Recommended Approach

for Selecting, Improving, and Developing Analytical Tools for Future Water Plan Updates

Motivation

- Would like more clarity around analytical methods
- Experiment with methods to improve development, communication, testing, and refining of analytical tools to produce quantitative deliverables
Before Selecting Tools

- Take a fresh look at collective understanding of how the water management system works
- Interact with subject matter experts to make sure we capture the latest thinking
- Document our collective understanding of important elements of water management system

Elements of an Analytical Tool

- Conceptual model
- Theoretical model
- Numerical model
- Data
- Data management
- Software
- Hardware
- Administrative aspects
- User community
Analytical Tool Life Cycle

- **Analysis** – emphasizes an investigation of the problem and requirements (Do the right thing)
- **Design** – emphasizes a conceptual solution that fulfills the requirements (Do the thing right)
- **Implementation** – the design is used to build functioning software
- **Application** – apply tool to conduct studies
- **Maintenance** – preserve, administer and refine
- **Retire** – replace or discontinue use

Quantitative Deliverables

- **Water Portfolios**
  - Describe where water originates, where it flows, and what it is used for based on recent data
- **Future Scenarios**
  - Describe expected changes by 2030 if water managers do not take additional action
- **Alternative Response Packages**
  - Describe packages of promising actions, predict expected outcomes, and compare performance under each scenario
How to Produce Other Deliverables?

- We have agreed on a **what** we want
- Getting specific about **how** to produce them
- Consider near-term and long-term

**Task:** Select or develop analytical tools
Getting to How

- Focus on one quantitative topic at a time (e.g., predicting urban water demand)
- Improve understanding & document requirements necessary to compute satisfactorily
- Interact with subject matter experts to define conceptual solution
- Select potential implementation strategy and test along the way

Method for Interaction

For each quantitative deliverable

1. Water Plan team prepare an incremental proposal for producing quantitative information
2. Discuss increments of the proposal with SWAN and others
3. Refine proposal
4. Repeat Steps 2-4 until reach broad agreement
5. Perform analysis
Incremental Proposal

- Requirements
- Conceptual Model
- Theoretical Model
- Numerical Model
- Data
- Data Management
- Software

Cross Training

- Recognized that software industry faces many of same challenges
  - Collaborative development
  - High complexity
  - Large amount of information to manage
  - Changing requirements
  - Stakeholder and developer interaction
  - Evolving capability
Method to Create Proposals

- Apply an iterative development process (IDP) widely used to create commercial software
  - Use exercises to define actors, their responsibilities, and their interactions
  - Keep it simple, do only what is required to reach understanding
  - Leads to system requirements
  - Supports creation of adaptive software

Phases in IDP

- **Analyze** – what are the questions we want to answer and what are the key components needed to answer it?
- **Design** – how might me represent our conceptual model of the actual system using math and software constructs?
- **Implement** – “code” design in a software development environment
IDP & Analytical Tools

- IDP is used in several stages of analytical tool life cycle
  - Analysis
  - Design
  - Implementation
  - Maintenance / refinement

Basic Steps in IDP

- **Define Use Cases** – write stories or scenarios of how people will use the analytical tool
- **Define Conceptual Model** – create a description of the important concepts, attributes, and associations using objects
- **Define Interaction Diagrams** – define responsibilities and interactions between software objects
- **Define Design Class Diagrams** – define software classes and their attributes and operations
- **Implement in Small Steps and test**
We Will Modify IDP Slightly

- Basic Steps
  - Define Use Cases
  - Define Conceptual Model
  - Define Interaction Diagrams
  - Define Design Class Diagrams (will not just be class diagrams – will use some existing analytical tools or existing modeling frameworks)
  - Implement in small steps and test frequently

Potential Artifacts from IDP

- Vision – a short overview of big ideas
- Use-Case Model – a set of typical scenarios of how analytical tool will be used
- Glossary – defines noteworthy terms and can include data dictionary
- Business Rules – describe requirements or policies relevant beyond this project
Potential Artifacts (2)

