Hydraulic Analysis Comparing Efficiency of One and Two-Zone Pressure Water Systems

Agenda:

- Background
- Objectives
- Water Distribution System Overview
- GIS and Hydraulic Modeling Relationship
- Hydraulic Modeling Concepts
- Project Approach and Methodology
- Project Timeline
- References

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GEOG 596A

MGIS Program

Penn State University

May 12, 2015

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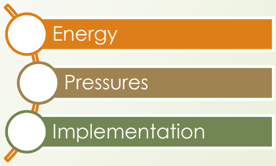
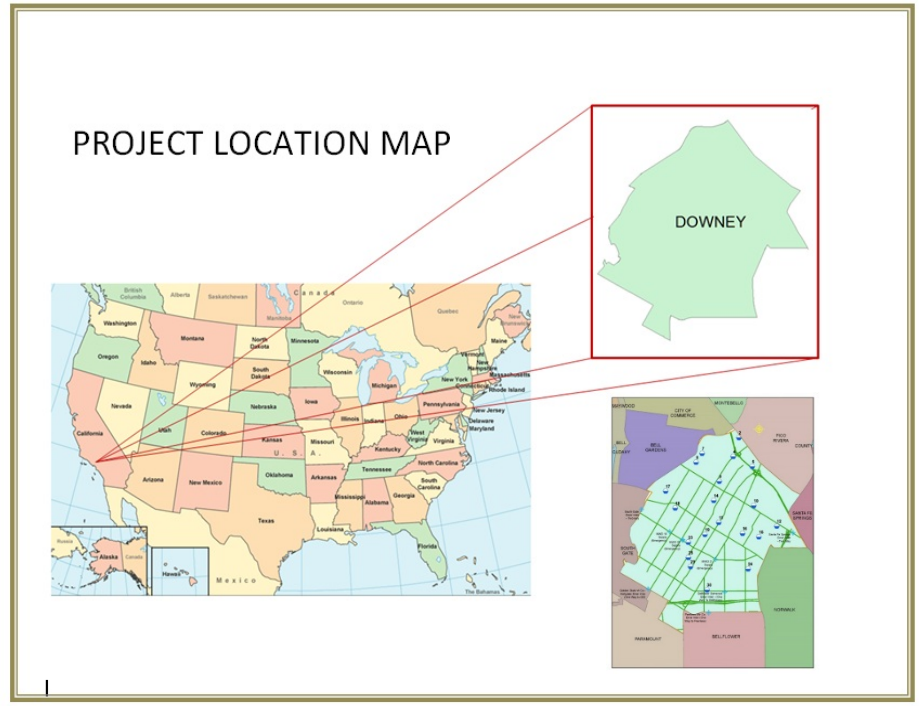


Background

- Overview of City of Downey
  - Location – 12 Miles SE of Downtown Los Angeles
  - Area - 12.8 Sq. Miles
  - Population - 113,000
  - Topography, Elevations 140 ft. to 85 ft.
  - Primary Drinking Water Purveyor
  - Five Emergency Connection with Other Water Agencies



onlineatlas.us(n.d.)

Background

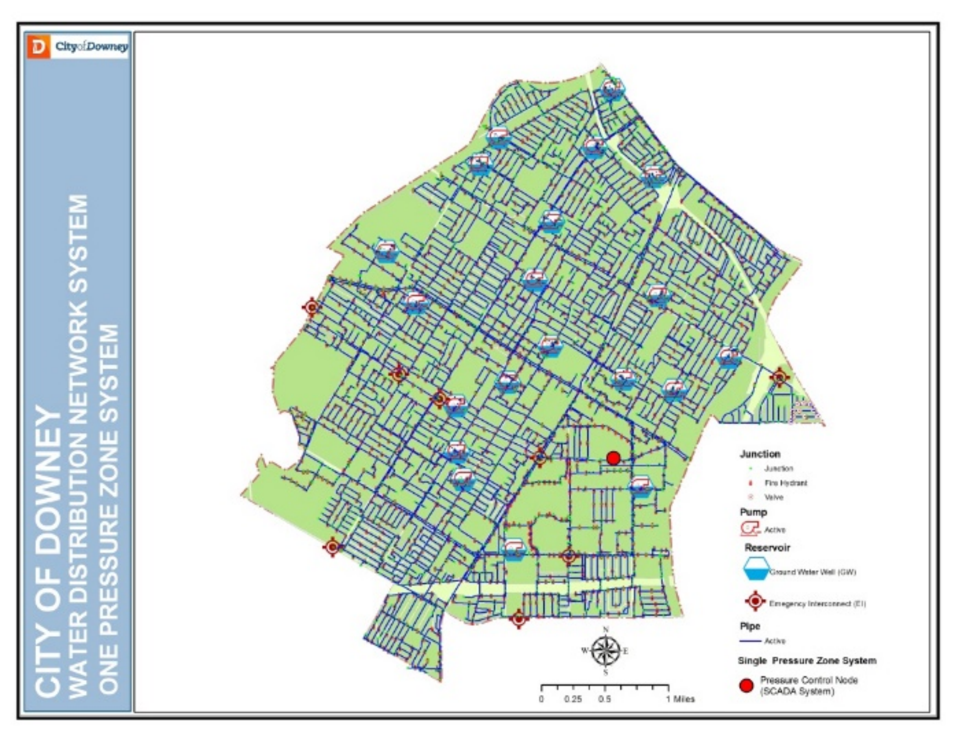
- Overview of Downey's Water Distribution Network
  - No of Customers 23,500
  - No. of Active Groundwater Wells 20
  - Average Daily Demand 10.2 MGD
  - Total Pipe Length in Mile – 260 miles
  - No. of Valves - 3800
  - No. of Fire Hydrants – 1,450
  - Elevation Difference Between

    North (140 ft.) and South (85 ft.)

