Integrated Water Flow Model (IWFM): A Hydrologic Modeling Toolset for Today's Water Resources Management Challenges

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IWFM: **I**ntegrated **W**ater **F**low **M**odel

- Generic integrated hydrologic modeling software
- Simulates water flow within the hydrologic cycle; land surface, root zone, unsaturated zone, groundwater, streams, lakes
- Calculates agricultural and urban water demands; uses stream diversions and groundwater pumping to meet the demands
- Notable applications: C2VSimCG

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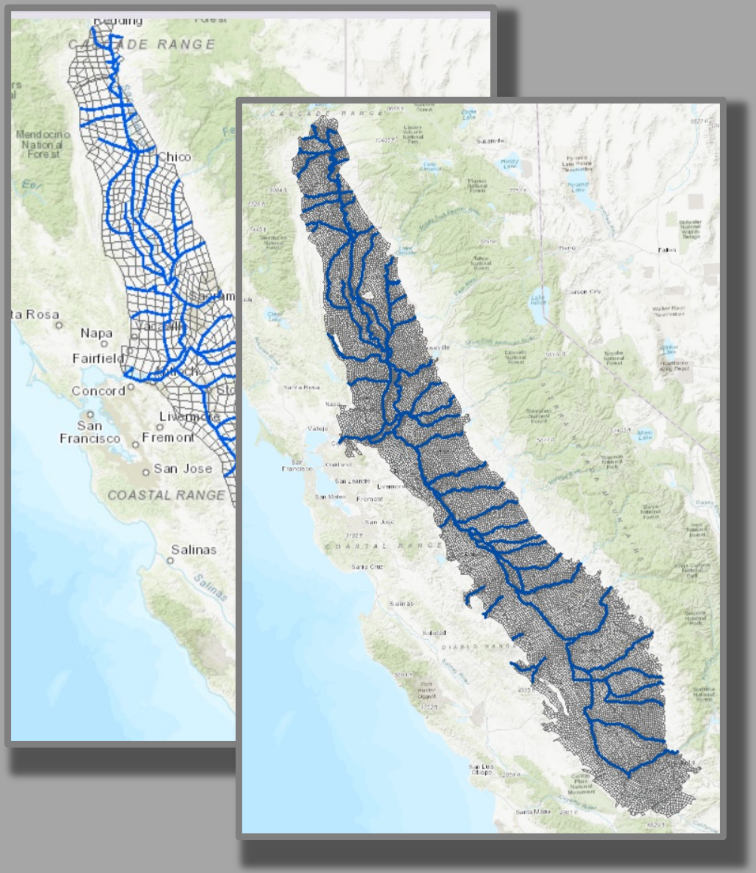

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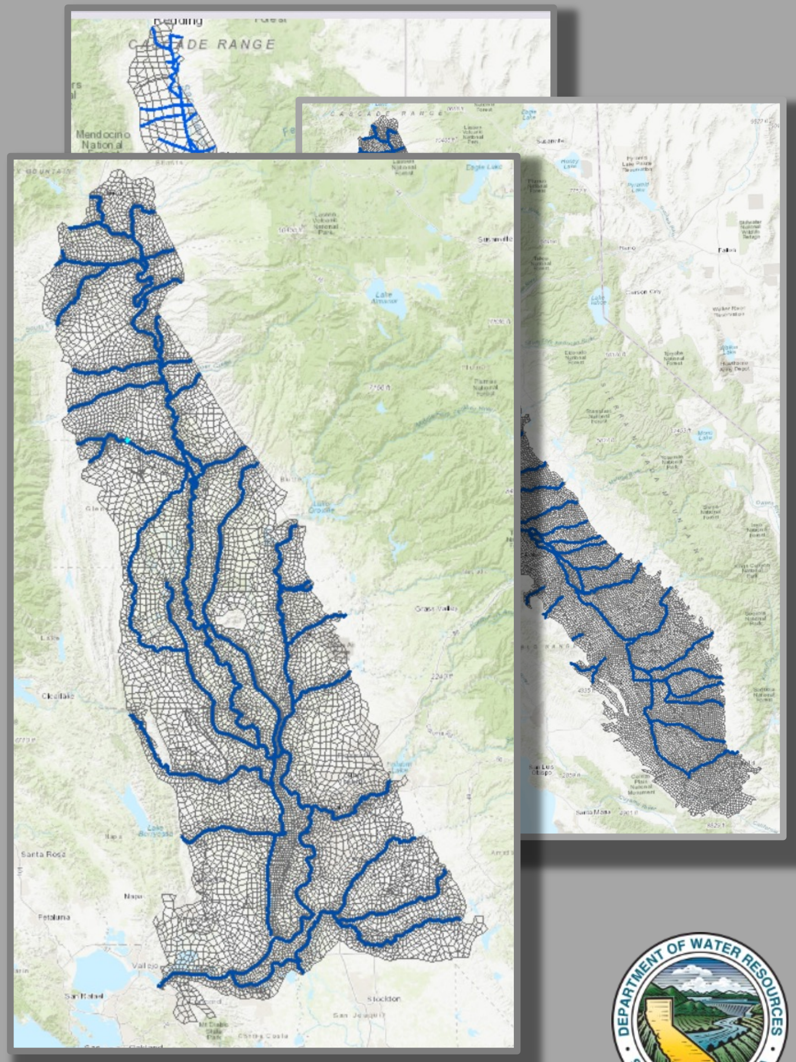

