Denver Water Dynamic and Adaptive Master Plan

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Water Research Foundation's
Intelligent Water Networks Summit

DENVER WATER

Denver Water

Colorado's oldest and largest water utility.

Established in
1918

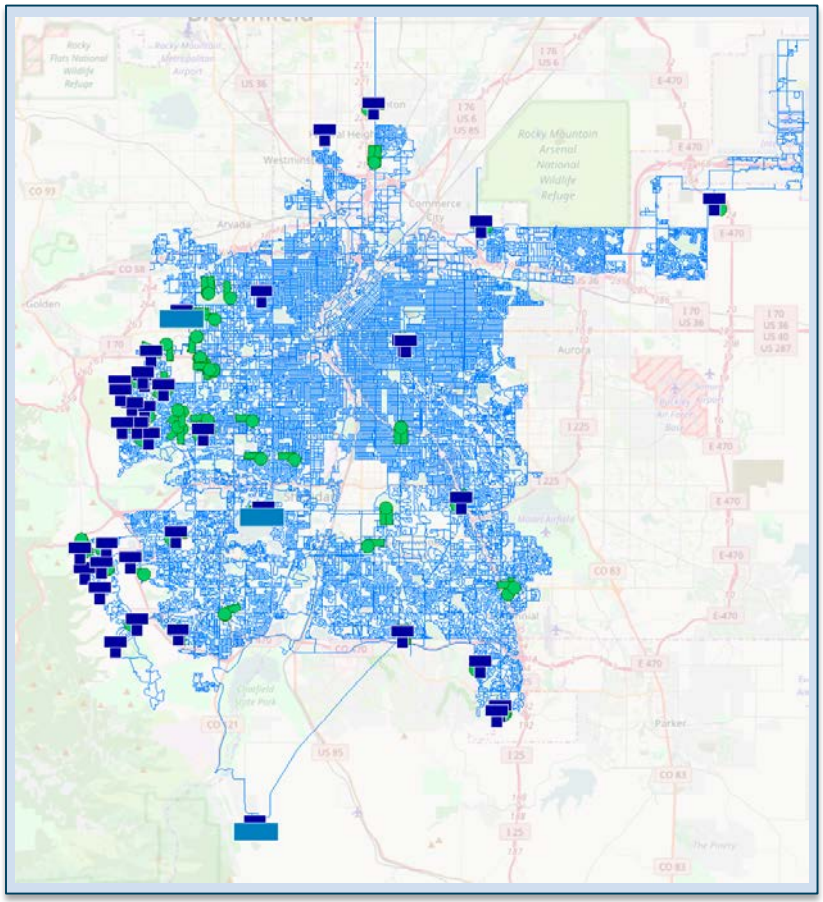
Serves
1.4 Million people

Denver and Suburbs

Collection, storage, and distribution of
Drinking water

Operating revenue
$284 Million (2016)

Denver Water System

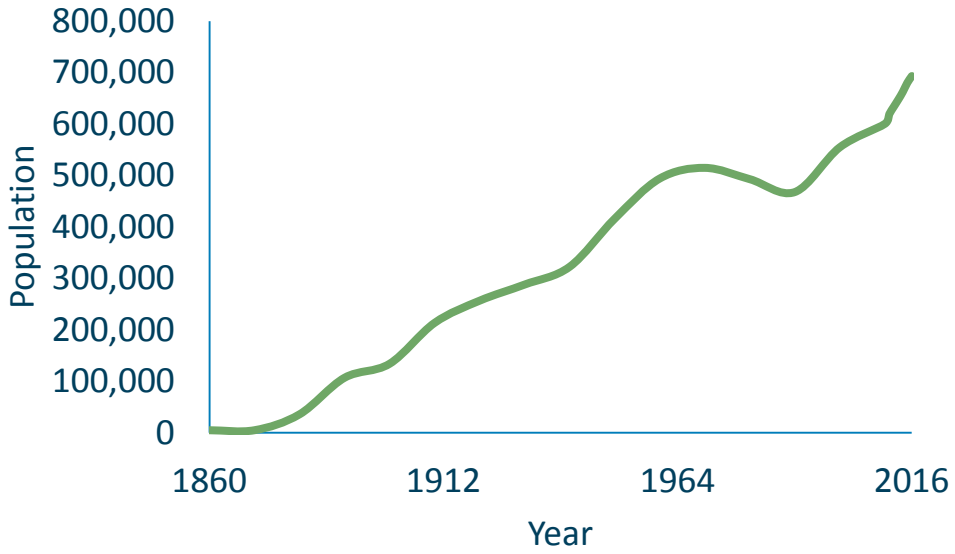


- Supply by 3 treatment plants
- 3,100 miles of pipelines
- 33,000 Hydrants
- 144 pressure zones
- 150 major control valves
- 520 PRVs
- 58 storage tanks
- 200 pump units in 51 stations
- Over 50 distributors