    Boundaries – 55 ft.
  - System Pressure Varies From

    North (48 psi) to South (98 psi)
  - Water System Pressure Controlled by SCADA

    at Single Location for 65 psi.

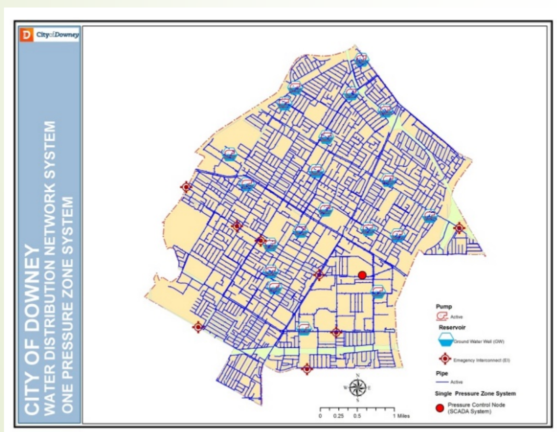


Background

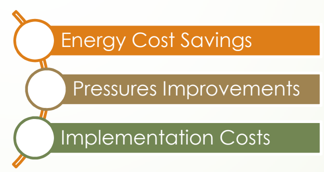
- Problem
  - High Costs of Pumping Energy Rates. Annual Energy Cost for Operating 20 Wells is about $1.4 Million
  - There is about 50 psi difference between North and South portion of the City
  - Existing Water Network System consists of Single Pressure Zone
  - Pumps Run more Frequently to keep the Required Pressure of 65 psi at the Water Yard Location.

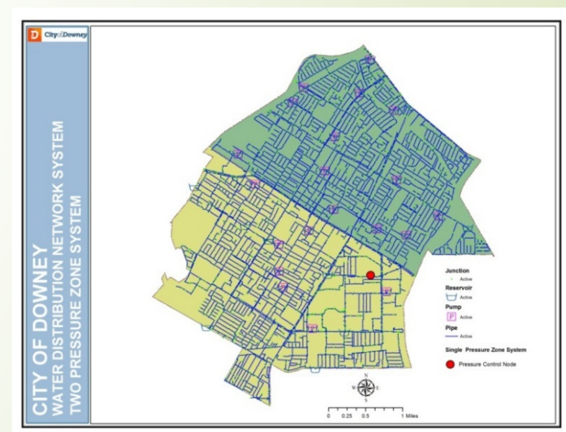
Objectives

- The factors that could help in maximizing the efficiency of the system
  - Energy Cost Savings
  - Water Distribution Network Pressures Improvement
  - Implementation Payback Analysis



Existing Condition

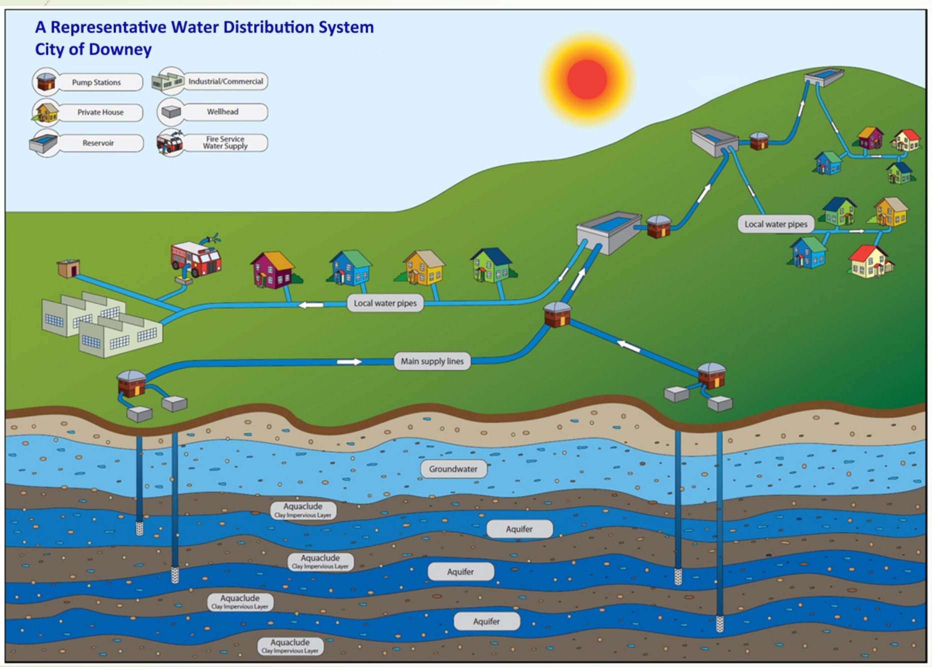




Project Goal

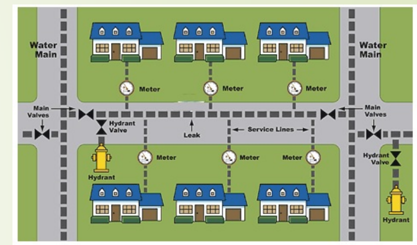
Water Distribution System Concept (GIS and Hydraulic Model)

- Major Components of the City of Downey's Water Distribution System



A Typical Groundwater Well System (Waterwise)