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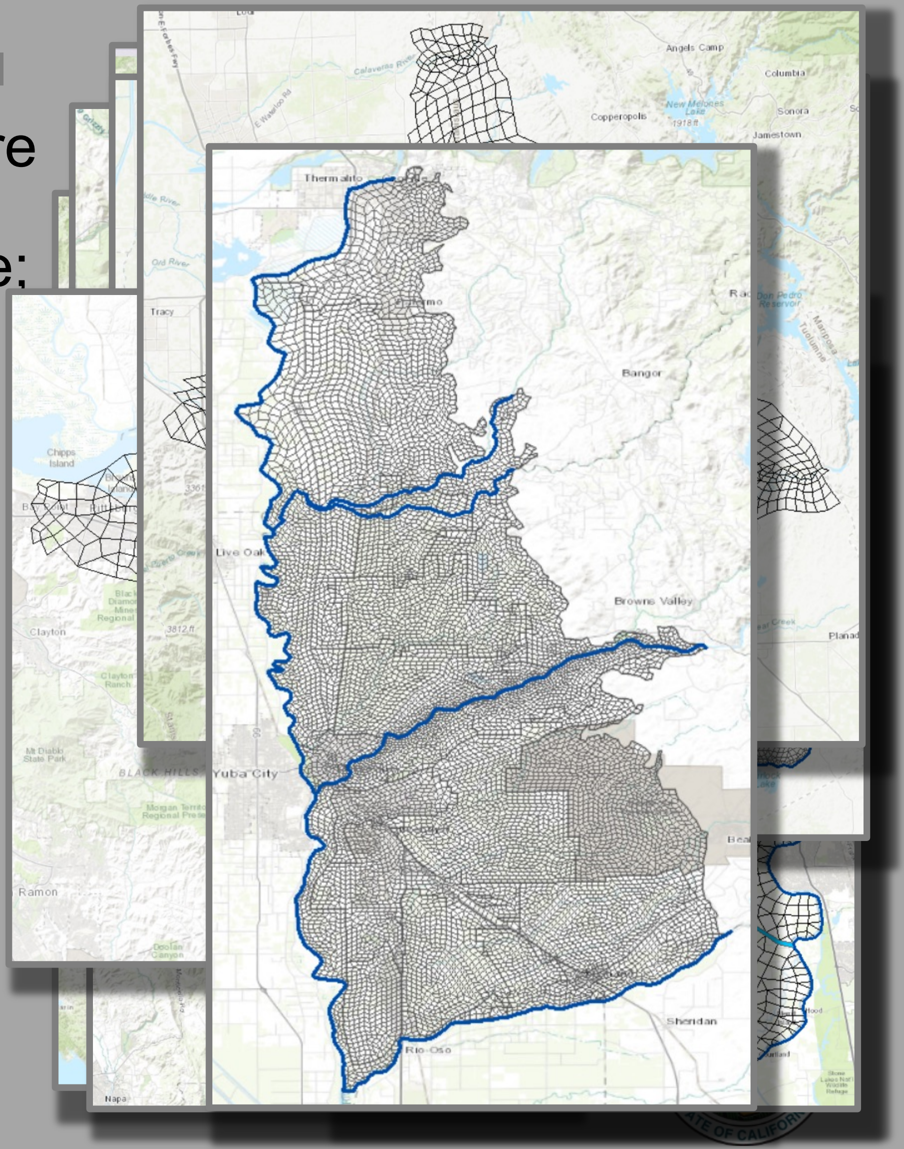
- Notable applications: C2VSimCG, C2VSimFG, SVSim, local models to assist development of GSPs

