Developing a Robust Water Strategy for Monterrey, Mexico: Diversification and Adaptation for Coping with Climate, Economic, and Technological Uncertainties

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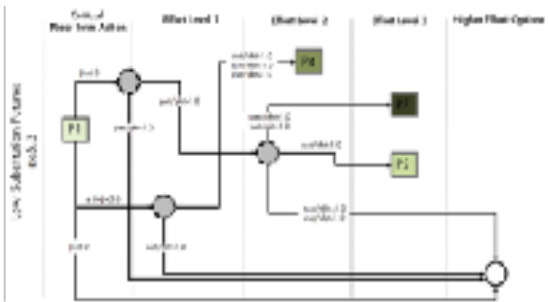
NO HAY AGUA QUE PERDER

Traditional infrastructure planning approaches are not pertinent in Latin-American

- Vast set of uncertain stressors
  - Complex social phenomena
  - Natural disasters
  - Rapid demographic change
  - Economic and regulatory instability

- Investment decisions with long lasting effects
  - Backward infrastructure systems
  - Highly sensitive to new investments

Robust Decision Making (RDM) has proven to be useful in thes sort of infrastructure planning contexts

Estructuración participativa

Algoritmos de optimización y aprendizaje maquina identifican y comparan diferentes estrategias adaptativas

1. Estructuración

4. Análisis de disyuntivas

Nuevas opciones

2. Generación de Escenarios

3. Análisis de Vulnerabilidades

Estrategias Robustas
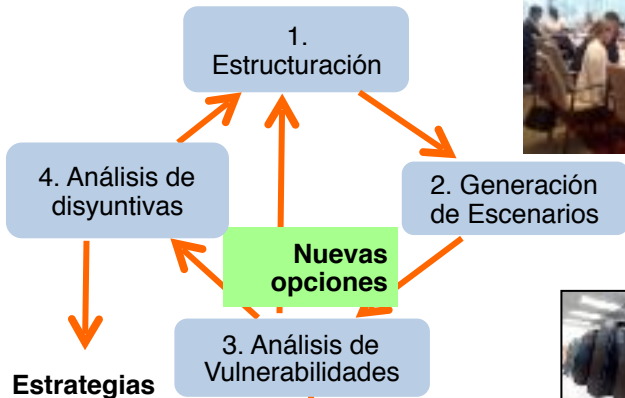
Recursos computacionales de alta capacidad

Escenarios que iluminan vulnerabilidades

Algoritmos de aprendizaje no supervisado identifican factores críticos

Tecnológico de Monterrey, FAMM and RAND reshaping long-term water planning in Monterrey, Mexico

- Monterrey is Mexico's 3rd largest metropolitan area

- Rapidly expanding population and economy

- At its limit of developed supplies

- Potentially sensitive to climate change
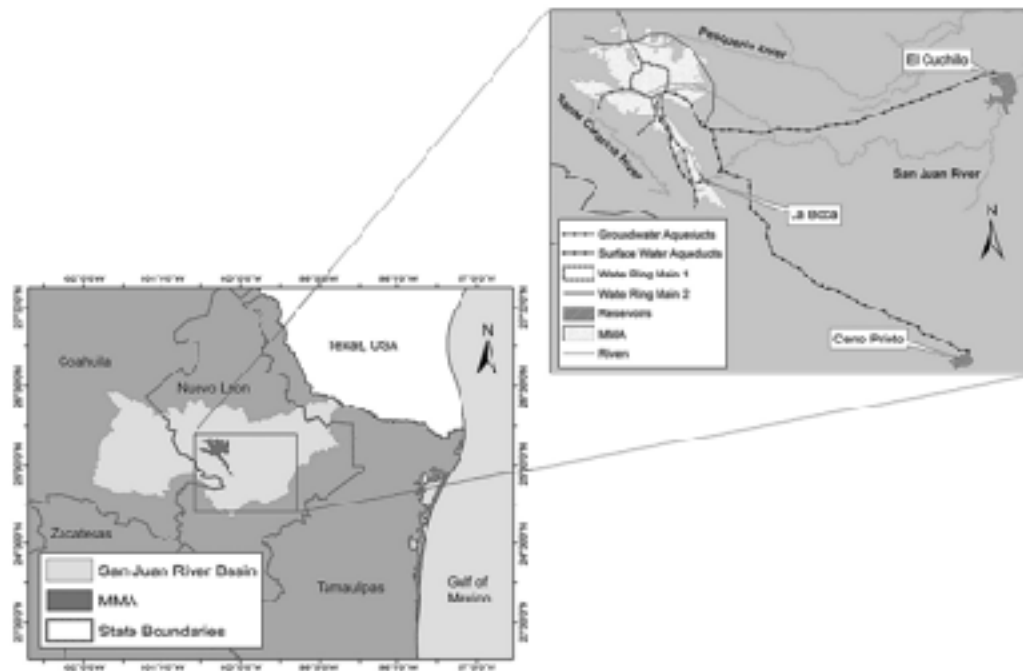
Fig. 1. San Juan River Basin (SJRB) Monterrey Metropolitan Area (MMA) and MMA water supply system.
Source: Authors' own.

Region was on the cusp of implementing a costly mistake

- Large expensive water transfer project

- Many potential impacts and opposition

- Uncertain benefits
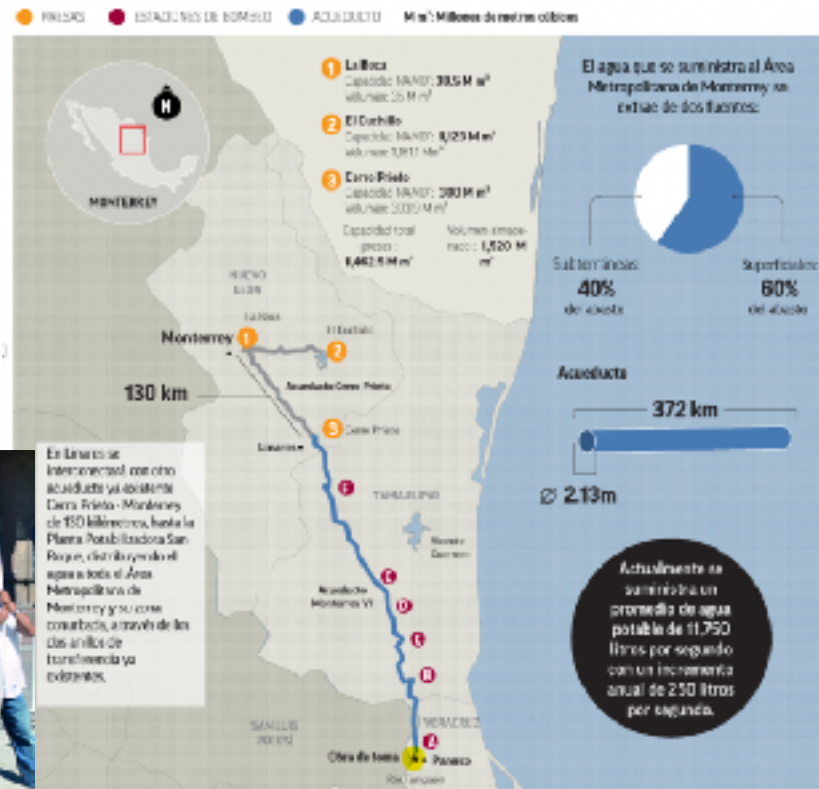
FAMM funded RAND and Tecnológico de Monterrey to support Monterrey Water Plan

Take a diversified water planning approach

Develop a water planning model w/ best available scientific information

Explore vulnerabilities of current system

Evaluate different portfolios that ensure reliability at lowest possible cost

Use RDM to develop adaptive plan

MONTERREY

Plan Hídrico de NL costará 6 mil mdp

Nuevo proyecto sustituye a Monterrey VI, el cual valía 62 mil millones de pesos.

