This presentation premiered at WaterSmart Innovations

watersmartinnovations.com

Identifying and Adapting to Water Demand Uncertainties

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Overview

Importance of water demand analysis and forecasts

Key segments of demand uncertainty

WRF Project 4554 survey of water utilities and methods

Closing remarks

“On Demand” delivery of water

Valuable benefits to consumers and producers

Revenue engine for utilities

Planning, managing, and operating comes at a significant cost – this introduces risk




Hazen

Water demand analysis and forecasting

1 Investment Decisions

2 Funding Priorities

3 Revenue and Rate-setting

4 Management Policies

Risks that can be tied to a long term water demand forecast

Over-sizing of a system

- Unused capacity (you still have to pay for)
- Opportunity costs (environment, financial)

Under-sizing of a system

- Chronic or more frequent shortages (economic damages)
- Lost water sales

Risk and Water Supply Planning

Risk in planning decisions commonly stems from forecasting the future

Predicting things that are variable

Predicting things that are uncertain

Predicting things that are both variable and uncertain ***as if they were fixed and certain***

Classification Scheme for Demand Factors

Things that make water demand uncertain and variable—what we know

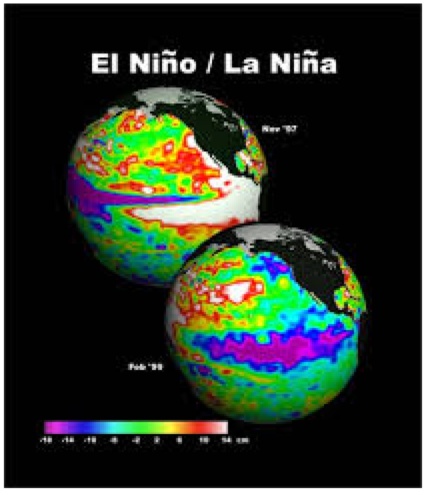
Cyclical – things that tend to repeat

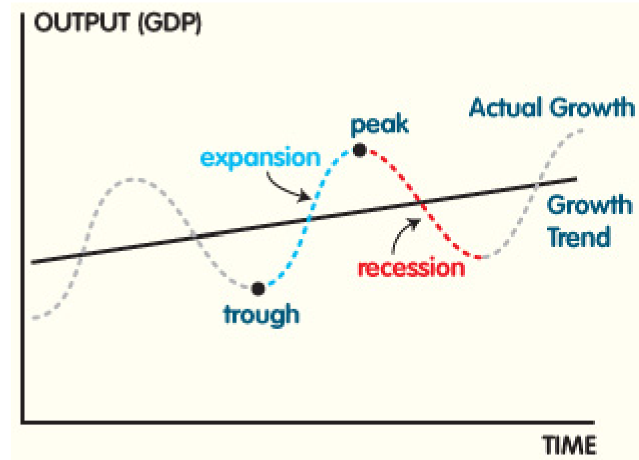
Structural – things that govern specific outcomes

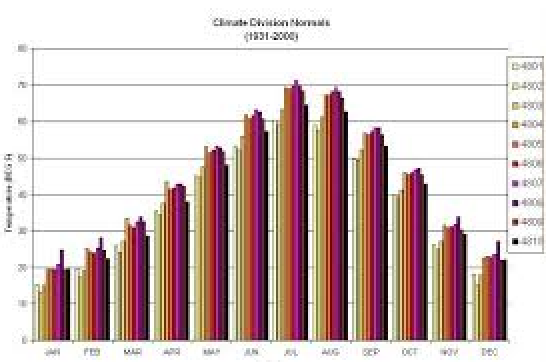
Trending – things that seem to be moving/evolving in a particular direction

Contextual – things that are generally understood but variable and seemingly random

“Cyclical” factors







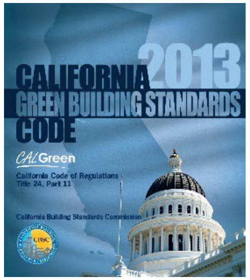
Climatic cycles

Economic cycles

“Structural” Factors that Affect Water Use

Standards

- EPAct
- Increasing efficiency of water fixtures “built-in”



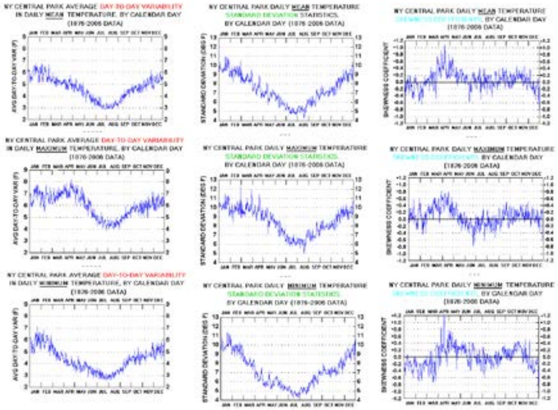
Regulations and codes

- Land use
- Building requirements
- Prohibition of certain activities/timing of activities

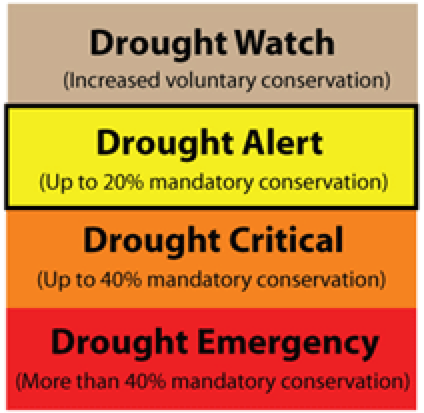
Trend ("Evolving") Factors that Affect Water Use

- Socioeconomics and markets
  - Population and demographic patterns
  - Development patterns
  - Production patterns
  - Costs and prices of water and other goods/services
  - Technology
- Utility policies
  - How water is priced
  - Promotion of efficiency
- Water using attitudes/norms
- Climate

“Contextual” Factors that Affect Water Use



- Observed weather conditions
  - Departures from “normal”
  - Spells and extremes
- Water supply shortage management
  - Restrictions on water use
  - Emergency pricing
- Sudden additions or losses of large water customers



Recent Water Research Foundation Projects

WRF 4263 – Changes in Water Use under Regional Climate Change Scenarios (2013)

WRF 4458 – Water Demand Forecasting in Uncertain Times: Isolating the Impact of the Great Recession (on-going/2015)

WRF 4558 – Uncertainty in Long-Term Water Demand Forecasting (on-going)

Models help us organize what we know and can measure into instruments for planning.