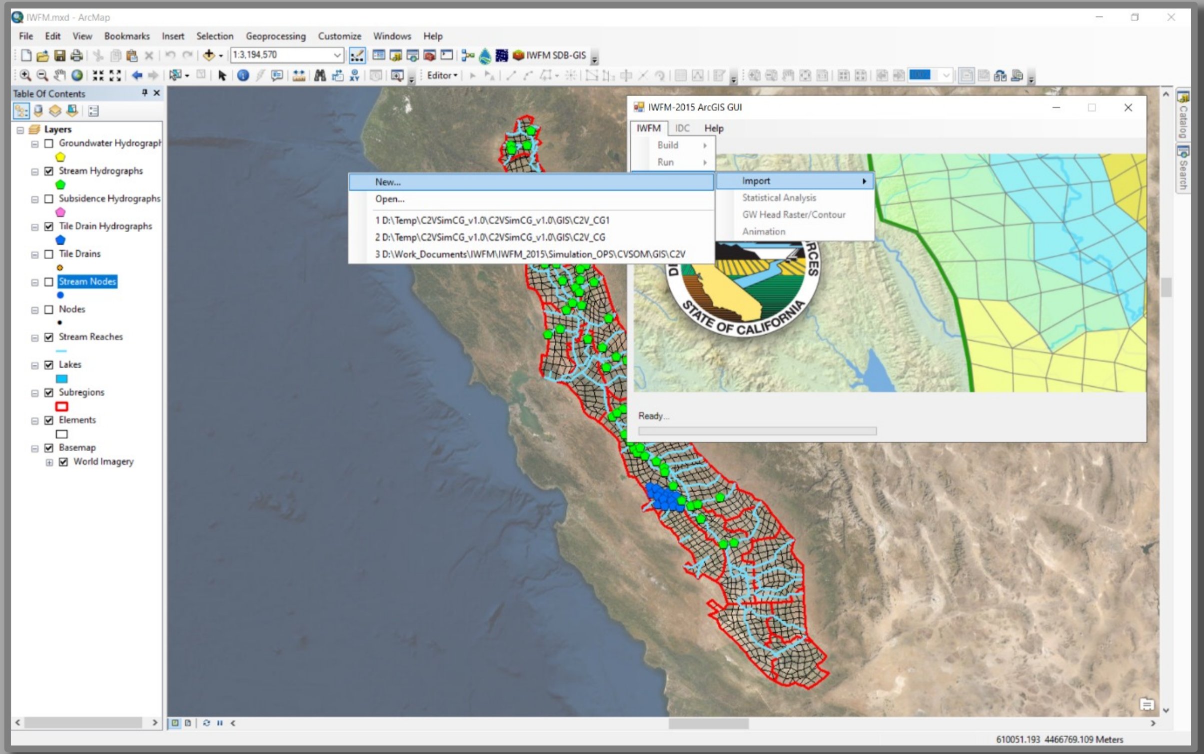


Some Requirements for IWFM

- Accurate simulation of the physical system
- Reusability: Ability to use the same model codeset for different purposes
  - Develop applications
  - Power visualization and analysis tools, graphical user interfaces
  - Link to other types of models
  - Callable from different programming languages
- Adoptability: Ability to incorporate new simulation techniques without affecting previously developed applications
- Modularity: Ability to split the model into smaller, stand-alone components
- Speed in running applications and in retrieving results

Reusability: Post-Processing and Analysis Tools

- Initial need emerged when developing post-processing tools
  - ❖ IWFM ArcMap Graphical User Interface



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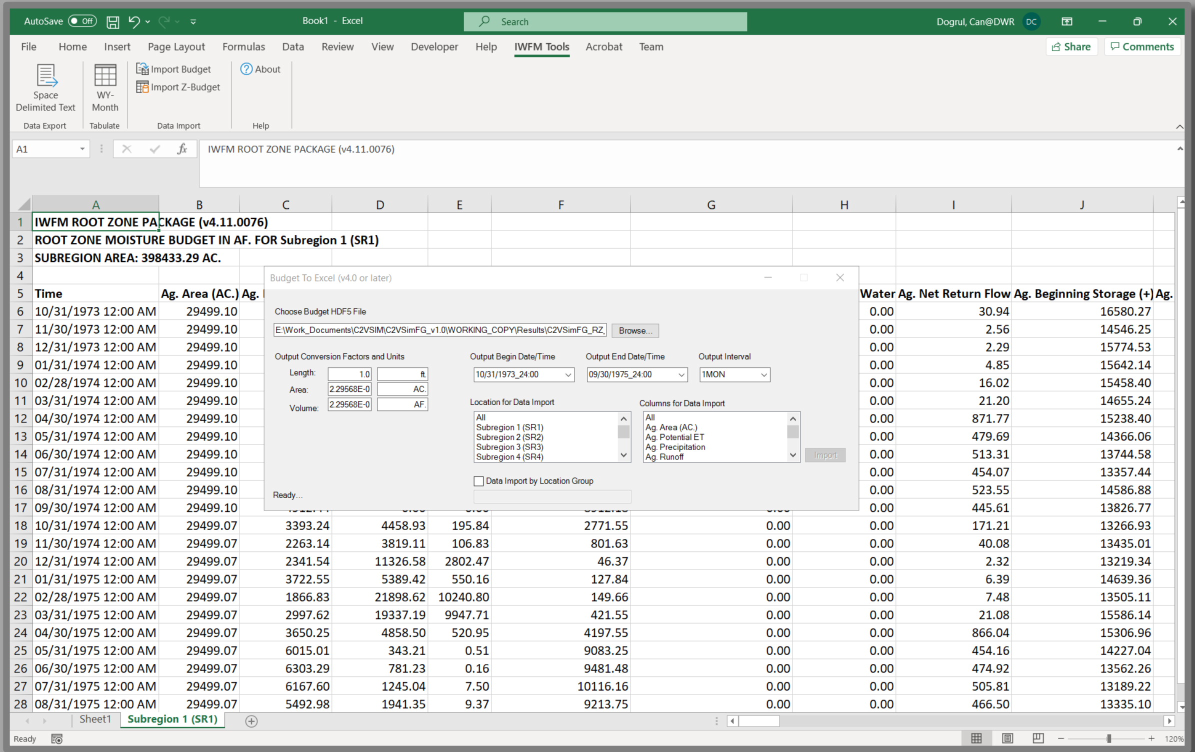

