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Klamath River Basin Revised Natural Flow Study (KNFS)

November 2 – 3, 2022
Stakeholder Workshop
Upper Klamath Basin Groundwater Flow Model (UKBGFM)

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Outline

- Model Purpose
- Model Methodology
- Model Calibration, Sensitivity, & Uncertainty Analysis
- Natural Flow Representation
- Comparison to 2005 Natural Flow Study

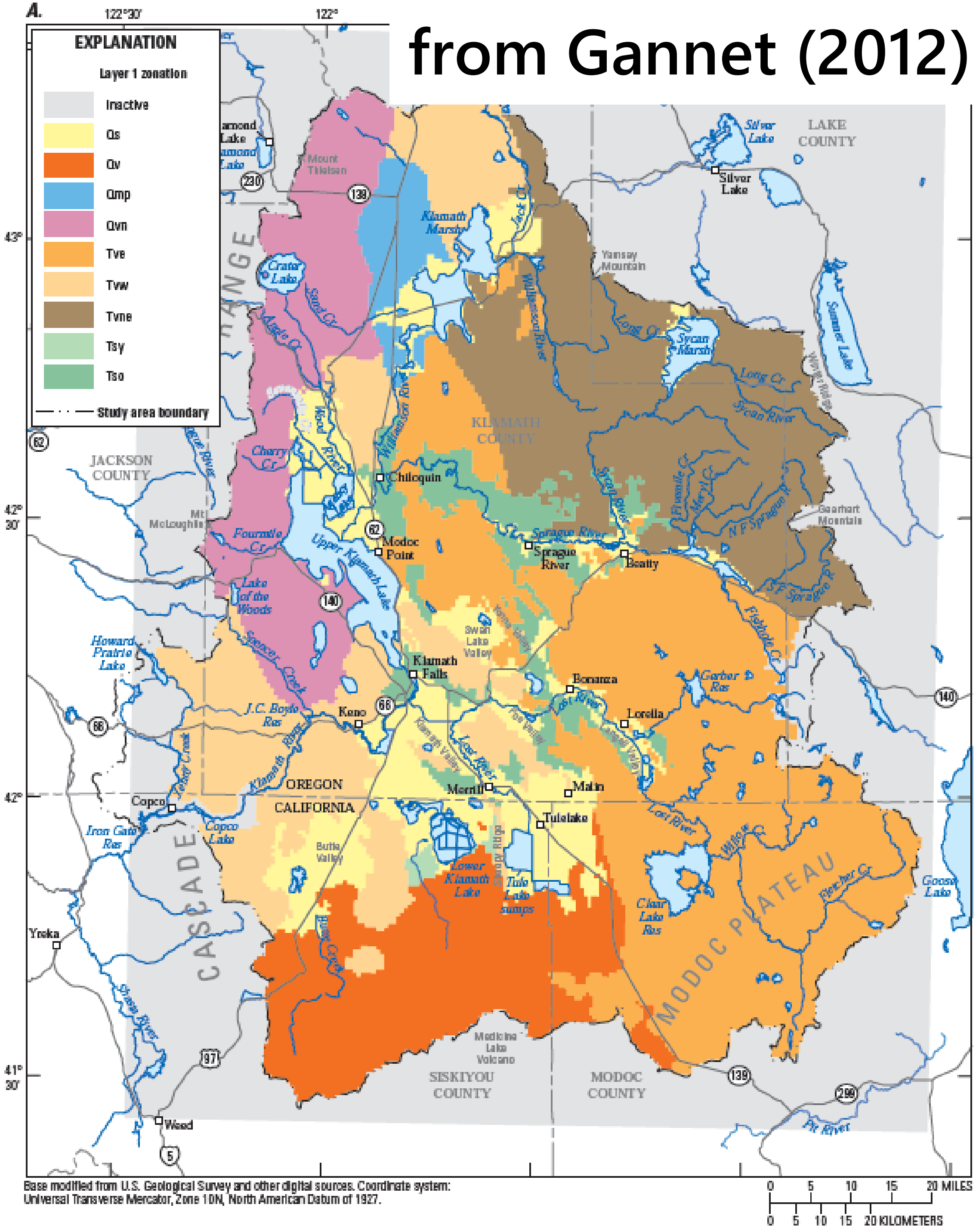
Model Purpose

- Simulate groundwater conditions in the Upper Klamath Basin (UKB)
  - Groundwater levels
  - Groundwater storage
  - Recharge from precipitation and irrigation
  - Evapotranspiration of groundwater
  - Boundary flow between neighboring basins
  - Base flow to streams
  - Seepage between the lakes/reservoirs and the groundwater system
  - Flow to tile drains
  - Groundwater pumping
  - Canal seepage