- Groundwater Wells
- Pumps
- Pipes
- Nodes
- Deep Aquifer Layers



Water Meter Consumption Nodes

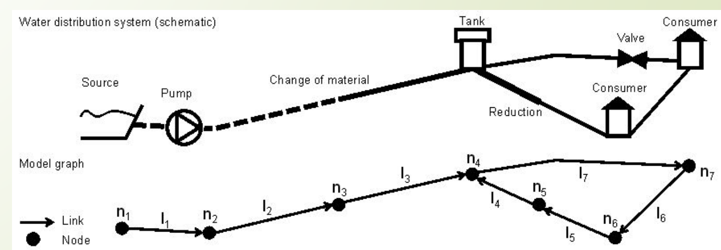


Illustration of a water distribution system and the corresponding model graph(Klingel, 2010)

- Hydraulic Model Representation

GIS and Hydraulic Modeling

- Feature Classes, GIS vs Hydraulic Model

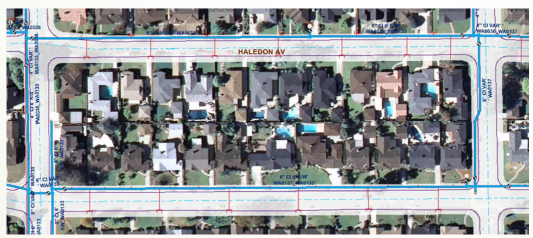
GIS Feature Classes

Mains

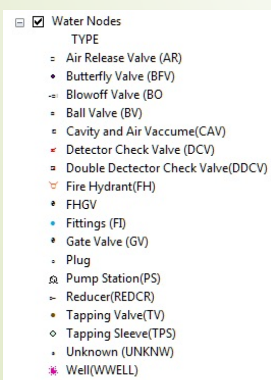
Laterals (Service Lines)

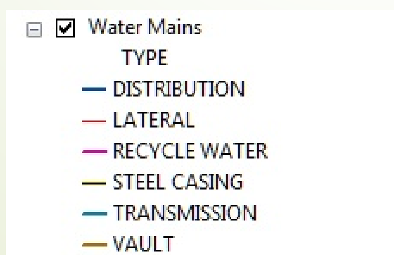
Main Nodes

Lateral Nodes



Water Mains in GIS



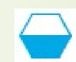


Hydraulic Model Elements

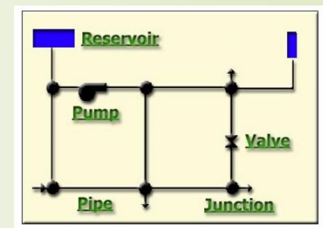
Pipes

Valves 

Junctions

Reservoirs 

Pumps 

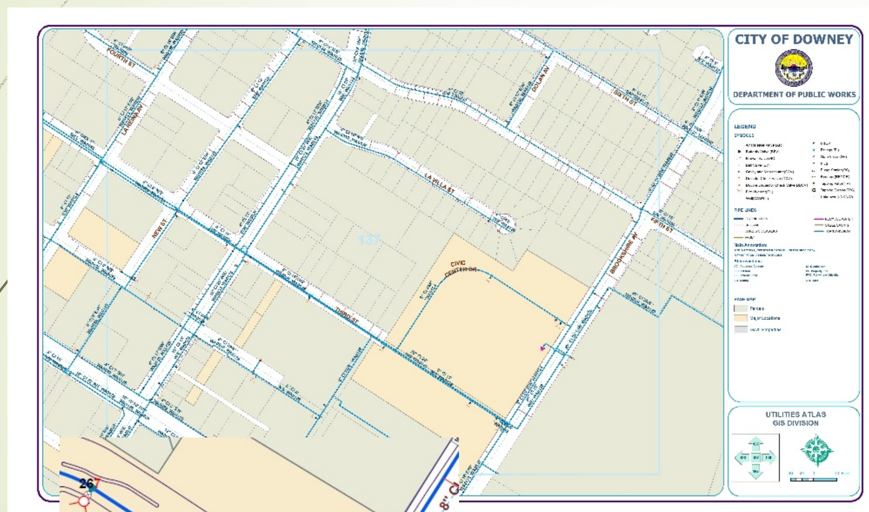


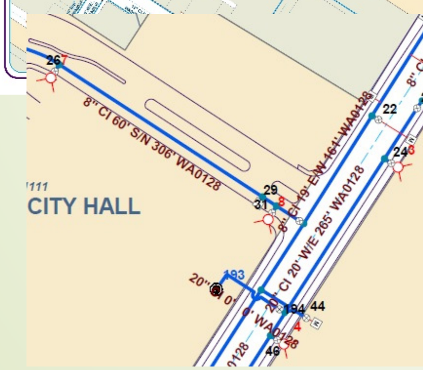
Model Schematics

GIS and Hydraulic Modeling

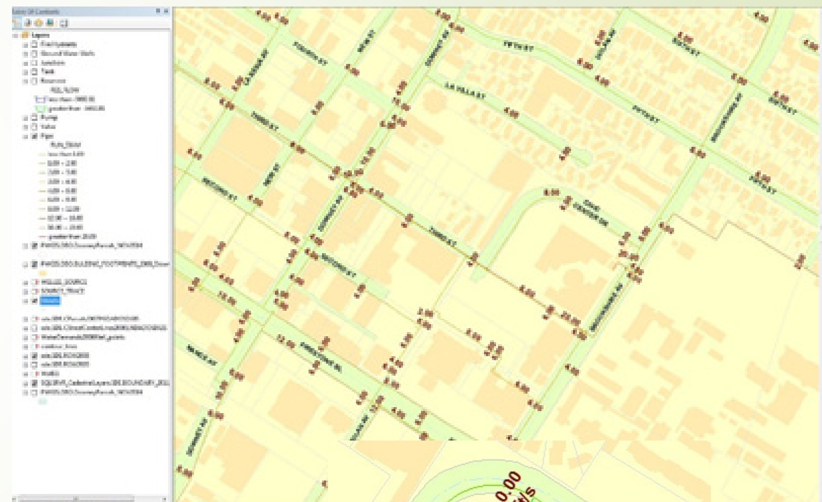
- Feature Classes, GIS vs Hydraulic Model