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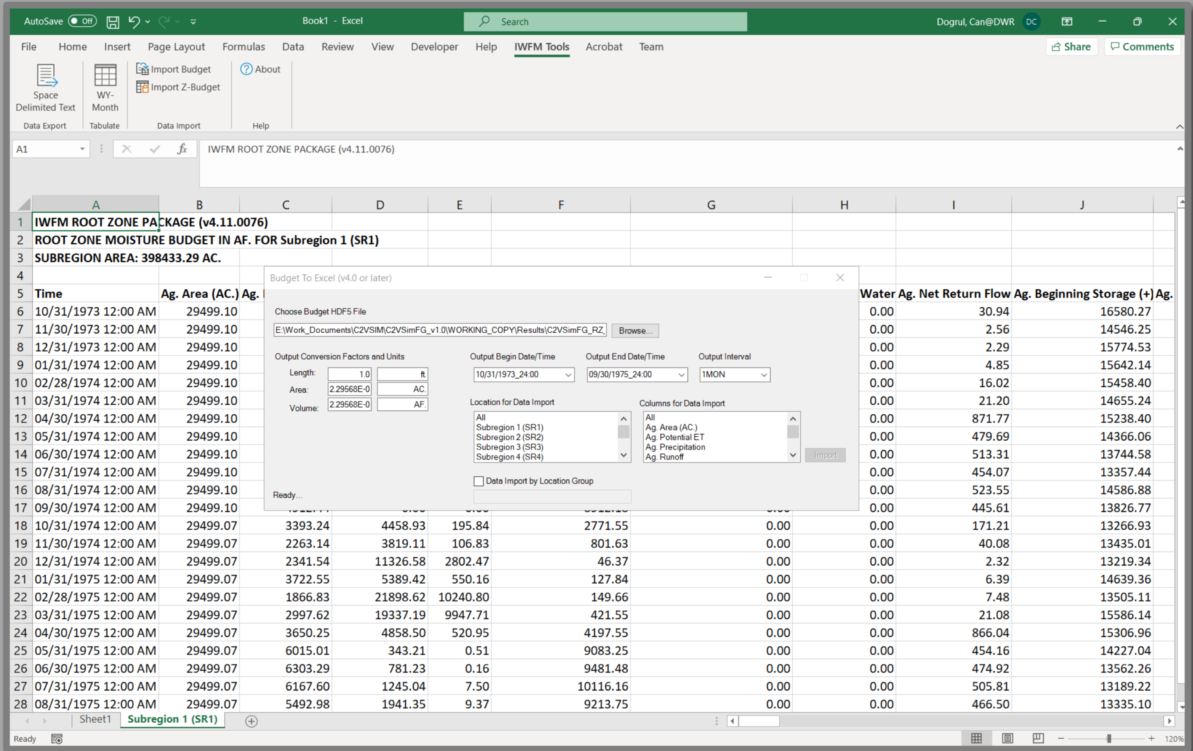
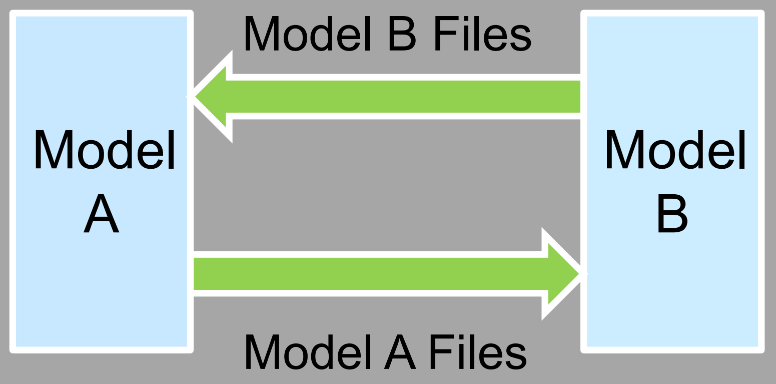
- Avoid replicating existing logic in a different programming language



Reusability: Linking Different Types of Models

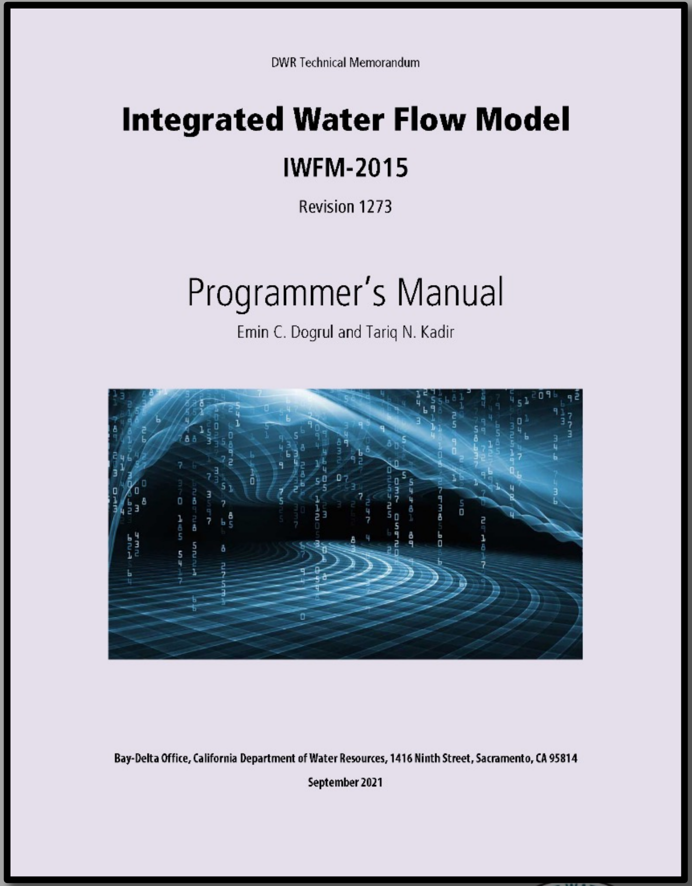
Traditional Approach: Data Passing via Files

- Requires code modification to generate files and to read files generated by other model(s)
- Model dependent; different files to read and write for different types of linked model
- Difficult to maintain



Reusability: IWFM API

- A library of callable functions
- Functions can be called in different order to achieve different goals
- Same codeset used for different purposes and in different types of applications eliminating repetitive coding and inconsistencies
- Callable from different programming languages
  - ❖ Python
  - ❖ Java
  - ❖ Fortran, C, C++
  - ❖ .NET languages (C#, VB)
  - ❖ Visual Basic for Applications