Alejandra Mendoza

ETIQUETAS: Monterrey, agua, Nuevo León, Presa, Monterrey VI, Fonadin, infy, Plan Hídrico,

Met with stakeholders and worked with modelers to develop tools to evaluate many plausible futures

Dynamic optimization engine
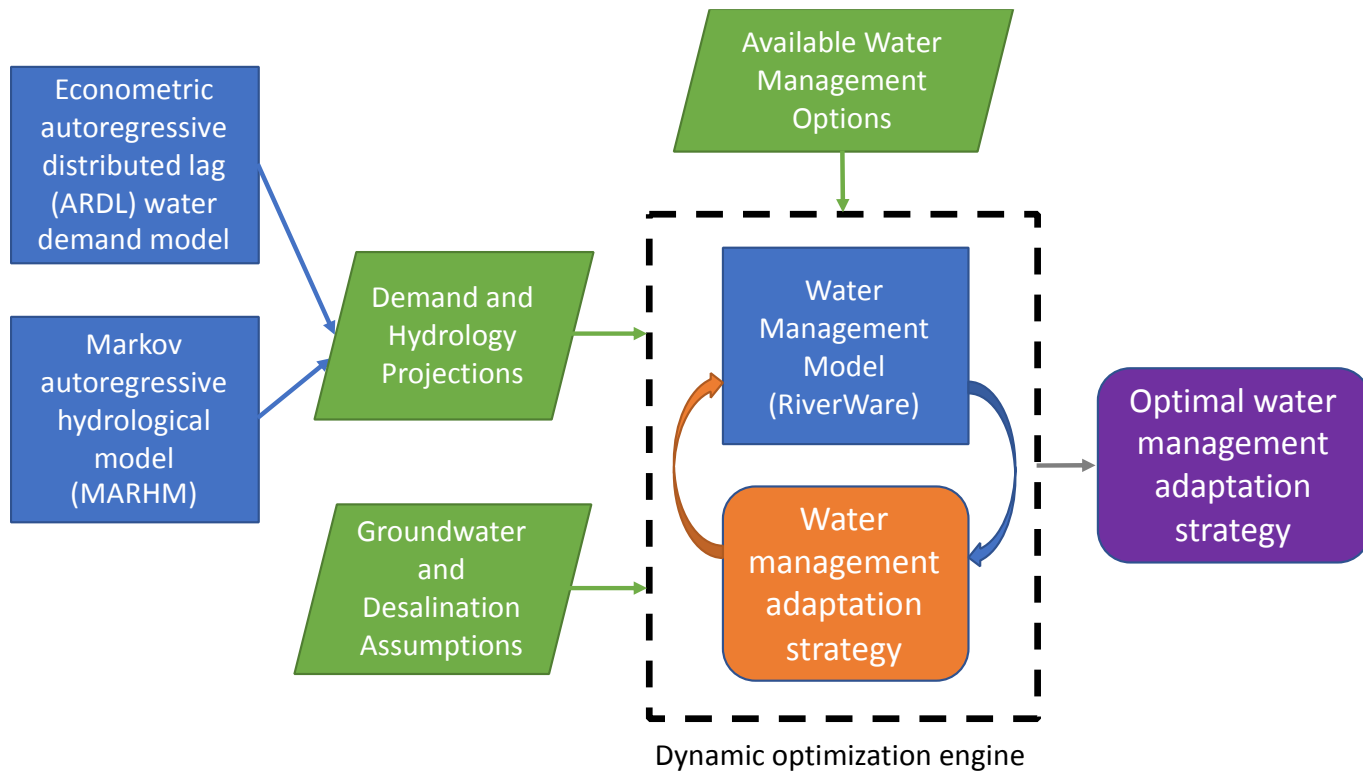
Identified future conditions in which current strategy would not suffice

- Evaluated model under 648 plausible futures

- Identified key drivers of low reliability (vulnerability)
  - High demand
  - Low inflows
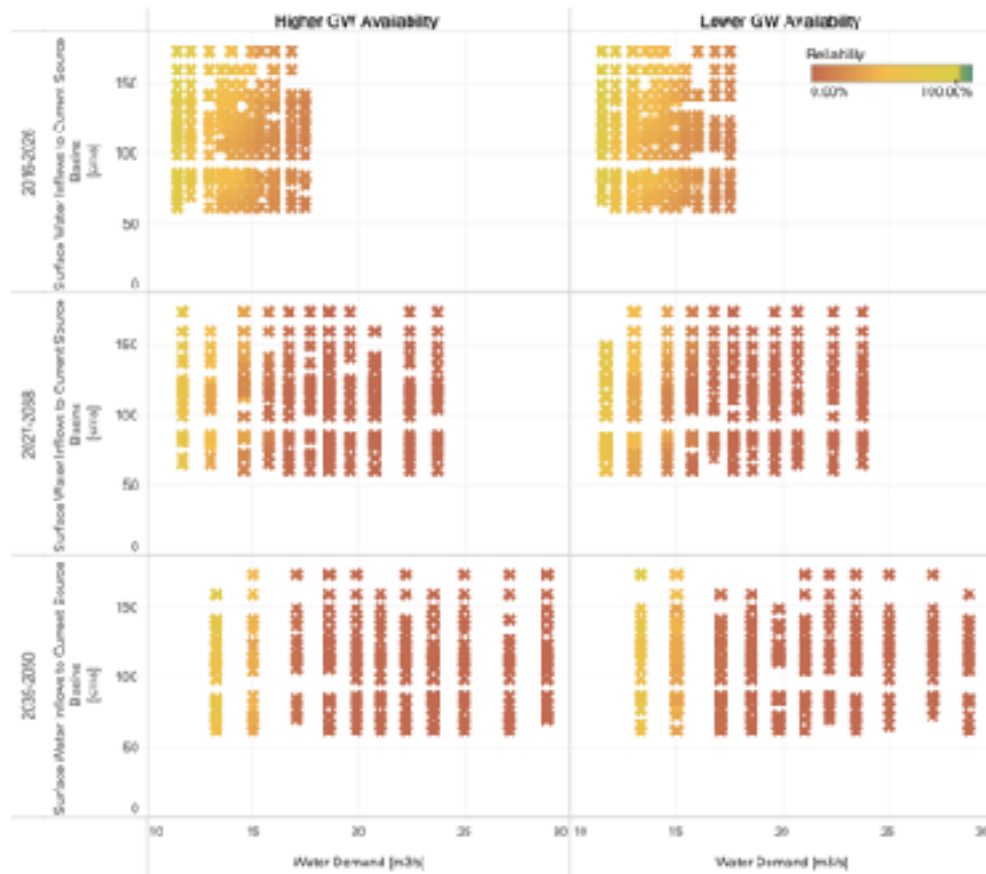
Used optimization to determine which investments would most cost effectively improve supply reliability