GIS Feature Classes





Hydraulic Model Elements



Common network modeling elements

Element	Type	Primary Modeling Purpose
Reservoir	Node	Provides water to the system
Tank	Node	Stores excess water within the system and releases that water at times of high usage
Junction	Node	Removes (demand) or adds (inflow) water from/to the system
Pipe	Link	Conveys water from one node to another
Pump	Node or link	Raises the hydraulic grade to overcome elevation differences and friction losses
Control Valve	Node or link	Controls flow or pressure in the system based on specified criteria

(Walski, 2003)

GIS and Hydraulic Modeling

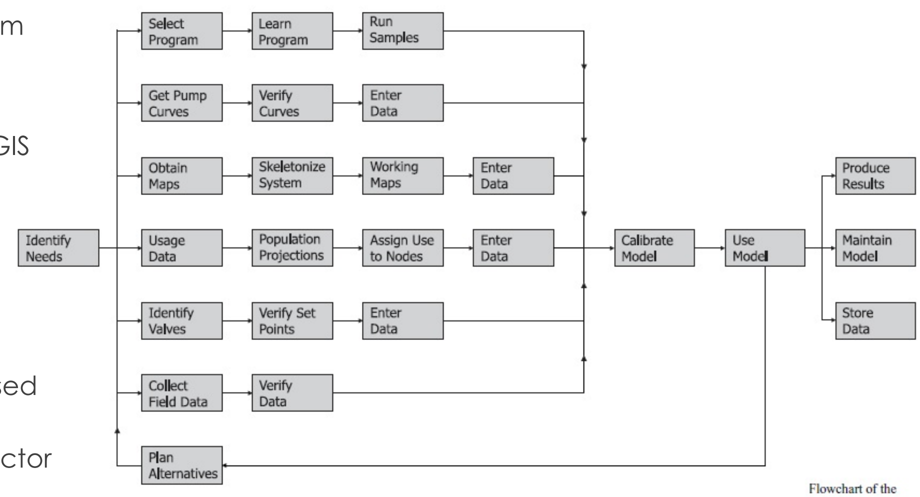
- Feature Class Attributes, GIS vs Hydraulic Model
  - Model (Pipes, Nodes), Pipe Material, Elevations, Demand Consumption, Water Depth, Pump Parameters and Other Attributes.
  - GIS (Lines, Points), Offset Distance, Size, Ownership, Source linkages, etc.

GIS VS HYDRALIC MODEL ATTRIBUTE COMPARISON

GIS	HYDRAULIC MODEL	GIS	HYDRAULIC MODEL
PIPES		NODES	
PIPE_ID	FEATUREID	NODE_ID	FEATURE_ID
DIAMETER	DIAMETER (in)	ATLAS_SHEET	
MATERIAL	MATRIAL	SEQUENCE	
ASBUILT_SOURCE_CODE		WELL_NUMBER	
OWNERSHIP		OWNERSHIP	
MAIN_TYPE		CONSTRUCTION_DATE	
MAIN_STATUS		UPDATE_DATE	
CONSTRUCTION_DATE	INSTALL_DATE	METER_NUMBER	INSTALL_DATE
UPDATES_DATE		SERVICE_ACCOUNT_NO	
OFFSET_DISTANCE		SERVICE_AREA	
OFFSET_FROM		NODE_TYPE	
OFFSET_DIRECTION		NODE_SIZE	DIAMTER
CATEGORY		STATUS	STATUS
METAL_TRACKING		MATERIAL	MATRIAL
SCAN1_LINK		NODE_CATEGORY	
SCAN2_LINK		METER_SIZE	
SCAN3_LINK		LOCATION_ADDRESS	
COMMENTS		SITE_DESCRIPTION	
	PIPE_LENGTH(ft)		ZONE
	MATERIAL_ROUGHNESS		ELEVATION (ft)
	CHECK_VALVE		FIRE_FLOW_JUNCTION
	ZONE		FIRE_FLOW_LANDUSE
			FIRE_FLOW_DEMAND
	PIPE_LINING		DEMAND (gpm)
	PIPE_JUMP		DEMAND PATTERN
			OUTPUTS
	OUTPUTS		
			DEMAND
	FLOW(gpm)		HEAD (ft)
	FLOW_DIRECTION		PRESSURE (psi)
	VELOCITY (ft/s)		WATER_AGE (hrs)
	HEADLOSS (ft)		ELEVATION (ft)
	STATUS(open/close)		

Hydraulic Modeling Concepts

- Mathematical Models 1) Mass Conservation 2) Energy Equations
- Methodology for Building a Hydraulic Model from GIS Data
  - Step 1: Extract and COGO Water Infrastructure Data from CAD Asbuilts
  - Step 2: Review GIS Data
  - Step 3: Integrate and Develop Network Topology from GIS Features Classes (Skelotonization)
  - Step 4: Collect Meter Data (Water Demands / Node Consumption)
  - Step 5: Input/Import Facilities
  - Step 6: Determine Node Elevations
  - Step 7: Assign Pipe Roughness / Material Coefficients Based on Pipe Material
  - Step 8: Allocate Node Demands /Demand Projection Factor Based on Land Use Zoning Criteria
  - Step 9: Integrate Pump Control Curves, Diurnal Curve, and Pump Sequencing Logics, Reservoirs / Wells Configuration (Ground Levels etc.)
  - Step 10: Import Fire Flow Demands
  - Step 11: Build Hydraulic Model
  - Step 12: Calibrate Model with Fire Hydrant Flow Tests