DWR Technical Memorandum

Integrated Water Flow Model

IWFM-2015

Revision 1273

Programmer's Manual

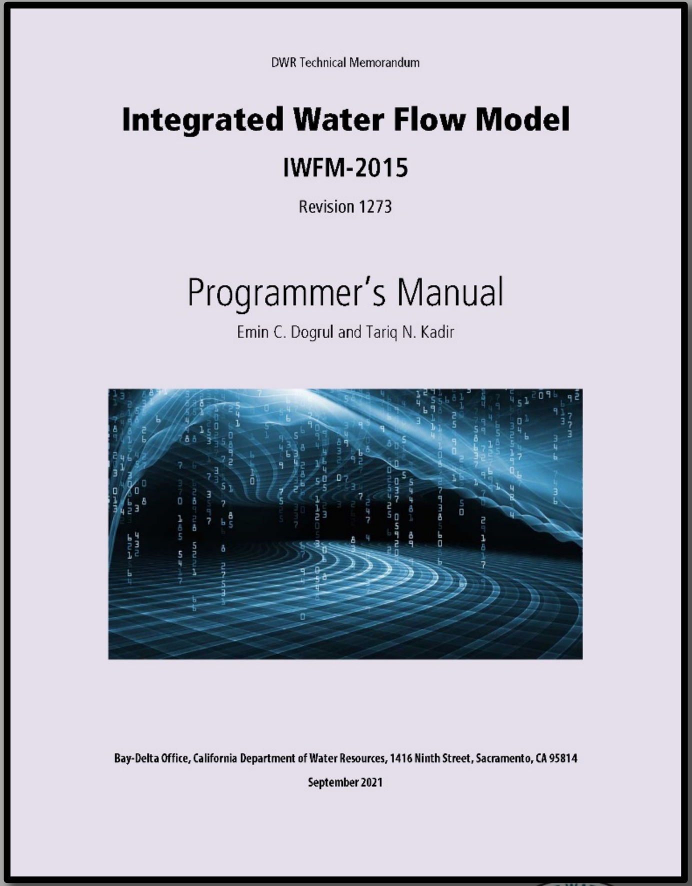
Emin C. Dogrul and Tariq N. Kadir

Bay-Delta Office, California Department of Water Resources, 1416 Ninth Street, Sacramento, CA 95814

September 2021

Reusability: IWFM API

- Allows interacting with an IWFM application during runtime (supports model linkage)
  - ❖ Modify crop areas based on water availability and economics (e.g. linked SWAP-C2VSim)
  - ❖ Modify stream boundary inflows and diversions based on legal and operational constraints (e.g. CVSOM)
  - ❖ Link neighboring IWFM models to simulate boundary flows dynamically (IWFM-MM)
  - ❖ Modify pumping and diversions based on water quality constraints
  - ❖ Dynamic visualization of simulation results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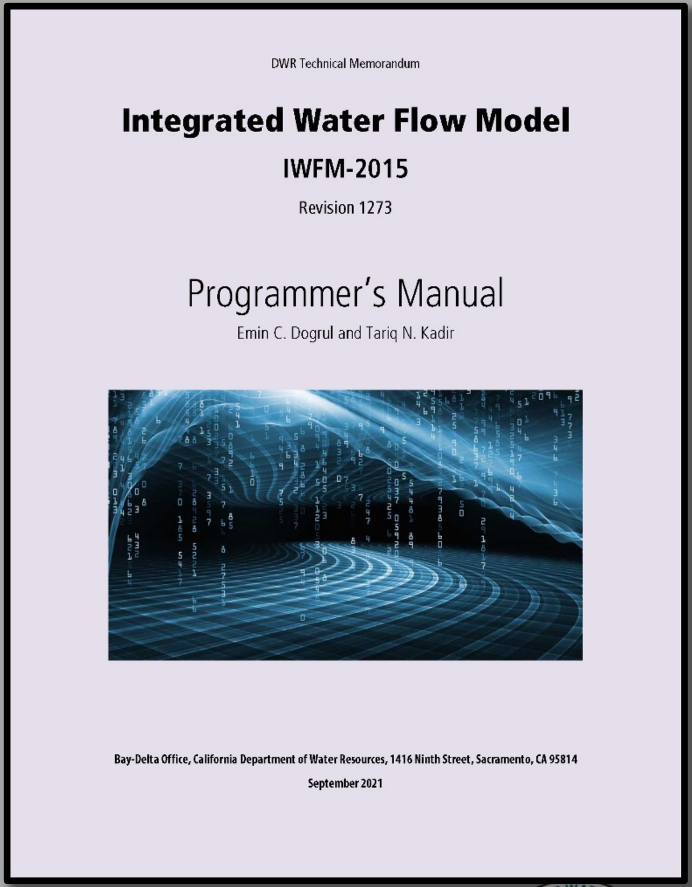
  - ❖ Pause model in the middle of a run
  - ❖ Simulate the same timestep as many times as needed
  - ❖ Retrieve model results for the timestep simulated last
  - ❖ Modify model input during the runtime
  - ❖ Do all of the above with a wrapper program using a predefined logic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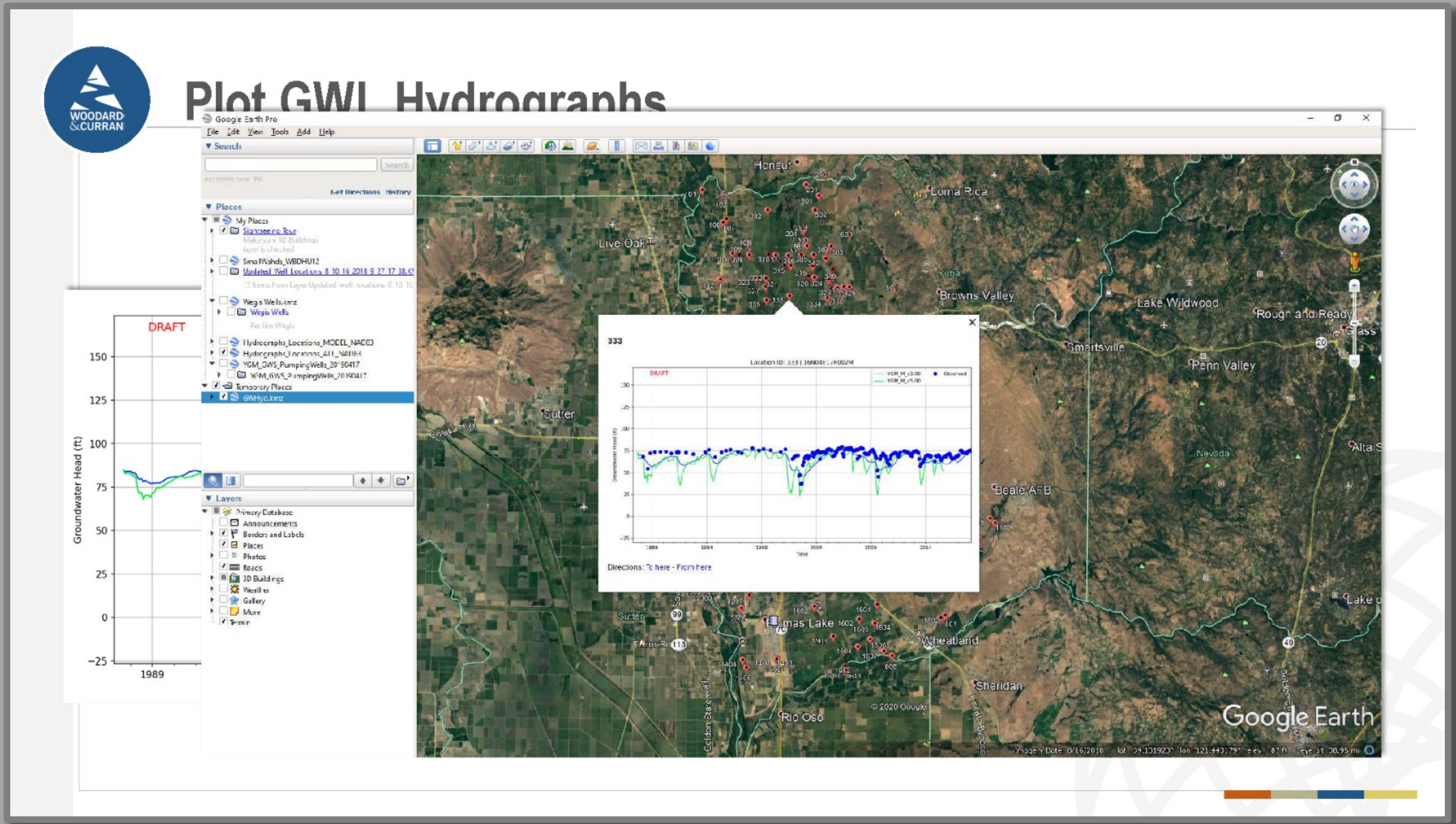
- “Democratization” of processing, visualization and analysis tools
  - ❖ User-developed Jupyter Notebooks



