDLE EAST IMPASS 1967-1994

- The World Bank will **not** fund water resources projects unless **all entities** in the watershed agree on a protocol spelling out management responsibilities and apportionment for such development.

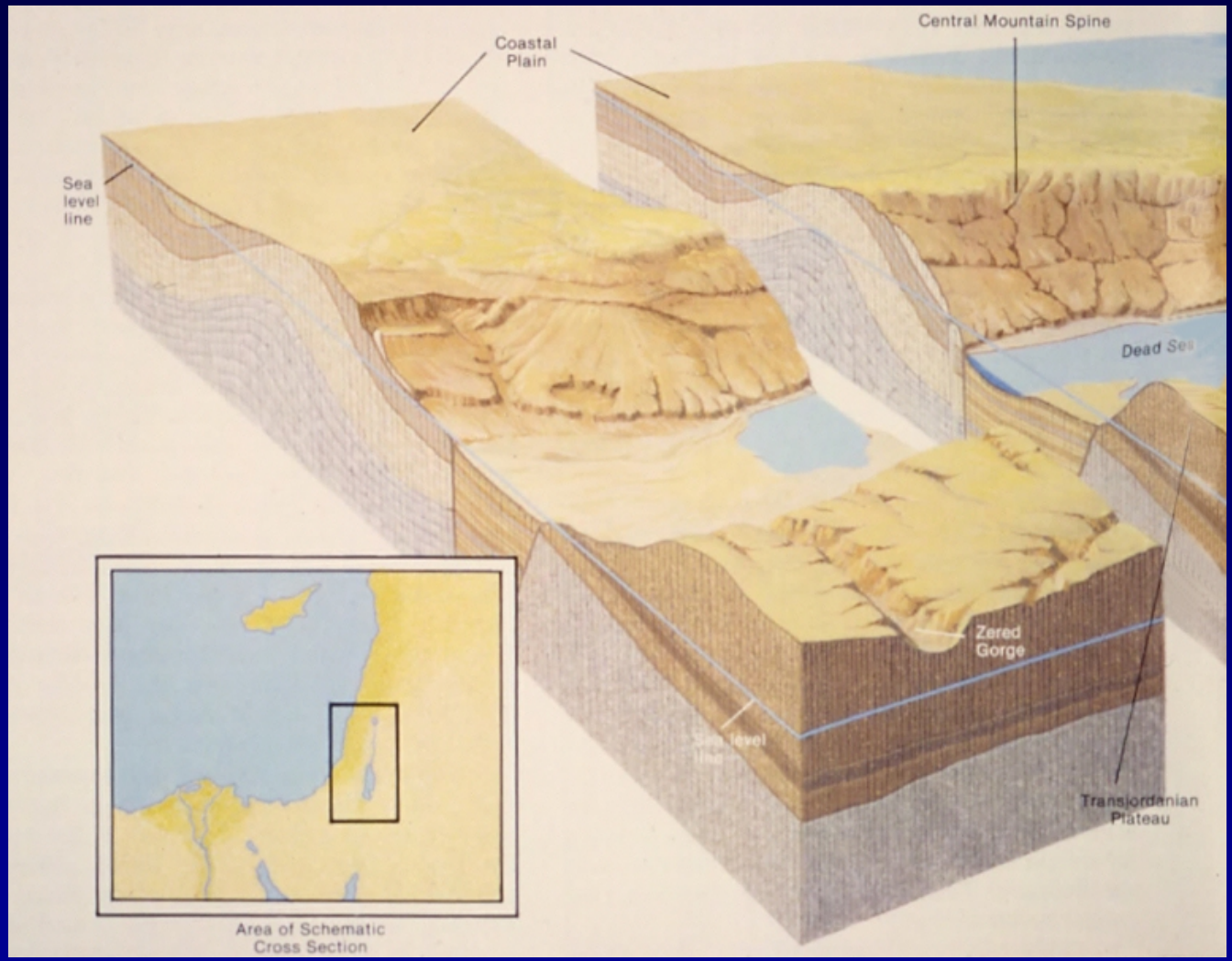
Forging cooperation between stake holders

- The Jordanians have been attempting to build the al-Wahda Dam on the upper Yarmouk River since 1955. Israel has been able to withhold cooperation because it controls 3% of the watershed.
- In 1999 Jordon and Syria agreed to build the dam using the Arab Fund for Economic and Social Development and the Islamic Development Bank.
- A condition is 40% of the contract monies must go to Syrian and Jordanian subcontractors. As a consequence, the project has stalled.

