Evaluation of municipal water supply system options using Water Evaluation and Planning System (WEAP): Jeddah

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Outline

- Study objective
- Research methodology
- Case Study: Jeddah-Saudi Arabia
- Proposed water scenarios planned by National Water Company (NWC)
- Performance evaluation of operating strategies
- Results and findings
- Conclusion

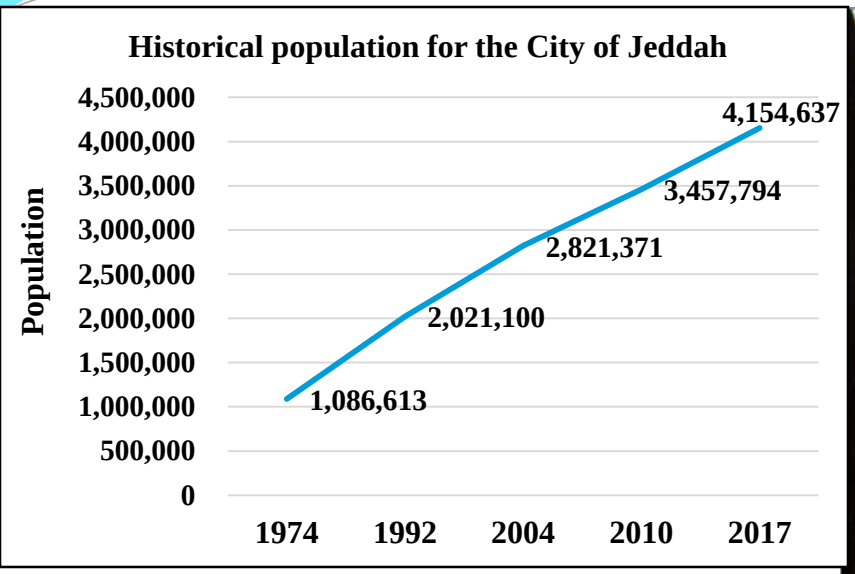
Study Objectives

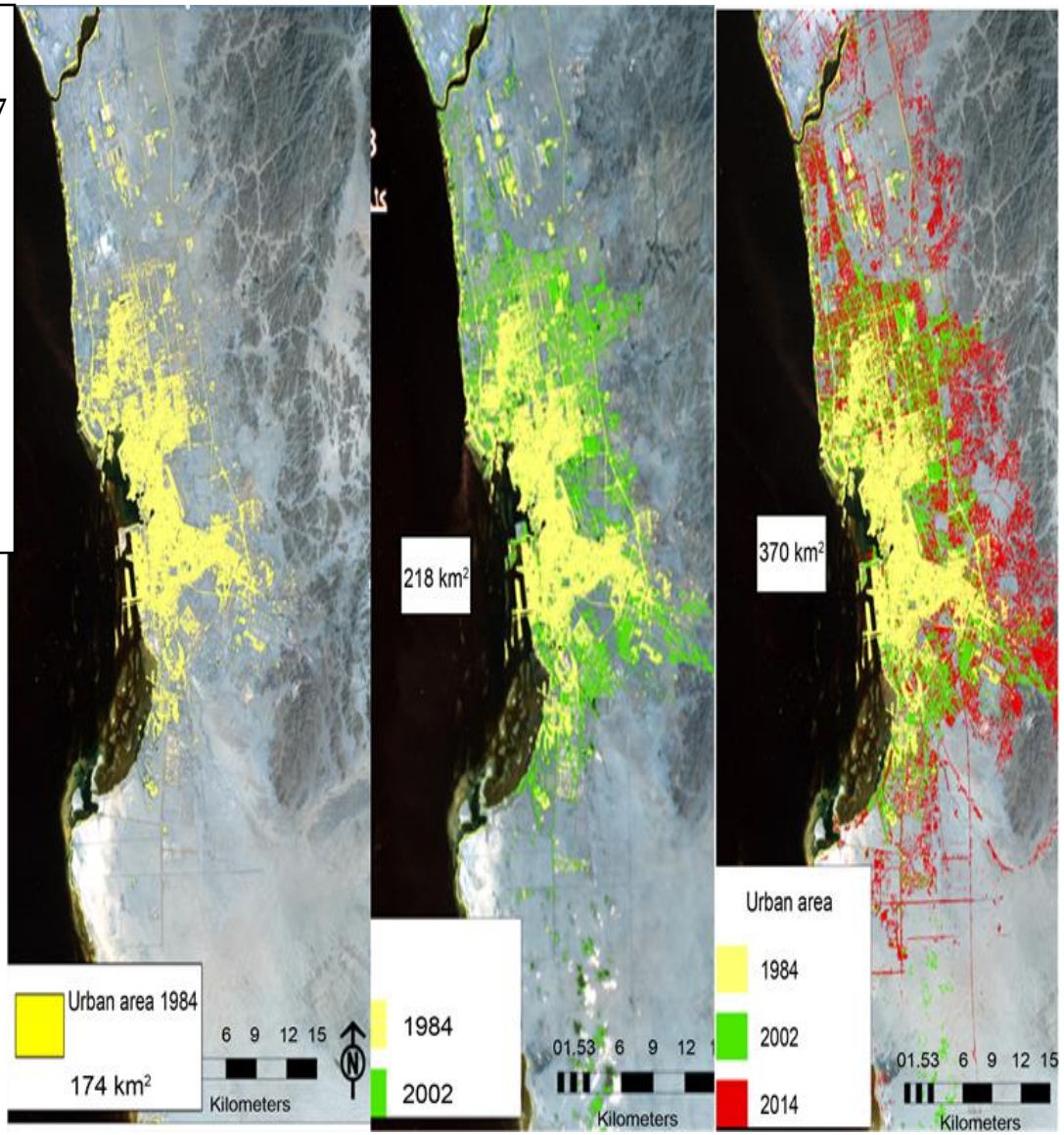
- To evaluate the existing condition related to water supply/demand in Jeddah
- To assess the long-term impact of the planned water management options using (WEAP)
- To find the best combination of water management options that meet future water demands
- To identify the years of water shortages and to assess the efficiency of various operating policies

Methodology

- First, data collection, (e.g., NWC, Jeddah municipality, MEWA)
- Second, water allocation system current practices (GIS, location of water utilities)
- Third, assessment of planned water supply/demand management strategies using WEAP until 2030.
- Last, recognize years of unmet demand /reliability, resiliency, and vulnerability of the supply system.