Water Demand Forecasting Methods

Basic Methods

Trend extrapolation

Unit use approaches

Econometric models

End use accounting

Hybrids

Others

(see Billings & Jones text)

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Generic model structure (deterministic)

Model of water use	$Q = f(X)$	
The ways in which x's affect water use	$f(*)$	
Factors that affect water use	X	

Specification

Model specification

The most important part of forecast model development

Reflective of:

(a) the degree of knowledge about what influences water use over time,

(b) the amount of information or skill available to derive associations among explanatory factors and water use

(c) the amount of emphasis and resources devoted to the demand forecasting process

Uncertainty stems from facts in the universe that we do not possess and inherent variability in the universe even beyond knowledge of all relevant facts.

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Uncertainty

Fundamental Components

Knowledge uncertainty

- Lack of understanding
- Lack of facts
- Lack of data

Inherent variability

- Irreducible randomness
- Nature
- Human

Generic model structure (deterministic)

Model of water use	$Q = f(X)$
The ways in which x's affect water use	$f(*)$
Factors that affect water use	X

Generic model structure (uncertain)

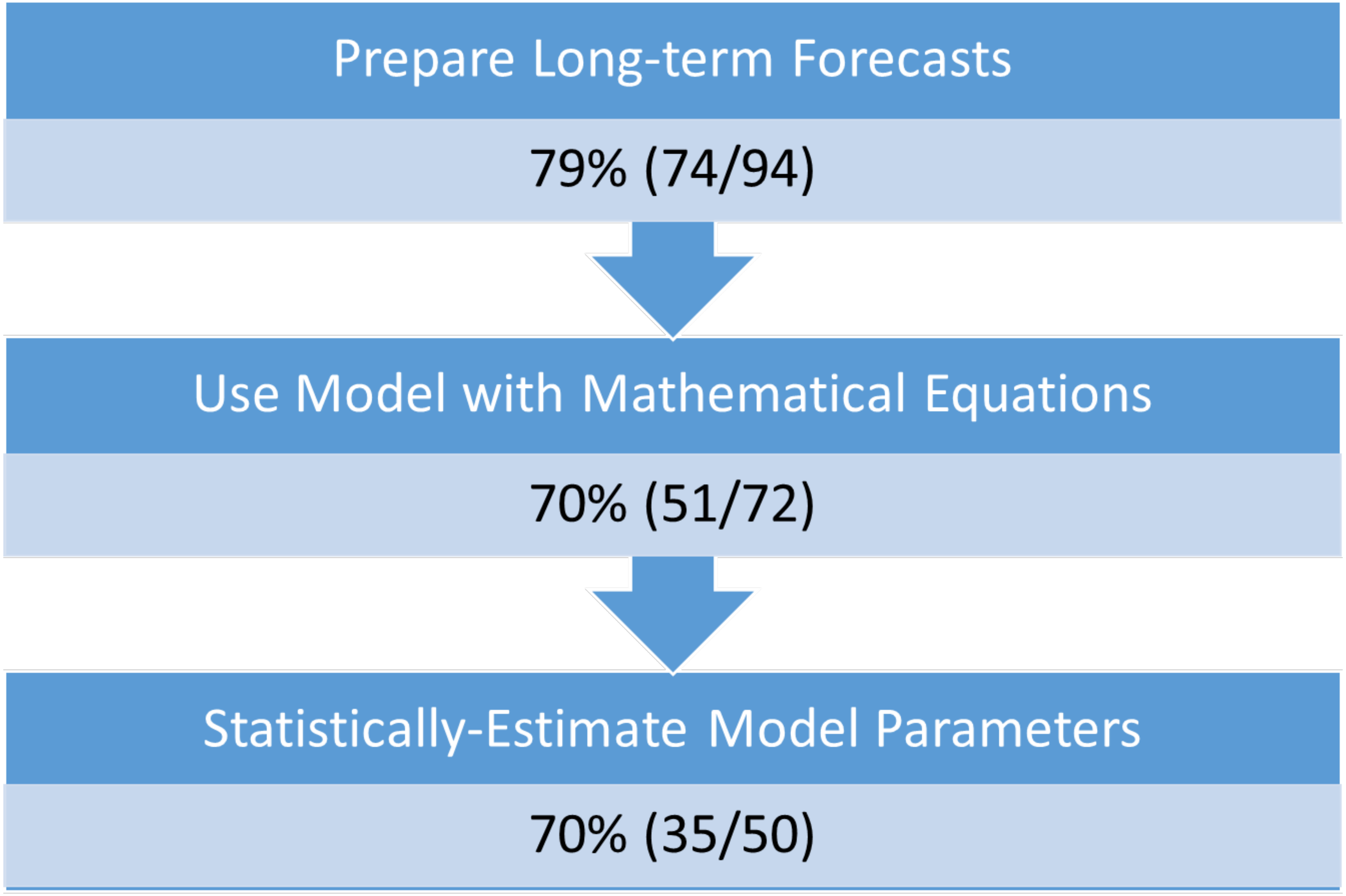
Model of water use	$Q = f(X)$	
The ways in which x's affect water use	$f(*)$	
Factors that affect water use	X	Incomplete, variable, and uncertain

