Optimizing Water Supply Operations: Beat the Heat Through Short-Term Demand Forecasting

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Tualatin Valley Water District

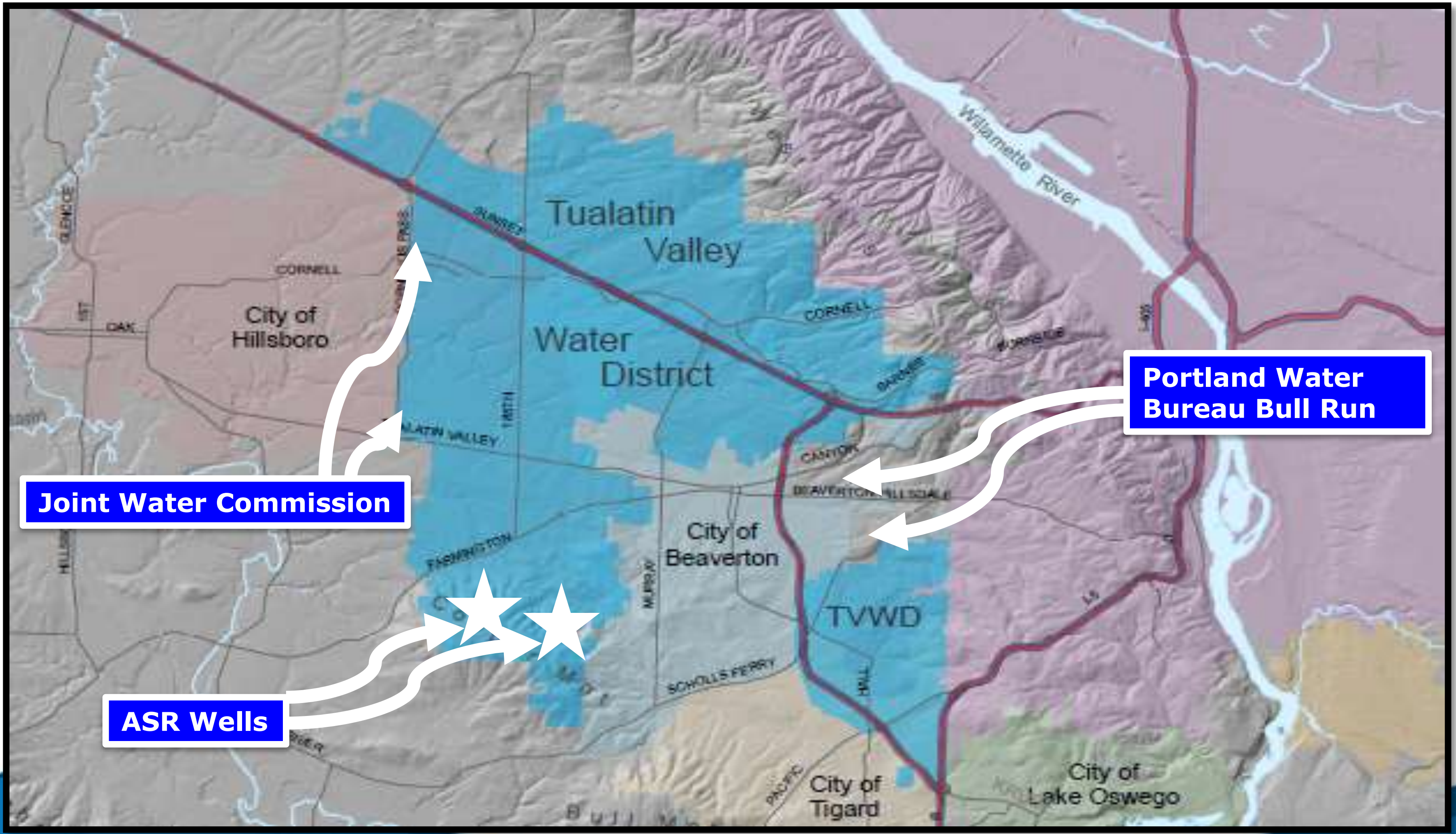
Presentation Overview

- Background
- Water Supply Management
- Supply Challenges & Opportunities
- Development of Demand Forecasting Model (AKA "The Knudson Model"
- Upgrading / Optimizing model
- Utilization of the Model
- Conclusions

Background

- Second largest water provider in Oregon
- 45 square mile service area
- Serve roughly 213,000 people thru over 60,000 connections
- 93% residential (70% of our water)
- 7% commercial/industrial (30% of our water)
- 19.5 MGD Avg.
- 23 Reservoirs
- 60 MG Storage