Case Study- Jeddah

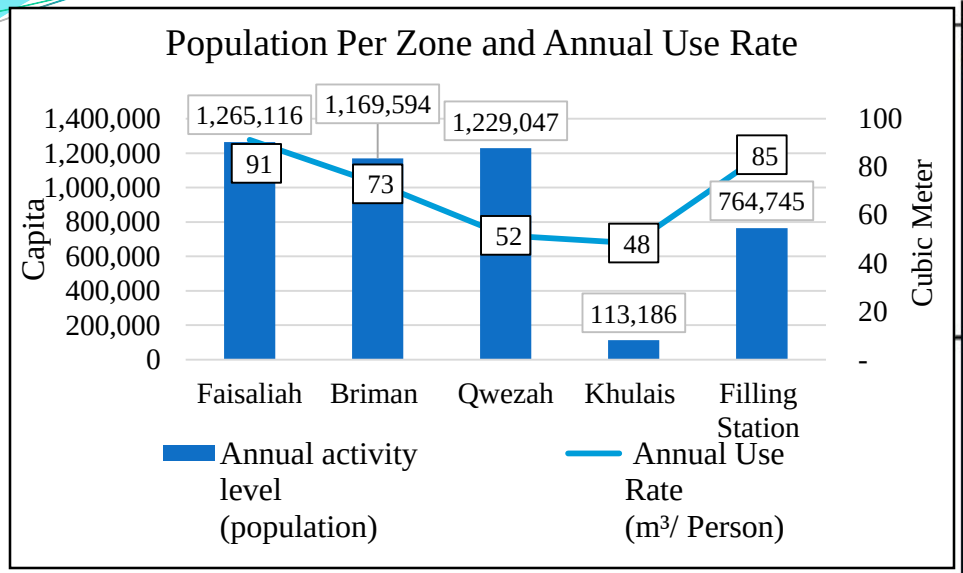


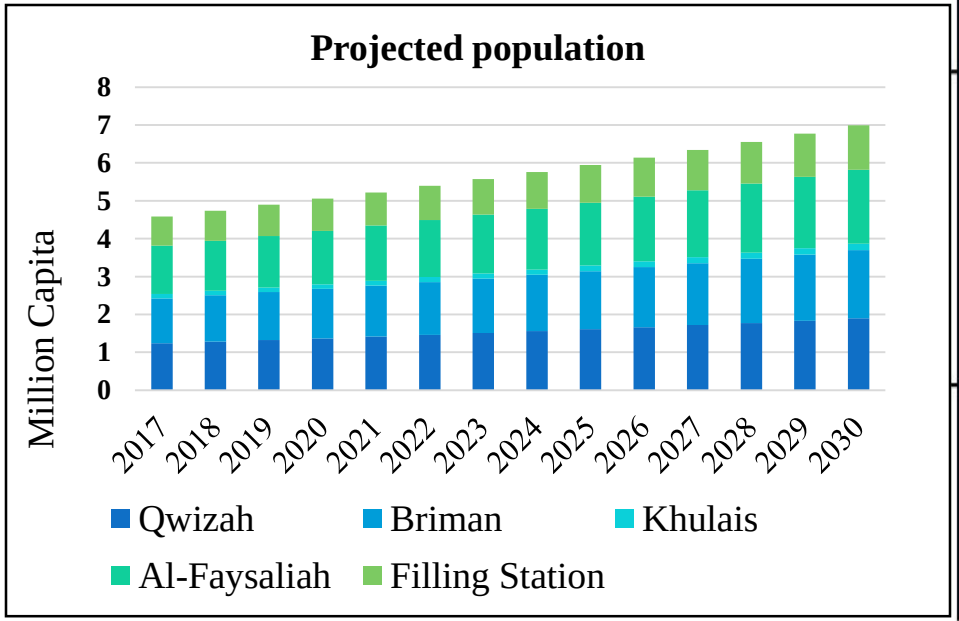


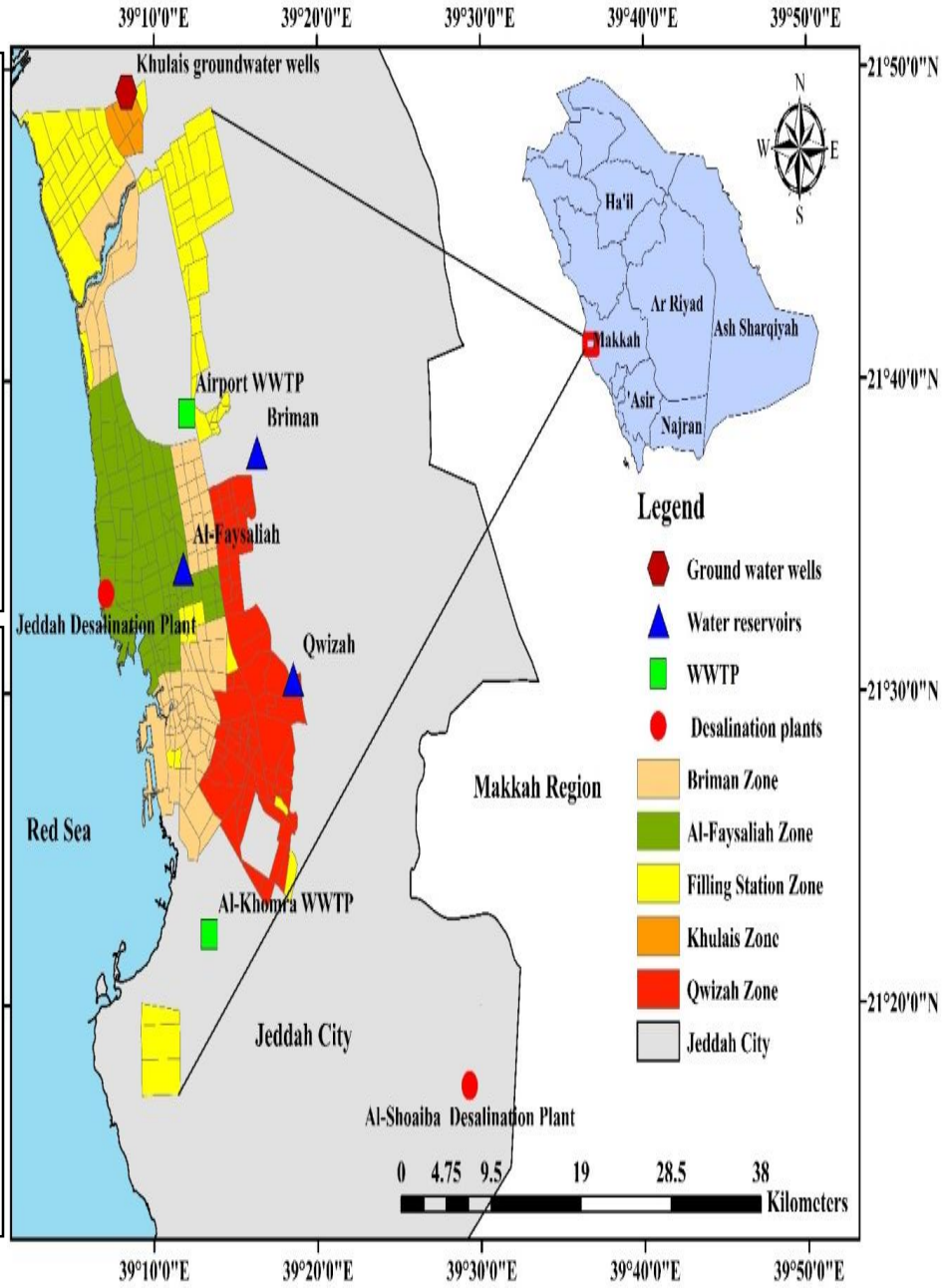
- NWC has three population growth rate scenarios:
  - optimistic 3.3%,
  - most likely 4.3%,
  - pessimistic 5.0%.
  - use the most likely one.