Innovation, strategic planning, advanced technologies are a chosen path for Denver Water

Denver Water Drivers and Motivation

- Population growth
- Climate change
- Periodic drought
- Competition for water resources
- Changing water usage
- Changing regulatory and political environment.
- Maximize water efficiency



Dynamic and Adaptive Master Planning

Beyond documents

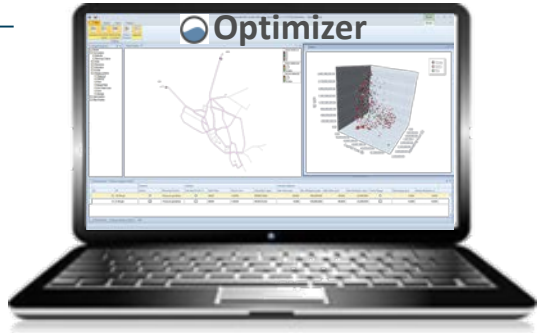
Dynamic Adaptive Master Plan Using an Optimization Approach

Why?

Optimization

Provides unbiased and transparent cost-effective solutions.

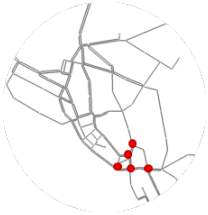
Software



Optimatics

Treated Water Planning Study and Integrated Resource Plan In Progress

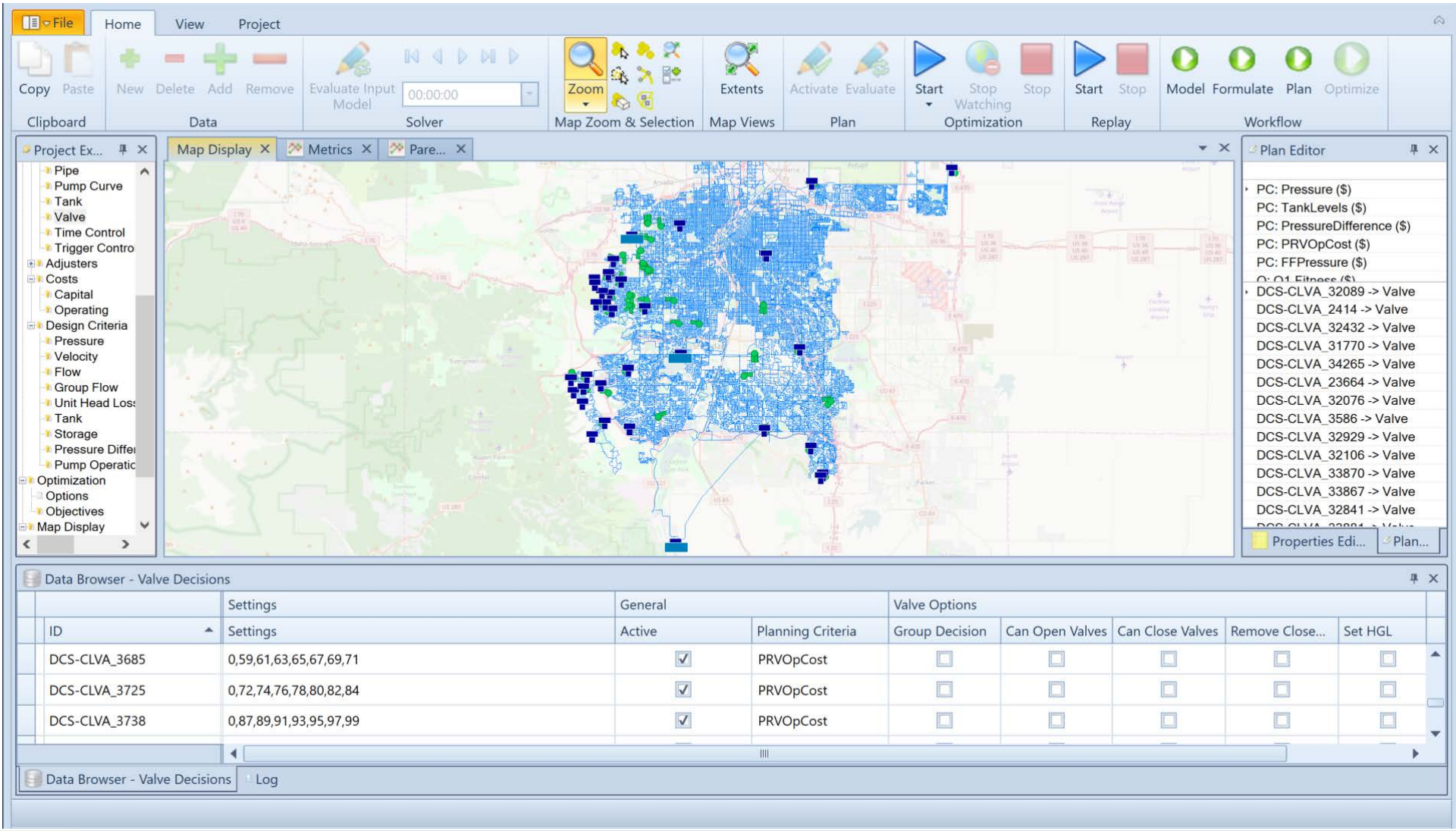
Guide decisions over the next 50 years.