JORDAN'S WATER USEAGE

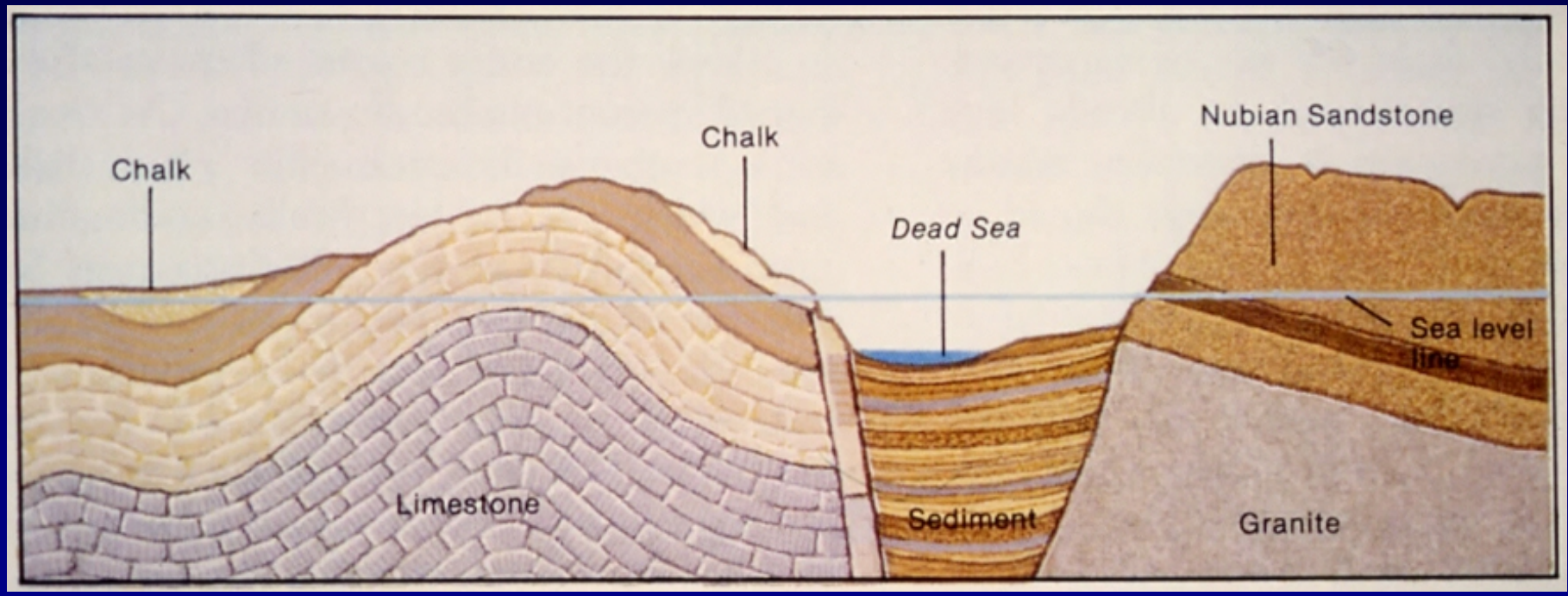


- 1996 water usage in Jordan in millions of cubic meters by district
- The Amman area consumes 35 million cubic meters of water annually, increasing 3% per annum
- The PNA population is increasing 4% annually

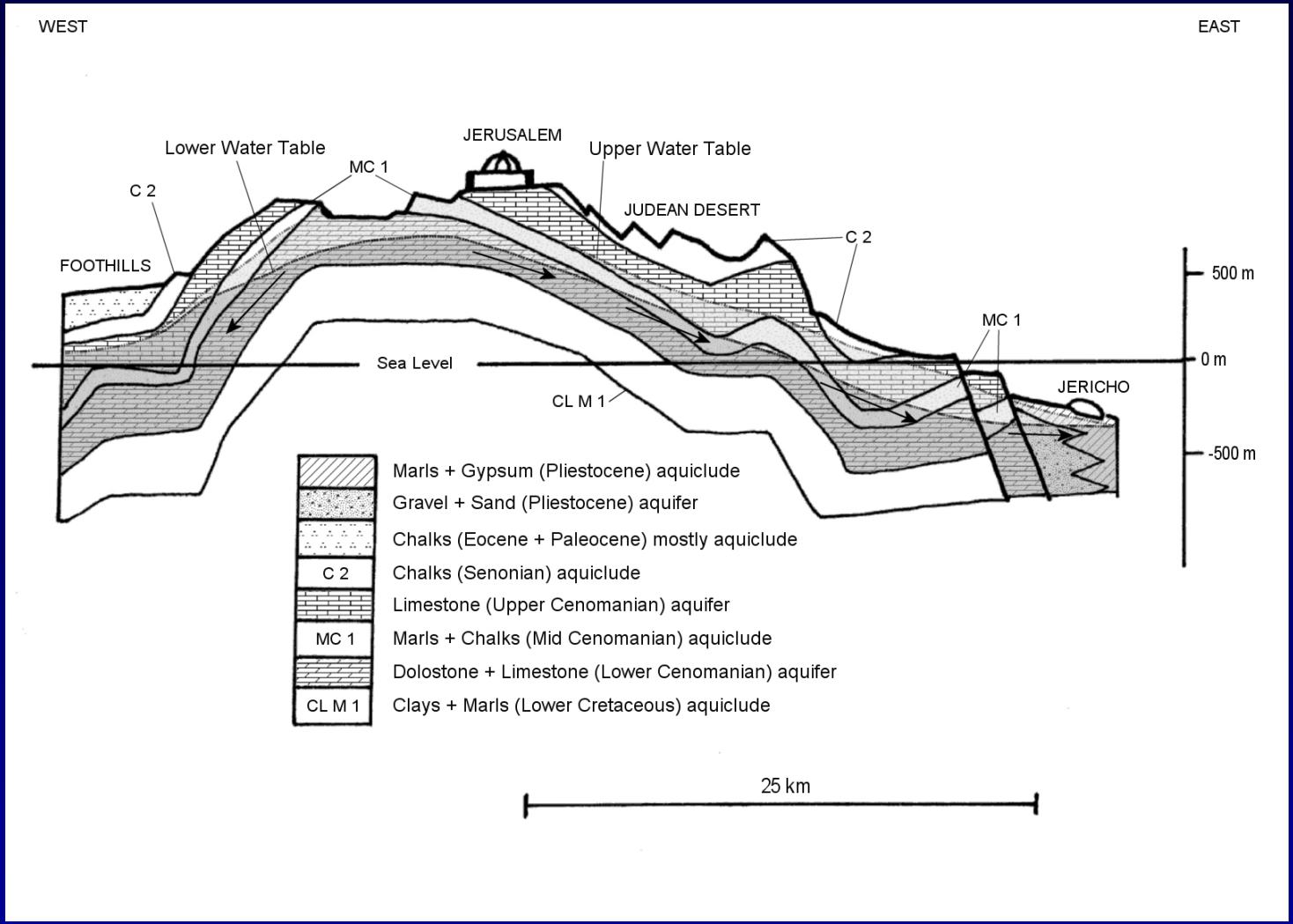


- **Block diagram of Israel, West Bank and Jordan showing the coastal plain, central mountain range, Dead Sea transform and the Transjordan Plateau.**