Generic model structure (uncertain)

Model of water use	$Q = f(X)$	
The ways in which x's affect water use	$f(*)$	Imperfect
Factors that affect water use	X	Incomplete, variable, and uncertain

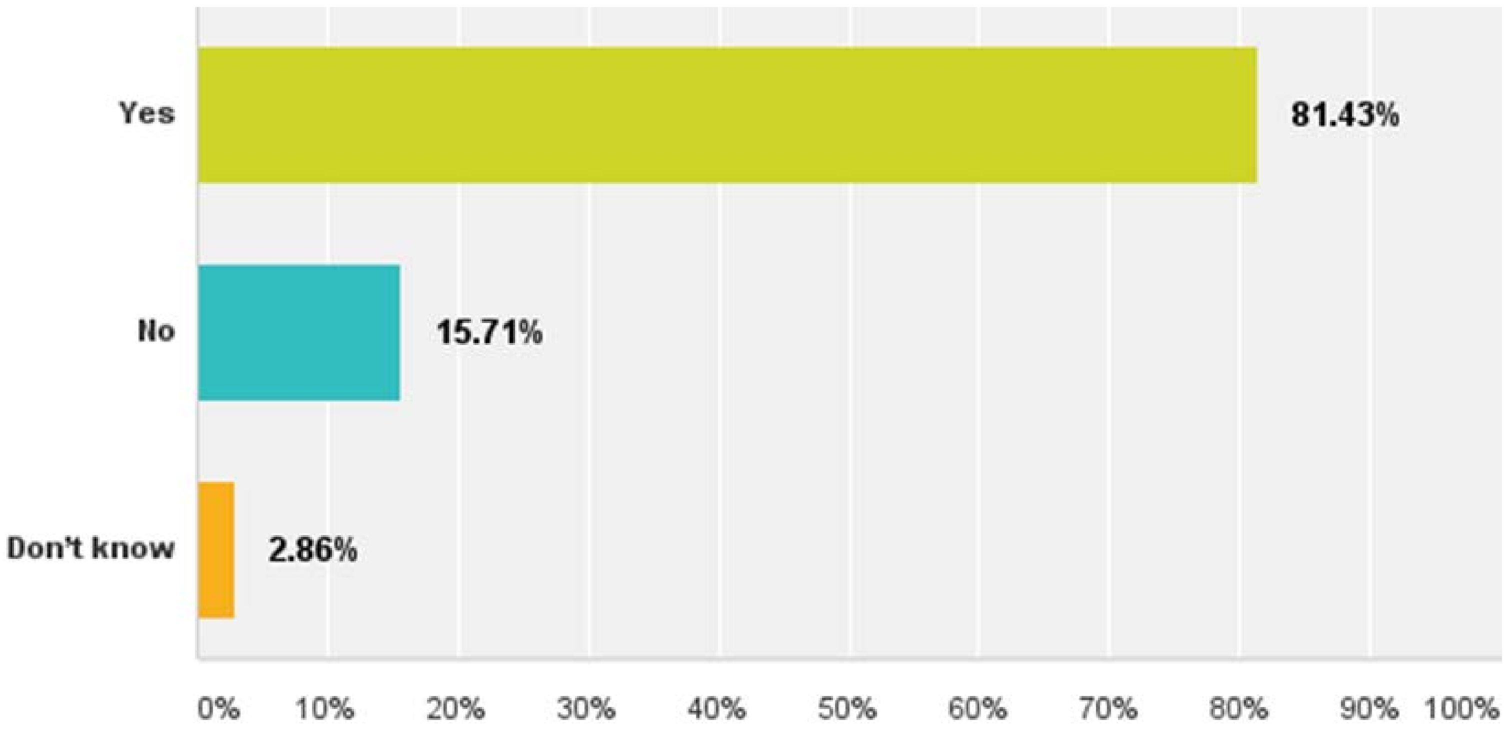
Generic model structure (uncertain)

Model of water use	$Q = f(X) + \epsilon$	
The ways in which x's affect water use	$f(*)$	Imperfect
Factors that affect water use	X	Incomplete, variable, and uncertain



Forecasting methods used by WRF 4558 survey sample.

Does your utility attempt to account for uncertainties about the future in your long term water demand forecast?



Methods for incorporating uncertainty

Qualitative methods

Rule of thumb range:

$$Q_{Predicted} \pm z\,\%$$

Qualitative scenario:

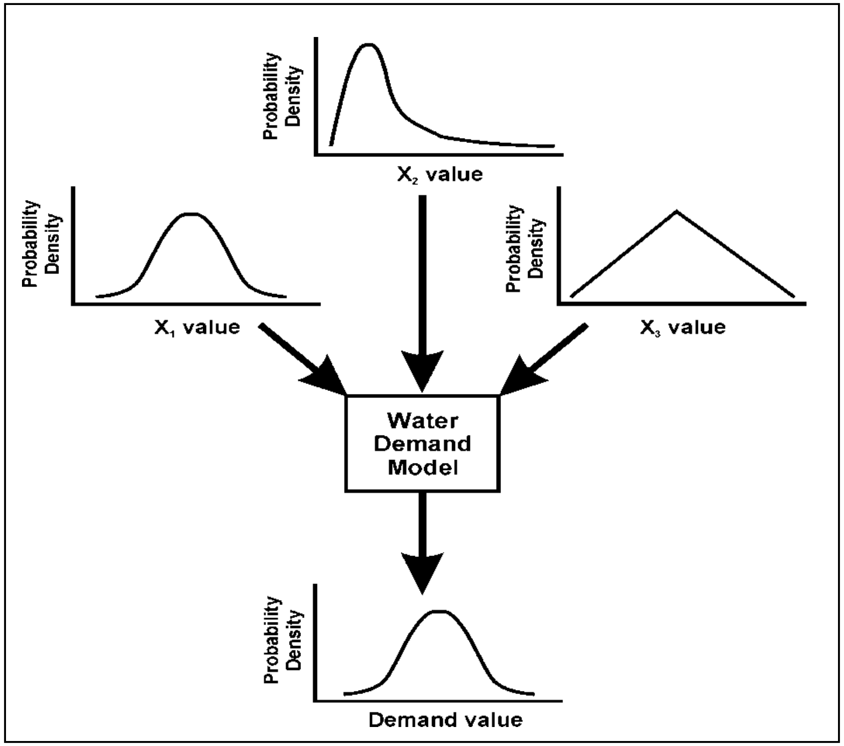
$$X_{Expected} \pm z\% \xrightarrow{\text{yields}} Q_{Predicted} \pm z'\%$$

Methods for incorporating uncertainty

Quantitative scenarios

Probabilistic scenarios:

$$X_{Simulated} \xrightarrow{\text{yields}} Q_{Simulated}$$



Methods for incorporating uncertainty

Quantitative scenarios

Statistical confidence intervals:

$$\left(\hat{Q} - t_{(1-\propto)/2} * \sqrt{s_f^2}\right) \leq Q_{Actual} \leq \left(\hat{Q} + t_{(1-\propto)/2} * \sqrt{s_f^2}\right)$$

Where for given value(s) of X:

$$s_f^2 = s_m^2 + \frac{s_m^2}{n} + \sum_k (X_k - \overline{X_k})^2 \; s_{\hat{\beta}_k}^2 + 2 \sum_{j<k} (X_j - \overline{X_j})(X_k - \overline{X_k}) \, Cov(\hat{\beta}_j, \hat{\beta}_k)$$

Methods for incorporating uncertainty

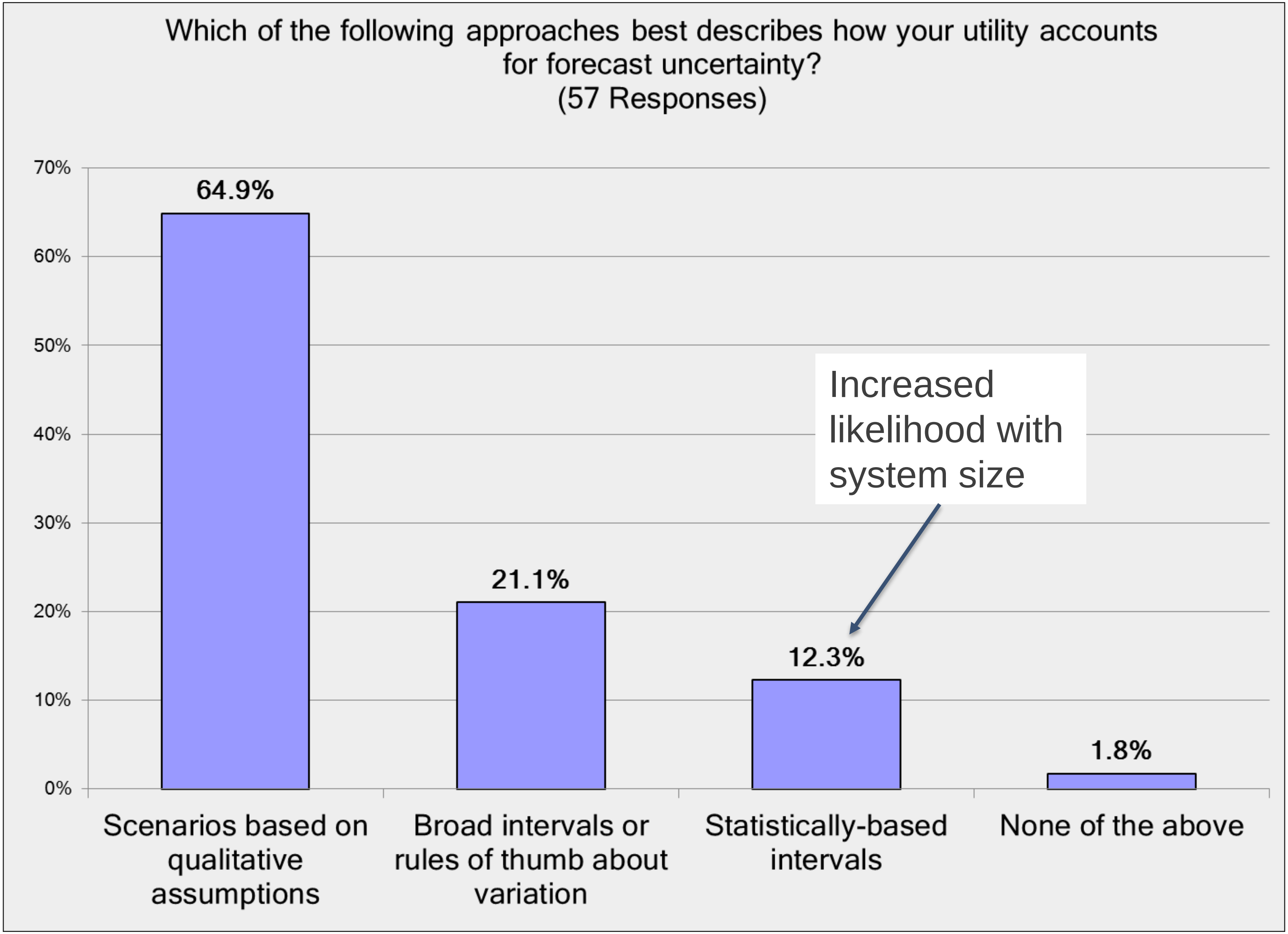
Quantitative scenarios

Probabilistic statistical simulation:

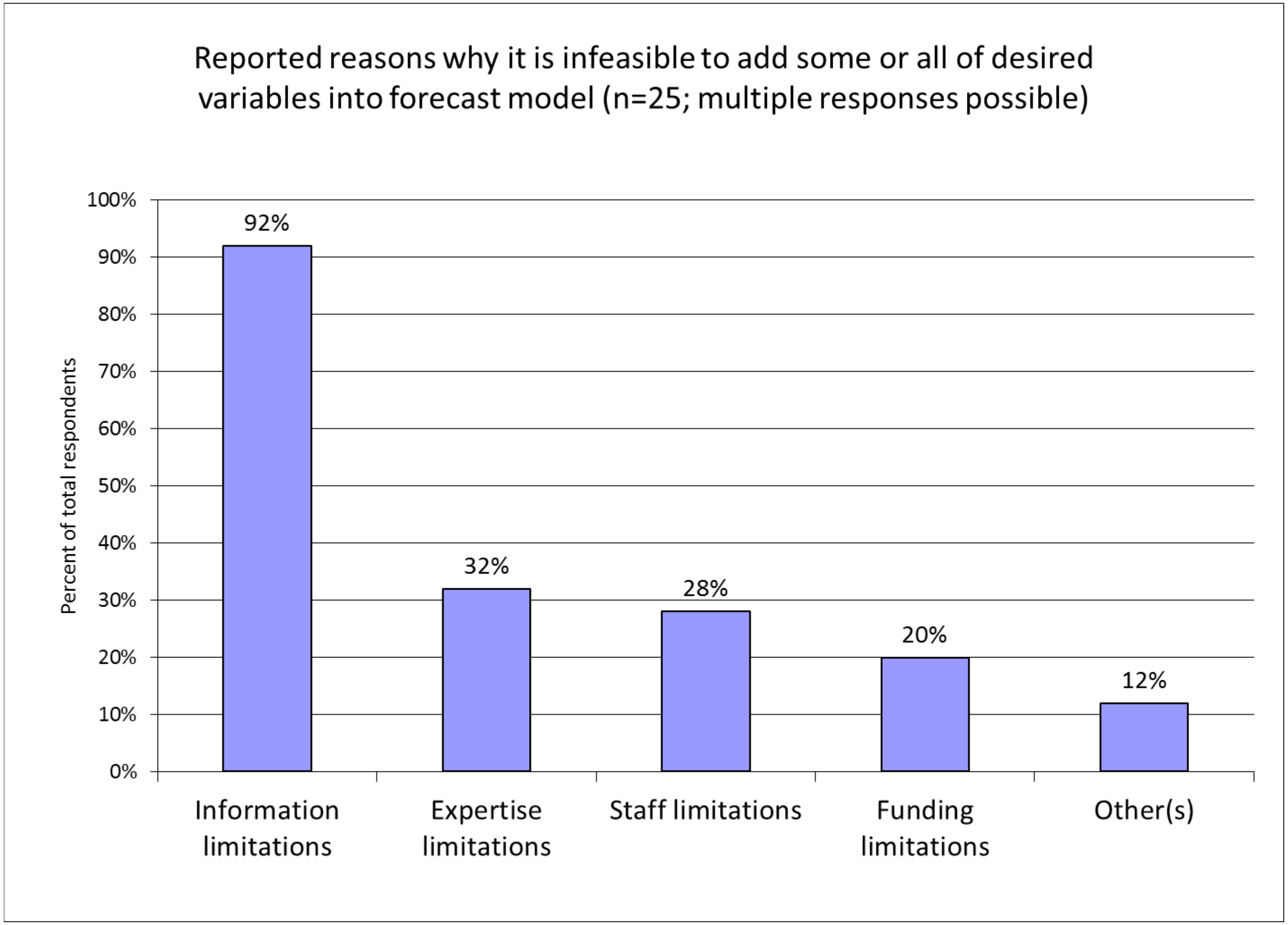
$$X_{Simulated}$$

$$s_f^2 = s_m^2 + \frac{s_m^2}{n} + \sum_k (X_k - \overline{X_k})^2 \, s_{\hat{\beta}_k}^2 + 2 \sum_{j<k} (X_j - \overline{X_j})(X_k - \overline{X_k}) \, Cov(\hat{\beta}_j, \hat{\beta}_k)$$