Recently updated Innovyze InfoWater Hydraulic Model

Evaluates the hydraulic performance of various alternatives.

Software: Optimizer WDS



A Step by Step Journey

Data Collection

Set-up Hydraulic Design Criteria

Identify Operating Alternatives

Interim and Final Optimization Runs

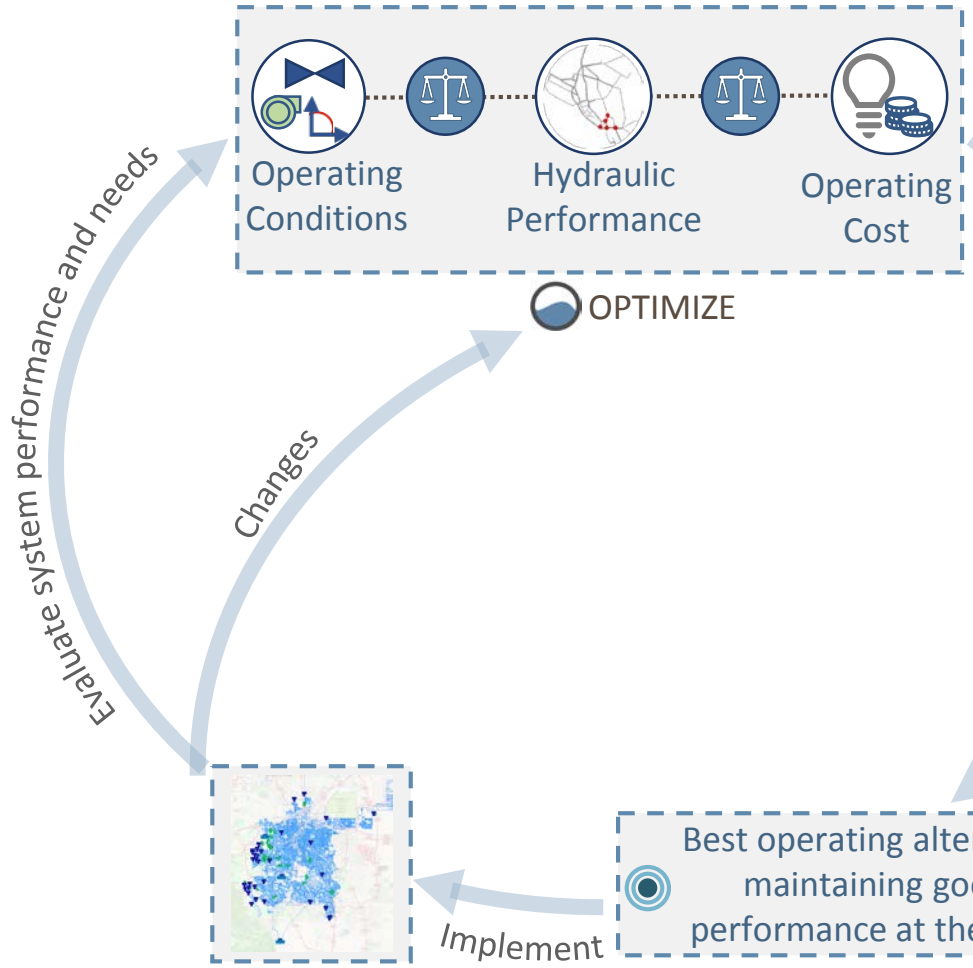
Select Best Option for Today Needs

4-5 Months Journey

Great Benefits

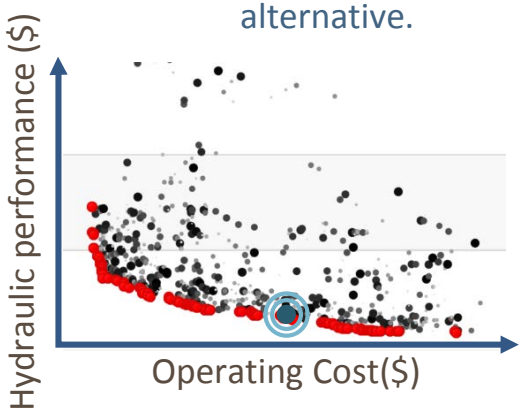
- Cloud Computing
- Multi-Objective Optimization
- Customized Scripts for DW needs
- Evaluate thousands of alternatives
- Basis for Future Optimization Efforts
- Easy to integrate within DW processes
- Transparence
- Confidence

Dynamic Adaptive Master Plan

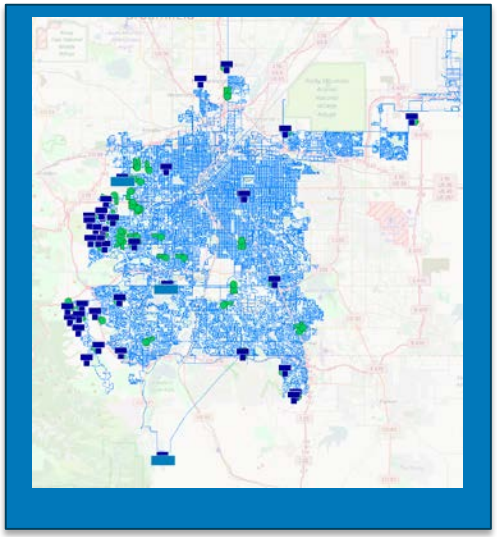


Evaluate thousands of alternatives and select the best

Every dot represents a different alternative.



Optimization Software Data Needs



Calibrated hydraulic model

- InfoWater model
- Hydraulic model skeletonized to 60,000 pipes, original model had 350,000
- Extended period simulation (24hr) of 2016 Maximum Day Conditions.

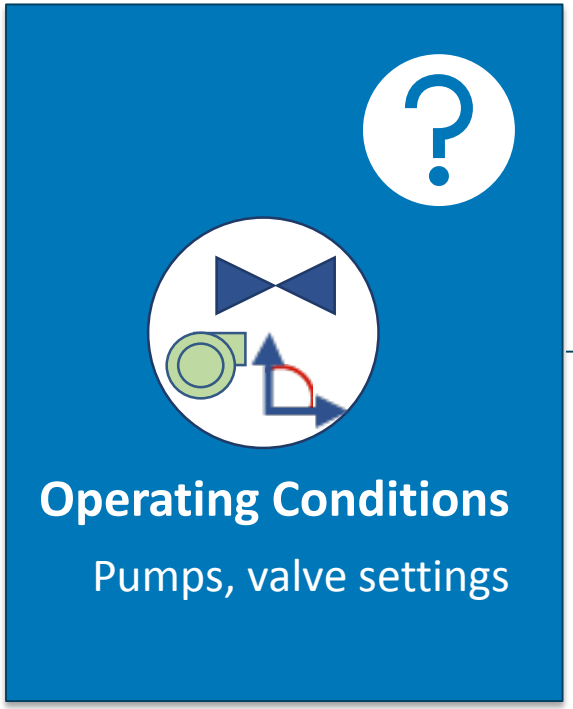
- Pump off/on level controls
- Control valve settings and status