Future water demand →

Total Cost
Reliability

Individual water management options and investments

↓

Develop an approach to define robust, adaptive strategies

Portfolio of low regret, near-term options

Mid-term Signpost Conditions

Mid-term Contingent Options

Long-term Signpost Conditions

Long-term Contingent Options

2018 - 2026

2027 - 2038

2039 - 2050
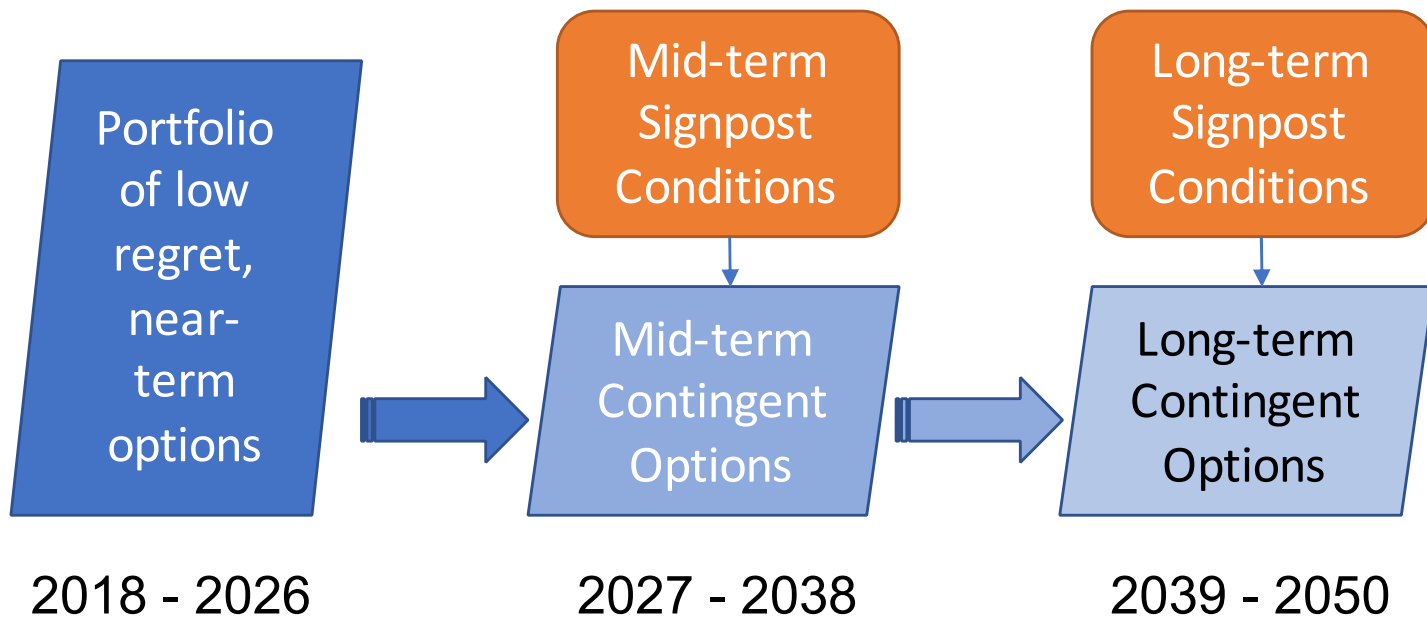
Analysis of optimal portfolios across scenarios reveal "low-regret, near-term options"
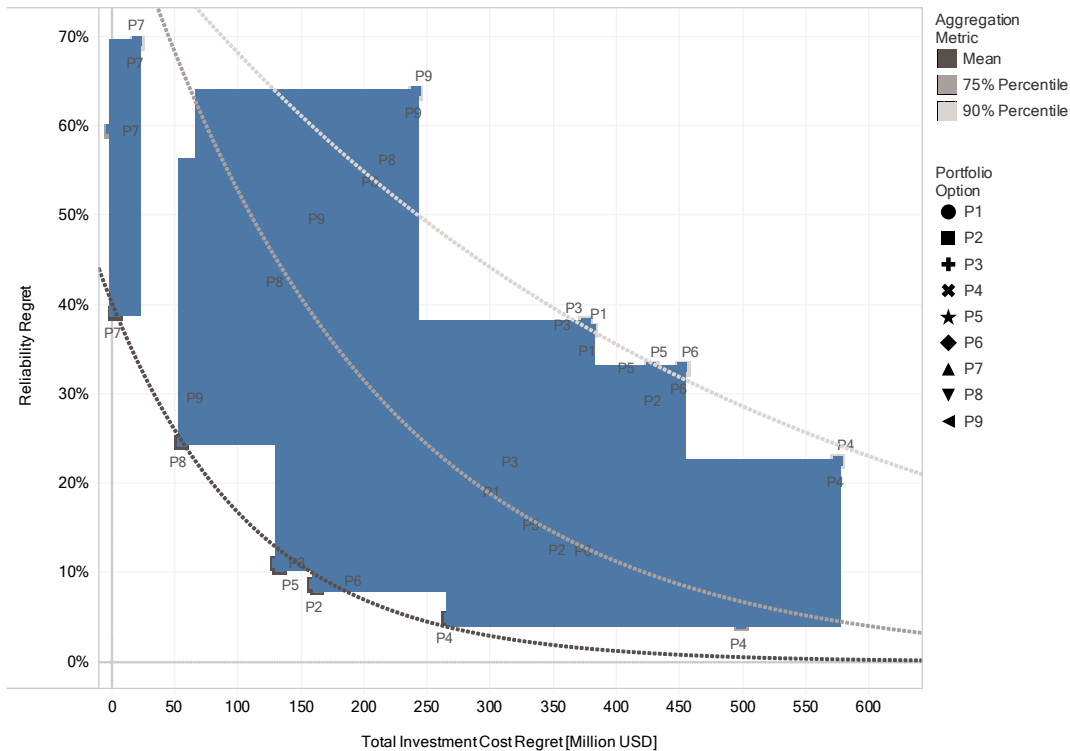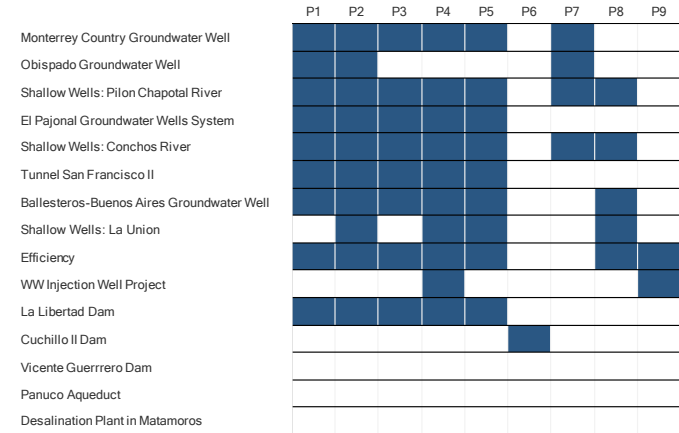
Successive optimizations (4.9 million runs) used to define decision trees describing later contingent options