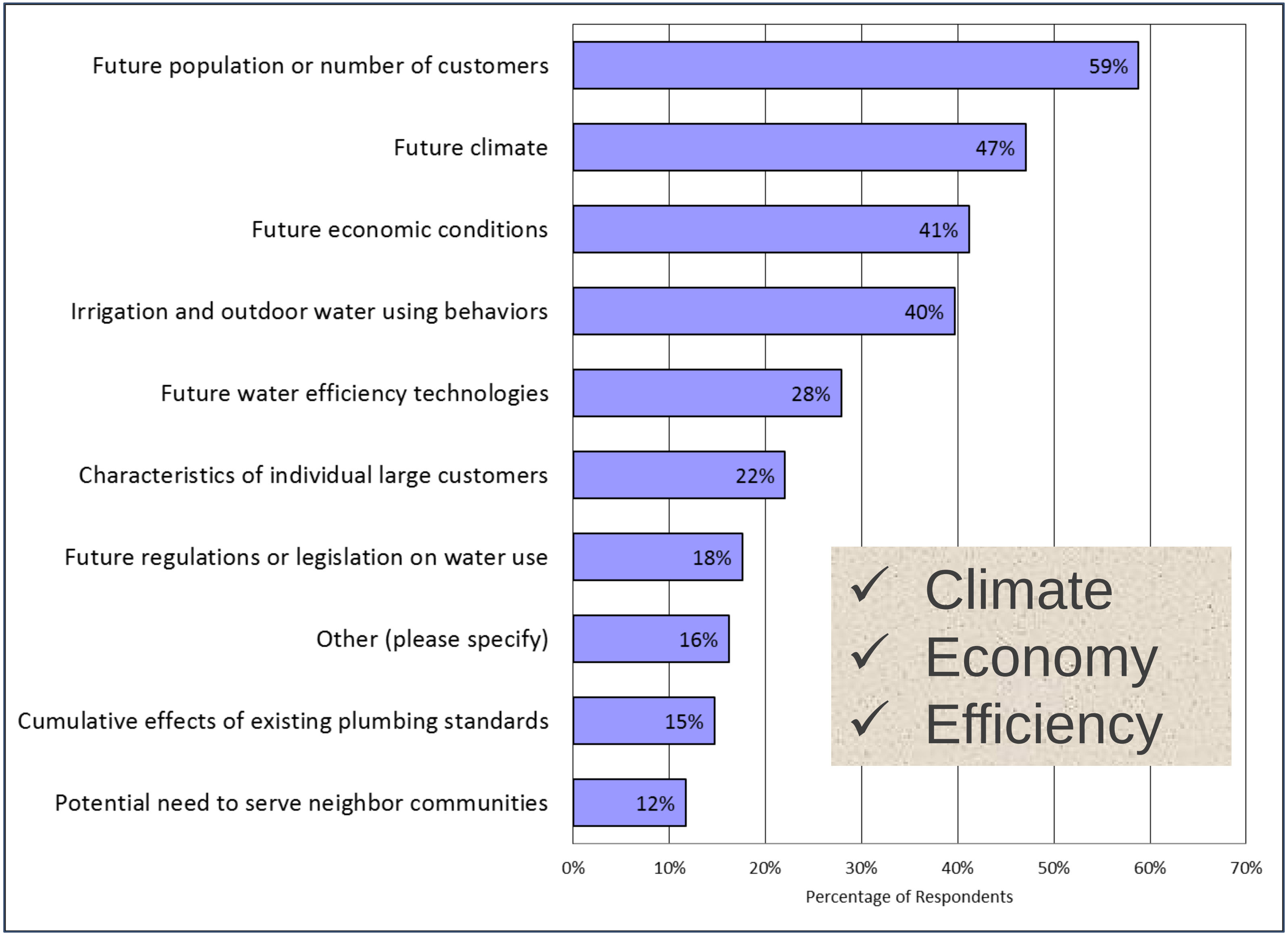
$$\left(\hat{Q} - t_{(1-\propto)/2} * \sqrt{s_f^2}\right) \leq Q_{Simulated} \leq \left(\hat{Q} + t_{(1-\propto)/2} * \sqrt{s_f^2}\right)$$