Model Extent

- Simulates the entire UKB
- 33,887 model cells that are 2,500 by 2,500 foot
- 3 vertical layers ranging from 5 to 3,600 feet
- Layer zonation corresponds roughly to hydrogeologic units (shown on map)
- Seasonal stress periods
- Calibration period from October 1980 to September 2020

from Gannet (2012)



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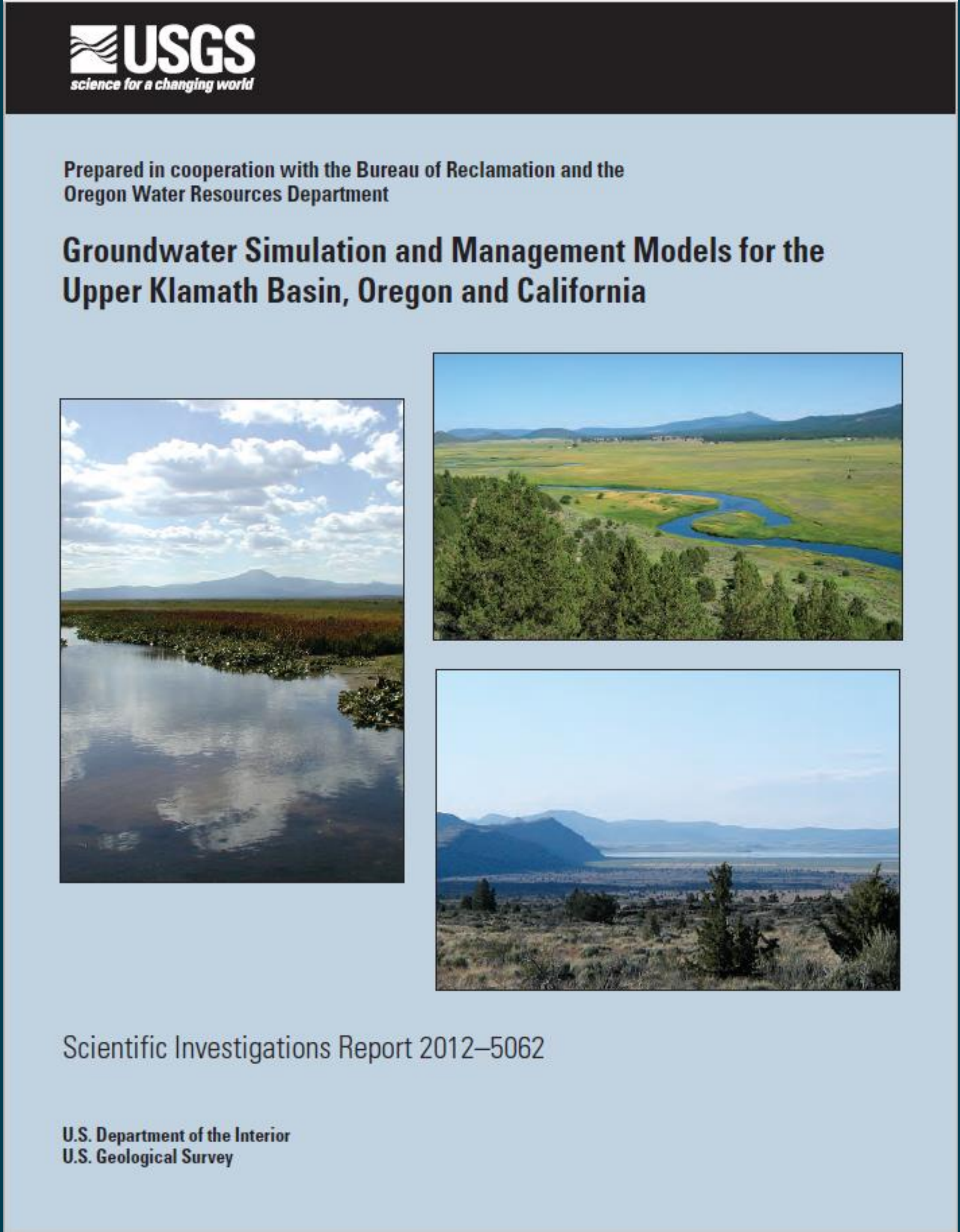
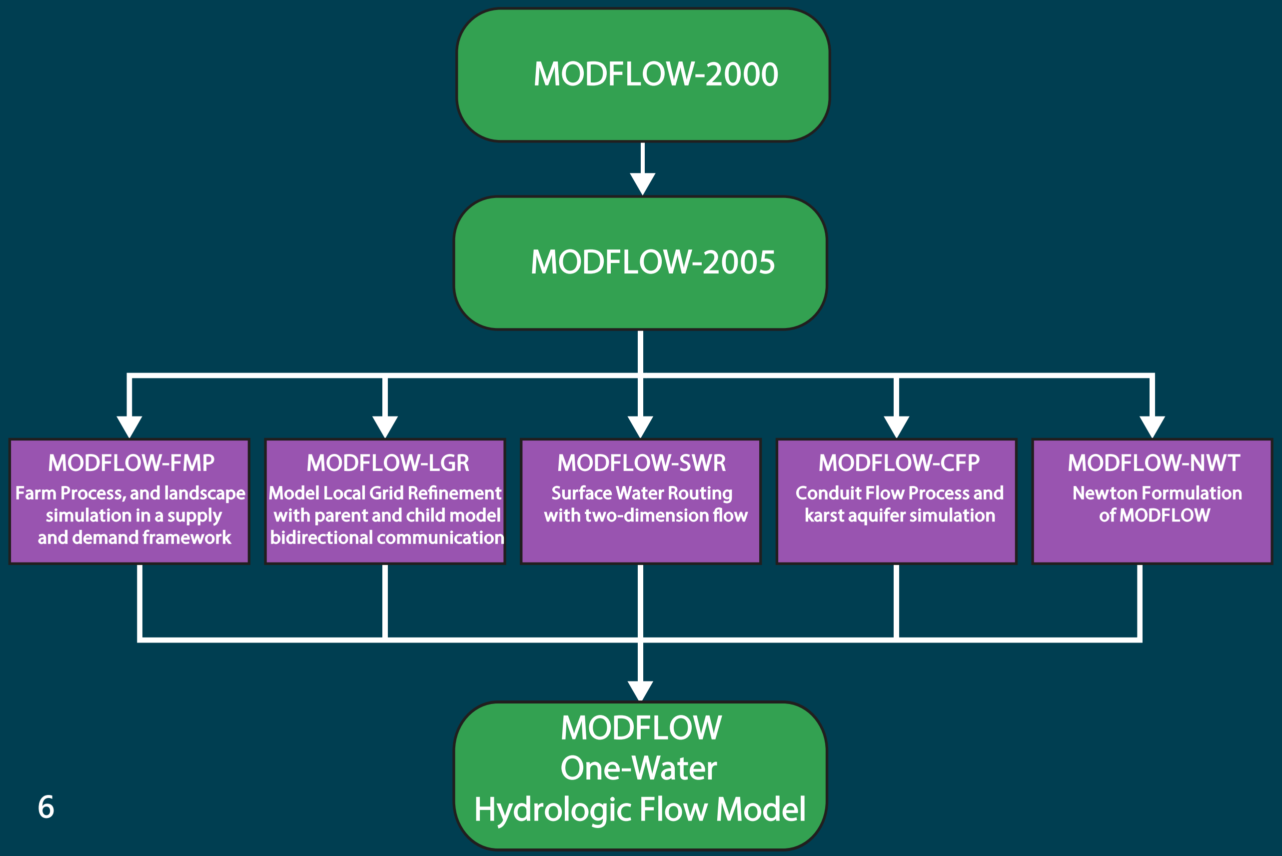
Modeling Methodology