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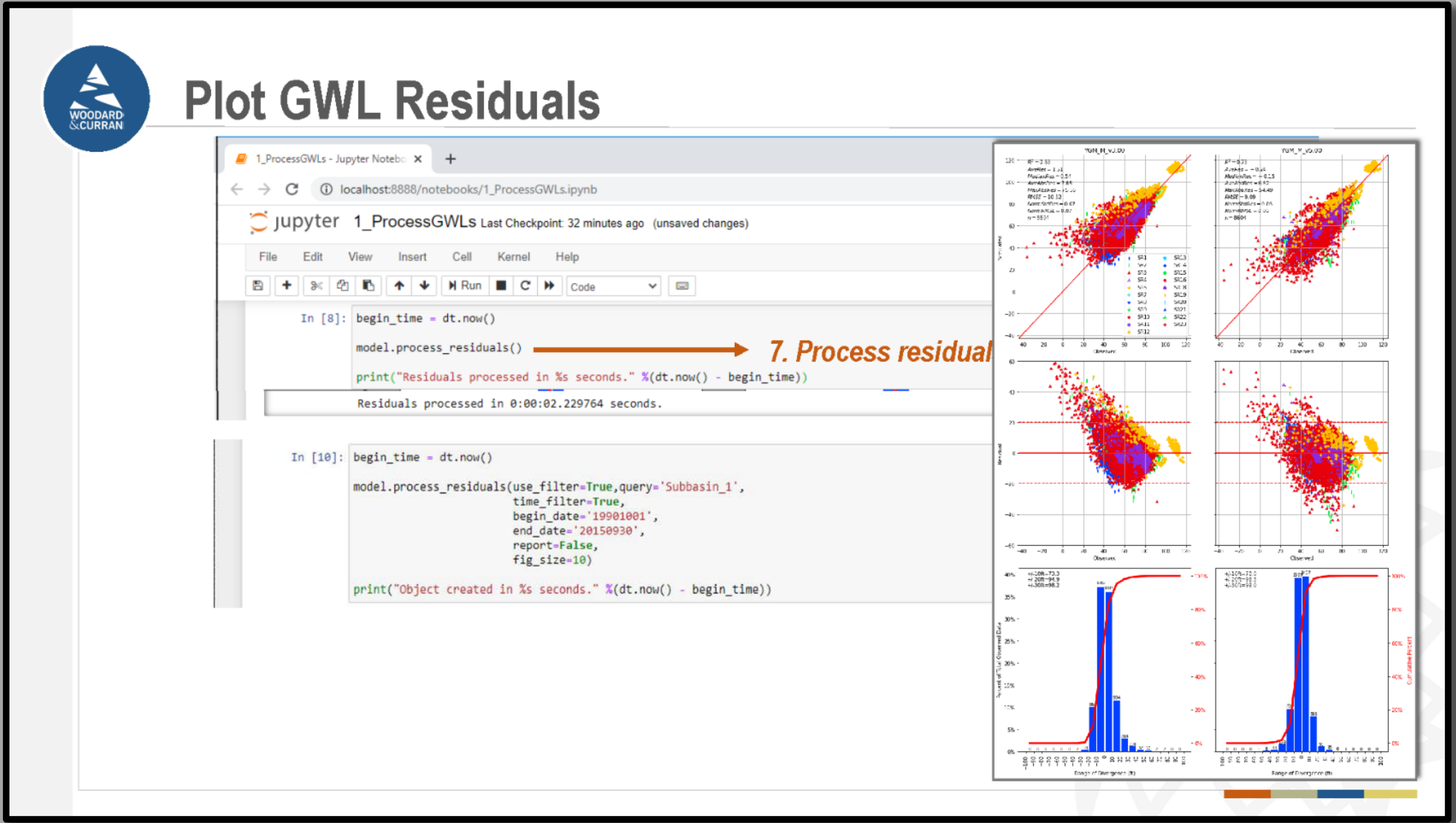