Percent of Futures
0% ▢▢▢▢ 50%

Demand [cms] <= 14.6

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] <= 15.01

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] > 15.01

GW Availability [percent] > -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 96

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] > 14.6 and Demand [cms] <= 15.76

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

GW Availability [percent] <= -6.0

Demand [cms] > 15.76 and Demand [cms] <= 18.61

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] <= 21.04

WW Injection Well Project
Cost [million usd] = 148
Reliability [percent] = 100

Panuco Aqueduct
Vicente Guerrero Dam
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 2758
Reliability [percent] = 100

Demand [cms] > 21.04

GW Availability [percent] > 15

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 99

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 97

Demand [cms] > 18.61 and Demand [cms] <= 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

GW Availability [percent] <= 15

Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
Cost [million usd] = 439
Reliability [percent] = 91

Demand [cms] > 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 99

No Action
Cost [million usd] = 0
Reliability [percent] = 99

<----------- 2016 -2026 ------------>   <----------------2027-2038-------------------------->   <----------------2039-2050----------------------->

Robust, adaptive strategy defers decisions on large, controversial projects...

Percent of Futures
0% ▢▢▢▢ 50%

Diversified near-term projects

Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
Cost [million usd] = 439
Reliability [percent] = 91

Demand [cms] <= 14.6

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] <= 15.01

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Demand [cms] > 15.01

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

GW Availability [percent] > -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 96

Desalination Plant
Cost [million usd] = 1406
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Demand [cms] > 14.6 and Demand [cms] <= 15.76

Desalination Plant
Cost [million usd] = 1406
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No Action
Cost [million usd] = 0
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GW Availability [percent] <= -6.0

Demand [cms] > 15.76 and Demand [cms] <= 18.61

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] <= 21.04

WW Injection Well Project
Cost [million usd] = 148
Reliability [percent] = 100

Panuco Aqueduct
Vicente Guerrero Dam
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 2758
Reliability [percent] = 100

Demand [cms] > 21.04

GW Availability [percent] > 15

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 99

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 97

Demand [cms] > 18.61 and Demand [cms] <= 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

GW Availability [percent] <= 15

Demand [cms] > 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
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WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 99

No Action
Cost [million usd] = 0
Reliability [percent] = 99

<----------- 2016 -2026 ------------>
<---------------2027-2038------------------------>
<---------------2039-2050-------------------------->

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Robust, adaptive strategy defers decisions on large, controversial projects...

Monitor Demand

Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
Cost [million usd] = 439
Reliability [percent] = 91

Demand [cms] <= 14.6

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] <= 15.01

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Demand [cms] > 15.01

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] > 14.6 and Demand [cms] <= 15.76

GW Availability [percent] > -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 96

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

GW Availability [percent] <= -6.0

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] > 15.76 and Demand [cms] <= 18.61

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] <= 21.04

WW Injection Well Project
Cost [million usd] = 148
Reliability [percent] = 100

Demand [cms] > 21.04

Panuco Aqueduct
Vicente Guerrero Dam
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 2758
Reliability [percent] = 100

Demand [cms] > 18.61 and Demand [cms] <= 19.61

GW Availability [percent] > 15

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 99

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 97

GW Availability [percent] <= 15

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] > 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 99

No Action
Cost [million usd] = 0
Reliability [percent] = 99

<----------- 2016 -2026 ------------->   <-----------------2027-2038----------------->   <-----------------2039-2050----------------->

14

Robust, adaptive strategy defers decisions on large, controversial projects…

Percent of Futures
0% ▢▢▢▢▢ 50%

Demand [cms] <= 14.6

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] <= 15.01

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Demand [cms] > 15.01

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

GW Availability [percent] > -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 96

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] > 14.6 and Demand [cms] <= 15.76

New Desalination Plant

No Action
Cost [million usd] = 0
Reliability [percent] = 100

GW Availability [percent] <= -6.0

Demand [cms] > 15.76 and Demand [cms] <= 18.61

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] <= 21.04

WW Injection Well Project
Cost [million usd] = 148
Reliability [percent] = 100

Demand [cms] > 21.04

Panuco Aqueduct
Vicente Guerrero Dam
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 2758
Reliability [percent] = 100