- Conceptual Model – a visual representation of important things in a real system of interest
- Interaction Diagrams – a visual representation of dynamic interaction between objects
- Design Models – describes object responsibilities and how to fulfill requirements with software

Applying an IDP

- How to Analyze, Design, and Implement?
- In software industry, often use **object-oriented** analysis, design, and programming techniques
Pilot Study

Applying Object-Oriented Methods and Visual Modeling Environments to Predict Urban Water Demand

Objectives for Pilot

- Experiment with different methods to improve understanding about how to produce Future Scenarios and Alternative Response Packages
- Determine if tested methods and tools help us interact more effectively with experts and other stakeholders
Focus for Pilot

- Chose one area of interest: predicting urban water demand
- Tested the usefulness of:
  - Object-oriented modeling techniques
  - Graphical modeling notation (UML)
  - Extend – a visual modeling environment

Object-Oriented Modeling
An Introduction
Object-Oriented Modeling

- Object-oriented **analysis** emphasizes finding and describing the objects or concepts in the system of interest.
- Object-oriented **design** emphasizes defining software objects and how they collaborate to fulfill requirements.
- Object-oriented **programming** emphasizes building software to fulfill requirements.

**mo • del – n.**

- A simplified representation of a system or phenomenon.
- A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics.
Model vs. Analytical Tool

- **Model** is used in this context to mean a simplified representation of a complex system developed to improve understanding of a problem or solutions.

- **Analytical tool** is used in this context to mean a computational aid created to produce quantitative deliverables.

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Object-Oriented Analysis

- Use a familiar way of human thinking and abstraction
- Describe system in terms of entities, interactions, and responsibilities

**object n.**
1. something perceptible by one or more of the senses, especially by vision or touch
2. something intelligible or perceptible by the mind

Example of an Object Model

[Diagram of a sailboat with object model showing relationships between sailboat, mast, and hull]
**What is UML?**

- The Unified Modeling Language is a visual language for specifying, constructing and documenting artifacts of systems.
- It is the de facto standard diagramming notation for drawing or presenting pictures related to object-oriented software.
- Can be complicated but we are keeping it simple.
No Silver Bullet

- UML is simply a standard diagramming notation – boxes, lines, etc.
- Visual modeling with common notation can be helpful
- Does not replace the need for system knowledge and sound design skills
- Just as a word processor does not write, UML does not analyze or design

Ways to Apply UML

- UML as Sketch – informal and incomplete diagrams to explore difficult parts of problem or solution
- UML as blueprint – relatively detailed design diagrams used either for
  - Reverse engineering to visualize and better understand existing code
  - Code generation
Perspectives to Apply UML

- **Conceptual** – the diagrams are interpreted as describing things in an actual system of interest
- **Specification (software)** – the diagrams describe software abstractions (technology independent)
- **Implementation (software)** – the diagrams describe software implementations in a particular technology (such as Java)

How Have We Used UML?

- As a **sketch tool** during interactive conceptual modeling of an actual system of interest (e.g. predicting urban water demand)
- To illustrate how existing analytical tools work (e.g. Urban Water Use Model)
- To help create new software implementations in Extend
An Example of IDP

- Demonstrate methods with simple predator-prey model
- Based on tutorial distributed with Extend software

Vision

- Allow user to study dynamic interaction of hare and lynx populations in a fixed geographic area
- Allow user to vary key assumptions to determine change in populations over time
Use Case

- Main actor: ecologist / analyst
- Main Success Scenario:
  - Analyst specifies area of habitat.
  - Analyst specifies starting populations.
  - Analyst specifies rate of hare kills per lynx.
  - Analyst specifies birth rates.
  - Analyst specifies lynx mortality rates.
  - Plot change in populations over time.