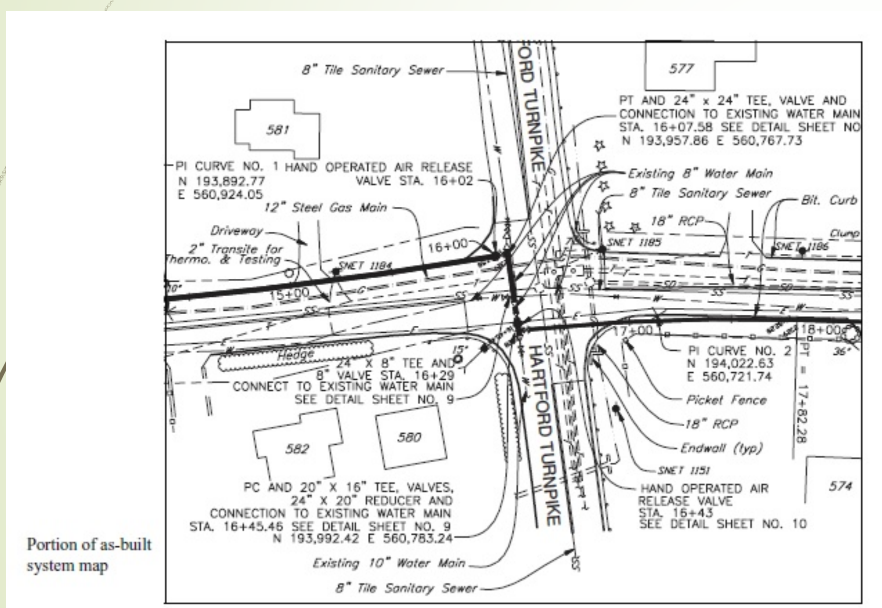


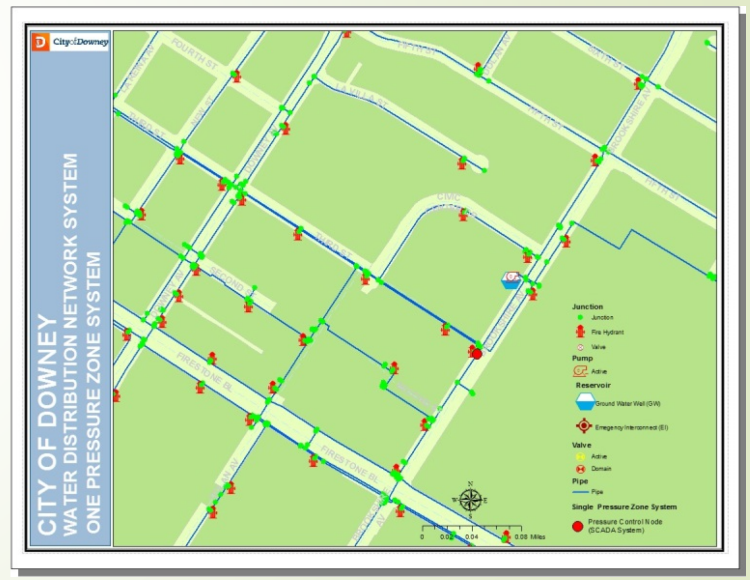
Flowchart of the modeling process

(Walski, 2003)

Hydraulic Modeling Concepts

- Summarization of Major Steps Involved in Building a Hydraulic Model using GIS Data
  - Extract, COGO, and Build GIS Feature Class From CAD and As-Built Paper Maps



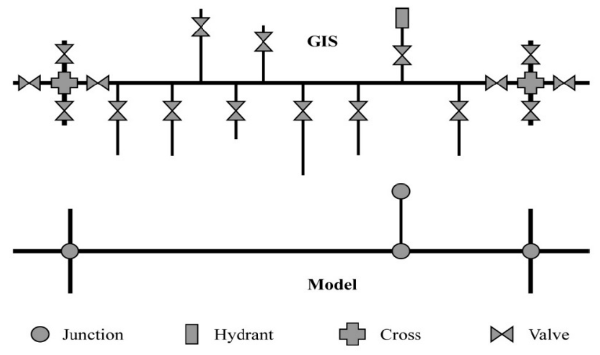


A typical Asbuilt/ Engineering Record (Walski, 2003)

GIS Feature Classes

Hydraulic Modeling Concepts

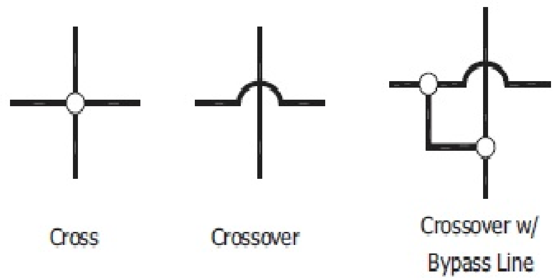
- Review, Import and GIS Data and Develop Network Topology (Skeletonization)



Single pipe GIS and network model representations.