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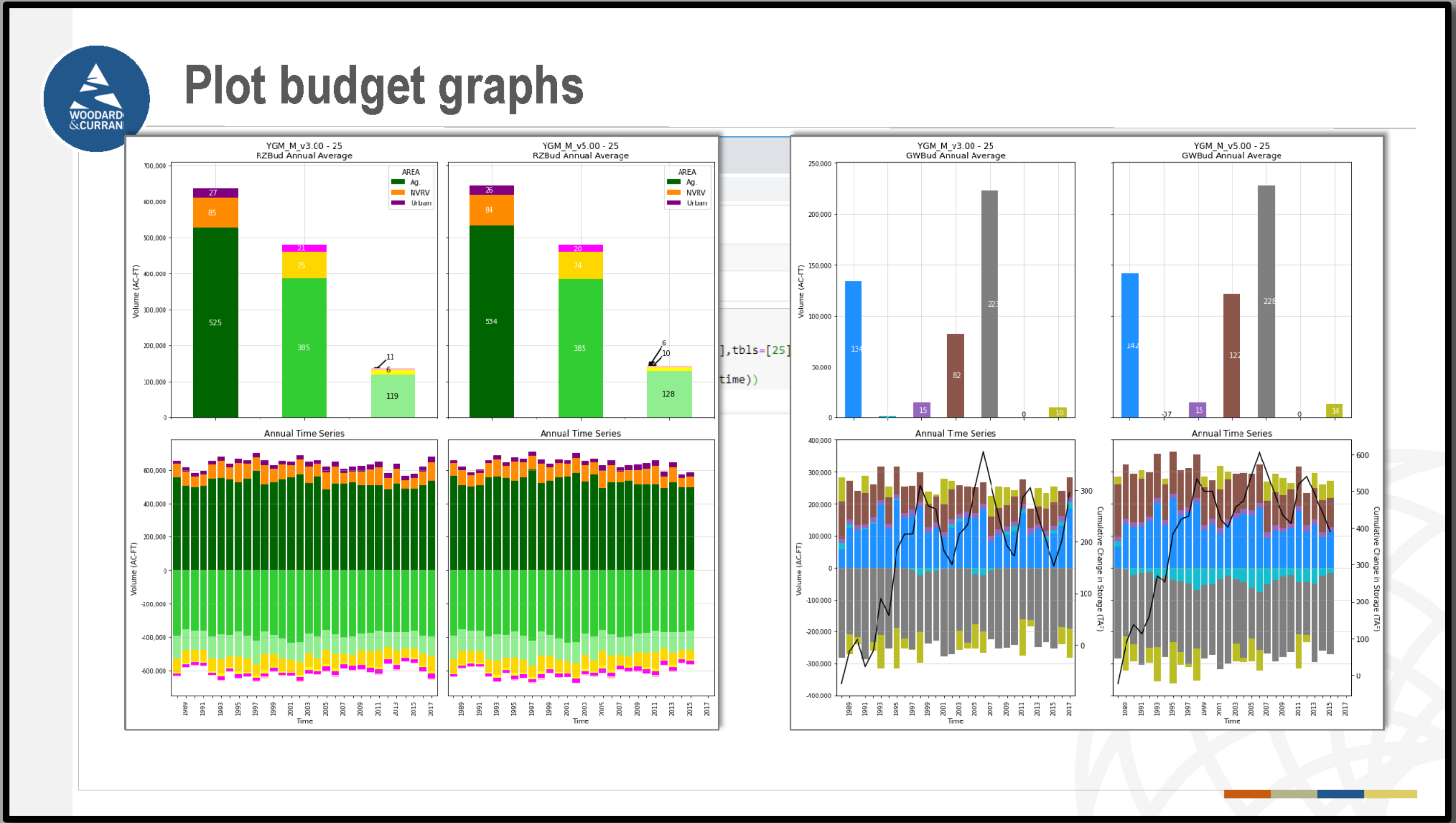

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  - A layer between user’s tool and the IWFM model that breaks the dependency between the two; user’s tool don’t depend on IWFM input/output data structure and format