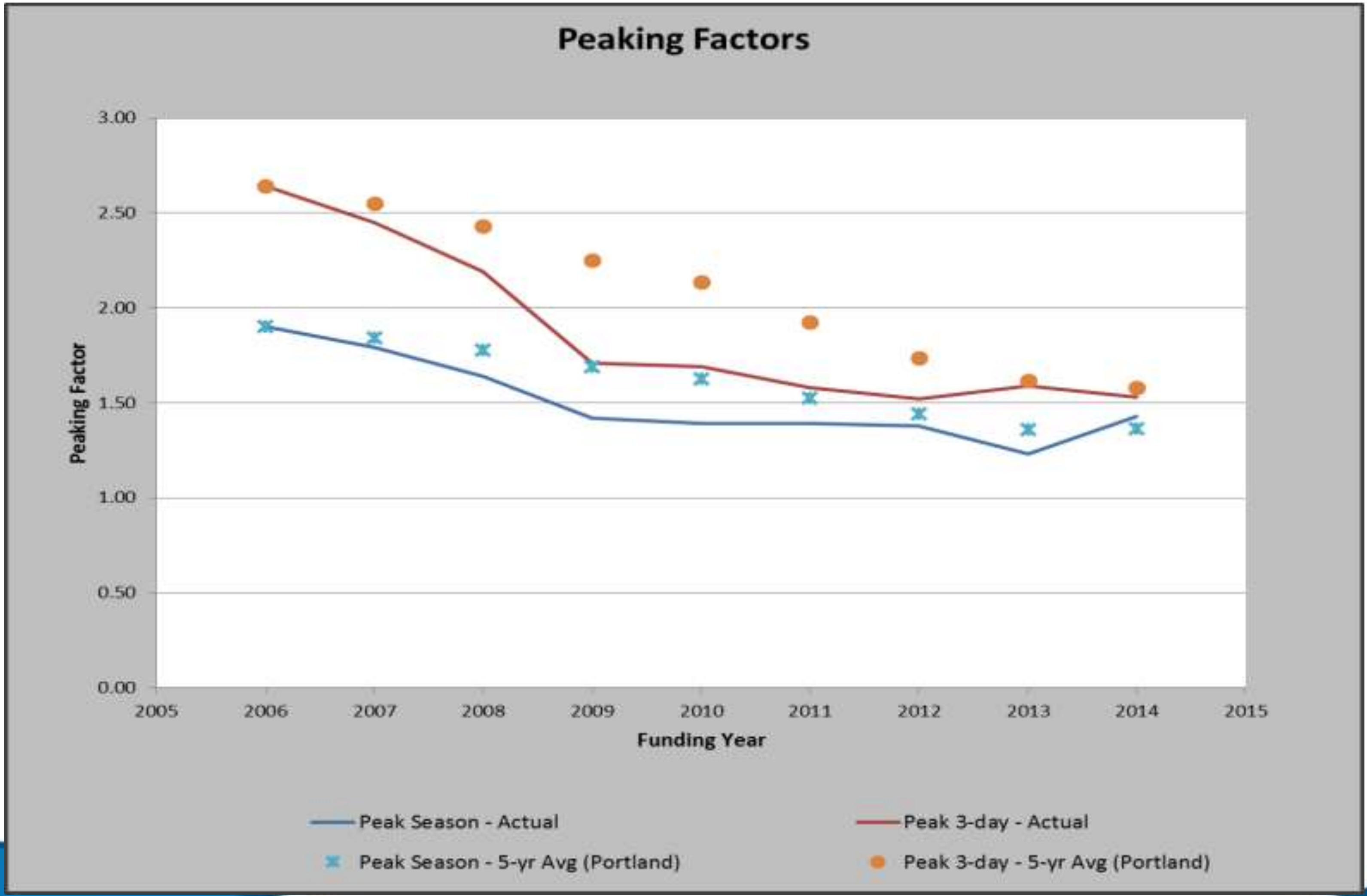
Background -
TVWD Summer Water Sources



Water Supply Management - Sources

- Portland Water Bureau – Base Supply
  - Minimum purchase of 13.16 MGD (not negotiable)
  - Peak hydraulic capacity of ~42 MGD but …
  - Peak 3-day and peak season peaking factors
  - Peak season = July, August, and September
  - 5-year residual impact of "excess peaking factors"

Peaking Factors from PWB Source



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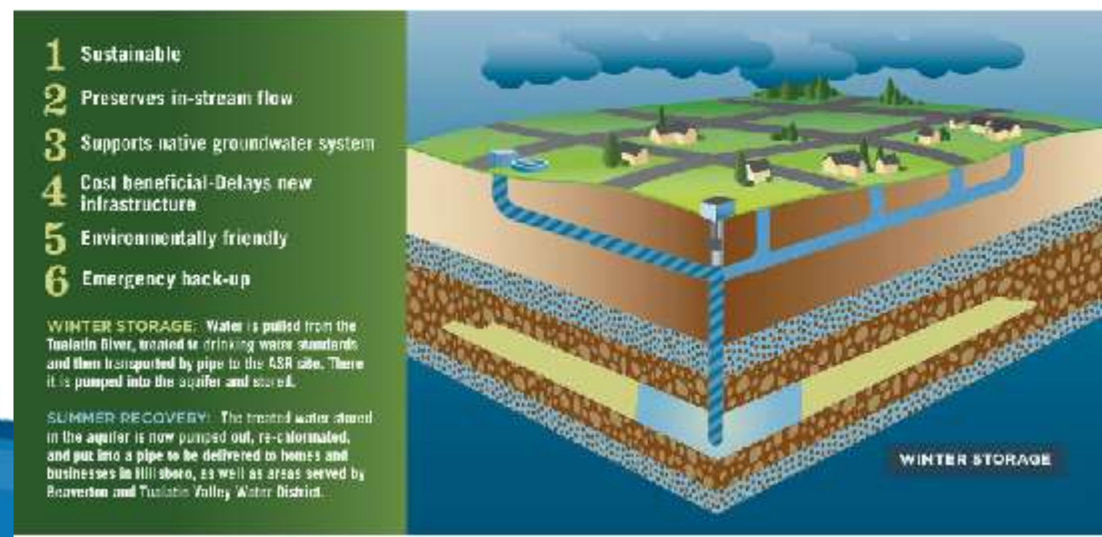
Water Supply Management - Sources

- Joint Water Commission Supply
  - No minimum purchase, Cost based on actual use
  - TVWD ownership capacity = 12.5 MGD, Capacity at Barney Reservoir
  - Peak capacity limited by ownership
  - “Excess use” if demand exceeds 12.5 MGD
  - Option to lease capacity but paid for entire year
  - No flow changes over weekends & holidays

Water Supply Management - Sources

- Aquifer Storage & Recovery (ASR) Supply
  - Owned exclusively by TVWD
  - Recharged with JWC water purchased prior winter
  - Recovery capacity ~ 2.5 MGD * 100 days (250 MG)
  - Minimum production of ~ 1.0 MGD
  - Groundwater rights



Water Supply Management - Sources

- Miller Hill ASR coming soon – Online by summer 2016
- Capacity: 2 MGD

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Water Supply Management - Sources

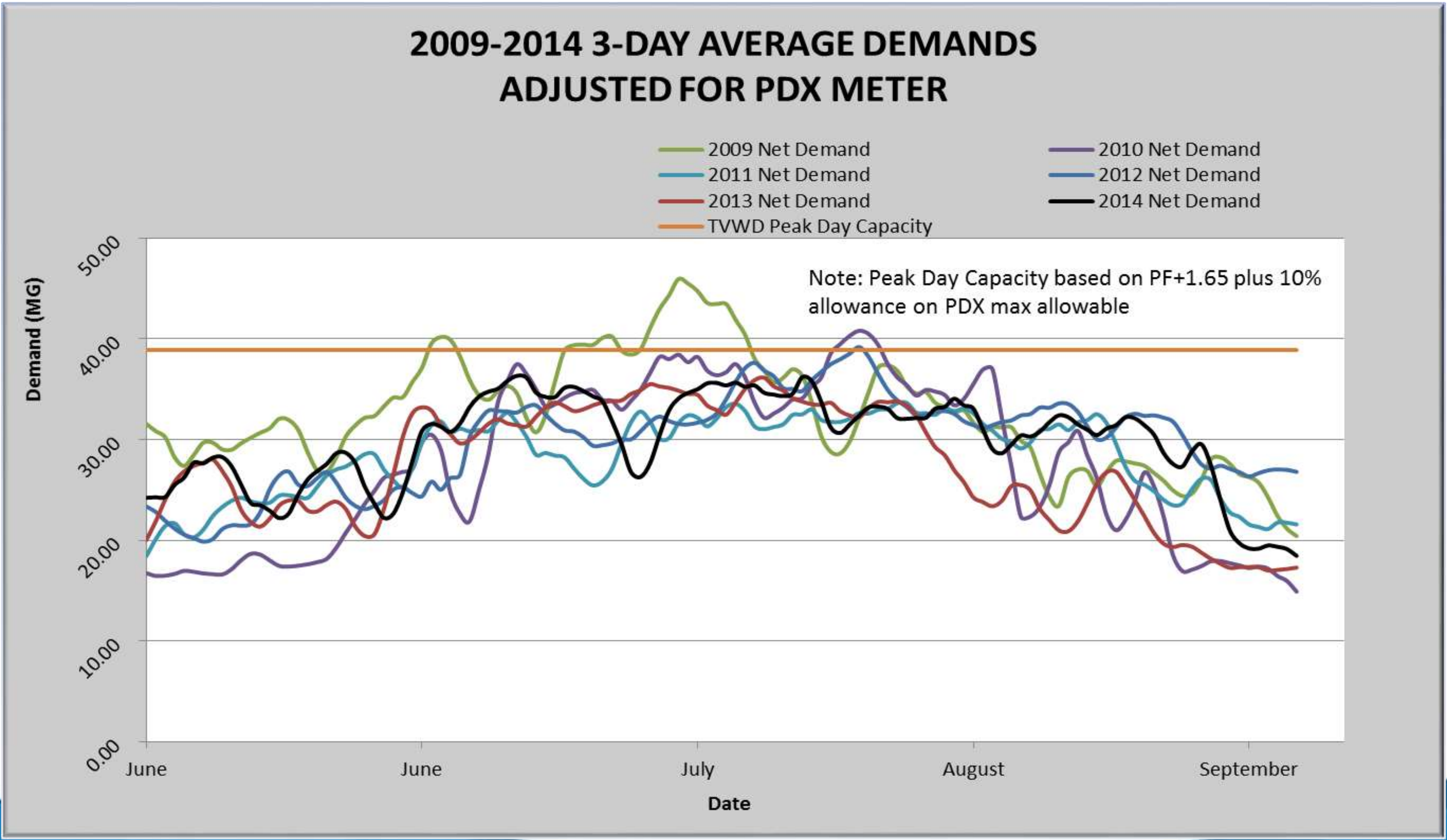
- Portland Water Bureau – Interruptible Supply
  - Summer interruptible = June – September
  - Potentially interrupted if inadequate supply
  - No impact on peaking factors
  - March deadline
  - Not guaranteed
  - Fixed quantity by month (million gallons)
  - Take or pay
  - Price is 45% of base rate