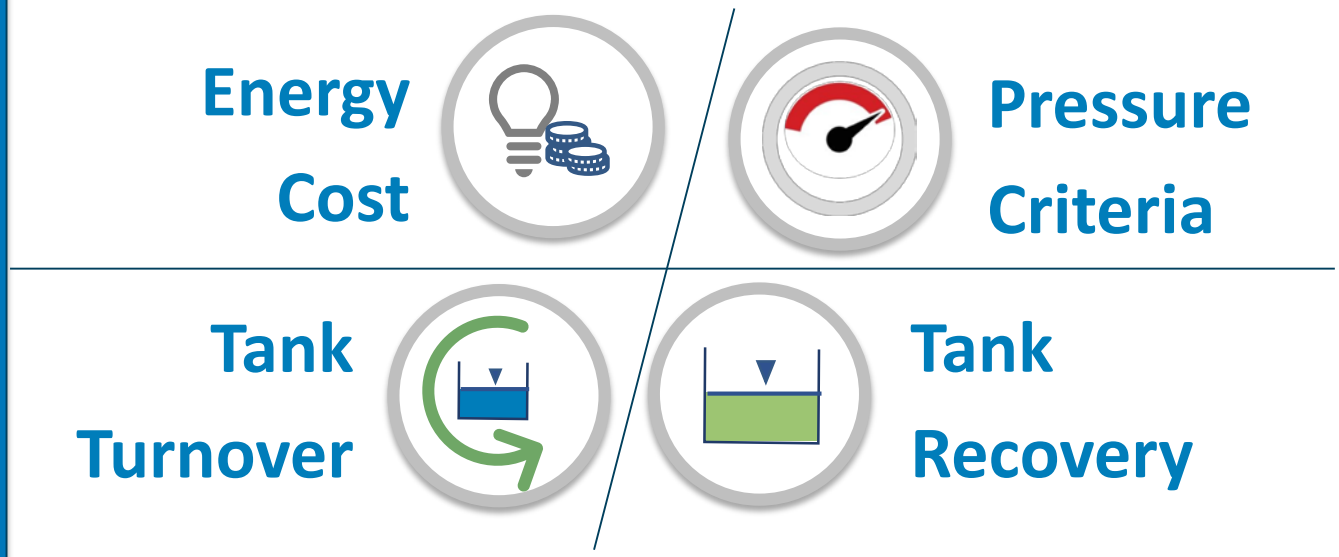
Improvement options

Cost information

Optimization Goals

Which set of operating conditions will have the least energy cost while meeting service level goals for pressure, tank turnover, and tank recovery.





Optimization Decisions

Pump Unit

- On and Off control levels
- Status (open/close)

Control Valves

- On and Off control levels
- Setting
- Status (open or close)