Comprehensive Water System (Boulos, 2006)

- Pipes and Junction Review

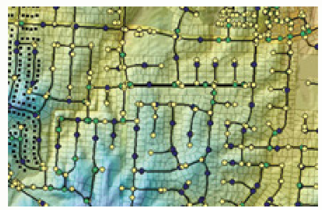


Pipe crossover and crossover with bypass

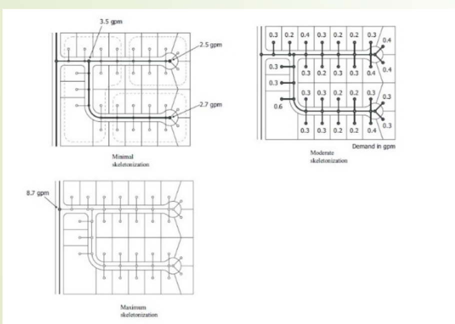
(Boulos, 2006)

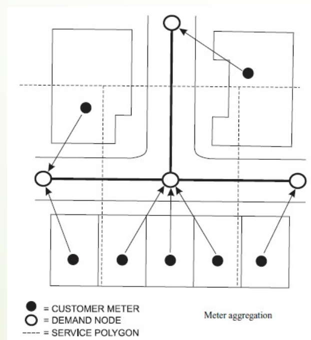
Hydraulic Modeling Concepts

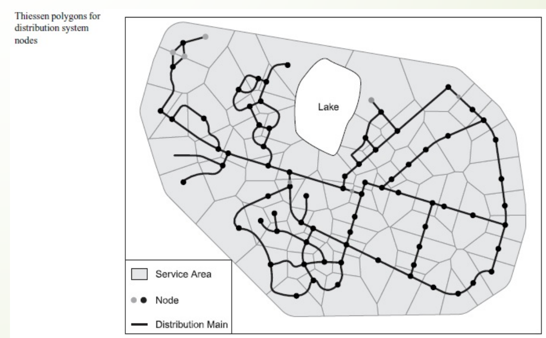
- Node Elevations and Water Meter Consumption Data Association and Aggregation
  - Elevation Extraction from a Digital Elevation Model (DEM) Model

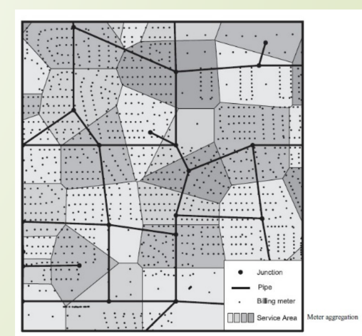


  - Allocate Water Consumption Demands





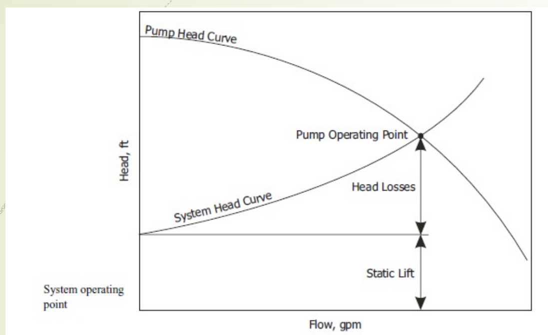




(Walski, 2003)

Hydraulic Modeling Concepts

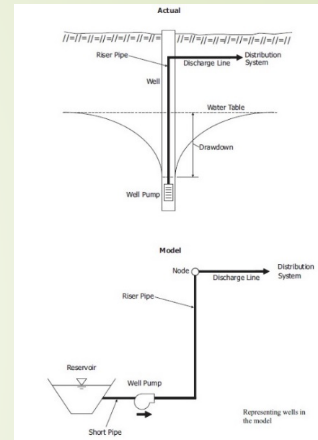
- Pump Data And Operating Curves



System operating point

Pump station

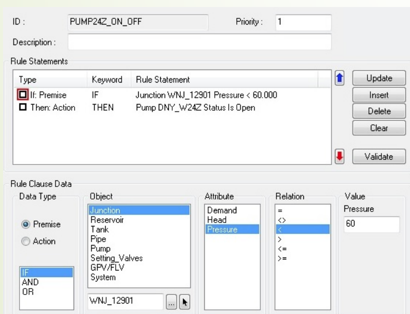
- Well Water Levels



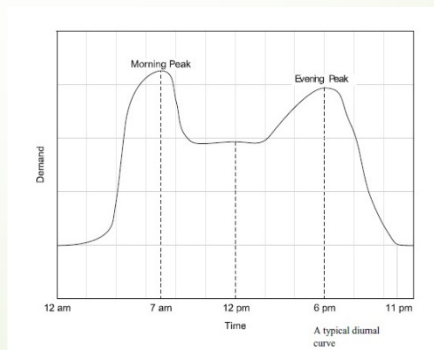
Representing wells in the model

Groundwater Well Representation (Walski, 2003)