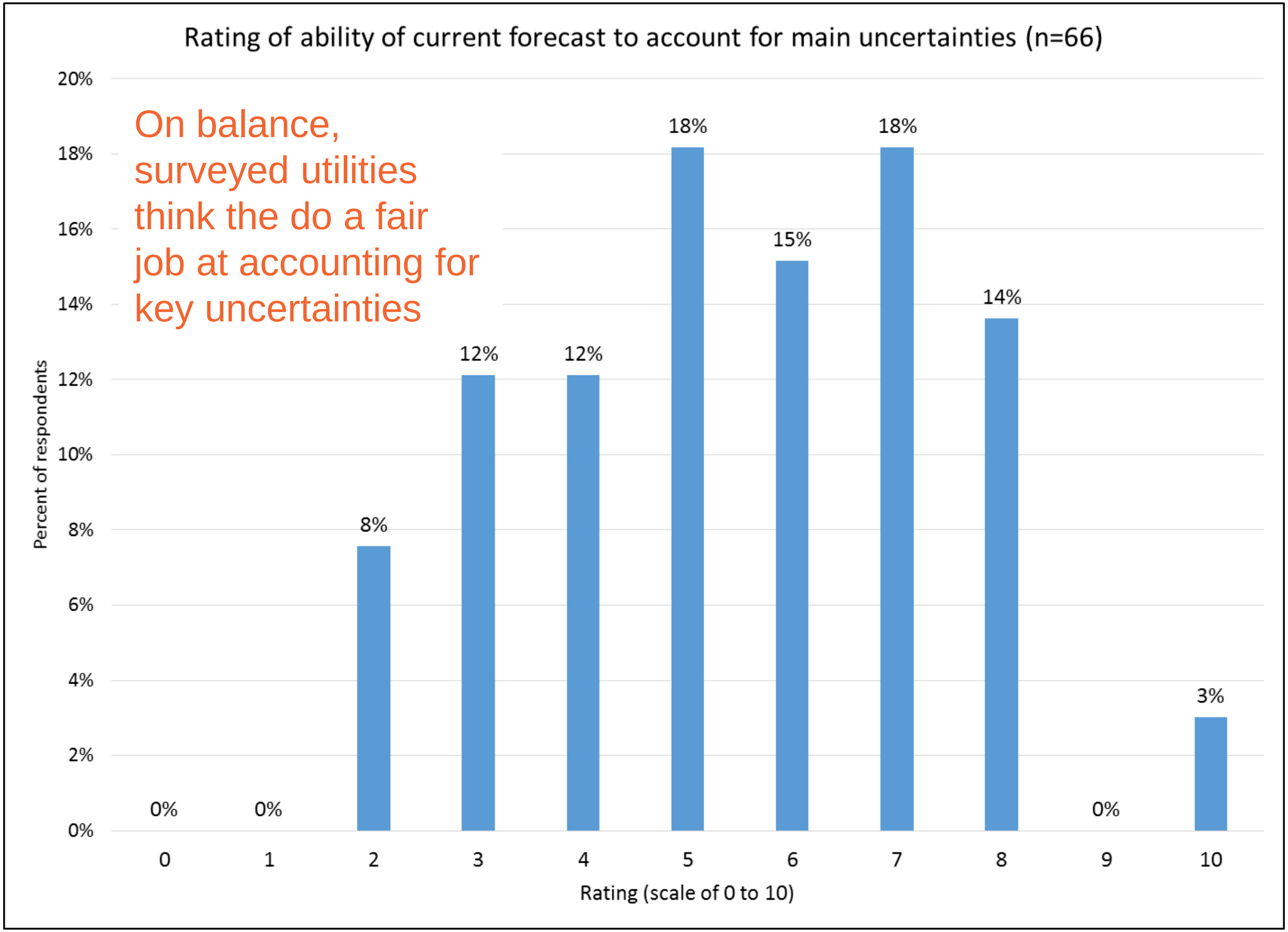

Which of the following approaches best describes how your utility accounts for forecast uncertainty?
(57 Responses)
70%
60%
50%
40%
30%
20%
10%
0%
64.9%
21.1%
12.3%
1.8%
Increased likelihood with system size
Scenarios based on qualitative assumptions
Broad intervals or rules of thumb about variation
Statistically-based intervals
None of the above

>50% addressing uncertainty would like additional variables in forecast model



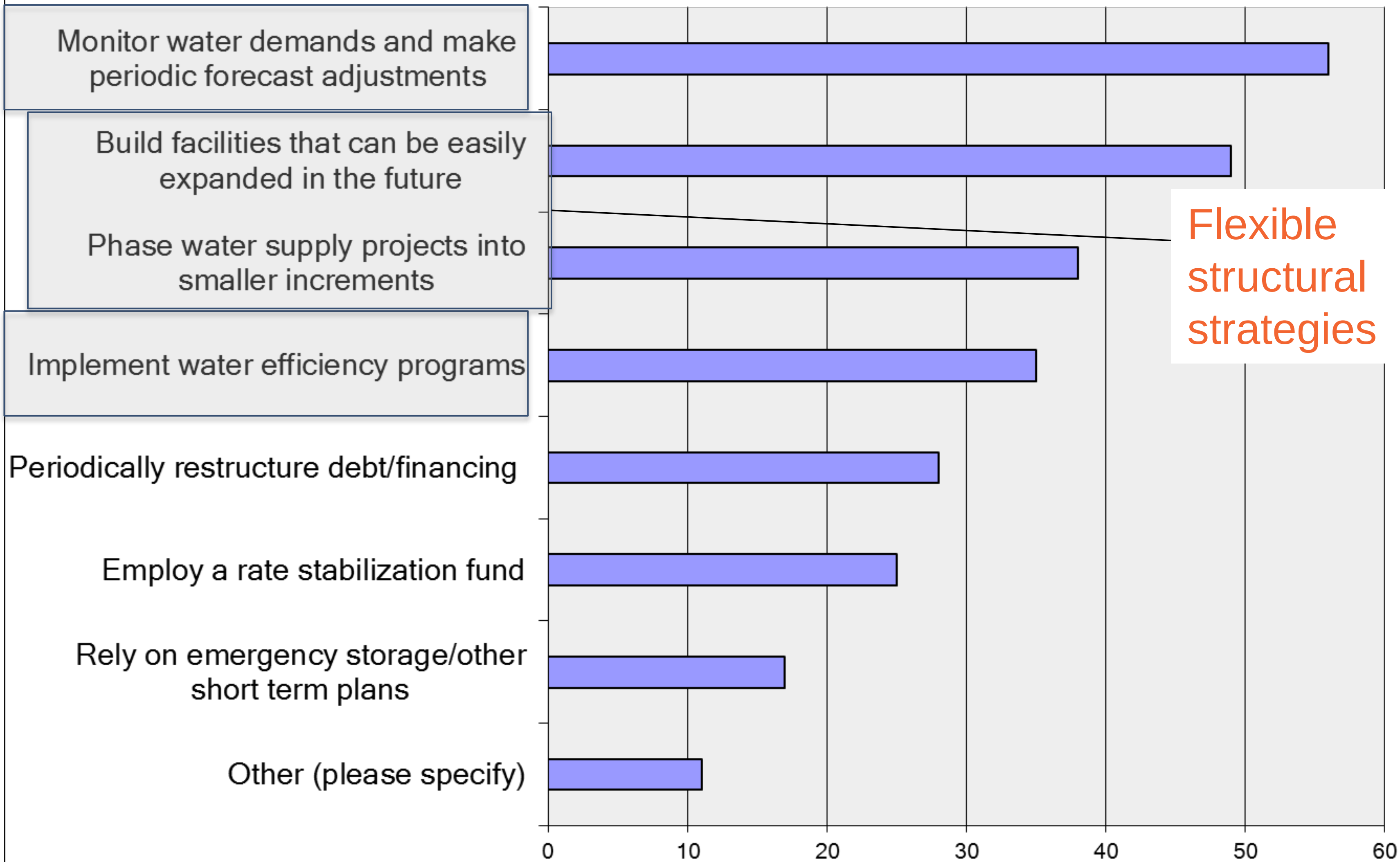
What would you consider to be the 3 main drivers of uncertainty about water demands over the next 20 to 30 years?