WTP

- Supply flow

Data Browser - Trigger Control Decisions

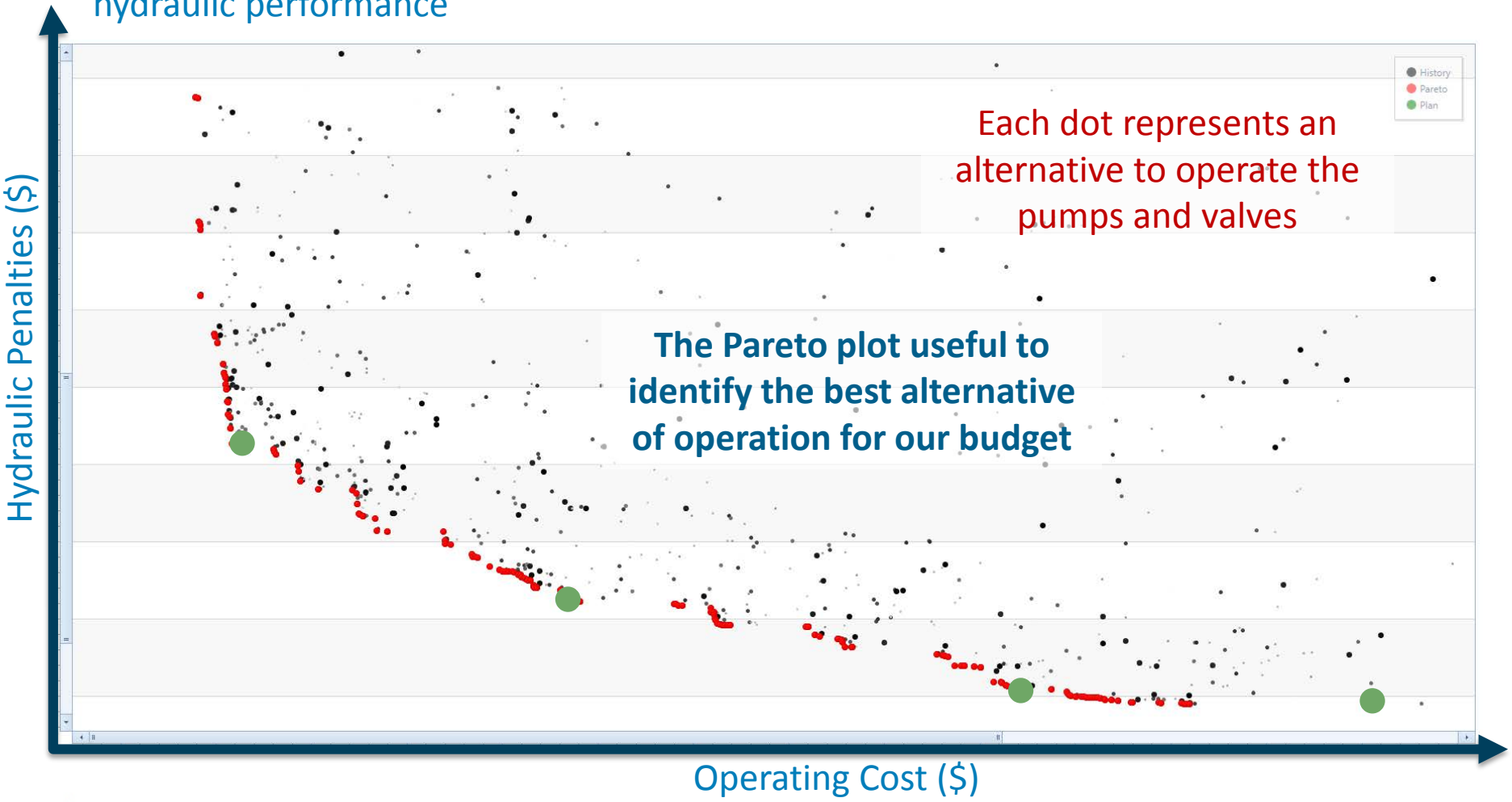
		General		Settings
R..	ID	Active	Planning Criteria	Settings (ft)
1	BELLEVIEW_HIGH_SIDE_P4-Off	☑	OperatingCost	16,18,19,20,21
1	BELLEVIEW_HIGH_SIDE_P4-On	☑	OperatingCost	12,14,16,19
1	BELLEVIEW_HIGH_SIDE_P5-Off	☑	OperatingCost	16,18,19,20,21
1	BELLEVIEW_HIGH_SIDE_P5-On	☑	OperatingCost	12,14,16,19
1	BELLEVIEW_HIGH_SIDE_P6-Off	☑	OperatingCost	16,18,19,20,21
1	BELLEVIEW_HIGH_SIDE_P6-On	☑	OperatingCost	12,14,16,19
1	BELLEVIEW_HIGH_SIDE_P7-Off	☑	OperatingCost	16,18,19,20,21
1	BELLEVIEW_HIGH_SIDE_P7-On	☑	OperatingCost	12,14,16,19
1	BELLEVIEW_LOW_SIDE_P1-Off	☑	OperatingCost	17,19,20,21