- UKBGFM is based on a groundwater flow model developed in a 2012 USGS study (Gannet, 2012)
- Code has been updated from MODFLOW 2000 (Harbaugh and others, 2000) to MODFLOW-OWHM (Boyce and others, 2020)
- OHWM's improved input and output options are greatly beneficial



Evolution from MODFLOW-2000 to MODFLOW-OWHM

(figure modified from Boyce and others, 2020)
Not all features shown will be used in the UKBGFM



Line Feed Input Option

- Input design can be used to replace entirely certain packages (WEL) (Harbaugh, 2005; Boyce, 2022) or work along side the current input (MNW2, GHB, SFR) (Harbaugh, 2005; Boyce, 2022).
- Each input is called a feed file and can easily be made in Excel.
- Below is an example Feed:

# Comments				Well
1	3	4		W1
1	7	3		W2
1	6	7		W3
1	5	5		W4
STRESS PERIOD				
# W1	W2	W3	W4	SP
-1000	**0.0**	-4500	**NaN**	# 1
-500	-1000	-3000	**NaN**	# 2
-1000	-1500	-1500	**NaN**	# 3
-1500	-1000	-4500	-1000	# 4
-1000	-1000	-3000	-2000	# 5
-1000	-1500	-3000	-3000	# 6
-1500	-1000	-1500	-2000	# 7
-1000	-1000	-1500	-2000	# 8
-1000	-500	-3000	-1000	# 9
-500	-1000	-4500	-2000	# 10

Package Budget Groups

- Package input can be tagged to belong to a specific budget group

- The group then appears in the Volumetric Budget as a standalone group
  - Also effects the Cell-By-Cell detailed output

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Package Budget Groups

- For example, the GHB Package (Boyce and others, 2020)
- Normally the budget just prints out:

  HEAD DEP BOUNDS

- Instead, the input can tag GHB cells with custom names, such as:

```
GHB_RIVER
GHB_BAY
GHB_MARSH
```

Example OWHM Budget (Not UKB)