- rapid population growth, urbanization, water stressed

Jeddah/Case Study



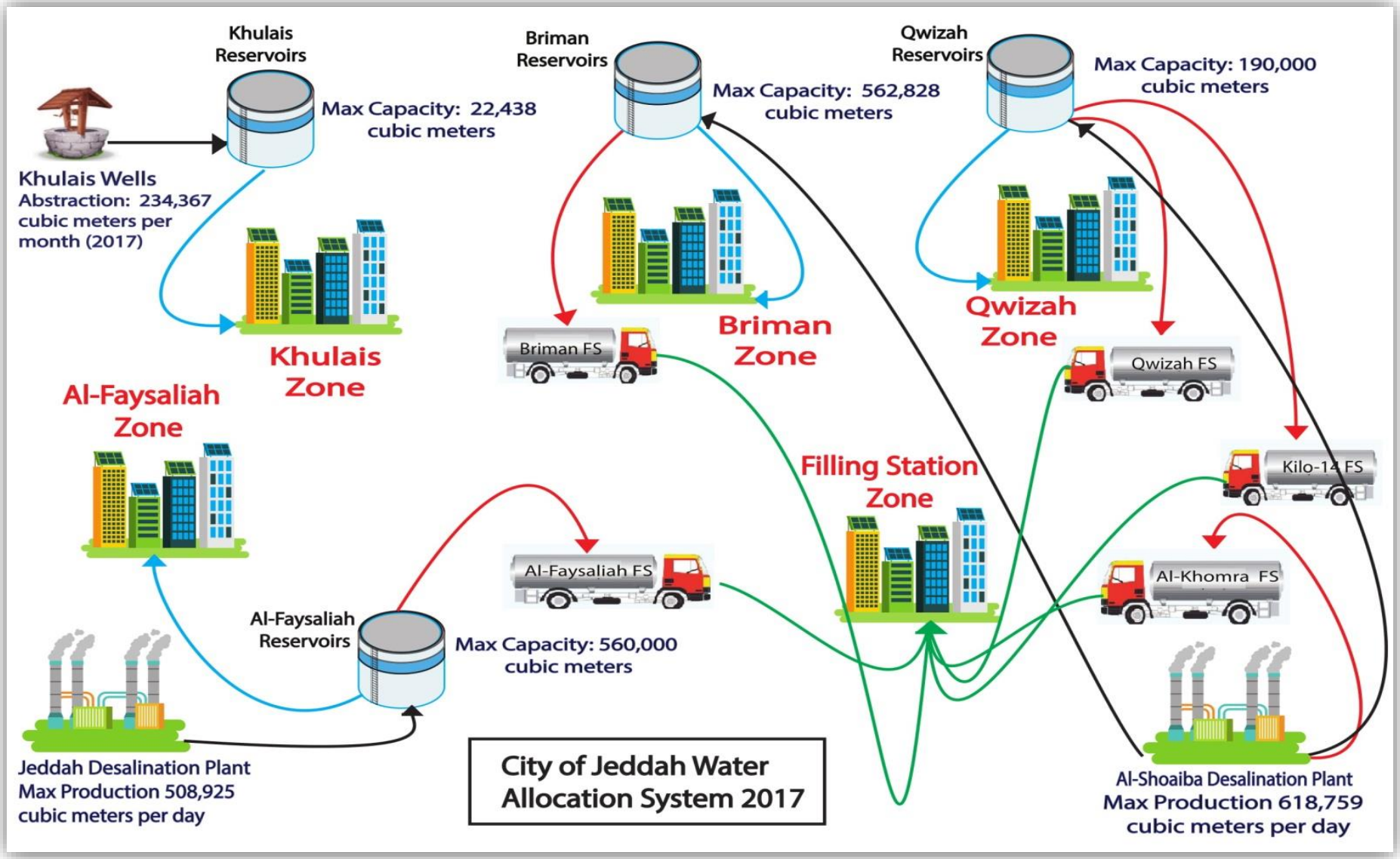




Current water distribution (2017)

Source	Supply	Type	Quantity m^3/month	Total Quantity m^3/month	Total m^3/month
Jeddah Desalination Plant	Al-Faysaliah	Network	11,861,631	27,382,542	34,064,895
Al-Shoaiba Desalination Plant	Briman		8,773,516		
Al-Shoaiba Desalination Plant	Qwizah		6,513,028		
Groundwater Wells	Khulais		234,367		
Jeddah Desalination Plant	Al-Faysaliah	Filling Station	3,406,122	6,682,353	
Al-Shoaiba Desalination Plant	Briman		625,868		
Al-Shoaiba Desalinaton Plant	Qwizah		911,790		
Al-Shoaiba Desalination Plant	Al-Khomrah		426,722		

Current Water Allocation System



Why WEAP?

- Analyze optimal water use within the water management system as a result of changing demand and supply scenarios

- Water Demand (WD): The requirements at each demand site, before demand site losses, reuse and demand management savings are considered

  Total demand = Total activity x water use rate

- Supply requirement (SR): (Site demand + Losses).

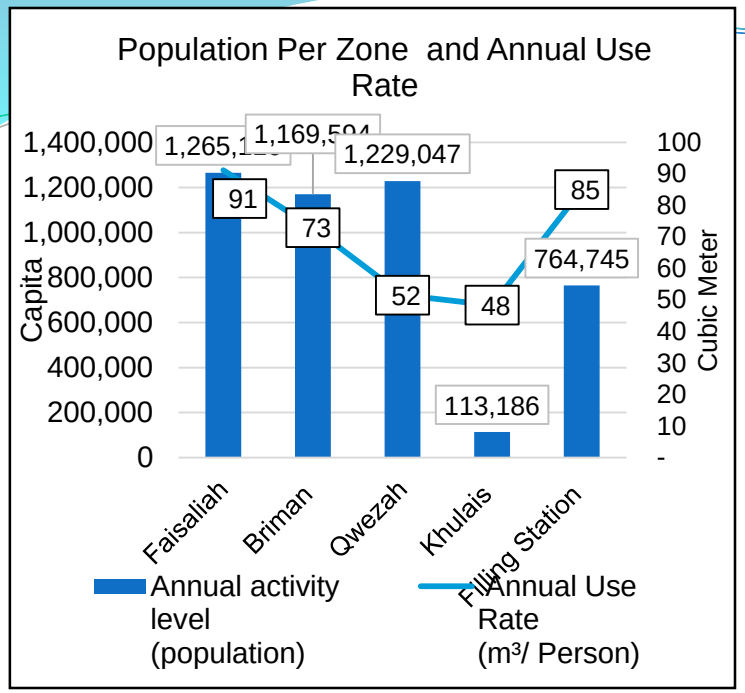
  If the demand site requires 1000 m^3 of water and water losses is 20%, then the SR is 1200 m^3 (1000 m^3 x 1.2)

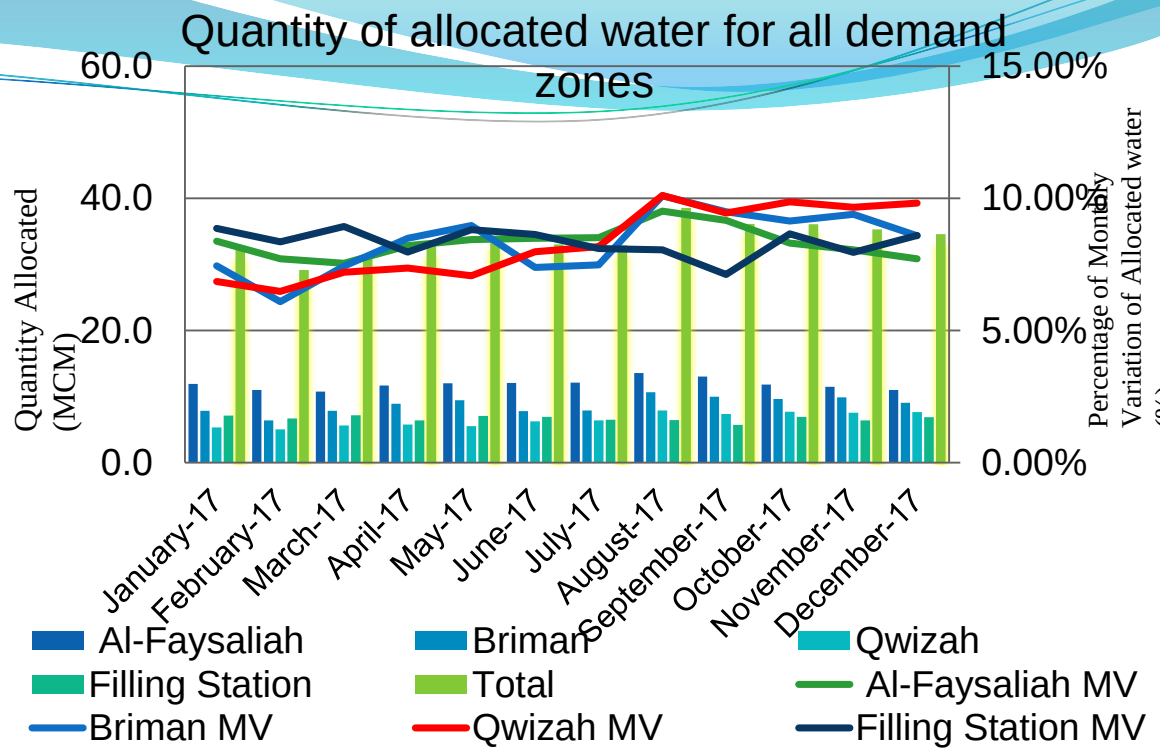
- Supply Delivered (SD): The amount of water supplied to demand site, listed by source (e.g. water reservoirs).