Water Supply Challenges & Opportunities

- Question 1: How to manage the various sources and keep within our Peak Capacity?
- Question 2: How to further optimize the system to reduce peaking?
- Question 3: How do we remove the guesswork in our daily operational planning?

- **Solution:** Develop a model / tool to accurately predict water demand behavior.

Peak 3-Day Average Demands



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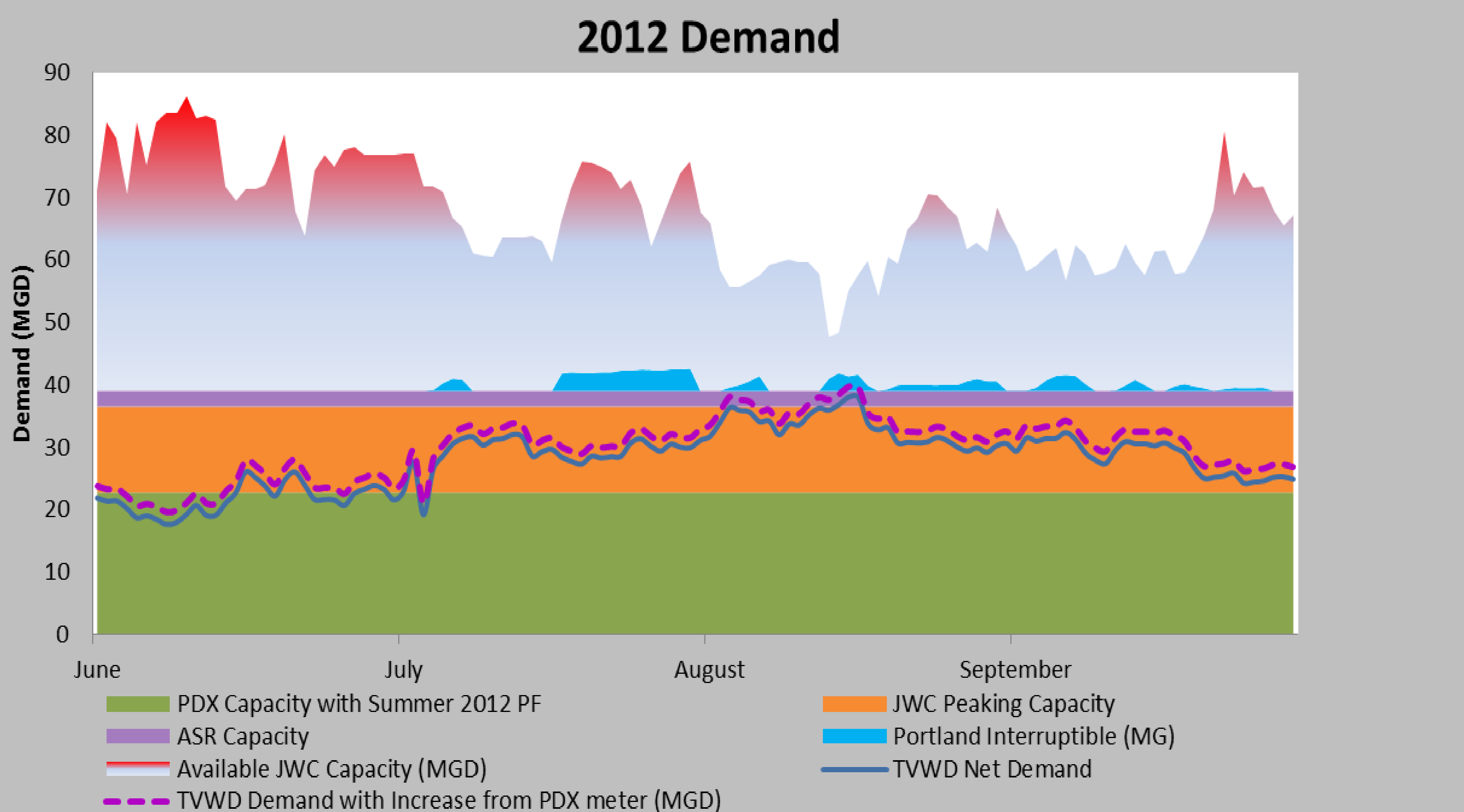
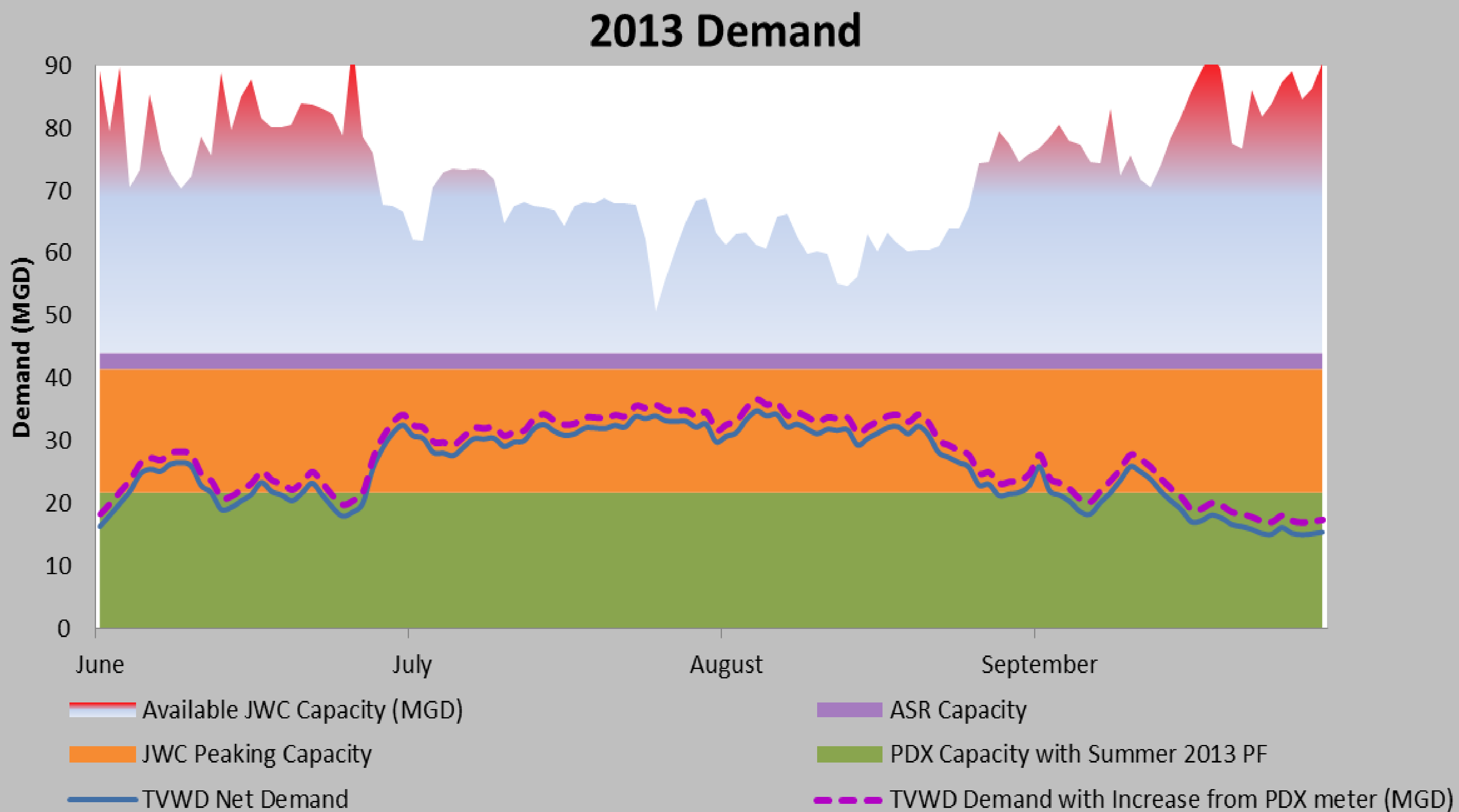
2012 Water Demand