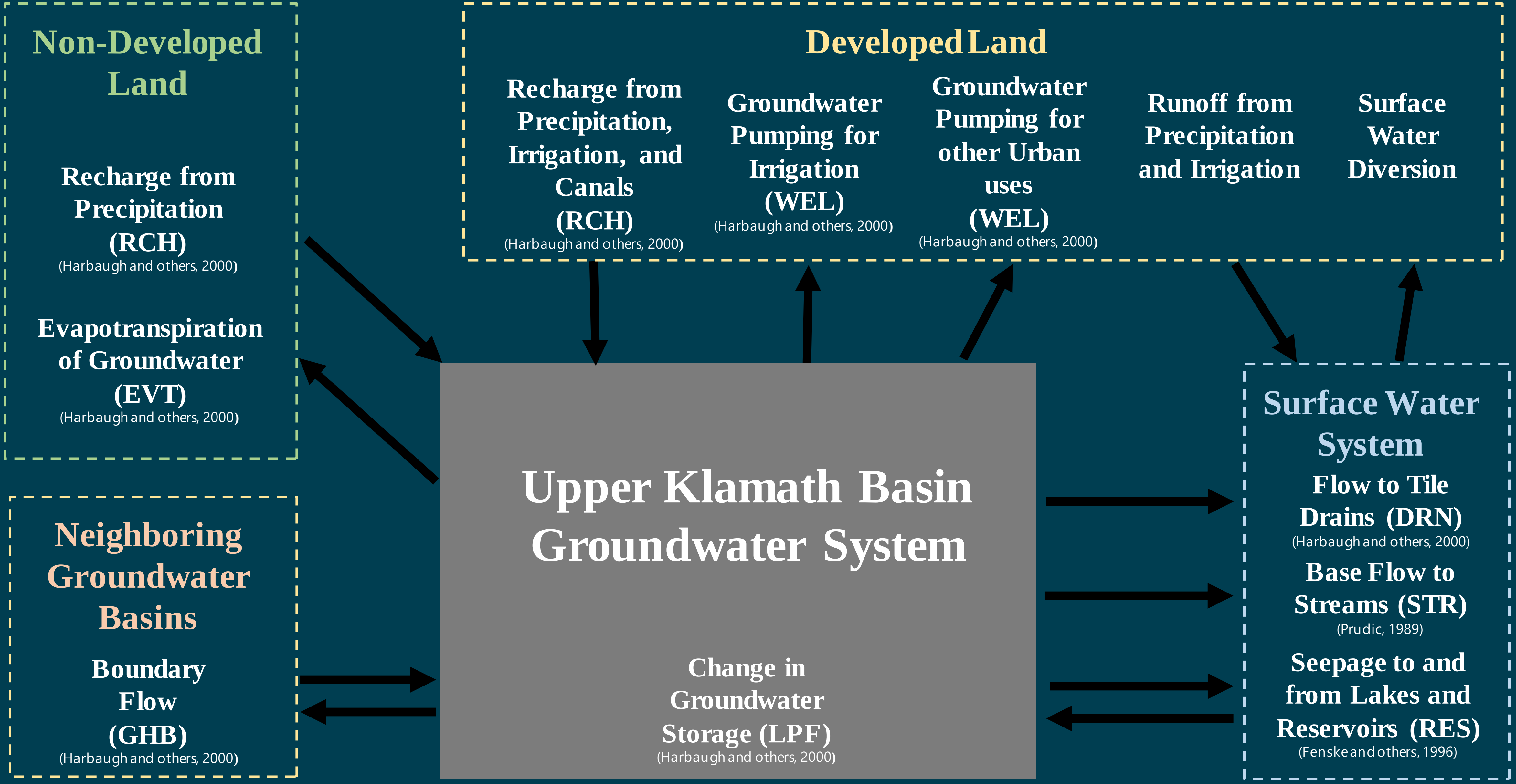
```
 ----------------------------------------------------------------------------------
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP    2 IN STRESS PERIOD      1
 ----------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3        RATES FOR THIS TIME STEP      L**3/T
    ------------------                  ------------------------

          IN:                                     IN:
          ---                                     ---
            STORAGE =    48054609.4324                STORAGE =     1063868.0255
      CONSTANT HEAD =          0.0000          CONSTANT HEAD  =          0.0000
    HEAD DEP BOUNDS =    13292913.8925        HEAD DEP BOUNDS =      137959.0091
     STREAM LEAKAGE =     5688847.7083         STREAM LEAKAGE =      129280.6578
         FARM WELLS =          0.0000             FARM WELLS =           0.0000
   FARM  NET  RECH. =      606564.9591      FARM  NET  RECH. =       19788.0392

           TOTAL IN =   103644847.5984               TOTAL IN =     2267888.3940

         OUT:                                    OUT:
         ----                                    ----
            STORAGE =    59716711.3035                STORAGE =     1188612.5844
      CONSTANT HEAD =          0.0000          CONSTANT HEAD =           0.0000
    HEAD DEP BOUNDS =      132913.8925        HEAD DEP BOUNDS =        1959.0091
     STREAM LEAKAGE =    16132211.6689         STREAM LEAKAGE =      334647.3482
         FARM WELLS =     1005616.5098             FARM WELLS =       32863.9139
   FARM  NET  RECH. =     5441472.2726      FARM  NET  RECH. =      173732.9247
```

*

Example OWHM Budget (Not UKB)