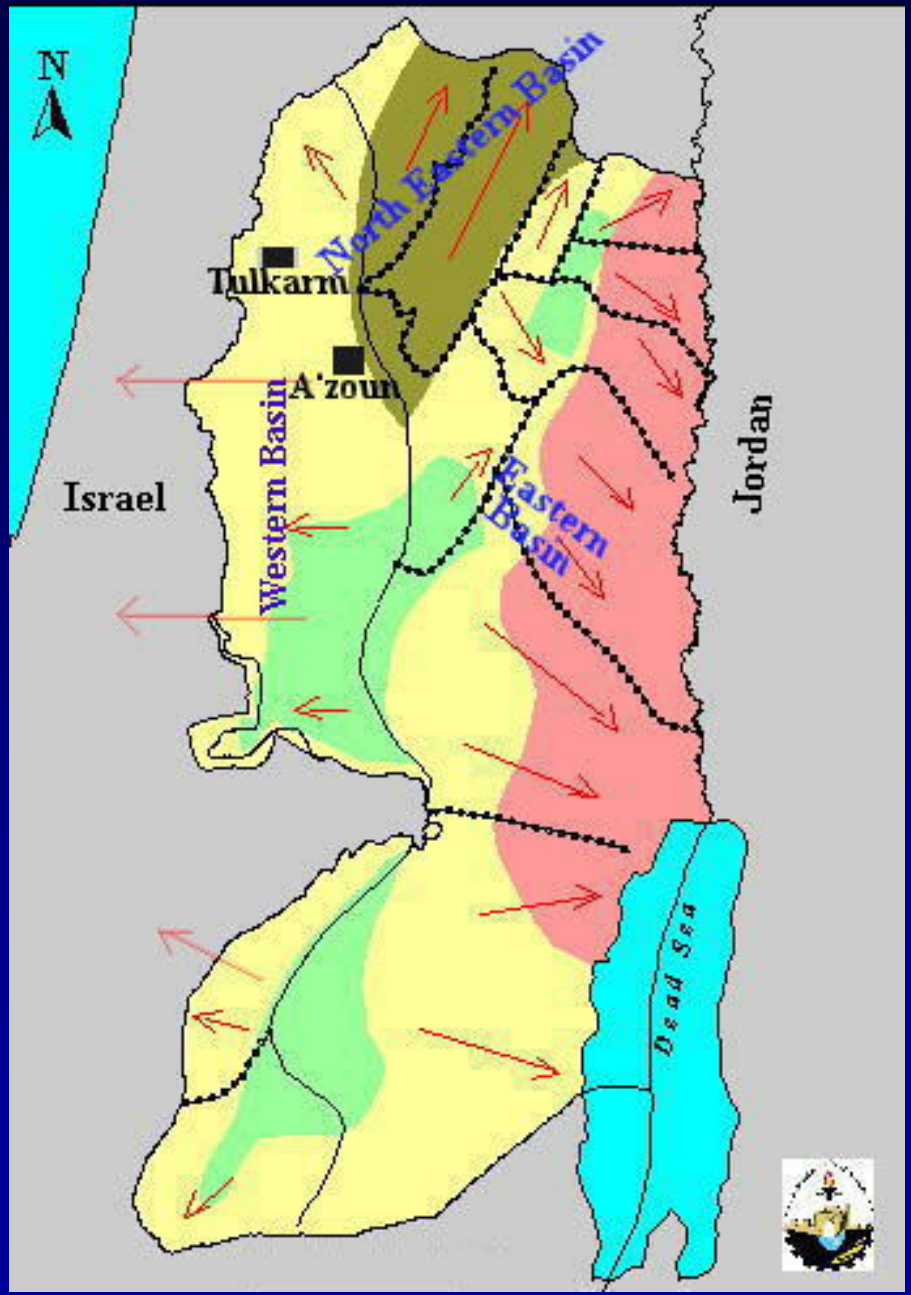
GEOLOGIC CROSS SECTION



- Cross section through Israel, the West Bank (PNA) and Jordan, described by the tectonic boundary between the Sinai and Arabian Plates along the Syrian-African Rift. This is the deepest graben on the Earth



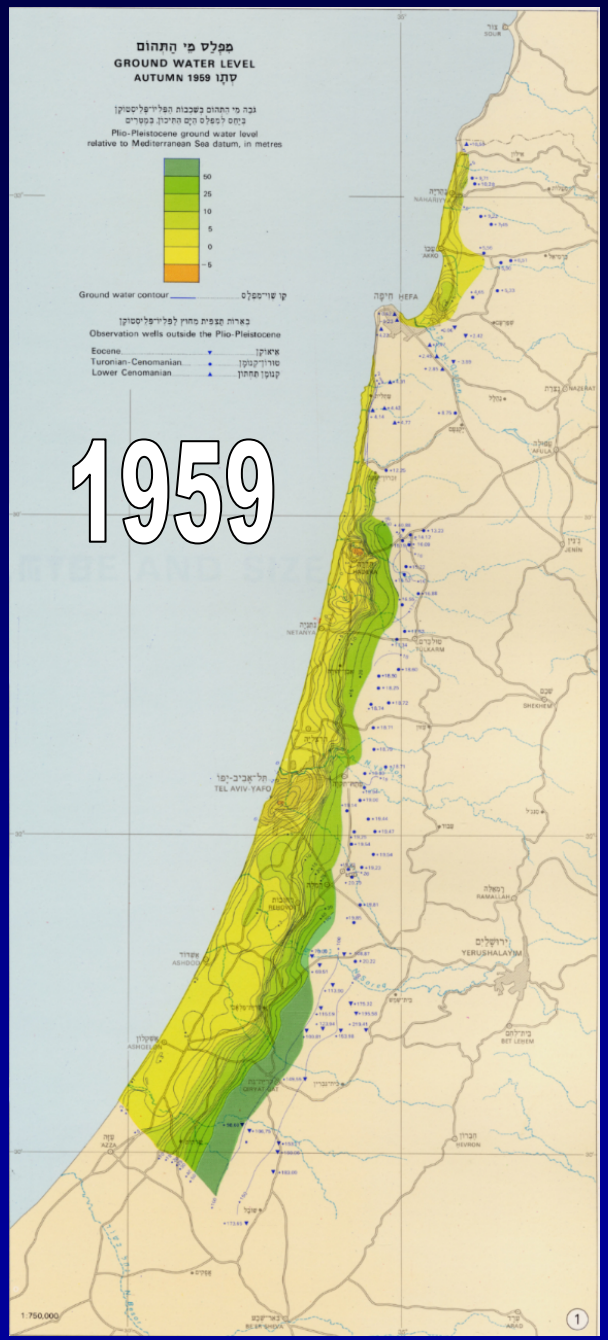
- Section through the **Mountain Aquifer** in central Israel. This aquifer has been steadily depleted since 1949. The Israelis have not been able to recharge this aquifer as easily as the units lying by the Mediterranean Coast.