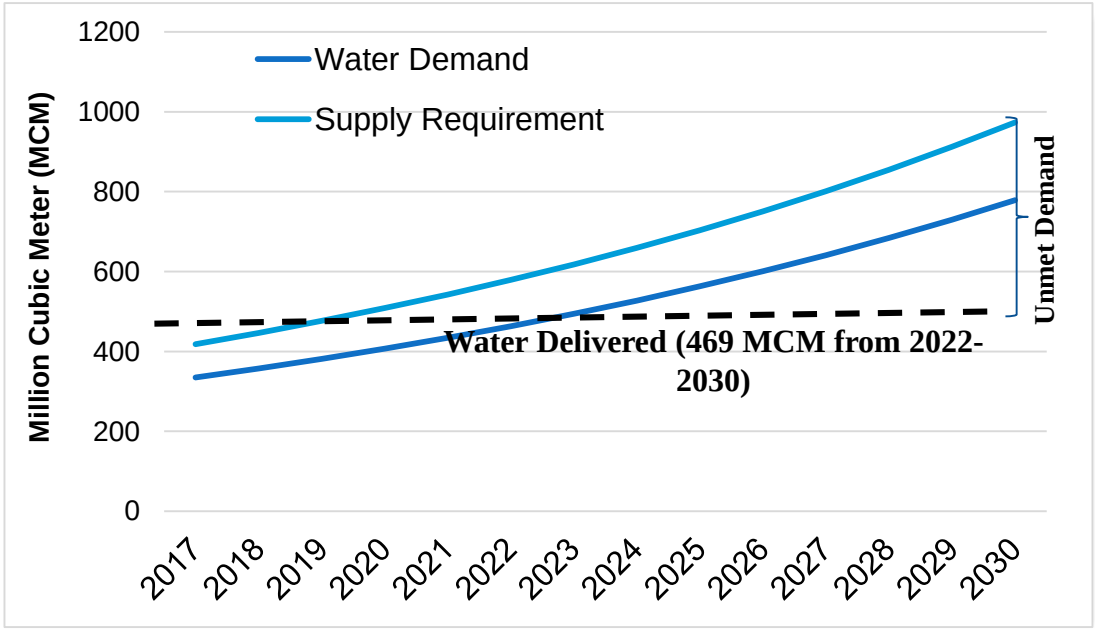
- Unmet Demand (UD): The amount of each demand site's requirement that is not met.

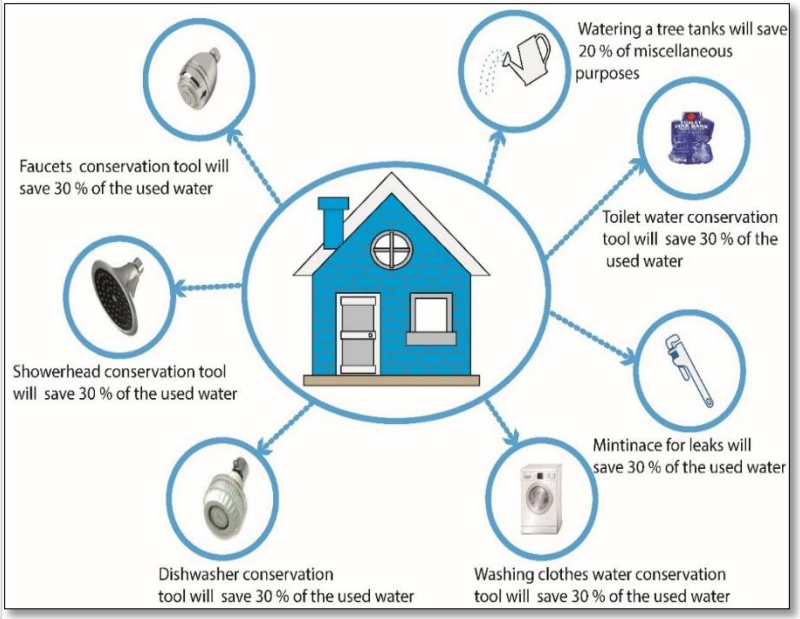
Proposed Scenario by National Water Company

Scenario	Main Assumption (Source National Water Company)
Base-case	➢Current water supply/demand system conditions (2017) ➢Population growth rate of 4.3% (2018-2030), losses 20% ➢WEAP is executed for the next 13 years (starting from 2017 until 2030)
Leakage reduction (LR)	➢The current leakage in Jeddah's distribution system is 20% ➢ illegal connections, leaks in the distribution system ➢Reduce the leakage from 20% to 10%
Water conservation (WC)	➢NWC is planning to implement water conservation to all existing and new building ➢Household retrofits by 32% (MEWA 30 - 40%) ➢Minimize the average consumption of water use/capita from 30% to 40%
WC & LR	➢Combine (Scenario 2 and Scenario 3)