2013 Water Demand



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Water Supply Summer Operation Plan

- Portland Water Bureau - Base
  - Base load with constant demand
  - Limit peak 3-day and peak season peaking factors
- JWC
  - Fluctuate to meet demand as needed
  - Up to TVWD's ownership share but avoid "excess use"
- TVWD Aquifer Storage & Recovery
  - Maintain relatively constant production
  - Ability to "trim" to meet system demand up to 2.5 MGD
- Portland Water Bureau - Summer Interruptible
  - Fluctuate to meet demand as needed

Water Supply Opportunities

OPTIMIZE!

Model Development

- Original model developed by Mark Knudson, P.E.

Data
- Compile Water Supply, Demand Data
- Meteorological Data (High Temp., Precip. from accuweather)

Analysis
- Scenario Development
- Regression Analysis

Testing
- Testing Prior Years / Refinement
- Operational Strategy Testing

Interface
- Interface Development / Refinement – Assistance from Roy Kunkle
- Operator Training

Implement
- Implement Routine Operations
- Verification

Optimize
- Add yearly data to model
- Test for additional factors that may improve accuracy

Model Development

- Data Analysis
- Multivariate regression base on:
  - Net water demand for previous day (actual)
  - High temperature for previous day (actual)
  - Precipitation for previous day (actual)
  - High temperature forecast for today
  - Precipitation forecast for today

Model Development

- Use linear equations to determine predicted flow:

$$Y = mX + b$$

  - Y = dependent variable
  - X = independent variable
  - m = coefficient (slope)
  - b = intercept

Model Development

- Using a multi-variable equation, the slope intercept formula appears like this:

$$Y = b + m_1X_1 + m_2X_2 + m_3X_3 + m_4X_4 + m_5X_5$$

  - Y = predicted demand for today (MGD)
  - b = intercept
  - m_1X_1 = yesterday's flow & coefficient
  - m_2X_2 = yesterday's forecast high temp & coefficient
  - m_3X_3 = yesterday's forecast precipitation & coefficient
  - m_4X_4 = today's forecasted high temp & coefficient
  - m_5X_5 = today's forecasted precipitation & coefficient

Model Development

Tualatin Valley Water District	**TVWD Water Demand Forecasting Tool** Version 9.0 - Summer 2014 PRINT WORKSHEET EACH DAY		Yellow - Entered by Operator Blue - Calculated by Tool
Step 1 - Enter Data:	Manual entry for Yesterday's Net Demand ---	34.34	**Comments / Notes**
Today	Enter Today's Date - mm/dd/yyyy:	8/26/2014	Weather Data
Yesterday — Monday, August 25, 2014	Yesterday's Actual Net Demand - MG:	34.34	
	Yesterday's Actual High Temp - degrees F:	90	
	Yesterday's Actual Rainfall - inches:	0.00	
	Desired Increase (+) or Decrease (-) in Storage - MG:	0.00	
Today — Tuesday, August 26, 2014	Today's Forecast High Temp - degrees F:	90	
	Today's Forecast Rainfall - inches:	0.00	
Tomorrow — Wednesday, August 27, 2014	Desired Increase (+) or Decrease (-) in Storage - MG:	0.00	
	Tomorrow's Forecast High Temp at PDX - degrees F:	88	
	Tomorrow's Forecast Rainfall at PDX - inches:	0.00	
	Desired Increase (+) or Decrease (-) in Storage - MG:	0.00	
Second Day — Thursday, August 28, 2014	Second Day's Forecast High Temp at PDX - degrees F:	83	
	Second Day's Forecast Rainfall at PDX - inches:	0.00	

Model Development

Step 2 - Water Demand Forecast Results:

Today	Tuesday, August 26, 2014	Today's Forecast Net Demand - MG (no change in storage	**34.94**
		Today's Desired Change in Storage:	-
		Today's Forecast Total Demand - MG (including storage):	**34.94**
Tomorrow	Wednesday, August 27, 2014	Tomorrow's Forecast Net Demand - MG:	**35.12**
		Tomorrow's Desired Change in Storage:	-
		Tomorrow's Forecast Total Demand - MG (including stora	**35.12**
Second Day	Thursday, August 28, 2014	Second Day's Forecast Net Demand - MG:	**34.70**
		Second Day's Desired Change in Storage:	-
		Second Day's Forecast Total Demand - MG (including sto	**34.70**

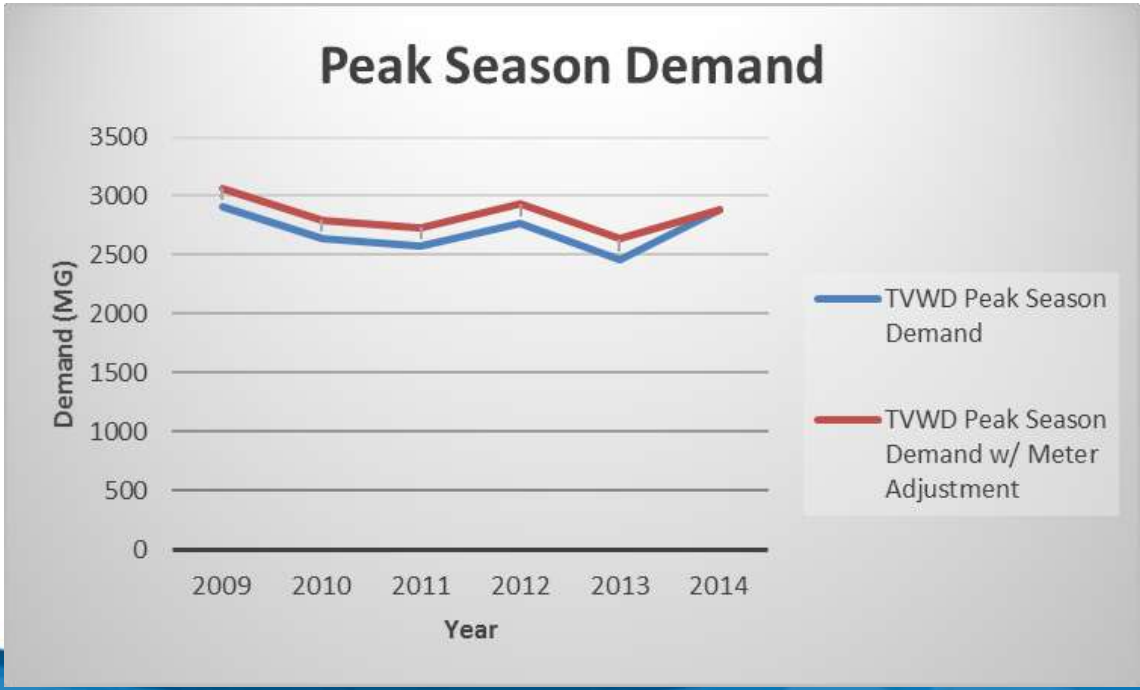
Model Development

Step 3 - Plan Water Supply Flows:

Tomorrow	Wednesday, August 27, 2014	Portland Base Supply - MG	20.00	OKAY
		JWC Total - MG	12.00	OKAY
		ASR Total - MG (enter recharge as negative number)	2.30	OKAY
		Portland Interruptible Supply - MG	0.00	OKAY
		Total Planned Supply - MG	34.30	OKAY
Second Day	Thursday, August 28, 2014	Portland Base Supply - MG	20.00	OKAY
		JWC Total - MG	11.50	OKAY
		ASR Total - MG (enter recharge as negative number)	2.30	OKAY
		Portland Interruptible Supply - MG	0.00	OKAY
		Total Planned Supply - MG	33.80	OKAY
TWO DAY AVERAGE	Average of Tomorrow and the Second Day	Portland Base Supply - MG	20.00	
		JWC Total - MG	11.75	Use this value when ordering JWC
		ASR Total - MG (recharge is negative number)	2.30	
		Total Planned Supply - MG	34.05	
start	5789.00	**Barney Reservoir Level (FT) - Full is ~1640'**	1639.50	
6/4/2014	5789.00	**Total TVWD allocation from Barney (Acre-Ft) -**	5470.61	Reconcile weekly from JWC repor
x=	5.50%	**Total TVWD allocation from Barney (MG)**	1782.57	Based on reconcile
		Amount used from Barney (MG)	575.93	
		TVWD allocation remaining (MG)	1310.39	Based on our Tracking
		Days remaining based on current usage of Bar	151.71	OK
		Max avg. daily use of JWC (MGD) remaining	12.50	
	(based on Oct. 31 season-end)	**Days remaining based on Max ave. usage of B**	142.61	OK
Step 4 - Print This Worksheet or e-mail to Mark, Nick and Troy			1/15/2015	

Model Development

- Issues / challenges:
  - Changes in behaviors (decreasing usage)
  - Changes in metering
  - Data management
- Model Updates:
  - Additional data



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Model Development & Optimization

- Model in 2014 increased in accuracy due to meter correction factors
- New meter installation for PWB connections in 2015