ISRAEL'S MOUNTAIN AQUIFERS

- Aquifers are formed in fractured limestones along an major anticlinal axis parallel to the Dead Sea Transform
- Groundwater flows away from the axis of the anticline (red arrows)
- Management boundaries for the mountain aquifers area shown at left

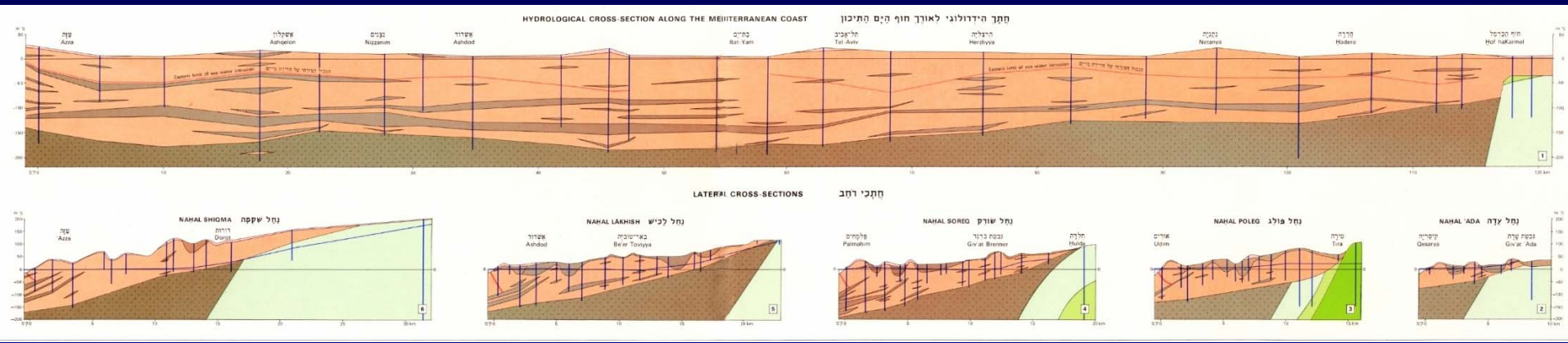
ISRAEL'S COASTAL AQUIFER



Plot at left shows gwt above sea level in 1959

Plot at right shows levels dropped markedly by 1973 due to overdrafting

MANAGING ISRAEL'S COASTAL AQUIFER

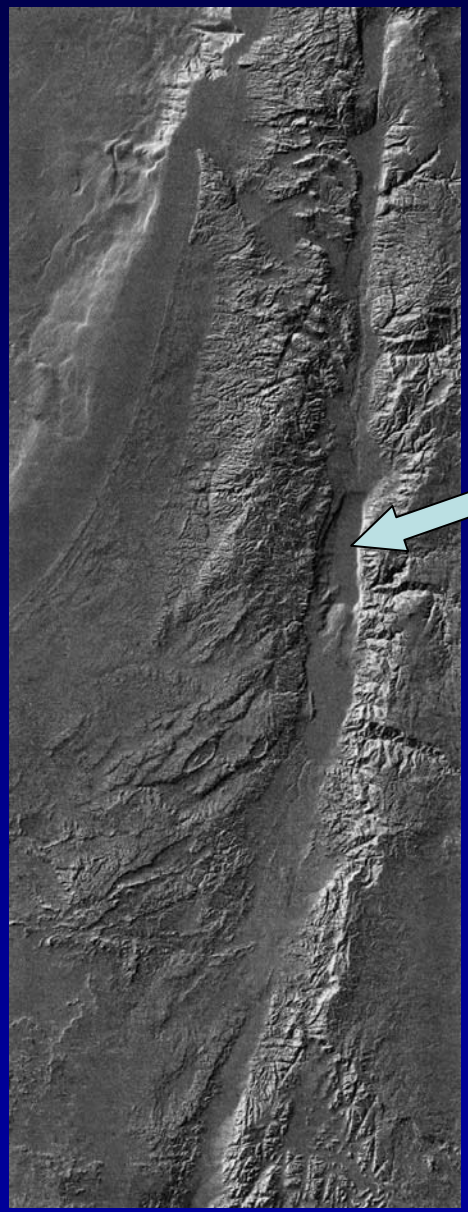


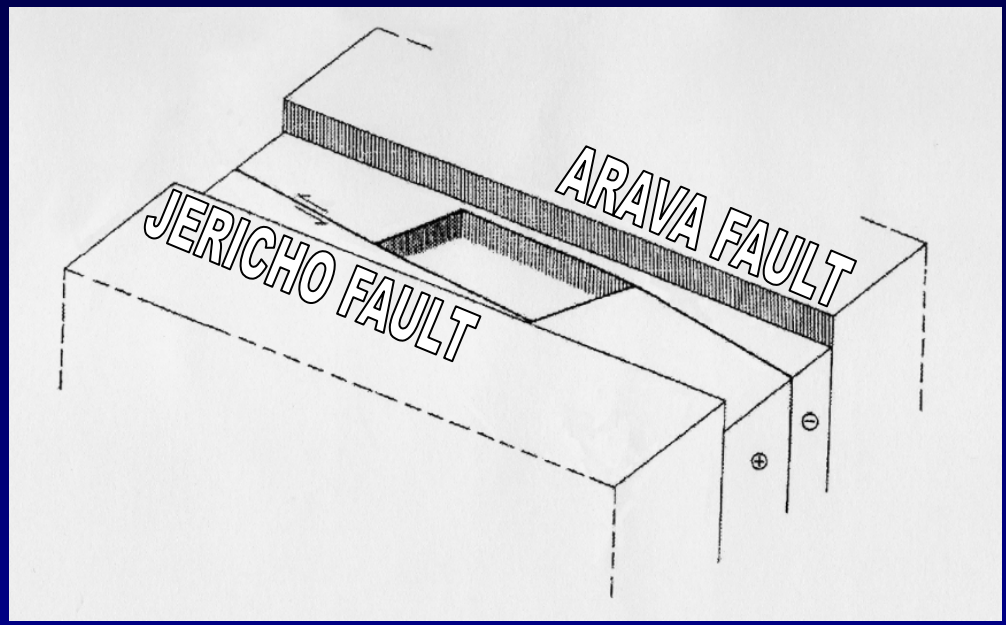
- The coastal aquifer has been depleted, allowing salt water seawater intrusion along the coast.
- The coastal aquifer has also been polluted by pesticides in the Gaza Strip
- The Israelis are using brackish water to recharge the southern limits of this aquifer