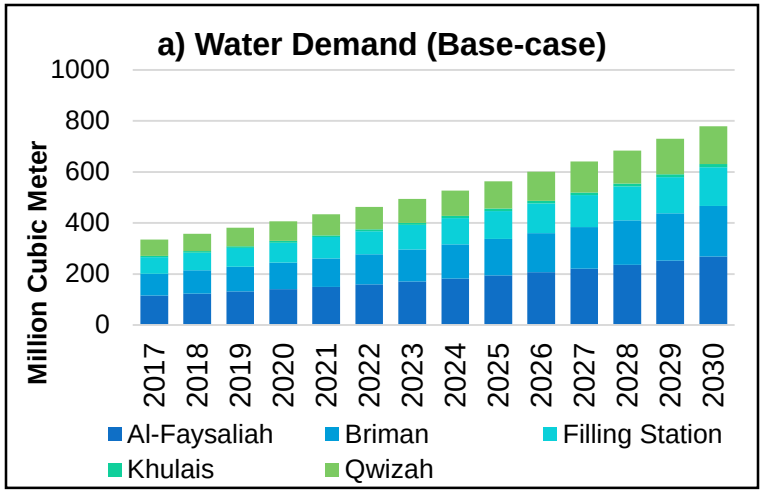

Population Per Zone and Annual Use Rate
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Capita
100
90
80
70
60
50
40
30
20
10
-
Cubic Meter
1,265,1
1,169,594
1,229,047
91
73
52
48
113,186
85
764,745
Faisaliah
Briman
Qwezah
Khulais
Filling Station
Annual activity level (population)
Annual Use Rate (m³/ Person)

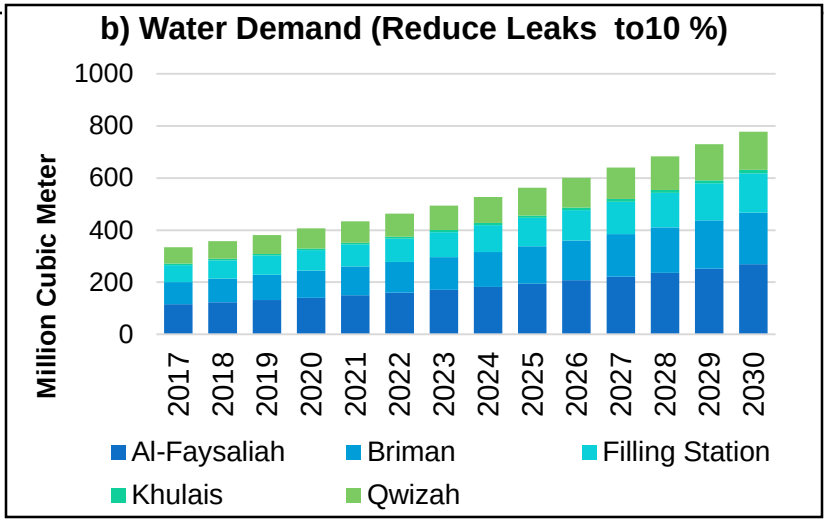

Quantity of allocated water for all demand zones
60.0
40.0
20.0
0.0
Quantity Allocated (MCM)
15.00%
10.00%
5.00%
0.00%
Percentage of Monthly Variation of Allocated water
January-17
February-17
March-17
April-17
May-17
June-17
July-17
August-17
September-17
October-17
November-17
December-17
Al-Faysaliah
Briman
Qwizah
Filling Station
Total
Al-Faysaliah MV
Briman MV
Qwizah MV
Filling Station MV

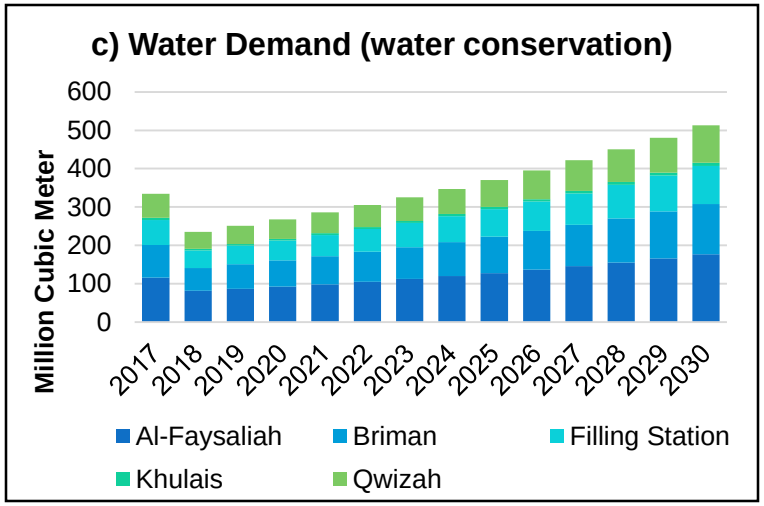

1200
1000
800
600
400
200
0
Million Cubic Meter (MCM)
Water Demand
Supply Requirement
Unmet Demand
Water Delivered (469 MCM from 2022-2030)
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030