1	BELLEVIEW_LOW_SIDE_P1-On	☑	OperatingCost	10,12,14,16
1	BELLEVIEW_LOW_SIDE_P2-Off	☑	OperatingCost	17,19,20,21
1	BELLEVIEW_LOW_SIDE_P2-On	☑	OperatingCost	10,12,14,16
1	CHATFIELD_HS_P5-Off	☑	OperatingCost	17,19,20,21,22
1	CHATFIELD_HS_P5-On	☑	OperatingCost	12,14,16,18
1	CHATFIELD_HS_P6-Off	☑	OperatingCost	17,19,20,21,22
1	CHATFIELD_HS_P6-On	☑	OperatingCost	12,14,16,18
1	CHATFIELD_HS_P7-Off	☑	OperatingCost	17,19,20,21,22
1	CHATFIELD_HS_P7-On	☑	OperatingCost	12,14,16,18
1	CHERRY_HILLS_P1-Off	☑	OperatingCost	15,17,18,19

144 Trigger Control Decisions

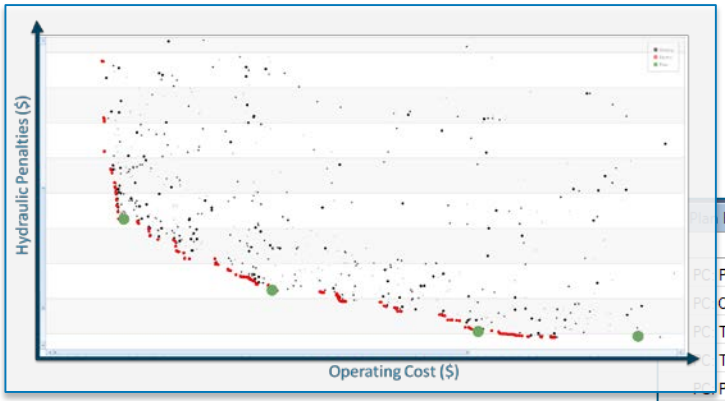
The Optimization software evaluates **the potential combinations** of the decisions for each pump unit, control valve and treatment plant.