DESALINATION PLANTS

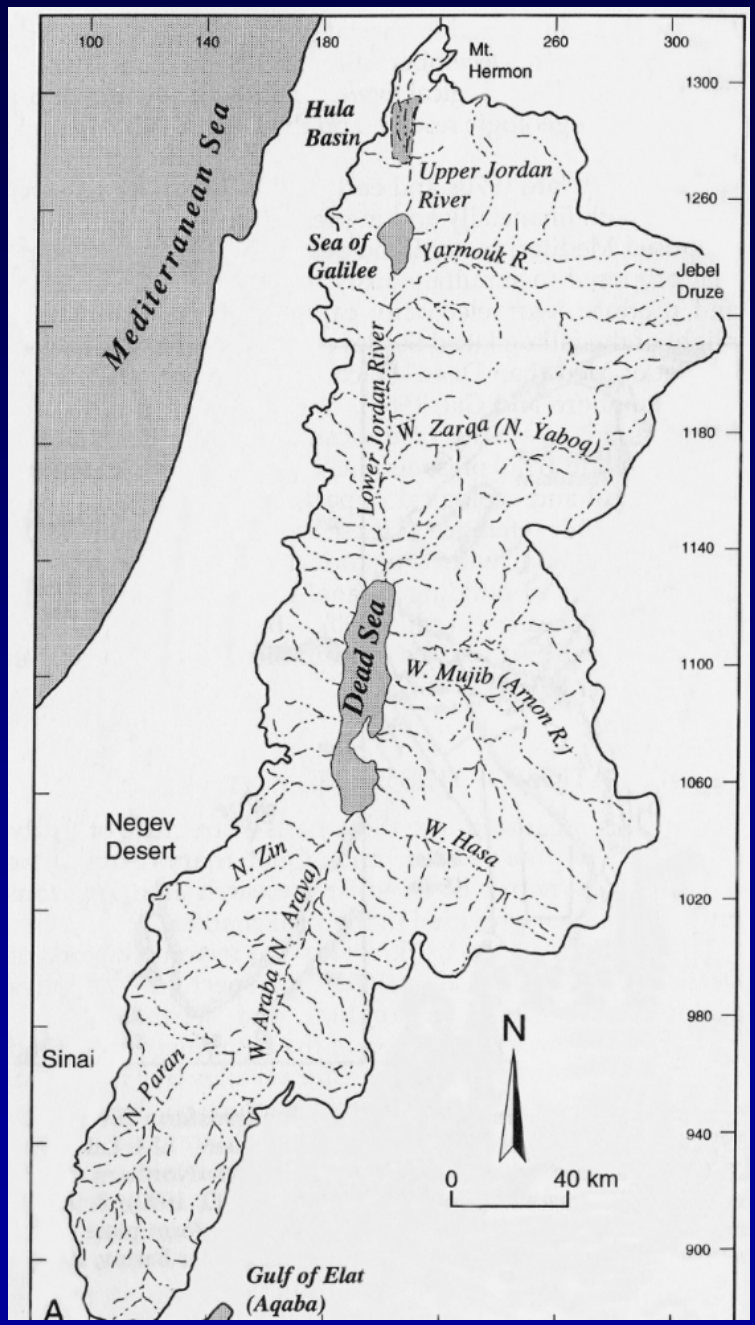
- By 2004 the Israelis will complete a reverse osmosis desalinization plant at Ashkelon which will produce 50 million cubic meters of fresh water per year.
- If a second pilot plant is successful, the Israelis hope to expand their desalinization capacity to between 500 to 600 million cubic meters per year by 2012.

DEAD SEA TRANSFORM





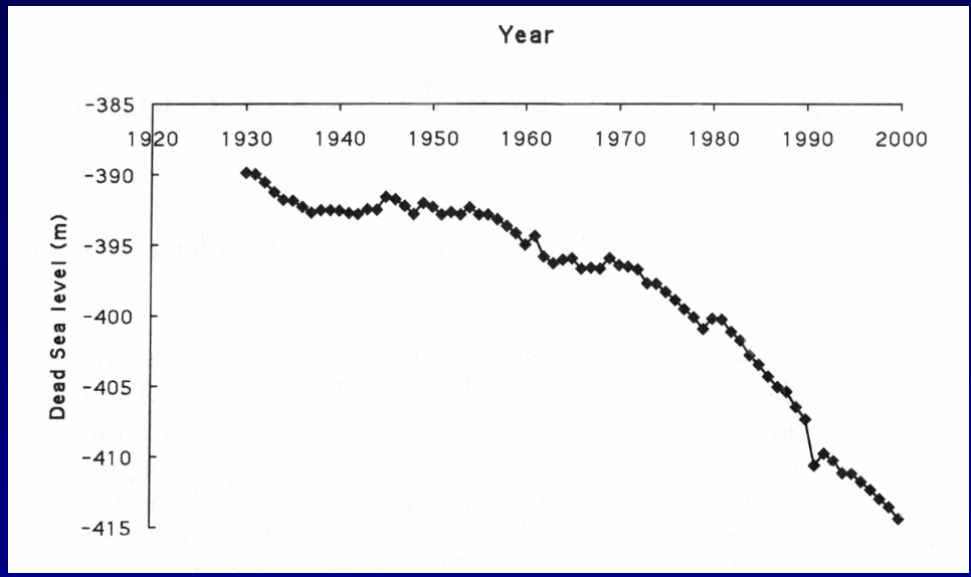
- The **Dead Sea** is a 14 km wide **pull-apart basin** formed between the Arava and Jericho faults
- It is the deepest land area above water, lying 1362 ft below sea level