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 99

GW Availability [percent] > 15

Cuchillo II Dam
Cost [million usd] = 460
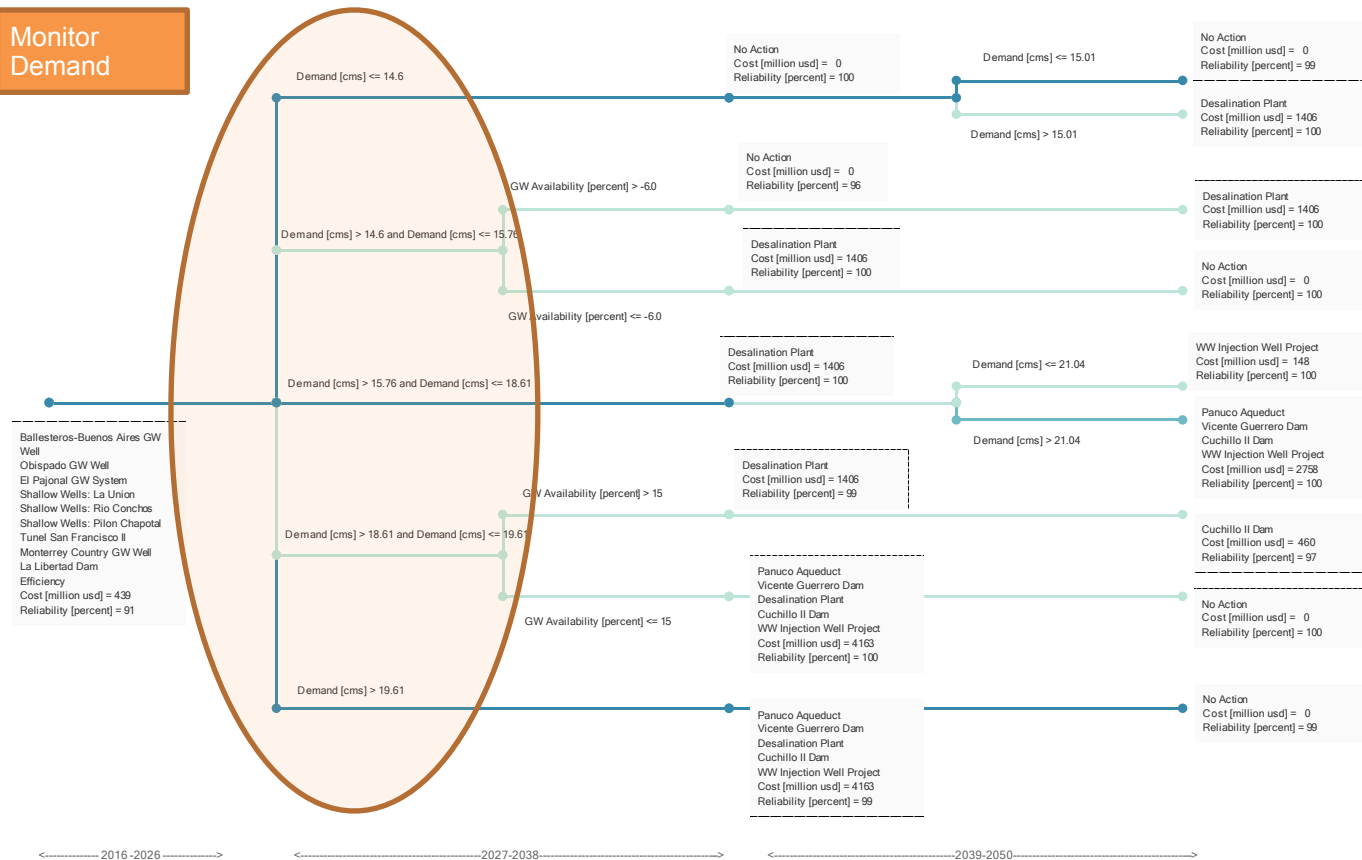Reliability [percent] = 97

Demand [cms] > 18.61 and Demand [cms] <= 19.61

Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
Cost [million usd] = 439
Reliability [percent] = 91

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 100

GW Availability [percent] <= 15

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] > 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 99

Large, costly Investments if very high growth

No Action
Cost [million usd] = 0
Reliability [percent] = 99

<-------------- 2016 -2026 -------------->   <----------------------2027-2038---------------------------->   <--------------------------2039-2050------------------------------>

15

Percent of Futures
0% — 50%

Monitor Groundwater

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] <= 15.01

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Demand [cms] > 15.01

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

GW Availability [percent] > -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 96

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] > 14.6 and Demand [cms] <= 15.76

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

GW Availability [percent] <= -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] > 15.76 and Demand [cms] <= 18.61

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] <= 21.04

WW Injection Well Project
Cost [million usd] = 148
Reliability [percent] = 100

Demand [cms] > 21.04

Panuco Aqueduct
Vicente Guerrero Dam
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 2758
Reliability [percent] = 100

Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
Cost [million usd] = 439
Reliability [percent] = 91

GW Availability [percent] > 15

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 99

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 97

Demand [cms] > 18.61 and Demand [cms] <= 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 100

GW Availability [percent] <= 15

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] > 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 99

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Robust, adaptive strategy defers decisions on large, controversial projects...

Percent of Futures
0% ▢▢▢▢ 50%

Demand [cms] <= 14.6

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] <= 15.01

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Demand [cms] > 15.01

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

No additional action required
If demand is low

GW Availability [percent] > -6.0

No Action
Cost [million usd] = 0
Reliability [percent] = 96

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] > 14.6 and Demand [cms] <= 15.76

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

GW Availability [percent] <= -6.0

Demand [cms] > 15.76 and Demand [cms] <= 18.61

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Demand [cms] <= 21.04

WW Injection Well Project
Cost [million usd] = 148
Reliability [percent] = 100

Demand [cms] > 21.04

Panuco Aqueduct
Vicente Guerrero Dam
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 2758
Reliability [percent] = 100

Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
Cost [million usd] = 439
Reliability [percent] = 91

GW Availability [percent] > 15

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 99

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 97

Demand [cms] > 18.61 and Demand [cms] <= 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 100

GW Availability [percent] <= 15

Demand [cms] > 19.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Cuchillo II Dam
WW Injection Well Project
Cost [million usd] = 4163
Reliability [percent] = 99