Create Conceptual Model

- Possible Objects:
  - Habitat
  - Hare
  - Lynx
  - Hares (or Hare Population)
  - Lynxes (or Lynx Population)
Conceptual Class Diagram

- Identifies key objects in actual system of interest
- Shows important relationships between objects
- Identifies key attributes
- Identifies key operations
- Represents a static view

Conceptual Class Diagram

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Hares</th>
<th>Lynxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Population</td>
<td>Population</td>
</tr>
<tr>
<td>Hare Density</td>
<td>Birth rate</td>
<td>Birth rate</td>
</tr>
<tr>
<td></td>
<td>Mortality rate</td>
<td>Mortality rate</td>
</tr>
<tr>
<td></td>
<td>Give birth</td>
<td>Give birth</td>
</tr>
<tr>
<td></td>
<td>Die</td>
<td>Eat</td>
</tr>
</tbody>
</table>

Hares:
- Birth rate
- Mortality rate
- Give birth
- Die

Lynxes:
- Population
- Birth rate
- Mortality rate
- Hare kill rate
- Give birth
- Eat
- Die
Sequence Diagram

- Demonstrate designed interaction of objects in software
- Illustrate sequence of events
- Shows communication between objects
- Represents a dynamic view

Sequence Diagram

Habitat
- Set Area

Lynxes
- Set Birthrate
- Set Initial Population

Hares
- Set Birthrate
- Set Initial Population

Hare Population

Calculate Hare Density
- Hare Density
- Calculate Hare Kills per Lynx
Summary

- So far, illustrated process to complete first two stages of Analytical Tool Life Cycle
  - Analysis
  - Design
- Next, illustrate stages 3 and 4
  - Implementation
  - Application

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Visual Modeling Environments

An Introduction

Role of Visual Modeling Tools

- In IDP can use to test
  - Theoretical model
  - Numerical model
  - Data
  - Data management
- In IDP can use to implement design
Features and Utility of Visual Modeling Environments

- Graphical display of system with on-the-fly simulation results
- Approximation of more complex models (e.g. look up tables)
- Quick run time (a few minutes)
- Perform screening or gaming type analysis for strategic or policy decisions
- Facilitates object-oriented modeling

Example Applications

- Visual modeling tools have been used successfully for years in water planning
- Some applications include:
  - Alabama-Coosa-Tallapoosa/Apalachicola-Chattahoochee-Flint River
  - Missouri River
  - Bill Williams River in Arizona
  - Washington State
  - Central and South Florida
Tools Evaluated by DPLA

- Extend
- Analytica
- Stella
- Vensim
- WEAP
- PowerSim
- Simile
- Model Maker

Desired Features

- Extensive pre-defined functions
- User defined functions and sub routines
- Ability to link to Excel and Access for input and output
- Built-in sensitivity and alternatives analysis
- Ability to organize model in to sub-systems
- Free reader
Extend Description

- Extend is a visual modeling environment that allows users to combine predefined “blocks” to build a simulation model of a system.
- The Extend blocks are essentially software objects that a user can easily manipulate and combine.
- Users can create their own custom blocks.

Extend Demo

Predator-Prey Example
Summary of IDP Example

- Defined Use Case
- Defined Conceptual Model
- Defined Interaction Diagrams
  - Define Design Diagrams (not needed here)
- Implemented in small steps (within Extend) and tested

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Summary

- Recommend using IDP to select, improve and create analytical tools for future CWP Updates
- Use object-oriented techniques to perform analysis, design, (and programming as needed)
- Use UML for graphical documents of conceptual model and implementation design
- Can use existing modeling frameworks to test the design and implement

After Lunch

- We will
  - Present IDP artifacts created to describe how DWR currently quantifies recent urban water use
  - Demo an Extend model for how future urban water demands were calculated for CWP Update 2005
  - Experiment with IDP to describe conceptual model to compute scenarios and management responses for urban water use
Lunch Break

Questions and Comments

- We would like to hear your thoughts about our proposal
  - IDP
  - Interaction plan
  - Object-oriented modeling
  - UML
  - Visual modeling environments
Urban Water Use