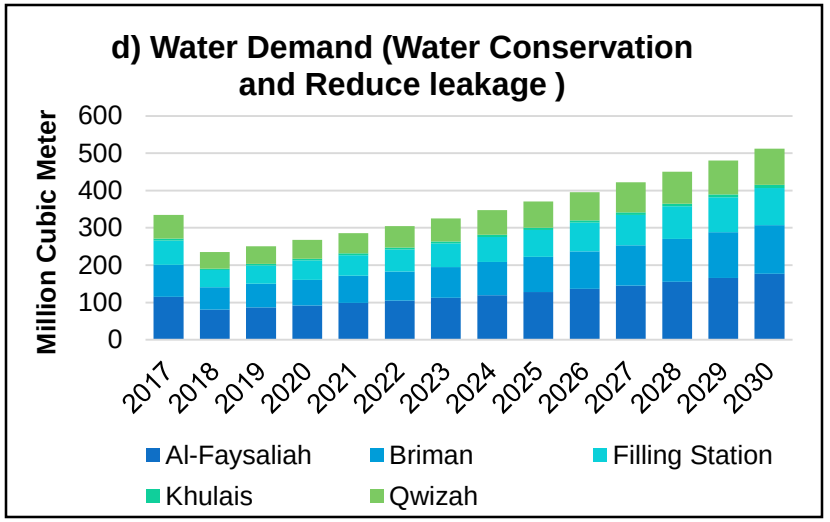

Watering a tree tanks will save 20 % of miscellaneous purposes
Faucets conservation tool will save 30 % of the used water
Toilet water conservation tool will save 30 % of the used water
Showerhead conservation tool will save 30 % of the used water
Mintinace for leaks will save 30 % of the used water
Dishwasher conservation tool will save 30 % of the used water
Washing clothes water conservation tool will save 30 % of the used water