DEAD SEA WATERSHED

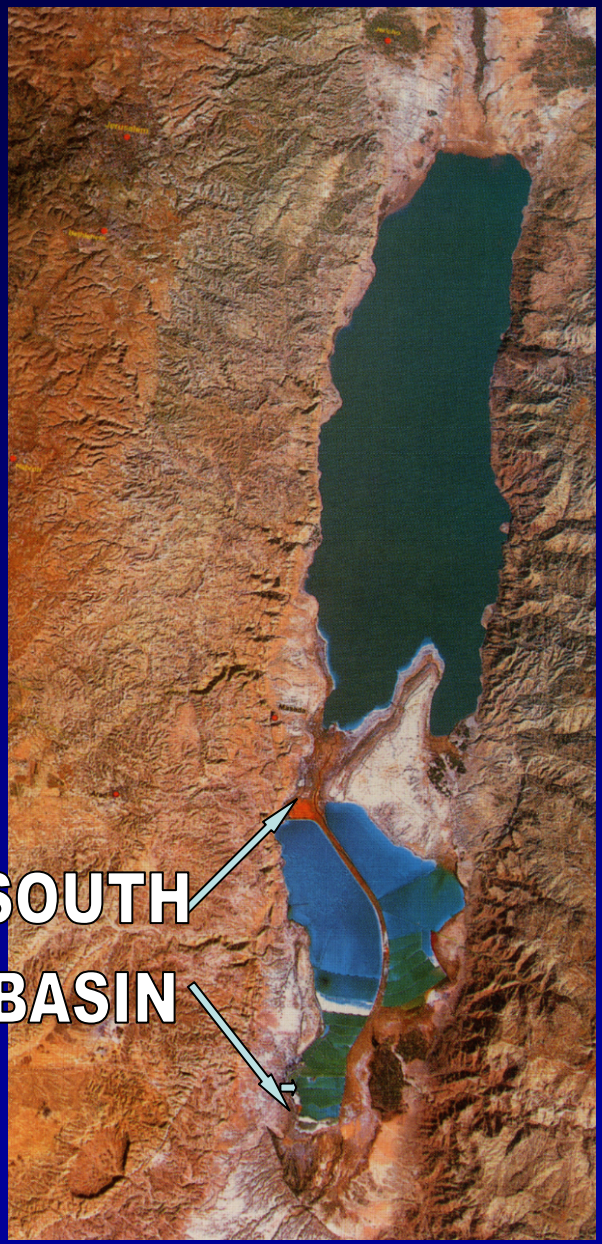
- 40,000 km^2 drainage basin
- Major sources are Mt Hermon range (in Syria and Lebanon) and Jebel Druze in Jordan
- One dam constructed on the lower Yarmouk River
- One dam on the Zarqa River, which supplies 25% of Jordan's needs
- Wadi Hasa and Wadi Mujib convey perennial trickles from area south of the Dead Sea

THE DEAD SEA IS DISAPPEARING



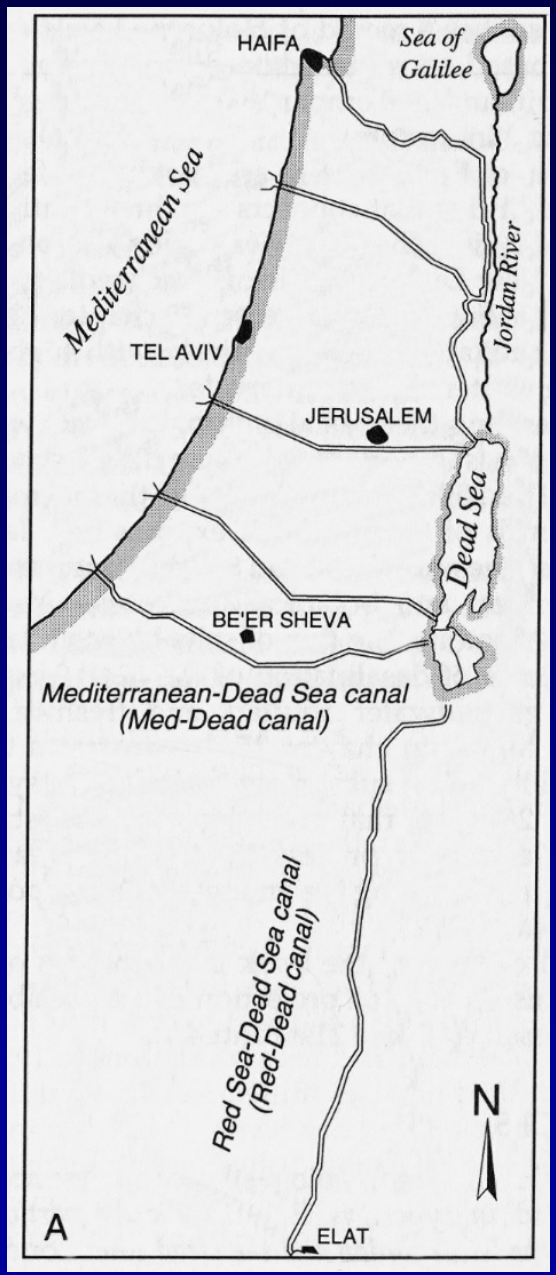
- The Dead Sea has been dropping since 1930 due to drafting of the Jordan River for irrigation and potash extraction. The South Basin of the Dead Sea has been reclaimed entirely for potash extraction.

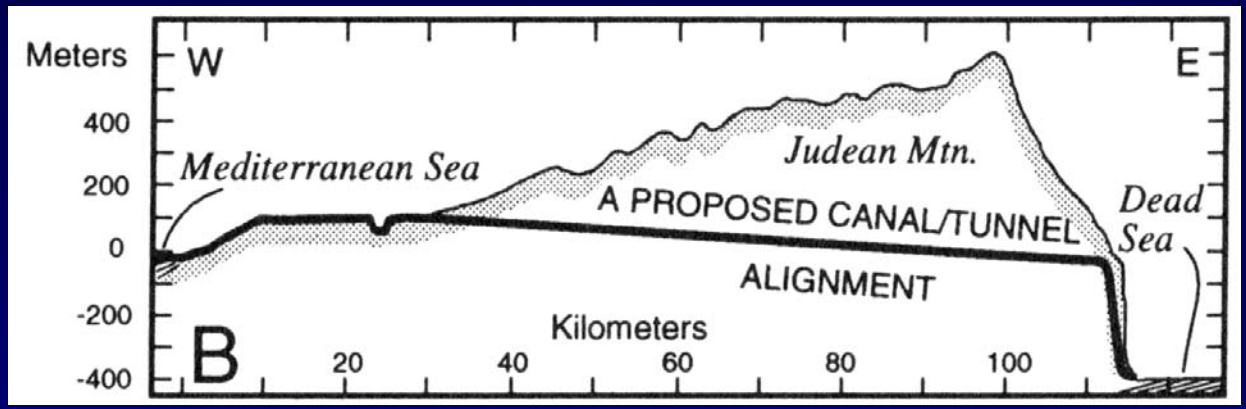
POTASH EXTRACTON



- The Israelis and Jordanians have been extracting increasing quantities of potash from the South Basin of the Dead Sea since 1966.
- Today, only 10% of the Jordan River's annual flow discharges into the Dead Sea

MED-DEAD SEA CANAL





- Originally envisioned by American Walter Lowdermilk in the 1950s
- In 1977 the Israelis considered four possible alignments
- Flow was to be 1.3 million ac-ft per year
- Israelis favored the southern route for security and environmental concerns
- Never constructed