Pareto Optimal Front – Multi-Objective

- Inflection points- good alternatives with different operating cost and different levels of hydraulic performance



Optimization Results



Plan Editor

	InputModel	Plan001	Plan002	Plan003	Plan004	Best SO
PC: Pressure ($)	31,958.63	43,394.53	43,494.21	2,528.09	2,765.39	2,045.00
PC: OperatingCost ($)	10,727.41	6,238.37	6,233.43	5,681.74	7,404.33	7,388.14
PC: TankLevels ($)	686,201.64	2,101,696.14	1,079,834.13	544,015.11	442,255.63	104.29
PC: TreatmentCost ($)	45,509.93	31,039.92	34,434.92	39,769.92	41,709.92	47,044.92
PC: PumpRun ($)	1,483.75	487.50	134.75	34.50	244.25	58.50
PC: PressureDifference ($)	0.00	0.00	0.00	0.00	0.00	0.00
O: O1-Cost ($)	56,237.34	37,278.29	40,668.36	45,451.66	49,114.26	54,433.06
O: O2-Performance ($)	719,644.02	2,145,578.17	1,123,463.09	546,577.71	445,265.27	2,207.79
MARSTONFLOW -> Valve MARSTON_FCV	Setting: 50000	Setting: 30000	Setting: 35000	Setting: 30000	Setting: 35000	Setting: 45000
KENDRICK_HS_P11-Off -> Control	17ft	21ft	21ft	21ft	21ft	21ft
KENDRICK_HS_P11-On -> Control	10ft	10ft	10ft	10ft	10ft	14ft
VD_CONTROLVALVES -> Valve CNVA_3127	Setting: 100	Setting: 5	Setting: 1e+006	Setting: 5	Setting: 5	Setting: 100
VD_CONTROLVALVES -> Valve CLVA_1269	Setting: 1e+006	Setting: 250	Setting: 250	Setting: 250	Setting: 250	Setting: 1000
VD_CONTROLVALVES -> Valve CLVA_1186	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006
VD_CONTROLVALVES -> Valve	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006	Setting: 1e+006	Setting: 1000
FOOTHILLSFLOW -> Valve FOOTHILLS_FCV	Setting: 155000	Setting: 140000	Setting: 155000	Setting: 155000	Setting: 155000	Setting: 155000
VD_CLVA_361 -> Valve CLVA_361	Setting: 50	Setting: 10	Setting: 1000	Setting: 1e+006	Setting: 1e+006	Setting: 250
LONE_TREE_HS_P7-Off -> Control	19ft	21ft	22ft	22ft	22ft	20ft
LONE_TREE_HS_P7-On -> Control	14ft	12ft	12ft	12ft	12ft	12ft
LONE_TREE_HS_P6-Off -> Control	20ft	17ft	17ft	17ft	22ft	17ft
LONE_TREE_HS_P6-On -> Control	14ft	16ft	16ft	16ft	12ft	16ft
LONE_TREE_LS_P5-Off -> Control SC0000FF	67psi	67psi	69psi	68psi	69psi	68psi
LONE_TREE_LS_P5-On -> Control	63psi	63psi	63psi	66psi	66psi	66psi
LONE_TREE_LS_P4-Off -> Control	67psi	68psi	70psi	68psi	67psi	69psi
LONE_TREE_LS_P4-On -> Control	63psi	63psi	64psi	63psi	63psi	64psi
LONE_TREE_HS_P8-On -> Control	18ft	14ft	12ft	18ft	18ft	14ft
LONE_TREE_HS_P8-Off -> Control	17ft	22ft	19ft	22ft	22ft	20ft

Project Outcomes

- Storage analysis matched views of O&M
- Interesting operations on max day
- Ideas for future analysis and optimization

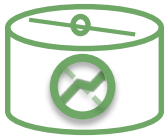
Hidden Issues – Water Optimization is More Complex than Sewer or Flooding

- Sewer / River / Combined Optimization
  - Cost
  - Minimize Flooding
- Water Optimization
  - Source Availability
  - Conduit Outages
  - WTP Outages
  - Fireflow
  - One Side Out Analysis
  - Demand Variations

Future Potential Optimization Projects at Denver Water

Downtown Area Pipe Replacement Project

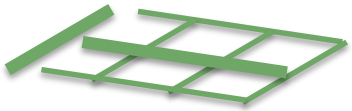
Shoulder Month Operations



Plant Outage Planning

Source Water Management Optimization

Continue Optimization of Operation Alternatives - 200-300 MGD and Raw Water



Major Improvements of Transmission System C25

Optimization for Risk Reduction and Resilience Enhancement

Real-Time Modeling

Future Goals

- Optimize Optimization
- Real-Time Modeling
- Raw Water Side
- CIP Optimization
- Finalize GIS Integration