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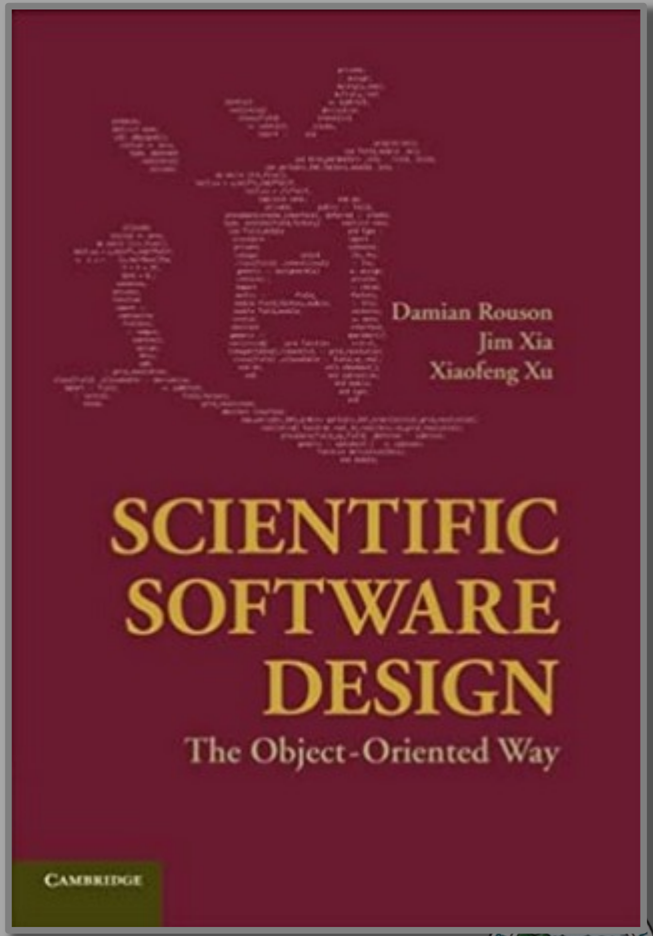
- Monte-Carlo simulations
- Development of surrogate models through machine learning

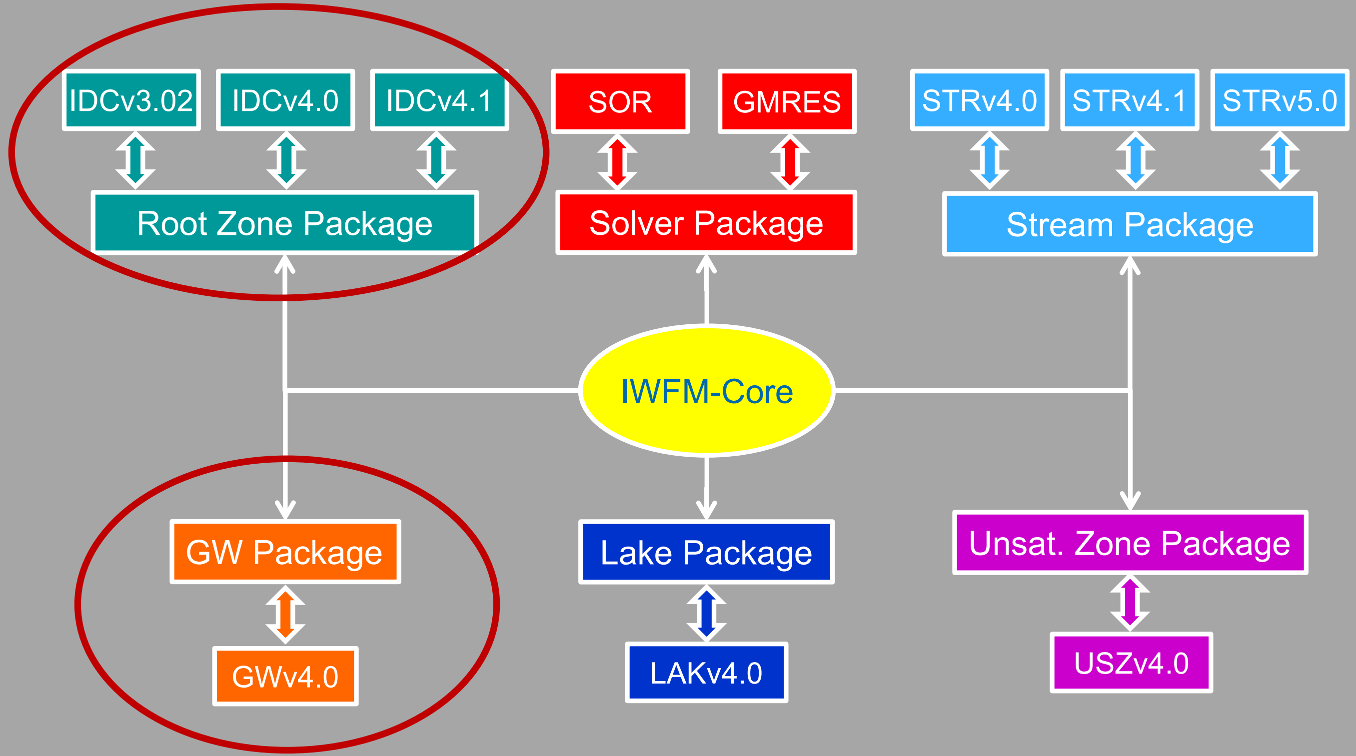
Adoptability

- Ability to incorporate new simulation techniques without affecting previously developed applications
- Use of Object Oriented Programming concepts
- Use of design patterns
- Code reusability and extension are emphasized
- Allows quick implementation of new simulation methods in addition to existing methods



Modularity

- Ability to split the model into smaller, stand-alone components
  - IWFM Demand Calculator (IDC)
  - Groundwater DLL
- Simplifies calibration process (IDC)
- Different components can be linked to different models (groundwater DLL in CalSim 3)



Speed

- Implementation of HDF files for fast results retrieval
  - ❖ Database designed for scientific applications to store numbers
  - ❖ Very efficient to retrieve data in different ways
    - Retrieve spatial data at a fixed time
    - Retrieve timeseries data at a fixed location
  - ❖ Especially useful in processing Z-Budget data
- Use of parallel processing (OpenMP)
  - ❖ Up to 50% faster runtimes depending on model and hardware

Questions?