1994 ARAVA TREATY BETWEEN JORDAN and ISRAEL

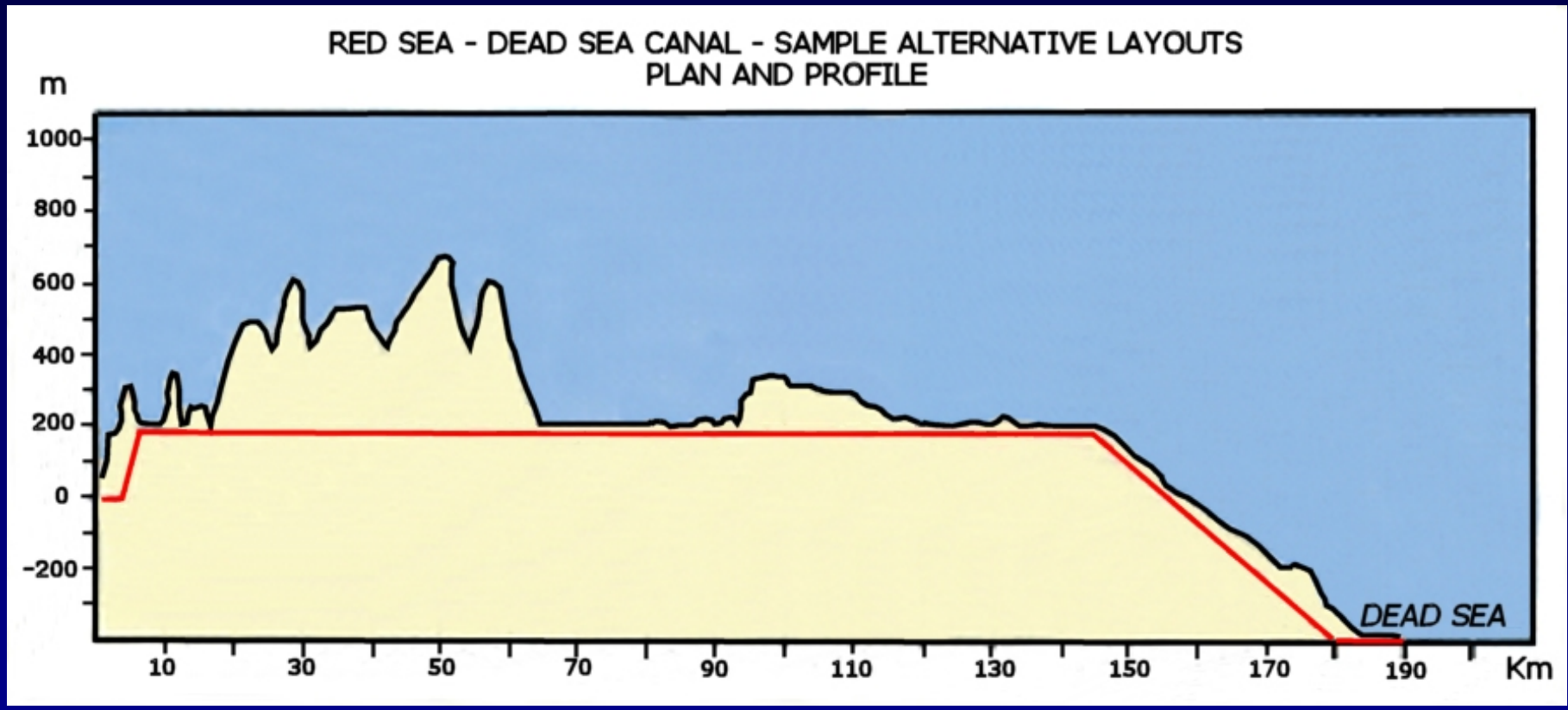
- The treaty signed at Arava promised crucial allocations of water from Israel, cooperative efforts aimed at finding additional resources, establishing increased storage within Jordan, water quality and protection measures and protection of shared groundwater resources
- The treaty also mandates exchange of technical data for the first time between the two nations
- Fresh water began moving again through a pipeline from the Sea of Galilee to Jordan's King Abdullah Canal (formerly the East Ghor Canal).

1994 TREATY BETWEEN ISRAEL AND THE PALESTINIAN AUTHORITY

- For first time since 1967, West Bank Palestinians are now permitted to drill water wells and may purchase additional water from Israel's National Water Carrier for a charge.
- The 1994 treaty failed to address Palestinian requests for additional water allotments, which would necessarily have come from Jordan or Israel.
- The subject of water allocation has become a non-negotiable agenda for the Palestinian Authority in its ongoing political strife with Israel.
- Desalination may emerge as the only practical long-term alternative