Projected Demand MCM

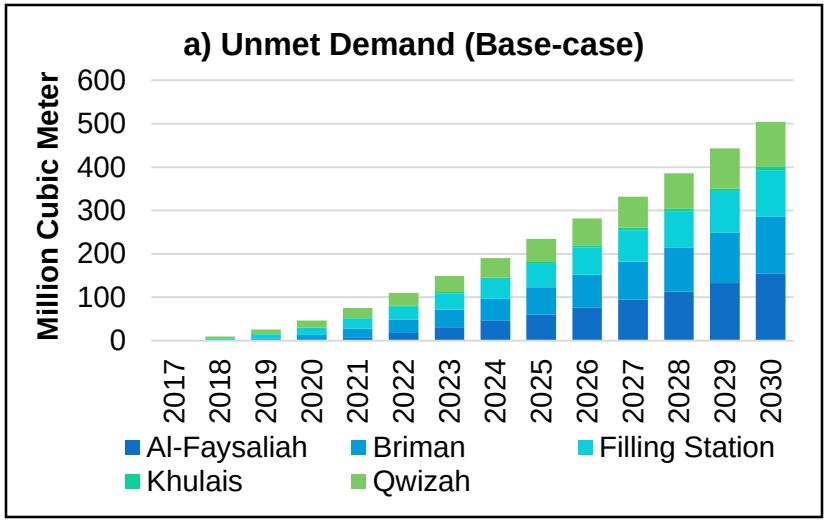


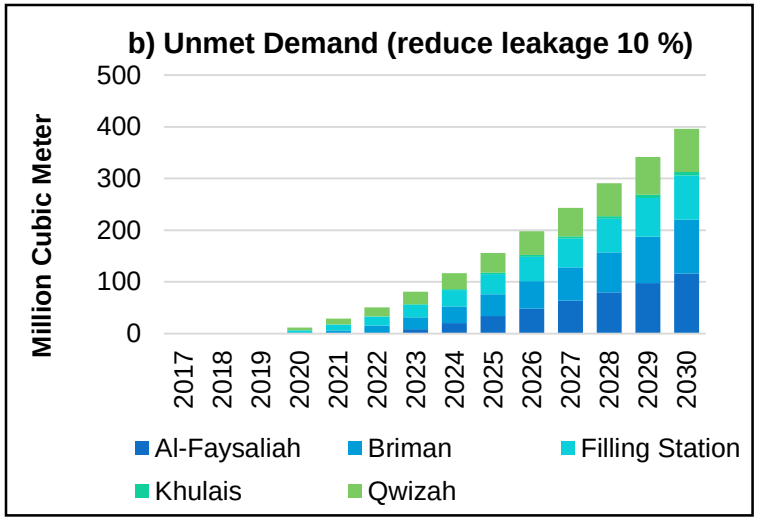


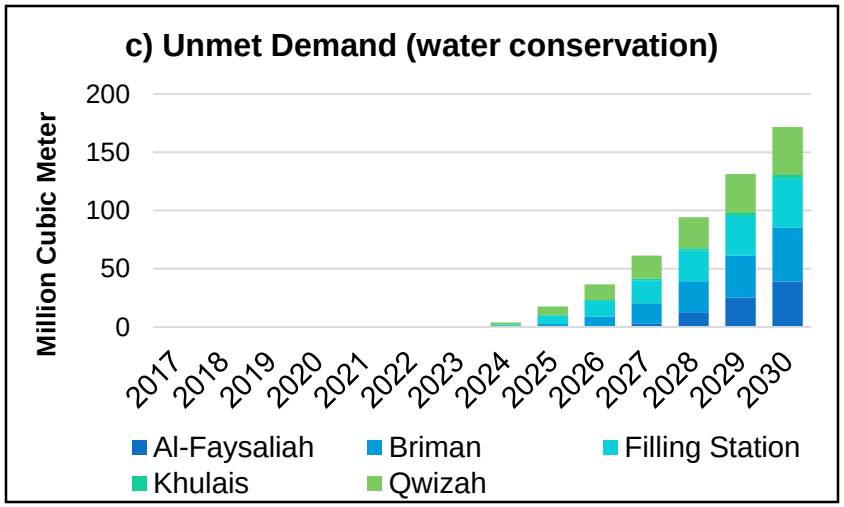


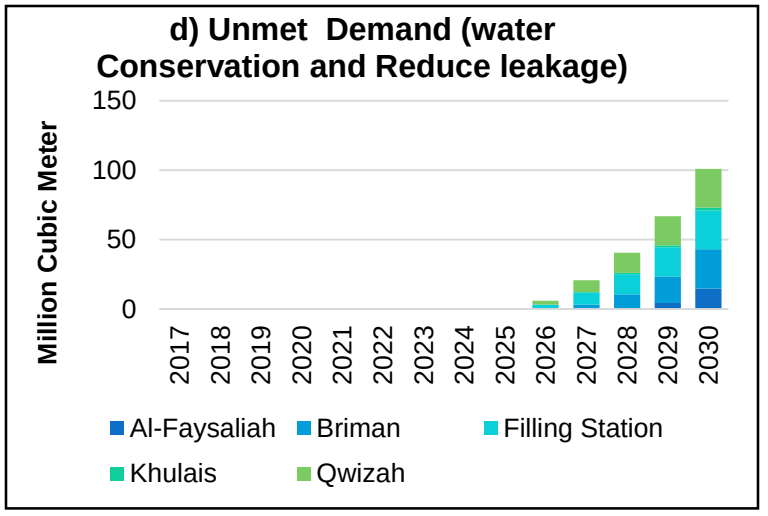


Projected Unmet Demand (MCM)









Summary of Results

Scenario as per NWC	Water Demand MCM		Supply Requirement MCM		Supply Delivered MCM		Unmet Demand MCM	
	2017	2030	2017	2030	2017	2030	2017	2030
Base-case	335	779	418	973	418	469	**0**	**504**
RL	335	779	418	865	418	469	**0**	**396**
WC	**335**	**513**	418	641	418	469	**0**	**172**
RL & WC	**335**	**513**	418	**570**	418	**469**	**0**	**101**

Supply Delivered (MCM)

Supply Delivered	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Base-case	418	437	451	462	468	**469**	**469**	**469**	**469**	**469**	**469**	**469**	**469**	**469**
WC	418	294	314	335	357	381	407	430	445	458	466	**469**	**469**	**469**
RL& WC	418	261	279	298	317	339	361	386	412	443	448	459	467	**469**

EFFICIENCY OF OPERATING STRATEGIES (Hashimoto et al., 1982)

- Reliability (%):
  - how often the system fails;
  - the number of months in which supply meets the demand over the total months from 2017 to 2030
- Resiliency (%):
  - how quickly the system returns to a satisfactory state once a failure has occurred;
  - The month that does not have water shortage after a month having a water shortage (e.g. unmet demand)
- Vulnerability (MCM):
  - how significant the likely consequences of failure may be;
  - Estimated based on the total deficit occurring within the planning horizon.

Efficiency of operating Policies (Results)

Scenario	Zone	(1)Total number of months	(2) satisfactory state (months)	(3) unsatisfactory (months)	(4) No. of successes	(5) Shortage unsatisfactory months (MCM)	(6) Reliability (Eqn.1)=(2/1)	(7) Resilience (Eqn.2)=(4/3)	(8) Vulnerability MCM (Eqn.3)=(5/3)
Reference	Al-Faysaliah	168	49	119	5	733,460,230	29%	4.20%	6,163,531
	Briman	168	23	145	4	734,528,288	14%	2.76%	5,065,712
	Filling Station	168	12	156	0	639,665,336	7%	0.00%	4,100,419