- Pump Turn On /Off Logic Sequencing



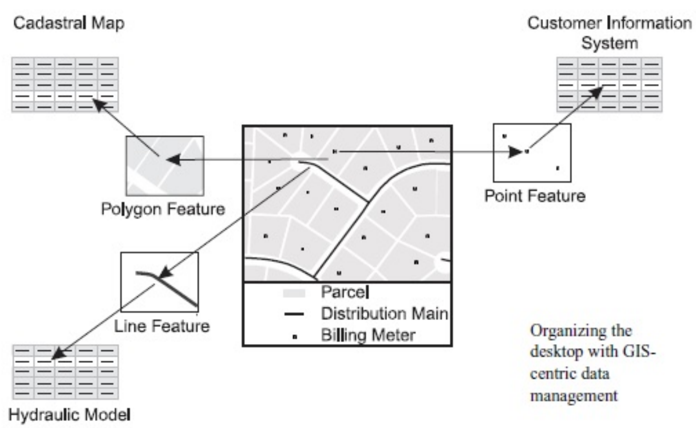
- Water Consumption Diurnal Curves



A typical diurnal curve

Hydraulic Modeling Concepts

- GIS and Hydraulic Model Integration

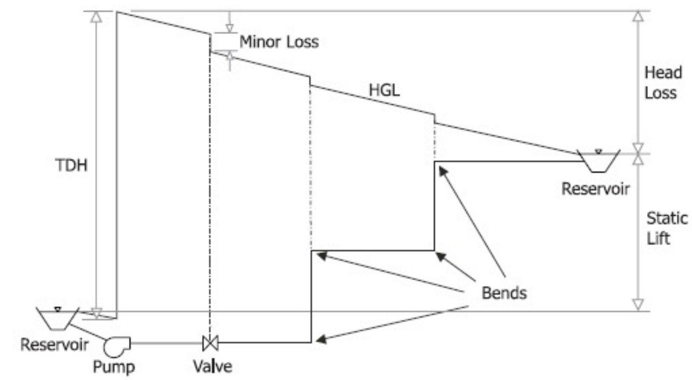


Organizing the desktop with GIS-centric data management

Hazen-Williams

$$K_P = \frac{C_f L}{C^z D^{4.87}}$$

where
K_p = pipe resistance coefficient (s^z/ft^{3z-1}, s^z/m^{3z-1})
L = length of pipe (ft, m)
C = C-factor with velocity adjustment
z = 1.852
D = pipe diameter (ft, m)
C_f = unit conversion factor (4.73 English, 10.7 SI)



$$H = h_l + \sum K_P Q^z + \sum K_M Q^2$$

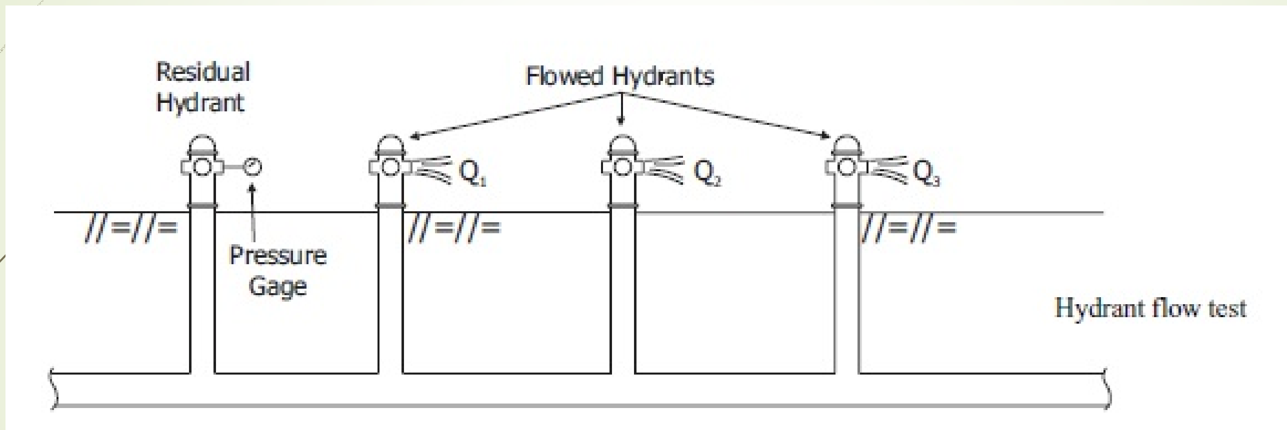
where
H = total head (L)
h_l = static lift (L)
K_p = pipe resistance coefficient (T^z/L^{3z-1})
Q = pipe discharge (L^3/T)
z = coefficient
K_M = minor loss resistance coefficient (T^2/L^5)

Schematic of hydraulic grade line for a pumped system

(Walski,2003)