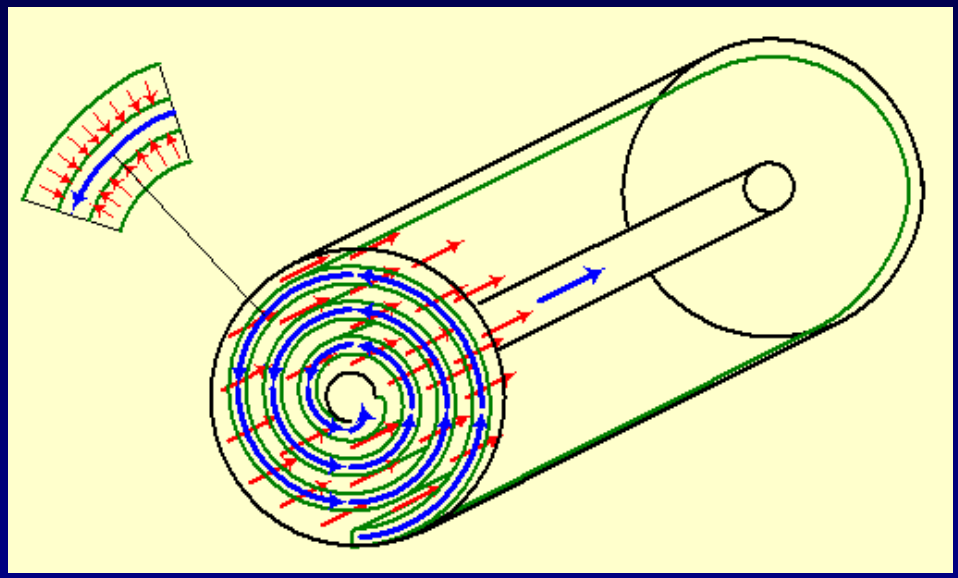
RED-DEAD SEA CANAL

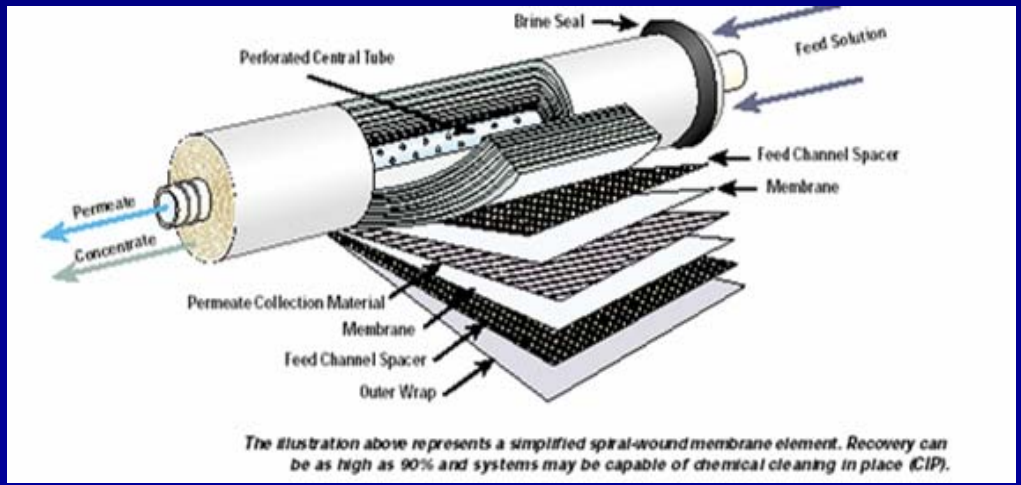
- Engineering studies by Harza Engineering Co. of Chicago in 1996-97 (paid for by the Italian government)
- The canal will extend from Aqaba 310 km north to the South Basin of the Dead Sea
- To provide desalination, hydropower, and raise level of the Dead Sea
- Cost will be about $800 million
- Announced in September 2002 that project will be built and operated jointly by the Israelis and Jordanians



- Red Sea water will be lifted 125 m (410 ft) and conveyed through two major tunnels, 45 and 24 km long
- Water will drop 533 m (1750 ft) into the Dead Sea, either through turbines for electricity or desalination for fresh water

HYDROPOWERED RO FILTRATION



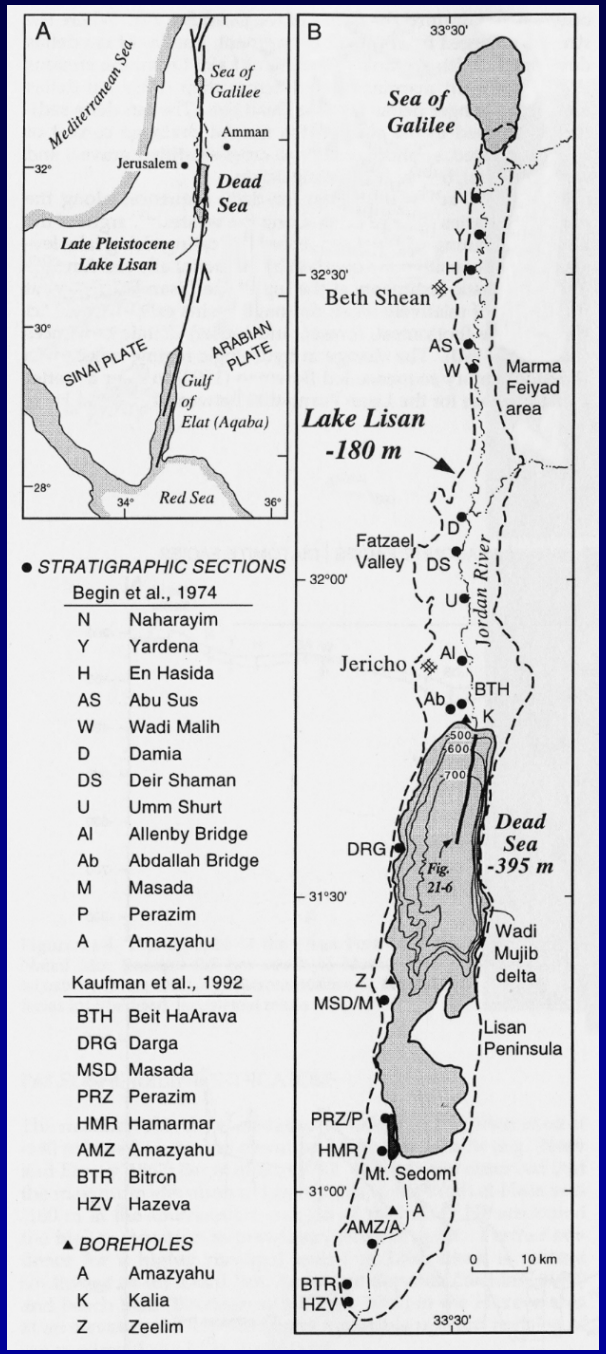


The illustration above represents a simplified spiral-wound membrane element. Recovery can be as high as 90% and systems may be capable of chemical cleaning in place (CIP).

- Seawater desalination now possible using spiral wound membranes for reverse osmosis (RO) process, called "**hyperfiltration**"
- Water flow continually cleanses the membrane by a process termed "**crossflow**", sweeping out the retained salt

GLACIAL LAKE LISAN

- The **Jordan River Valley** (JRV) is typified by treacherous foundation conditions
- Lake Lisan filled the JRV between 63 and 14 ka
- Lake Lisan was up to 220 km long
- Lake level fluctuated between -180 m, about 180 m deeper than present
- Lowest level was -700 m (285 m deeper than present)



THRUST FAULTS COMMON OVER RISING SALT DIAPIRS

DIATOMACEOUS SEDIMENTS

- The Jordan Valley contains soft compressible silts, clays and marls as well as collapsible diatamaceous soils deposited in glacial Lake Lisan

HIGH VISIBILITY FAILURES

- In Late March 2000 2.5 km of a newly completed 22 m high dike on the Lisan Peninsula failed catastrophically upon its initial filling by the Jordanian Arab Potash Company.
- 30 million cubic meters of material washed away in 30 minutes.
- Very soft foundation materials developed excessively high pore water pressure, which caused a bearing capacity failure
- The Israeli dikes have experienced similar problems