No Action
Cost [million usd] = 0
Reliability [percent] = 99

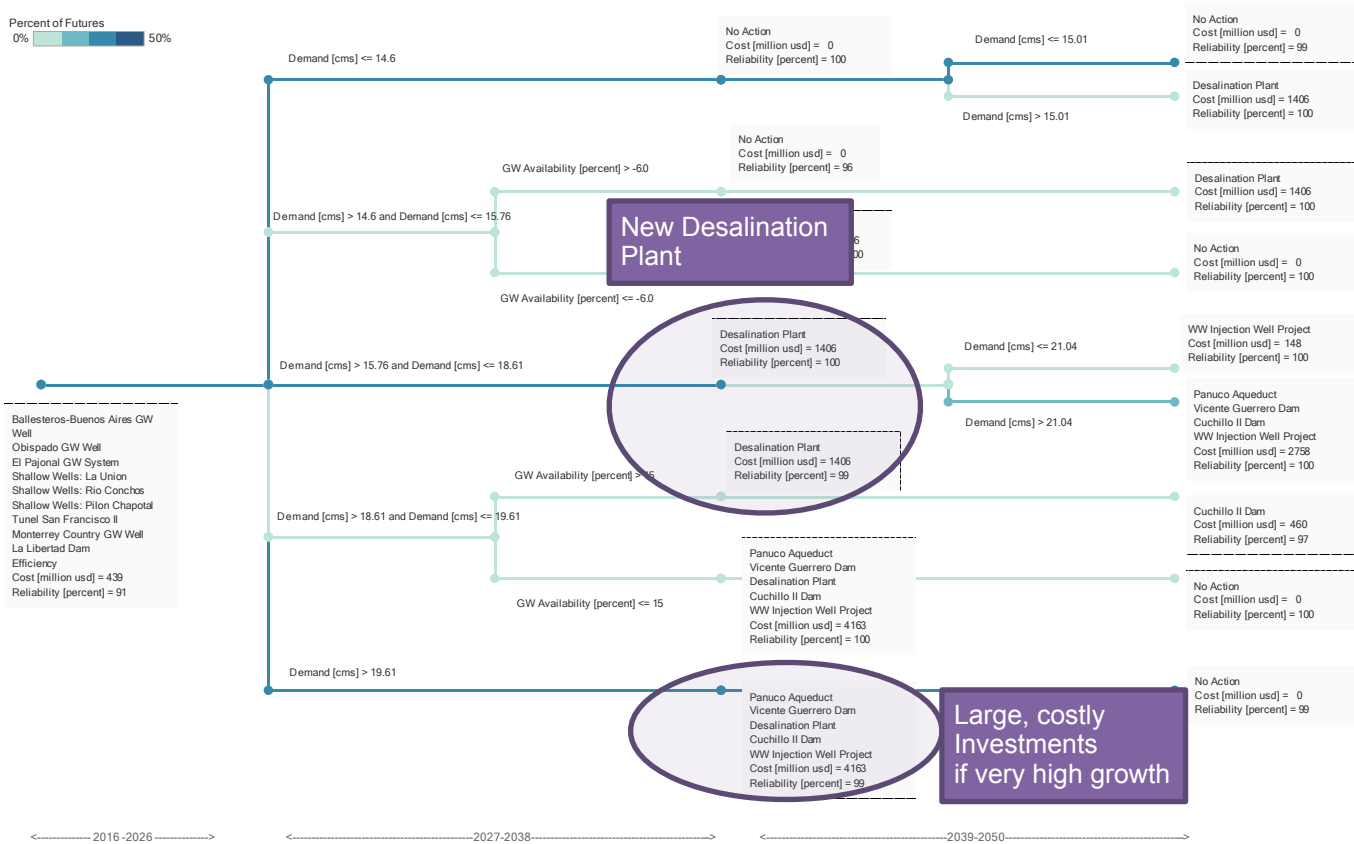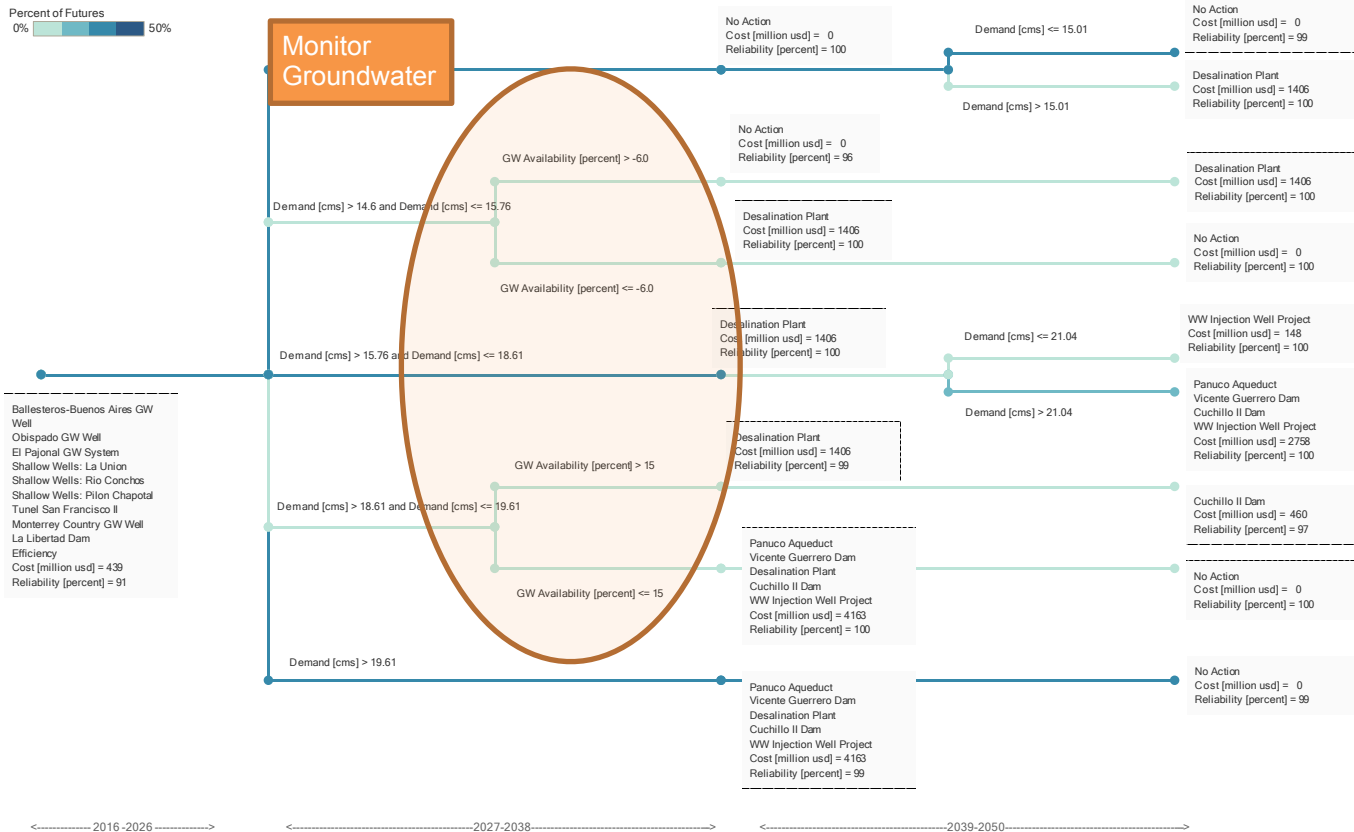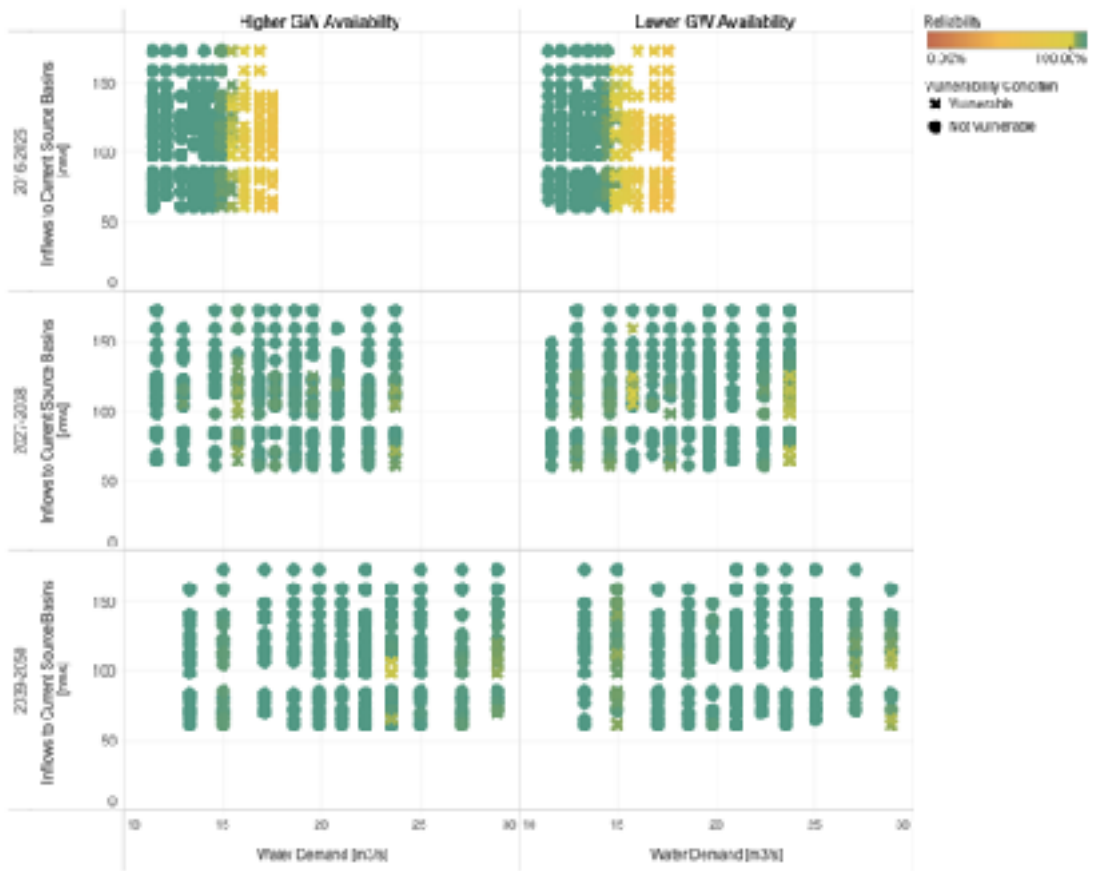<------------ 2016 -2026 ------------>   <-------------------2027-2038-------------------------->   <-------------------2039-2050-------------------------->
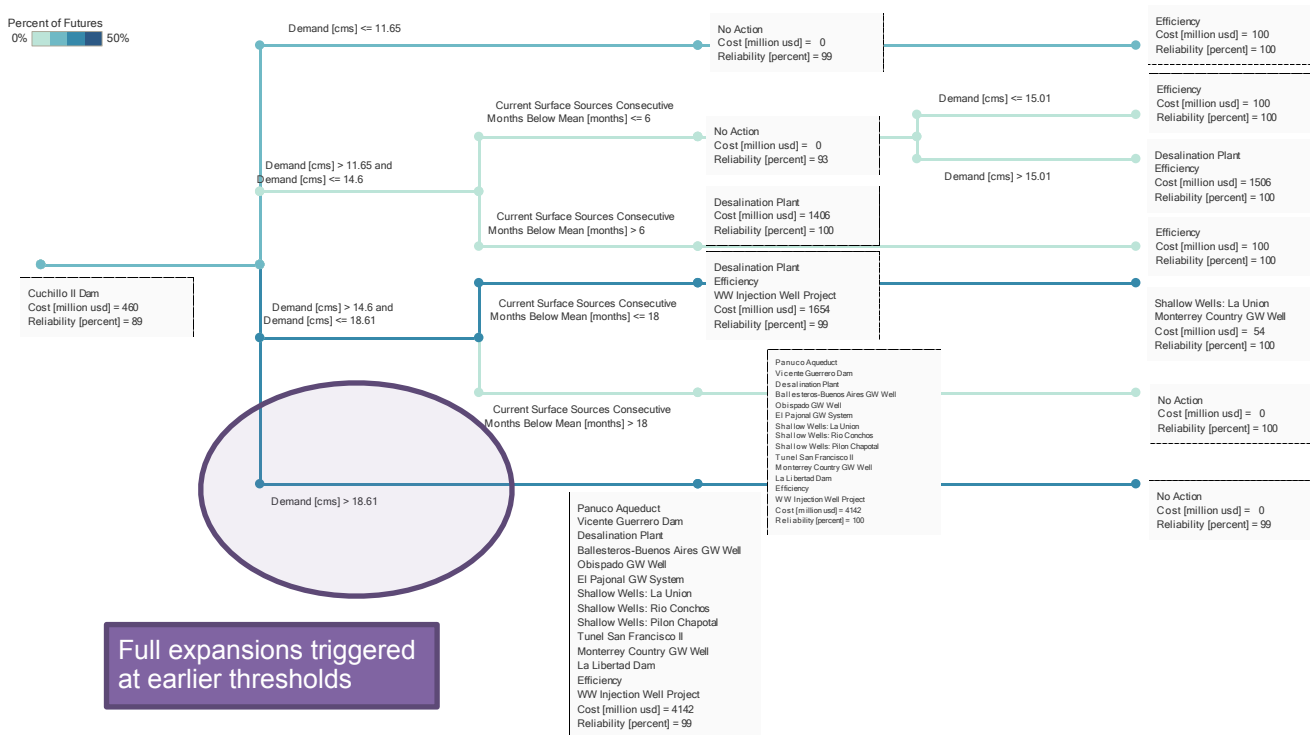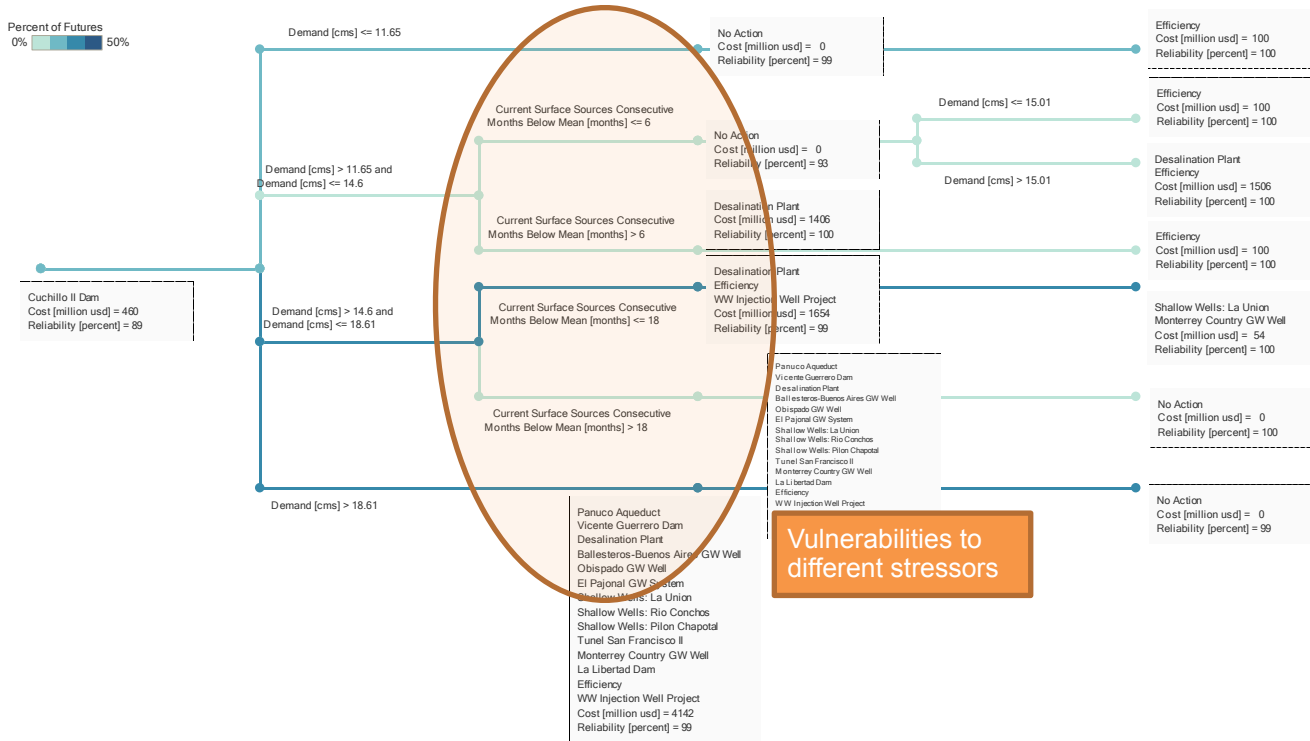
…and ensures water supply reliability over wide range of plausible futures