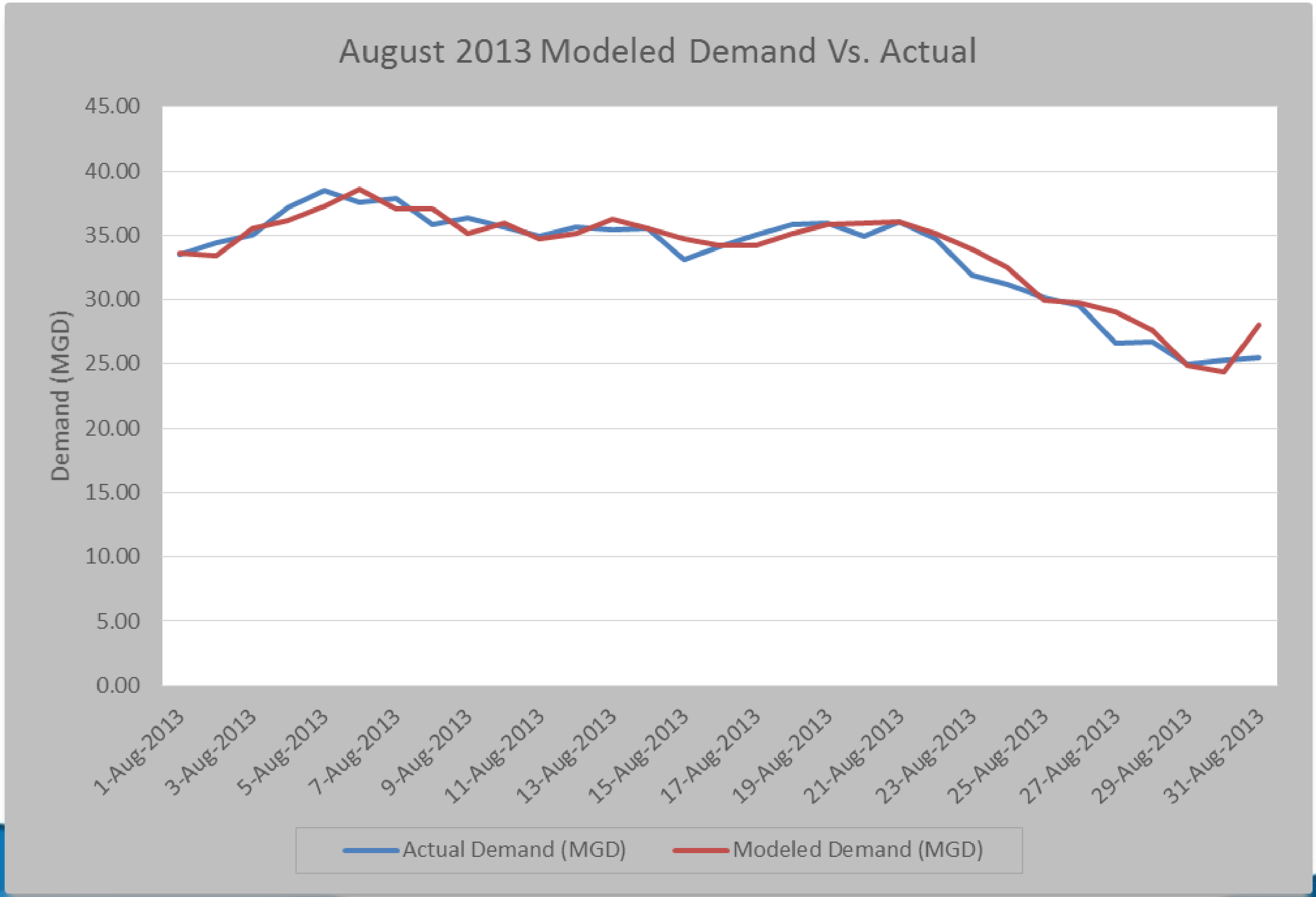
Model Development & Optimization

- Original model calibrated against 2008 & 2009 data
  - June, July, August & September by month
- Model is updated each year with new data and calibrated based on this additional data
- R-squared value = 0.83-0.92

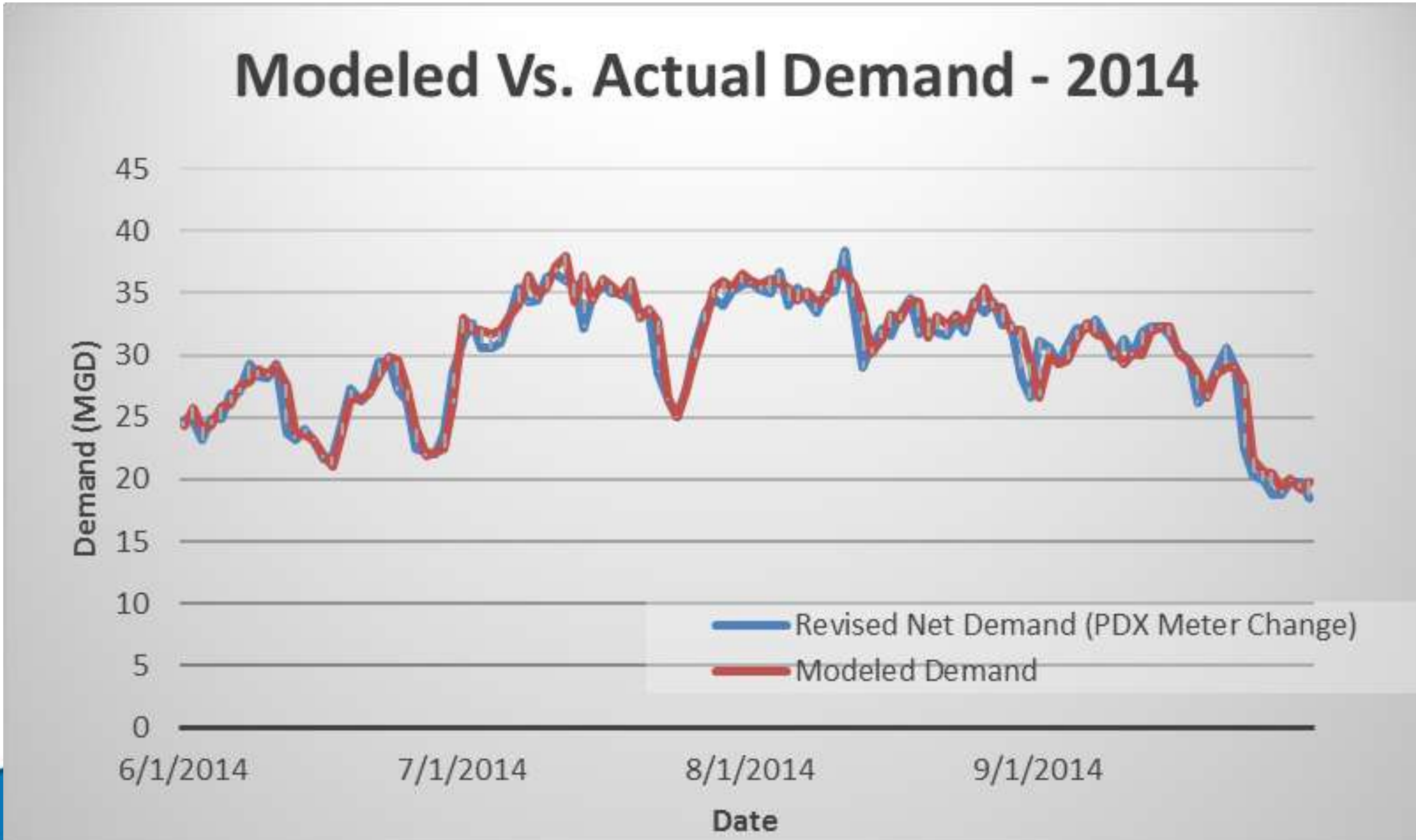
  for 2014 model.