	Khulais	168	23	145	4	49,212,048	14%	2.76%	339,393
	Qwizah	168	12	156	0	629,890,640	7%	0.00%	4,037,761
	Sum	168	12	156	0	2,786,756,541	7%		17,863,824
Leakage Reduction	Al-Faysaliah	168	70	98	6	470,052,125	42%	6.12%	4,796,450
	Briman	168	46	122	5	507,877,090	27%	4.10%	4,162,927
	Filling Station	168	33	135	3	455,304,150	20%	2.22%	3,372,623
	Khulais	168	42	126	7	34,409,152	25%	5.56%	273,089
	Qwizah	168	33	135	3	449,374,217	20%	2.22%	3,328,698
	Sum	168	30	138	5	1,917,016,733	18%		13,891,426
Conserva-tion	Al-Faysaliah	168	96	72	6	244,972,321	57%	8.33%	3,402,393
	Briman	168	70	98	5	304,309,506	42%	5.10%	3,105,199
	Filling Station	168	59	109	1	286,678,871	35%	0.92%	2,630,081
	Khulais	168	68	100	6	21,030,457	40%	6.00%	210,305
	Qwizah	168	60	108	0	283,817,310	36%	0.00%	2,627,938
	Sum	168	57	111	3	1,140,808,464	34%		10,277,554
LR+ Conservation	Al-Faysaliah	168	157	11	5	5,144,497	93%	45.45%	467,682
	Briman	168	132	36	5	35,011,127	79%	13.89%	972,531
	Filling Station	168	120	48	0	48,129,079	71%	0.00%	1,002,689
	Khulais	168	131	37	4	2,992,618	78%	10.81%	80,882
	Qwizah	168	121	47	0	48,758,173	72%	0.00%	1,037,408
	Sum	168	120	48	0	140,035,494	71%		2,917,406

Conclusion

- **Current Situation:** An additional amount of 504>469 MCM would be required in 2030 to satisfy water needs and development.
- **Leak reduction (less beneficial alone):**
  - The SR in 2030 reduced from 973 MCM to 865 MCM.
  - WD did not reduced from the base-case
- **Water conservation (beneficial):**
  - WC is highly beneficial
  - The WD in 2030 reduced from 779 MCM to 513 MCM.
- **Water Conservation and leak reduction (Highly beneficial)**
  - The lowest unmet demand in 2030 (UD: 2026-2030)
  - SD reached the maximum capacity of reservoirs storage (469 MCM) only in 2030.
  - Highest reliability of 71 % of meeting demand is achieved for all demand zones.
  - Lowest vulnerability 2,917,406 MCM is achieved for all demand zones
- **Future work (recycle of treated wastewater, rainfall harvesting, building new desalination plant)**

Thank you