Applying Object-Oriented Techniques and UML to Document DWR Process

IDP Artifacts as Documentation

- This information is contained in paper
- Completed in June 2006
- Artifacts describe how DWR
  - Estimates water use in a study area
  - Calculates water use by customer classes in a DAU
Modeling Multiple Perspectives

Actual Water Management System

- People
- Physical structures
  - Natural
  - Constructed
- Water
- Nature

Interested Public
Informed Public
Regional Water Planning Efforts
Conceptual Model of Water Management System

Laws and regulations
Institutions
Markets

Documentation of Existing Tool

Use Cases, Class Diagrams, and Sequence Diagrams
What We Learned

- Object-oriented techniques are powerful aids for creating conceptual models and for designing and describing analytical tools and processes
- There are start-up costs
- We learned by doing
- Can be helpful to improve understanding of and document existing analytical tools
- Keep it as simple as possible

Questions and Comments

- Do you see value in this approach for documenting analytical tools?
- Were the artifacts presented helpful in understanding our approach for quantifying recent urban water use?
Extend Demo

Predicting Urban Water Demand

Visual Modeling

- This Extend Model shows visual relationships of data and approach used to estimate urban water use in Scenarios published in CWP Update 2005

- View Visual Urban Use Model
What We Have Learned

- Extend has a lot of capability
- There are start-up costs
- We learned by doing
- Can be helpful to improve understanding of and document existing analytical tools
- Clearly shows data flows
- Allows for rapid testing of conceptual, theoretical, and numerical approaches

Questions and Comments

- Was this perspective helpful to understand quantitative approach for estimating future water use?
- Can you see a role for visual modeling tools in shared vision planning?
Conceptual Modeling Exercise

Creating a Conceptual Model to Study Future Urban Water Demand and Supply

Vision

- Develop capability to quantify changes in future water demand
- Develop capability to quantify changes in future water supply
- Model relevant system interactions related to supply and demand
- Easy to understand by stakeholders
Use Case

- A water agency forecasts demand for water in its service area at some point in the future
- A water agency evaluates ability to meet expected demand with existing resources
- A water agency evaluates potential investments to improve ability to meet expected demands for service

Develop Conceptual Model

- Identify necessary objects or concepts that sufficiently describe key elements of the actual system to fulfill desired steps in use case
- Use graphical modeling notation to capture ideas
- Do iteratively with interaction
Brainstorm Potential Objects

- We will try an experiment
- Use CRC method in groups
  - Use index cards to create set of potentially useful objects
  - Start to arrange the cards to represent possible relationships between objects
- After this exercise we will show you some preliminary diagrams we have created

Review Draft Diagrams

- Use your own recent exercise to inform your review of our draft diagrams
- We will give a brief primer on how to read the notation
Object

**water provider**
- No. of customers
- quantity of water delivered
- risk preference
- objectives

*obtain water()
*treat water()
*deliver water()
*add infrastructure()
*remove infrastructure()
*maintain infrastructure()
*set price()
*bill customer()
*add customer()
*remove customer()
*collect revenue()
*store water()
*plan for future()

Relationships

- Geographic Area
- Water Source
- Facility

1:1 relationship between Geographic Area and Water Source
1:1 relationship between Water Source and Facility
0:1 relationship between Geographic Area and Facility
Views at Different Detail

Discuss and Comment

- Please review diagrams and comment within your workgroups
- Feel free to mark up
Next Steps in IDP

- Analysis
  - Additional requirements
- Design
  - Theoretical model
  - Numerical model
- Implementation
  - Data
  - Data management
  - Software

Questions and Comments

- Do you think this approach can help improve clarity?
- Are you interested in participating in these types of analysis and design sessions?
- Can it get us where we want to go?
Next Steps

- We will conduct a workshop to discuss, refine, and adopt our conceptual model for urban supply and demand
- We will conduct a workshop to present and discuss ideas for implementation
  - Theoretical and numerical models
  - Software
- Repeat for other areas of CA Water Management System
- Would you like a workshop to learn more about IDP, OOM and UML?