Rating of ability of current forecast to account for main uncertainties (n=66)
On balance, surveyed utilities think the do a fair job at accounting for key uncertainties
Percent of respondents
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0%
0%
8%
12%
12%
18%
15%
18%
14%
0%
3%
0
1
2
3
4
5
6
7
8
9
10
Rating (scale of 0 to 10)

What types of management methods do you use to cope with uncertainty and mitigate potential consequences?

(n=66; multiple answers possible)



Adaptive management of uncertainty

Coping with knowledge uncertainty

- Demand monitoring
- Periodic forecast updates
- "*When the facts change, I change my mind*." (John Maynard Keynes via Nate Silver)

Implementation of water efficiency programs

- Alternative source of supply
- Highly scalable risk reduction alternative

Closing remarks

The *raison d'être* for urban water supply planning is to meet current and future demands

The demand for water depends on structural, trending, cyclical, and contextual factors that are uncertain

- Economy
- Demographics
- Climate
- Efficiency
- Pricing
- Many more…

Closing remarks

Practical barriers exist for specifying all “known” sources of uncertainty and variability

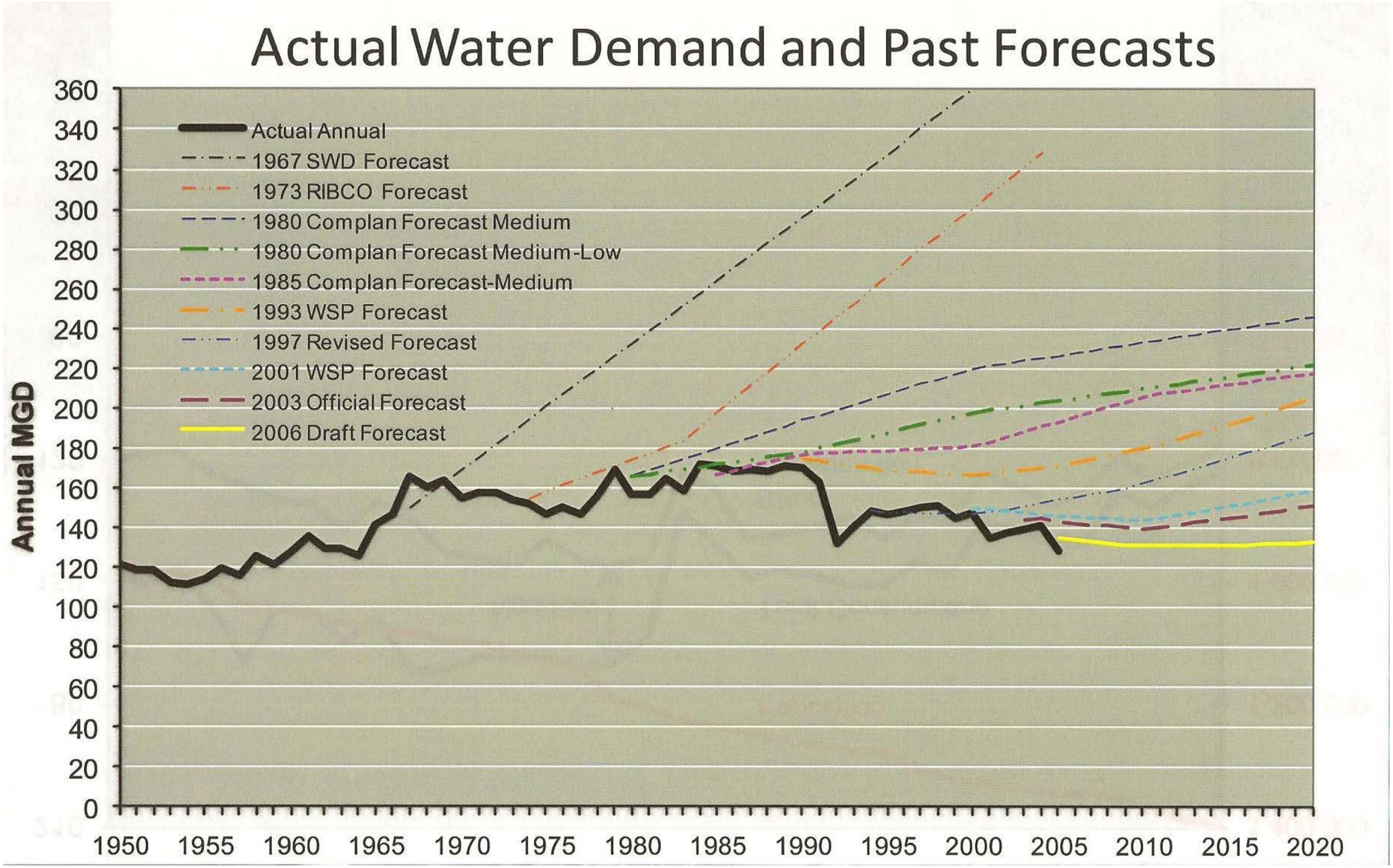
Understanding the array of factors presented an important starting point

Resist the urge to think deterministically—start thinking probabilistically

Closing remarks

Recognizing and developing forecasts scenarios for most impactful factors another good starting point

Periodic monitoring of water demand and forecast performance supports anticipatory and adaptive actions—knowledge building



Source: Bruce Flory

Enhance the role of Water Demand Manager

Adopt the risk analysis paradigm

Be a forecaster

Be a risk analyst

Be a knowledge manager

Analyze and interpret water use patterns

Collect and monitor information on the 4 classes of uncertain factors

Thank You! Questions?

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