Partnerships

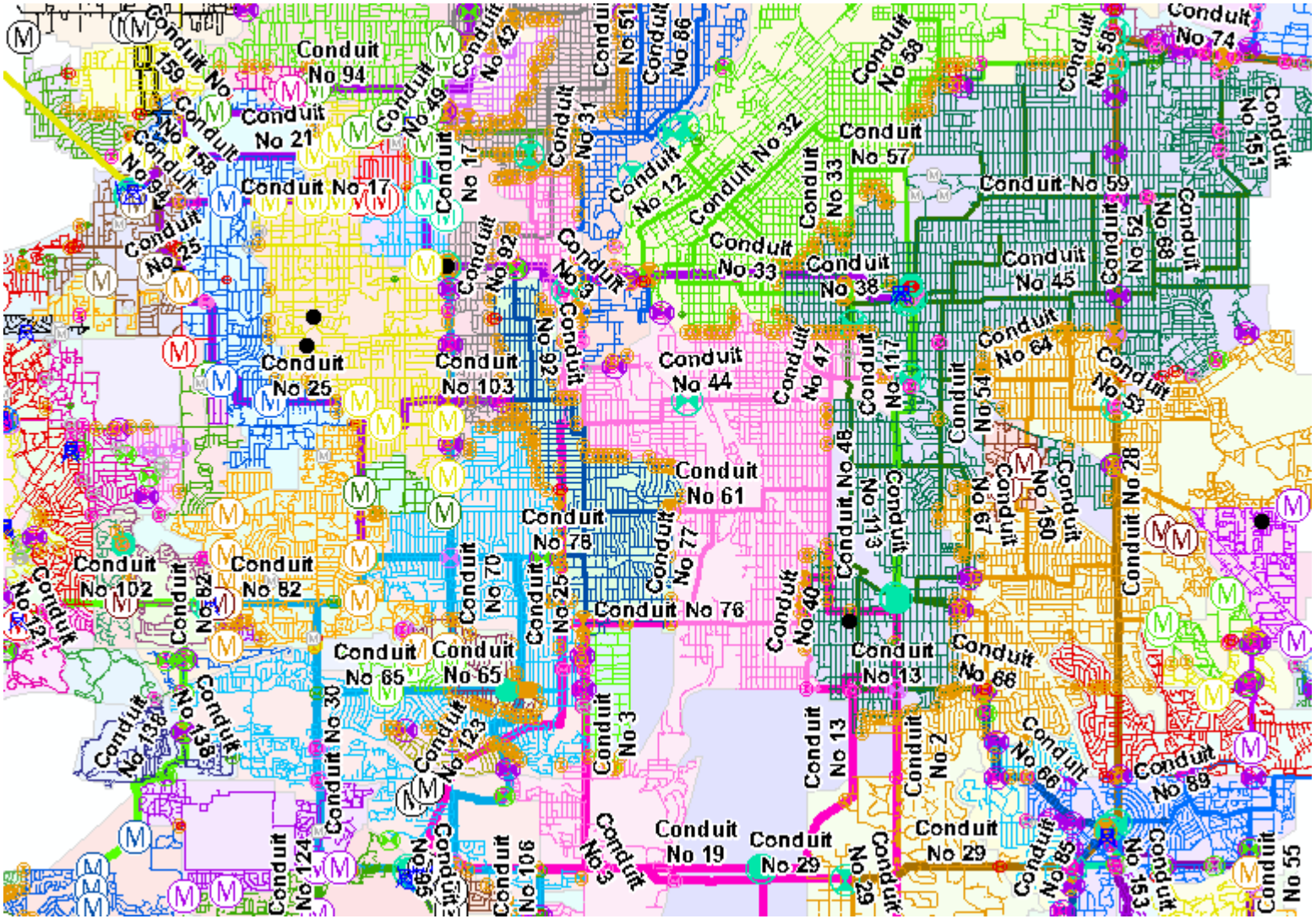
WaterPlans

HDR

Innovyze®

Optimatics

Thank You!


Conduit No 94
Conduit No 21
Conduit No 17
Conduit No 25
Conduit No 103
Conduit No 44
Conduit No 61
Conduit No 78
Conduit No 76
Conduit No 102
Conduit No 82
Conduit No 65
Conduit No 65
Conduit No 19
Conduit No 29
Conduit No 29
Conduit No 57
Conduit No 59
Conduit No 33
Conduit No 38
Conduit No 45
Conduit No 74
Conduit No 13
Conduit No 66
Conduit No 89