Use these values for 2014:				
Data used: 2007-2013 with PDX meter adjustment from 2010-2013.				
Regression values:	June	July	August	September
Intercept	**-1.47449**	**-2.80995**	**1.450831**	**-2.78492859**
Demand day-1	**0.879712**	**0.763759**	**0.830189**	**0.833740992**
High Temp day-1	**-0.08667**	**-0.02615**	**-0.09983**	**-0.01472445**
Precip day-1	**-1.27663**	**-3.64402**	**-6.92531**	**-0.72947719**
High Temp-F˚	**0.155177**	**0.163497**	**0.155117**	**0.105515867**
Rainfall-In's	**-1.9045**	**-0.42364**	**-7.449**	**0.241531964**

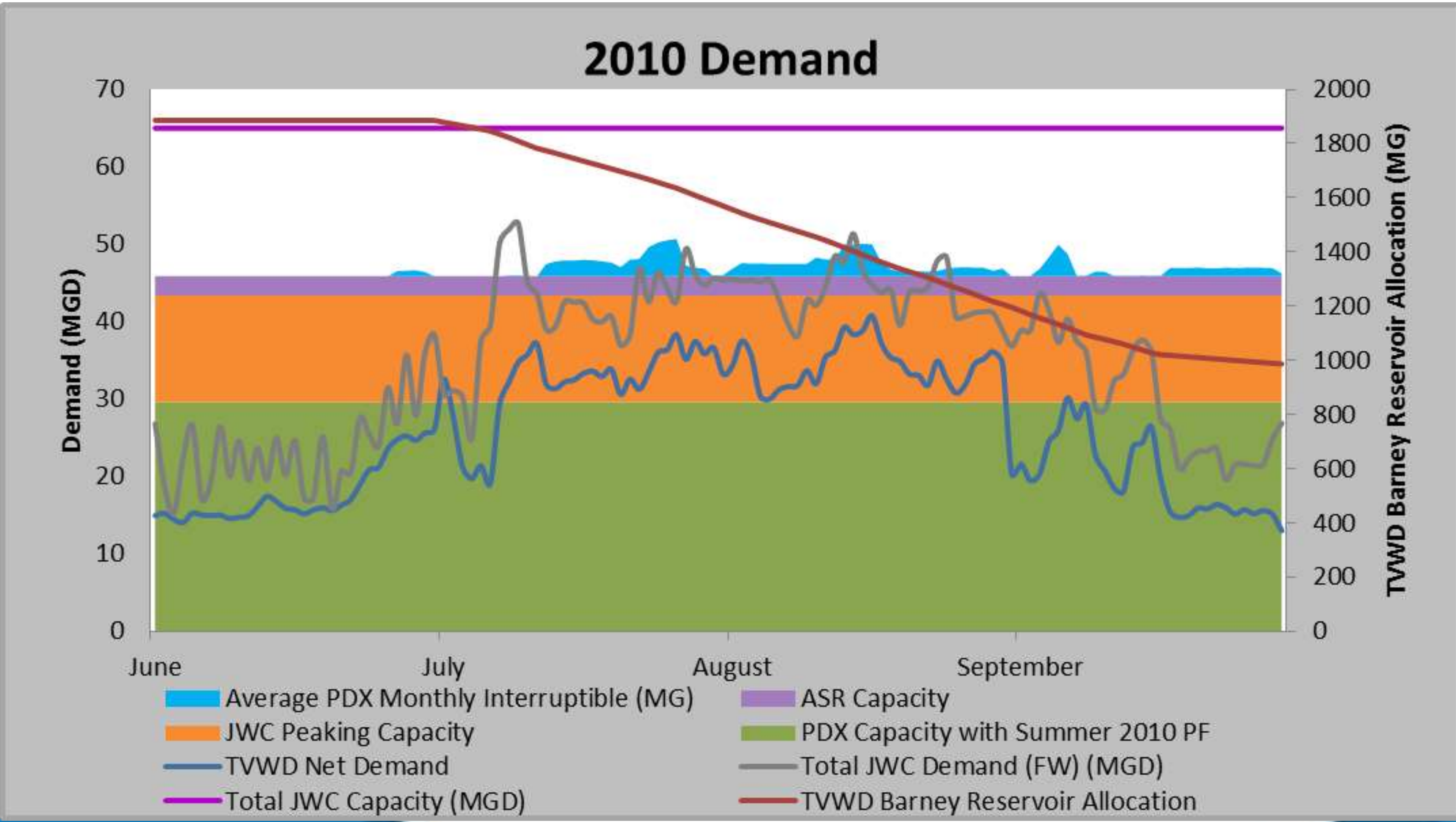
Model Testing



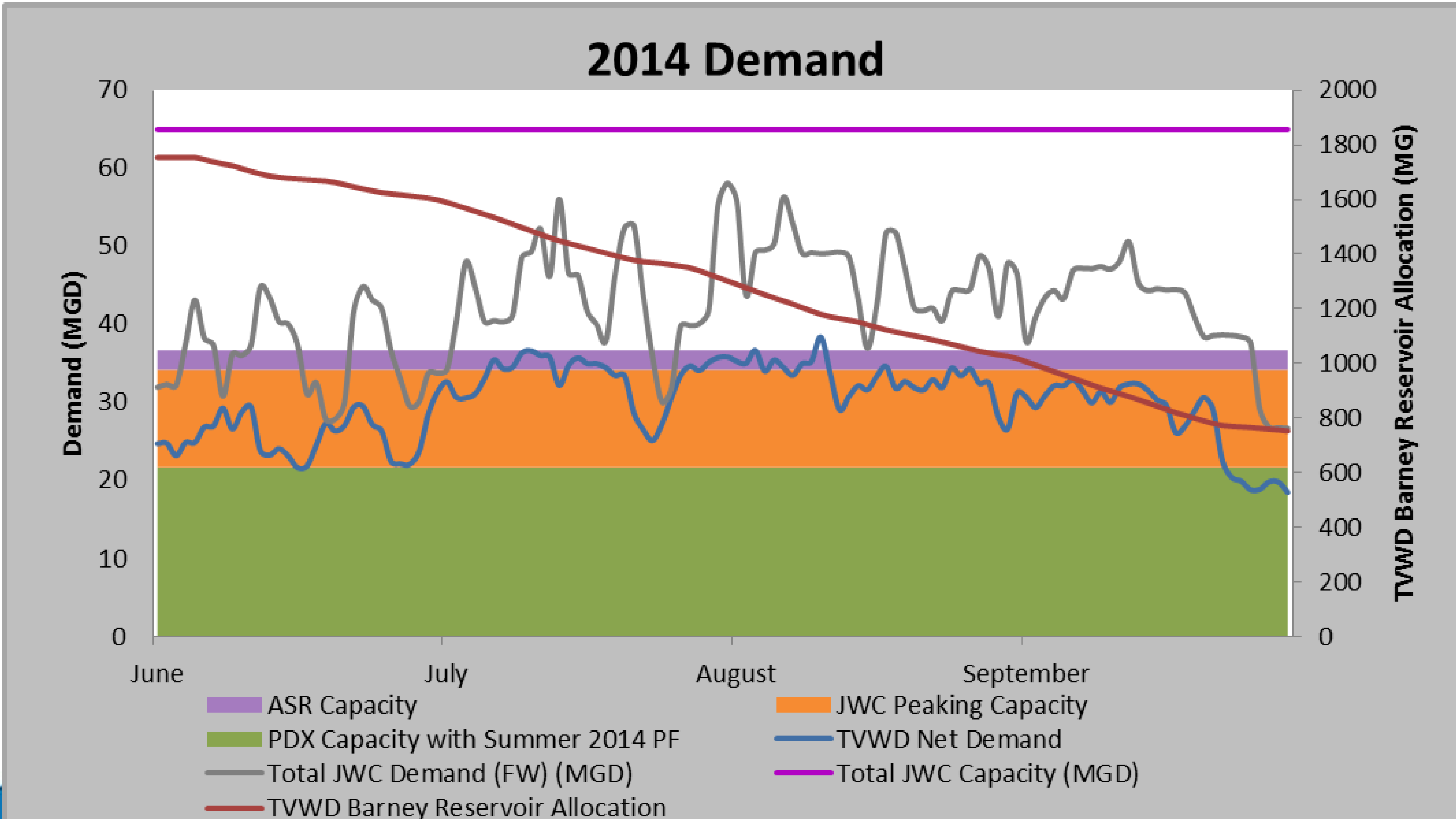
Model Testing



2010 Water Demand



2014 Water Supply



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Original Model Development

Variable / Option	Weather Station	r Squared				
		June	July	Aug	Sept	Mean
Previous day's Q	Hillsboro	0.924	**0.751**	**0.747**	0.788	0.802
Previous Q & Today high T	Hillsboro	0.925	0.767	0.749	0.795	0.809
Prev Q, T, P and Today T, P	Hillsboro	0.958	**0.815**	**0.873**	0.807	0.863
Prev Q, T, P and Today T, P	Portland	0.957	0.822	0.875	0.811	0.866

- Previous day's net demand adequate to predict June demands
- Addition of weather data improves overall performance
- Portland weather data offers marginal improvement over Hillsboro
- R-squared values range from 0.81-0.96

Model Updates / Optimization

- What other variables might impact the regression model?