Hydraulic Modeling Concepts

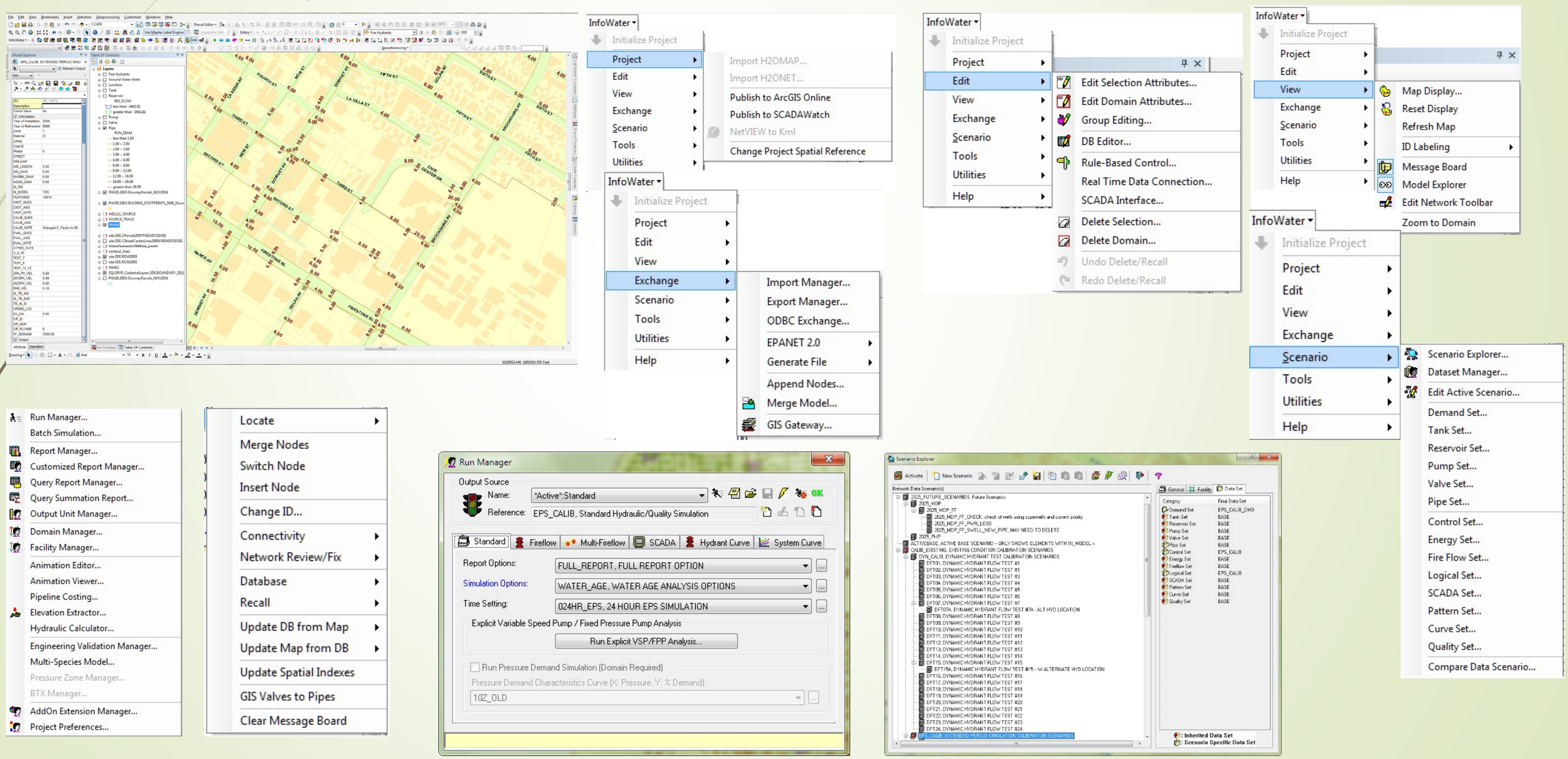
- Hydraulic Model Calibration



(Walski,2003)

Hydraulic Modeling Software

- InfoWater Software from Innovyze Company (Create, Edit, Run, Analyze, Design, and Optimize the Water Distribution Network)

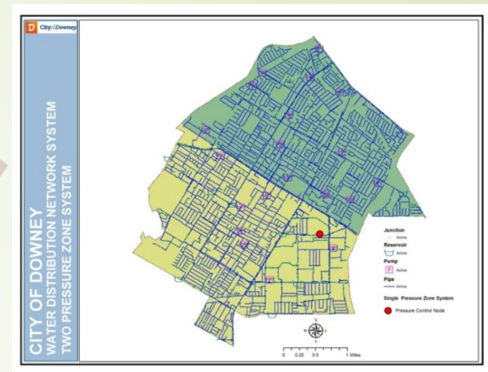


Hydraulic Modeling Capabilities

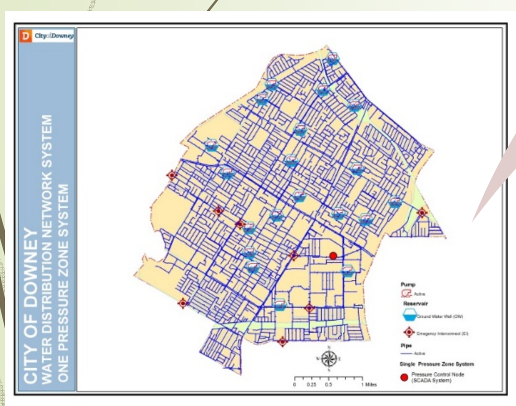
- **Steady State / Extended Period Simulation**
- Water Quality Evaluation(Chemicals / Water Age / Trace)
- Fire Flow Analysis (Residual Pressure / Available)
- Master Planning
- **Energy Management**
- Development Assessment (Helps in System Reliability ,Modeling Wells and Pumps Analysis)
- System Operational Studies

Project Approach and Methodology

- What will it take to accomplish this?
  - Use City's Existing One Pressure Zone System
  - Dividing the Pipe Network into Two Zones



1. Use existing City of Downey's water distribution system hydraulic model, one pressure zone
2. Divide and create two zone system, create new well sequencing logic, balance water well flows, and collect pump energy consumption meter data from billing cycles to be used for analyses
3. Configure and prepare hydraulic model for simulation studies. Run and analyze model for two pressure zone system
4. Present findings of one and two pressure zone simulated hydraulic model systems with observed values about zone pressures differences and Energy efficiencies



- Collect Pump Meter Billing Data
- Update Node Demands to Current Usage
- Create Two Zones in the System
- Assign Pressure Control Points
- Add / Remove Valves and Other Appurtenances
- Add Pumping Sequence
- Balance Flow / Recodify Boundary for Zone
- Run Model to Assess Pump Flow Times
- Evaluate One Zone and Two Zone Pump Flows / Duration to Evaluate Energy Use in Comparing map patterns of pressure
- Generate Comparison Excel Document
- Generate Map of Two Zone Distribution System

Anticipated Results

- Water Distribution Network Local Pressures will Improve
- Two Pressure Zone System will optimize the Distribution System and doing so It will help in Saving Energy Costs
- Implementation Costs are Estimated to be Recovered in 3 – 4 Years

Project Timeline

#	TASK	MAY 2015		JUNE 2015				JULY 2015			
		WEEK 3	WEEK 4	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 1	WEEK 2	WEEK 3	JULY 22
1	Collect water consumption data from billing meter read										
2	Collect pump energy use data										
3	Create two pressure zone model from existing model										
4	Update model with current consumption data										
5	Create pump sequencing logic										
6	Update model with pumping electrical usage data										
7	Test and trials of balancing flow in two pressure zone										
8	Run hydraulic model and extract results										
9	Presentation at ESRI UC San Diego										

22

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Acknowledgements

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Questions?