Comparison of all alternatives highlights long-term resilience implications of short-term decisions

Percent of Futures
0% ▢▢▢▢▢ 50%

Demand [cms] <= 11.65

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Efficiency
Cost [million usd] = 100
Reliability [percent] = 100

Current Surface Sources Consecutive
Months Below Mean [months] <= 6

Demand [cms] <= 15.01

Efficiency
Cost [million usd] = 100
Reliability [percent] = 100

Demand [cms] > 11.65 and
Demand [cms] <= 14.6

No Action
Cost [million usd] = 0
Reliability [percent] = 93

Desalination Plant
Efficiency
Cost [million usd] = 1506
Reliability [percent] = 100

Demand [cms] > 15.01

Current Surface Sources Consecutive
Months Below Mean [months] > 6

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Efficiency
Cost [million usd] = 100
Reliability [percent] = 100

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 89

Desalination Plant
Efficiency
WW Injection Well Project
Cost [million usd] = 1654
Reliability [percent] = 99

Current Surface Sources Consecutive
Months Below Mean [months] <= 18

Demand [cms] > 14.6 and
Demand [cms] <= 18.61

Shallow Wells: La Union
Monterrey Country GW Well
Cost [million usd] = 54
Reliability [percent] = 100

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
WW Injection Well Project
Cost [million usd] = 4142
Reliability [percent] = 100

Current Surface Sources Consecutive
Months Below Mean [months] > 18

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Demand [cms] > 18.61

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
WW Injection Well Project
Cost [million usd] = 4142
Reliability [percent] = 99

Full expansions triggered at earlier thresholds

Comparison of all alternatives highlights long-term resilience implications of short-term decisions

Percent of Futures
0% ▢▢▢▢▢ 50%

Demand [cms] <= 11.65

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Efficiency
Cost [million usd] = 100
Reliability [percent] = 100

Current Surface Sources Consecutive
Months Below Mean [months] <= 6

Demand [cms] <= 15.01

Efficiency
Cost [million usd] = 100
Reliability [percent] = 100

No Action
Cost [million usd] = 0
Reliability [percent] = 93

Demand [cms] > 11.65 and
Demand [cms] <= 14.6

Desalination Plant
Efficiency
Cost [million usd] = 1506
Reliability [percent] = 100

Demand [cms] > 15.01

Current Surface Sources Consecutive
Months Below Mean [months] > 6

Desalination Plant
Cost [million usd] = 1406
Reliability [percent] = 100

Efficiency
Cost [million usd] = 100
Reliability [percent] = 100

Cuchillo II Dam
Cost [million usd] = 460
Reliability [percent] = 89

Desalination Plant
Efficiency
WW Injection Well Project
Cost [million usd] = 1654
Reliability [percent] = 99

Current Surface Sources Consecutive
Months Below Mean [months] <= 18

Shallow Wells: La Union
Monterrey Country GW Well
Cost [million usd] = 54
Reliability [percent] = 100

Demand [cms] > 14.6 and
Demand [cms] <= 18.61

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
WW Injection Well Project

No Action
Cost [million usd] = 0
Reliability [percent] = 100

Current Surface Sources Consecutive
Months Below Mean [months] > 18

Vulnerabilities to different stressors

Panuco Aqueduct
Vicente Guerrero Dam
Desalination Plant
Ballesteros-Buenos Aires GW Well
Obispado GW Well
El Pajonal GW System
Shallow Wells: La Union
Shallow Wells: Rio Conchos
Shallow Wells: Pilon Chapotal
Tunel San Francisco II
Monterrey Country GW Well
La Libertad Dam
Efficiency
WW Injection Well Project
Cost [million usd] = 4142
Reliability [percent] = 99

No Action
Cost [million usd] = 0
Reliability [percent] = 99

Demand [cms] > 18.61

<----------- 2016 -2026 ------------->   <-------------------------2027-2038----------------------->   <-------------------------2039-2050-------------------------->

Monterrey Study Outcomes

- Monterrey Water Plan complete and moving towards implementation (first Water Plan in Mexico) http://planhidriconl.mx/

- Inclusion of innovative options such as network efficiency and ww injection

- New groundwater monitoring program established

- Elevated role of planning in state, supported by the Water Fund

Report will be published in the coming days

Monterrey, Mexico's third-largest metropolitan area, faces future water security challenges as the region grows. Fondo de Agua Metropolitano de Monterrey (FAMM) commissioned staff from Tecnológico de Monterrey in partnership with the RAND Corporation to conduct an analysis of the long-term trends and vulnerabilities to water management in Monterrey and to help design a long-term robust water strategy for City of Monterrey. The study documented in this report uses the Robust Decision Making (RDM) framework to organize the analysis and was carried out in close collaboration with Monterrey's water planning community. The results of the initial assessment of vulnerabilities showed that the current capacity of Monterrey's water system is not sufficient to sustain current reliability levels in the short, medium, or long term. Increases in water demand will reduce the reliability of the system below current levels (i.e., 97 percent); the same is true for declines in water availability across current surface basins and groundwater sources. These results confirm the intuition and previous analysis of local stakeholders regarding the need for increasing the supply capacities of the current system. If nothing is done to expand the capacities of the system—or to make it more efficient—the reliability of Monterrey's water system is likely to progressively erode in the coming years.

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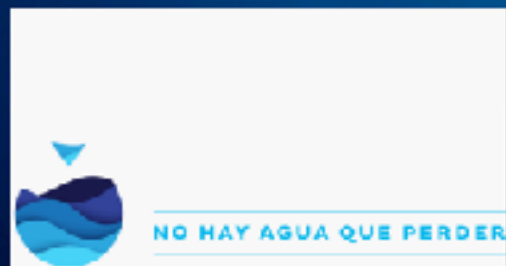
Diversification and Adaptation for Coping with Climate, Economic, and Technological Uncertainties

Edmundo Molina-Perez, David G. Groves, Steven W. Popper, Aldo I. Ramirez, Rodrigo Crespo-Elizondo

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