- How to model behavioral traits?
- Day of the week model?
- 2 days prior?
- Additional data
- Operator input

Summer 2014 Operational Performance

2014 Operational Targets and Performance			
Factor	**Target**	**Result**	**Target Hit?**
Water Demands			
Portland Minimum Purchase (MG)	1755.544	1735	Almost
Interruptible Water Utilization (MG)	105	103.78	Yes
JWC Utilization (MG)	[redacted]	853.1	n/a
ASR Utilization (MG)	[redacted]	187.6	n/a
Operational Control			
Portland Peak Season PF	< 1.45	1.43	Yes
Portland Peak 3-Day PF	< 1.65	1.53	Yes
JWC Peak Day Demand (MGD)	< 12.50	12.59	*No

Conclusion

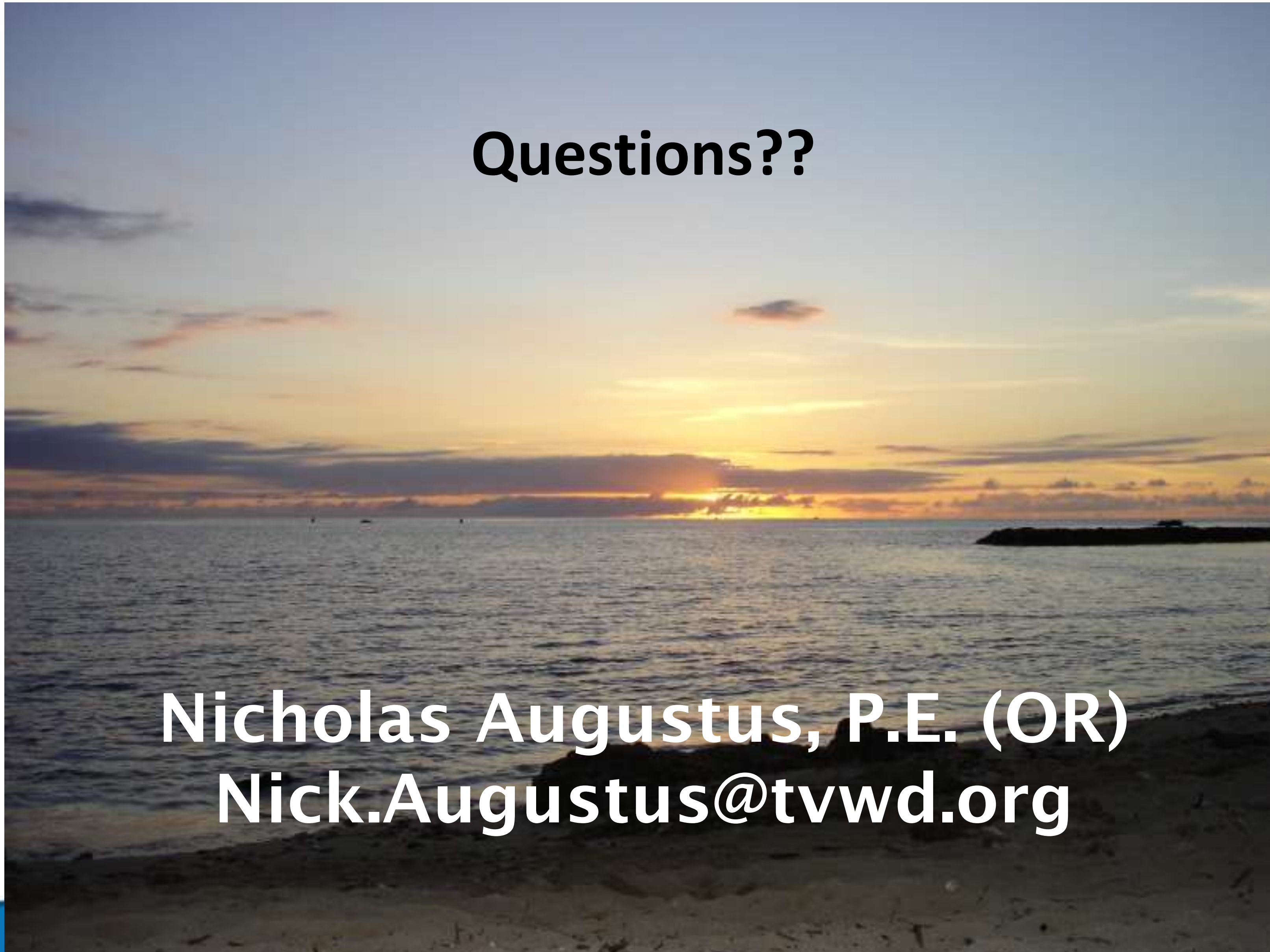
- Managing four supplies presents unusual challenges and opportunities
- Addition of “Summer Interruptible” in 2010 necessitated new approach to managing supplies
- Accurate short-term demand forecasting is possible using available data and simple tools
- Yearly optimization including additional data assists with model accuracy

Conclusion

- Calibration of meters is very important (re-work required to obtain higher model accuracy based on new meter readouts)
- Use of the short-term water demand model:
  - Established consistent demand planning procedures
  - Improved performance to meet operational targets
  - Resulted in lower peaking factors and reduced costs

    And

  - Helped to BEAT THE HEAT!!


Questions??
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