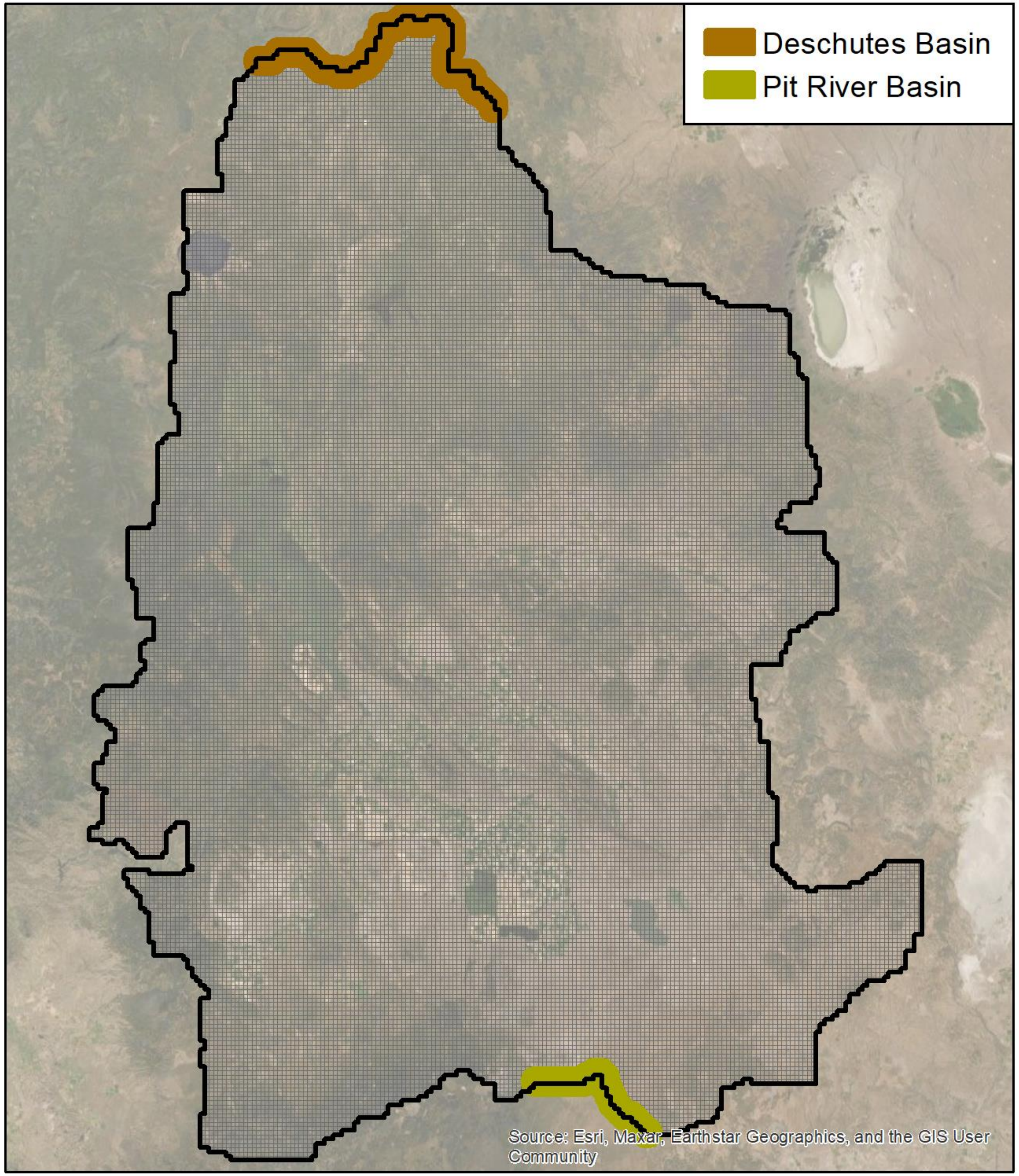
```
 --------------------------------------------------------------------------------------
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP    2 IN STRESS PERIOD      1
 --------------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                      IN:
          ---                                      ---
            STORAGE =    48054609.4324                 STORAGE =     1063868.0255
      CONSTANT HEAD =           0.0000           CONSTANT HEAD  =          0.0000
          GHB_RIVER =      292913.8925               GHB_RIVER =        7959.0091
            GHB_BAY =      127738.3006                 GHB_BAY =        2766.0901
          GHB_MARSH =     1067712.0409               GHB_MARSH =       27508.3903
     STREAM LEAKAGE =     5688847.7083          STREAM LEAKAGE =      129280.6578
         FARM WELLS =           0.0000              FARM WELLS =          0.0000
    FARM  NET  RECH. =      606564.9591        FARM  NET  RECH. =       19788.0392

           TOTAL IN =   103644847.5984                TOTAL IN =     2267888.3940

         OUT:                                     OUT:
         ----                                     ----
            STORAGE =    59716711.3035                 STORAGE =     1188612.5844
      CONSTANT HEAD =           0.0000           CONSTANT HEAD =          0.0000
          GHB_RIVER =      527980.5309               GHB_RIVER =        1099.0253
            GHB_BAY =           0.0000                 GHB_BAY =          0.0000
          GHB_MARSH =     1860597.9330               GHB_MARSH =       22822.0533
     STREAM LEAKAGE =    16132211.6689          STREAM LEAKAGE =      334647.3482
         FARM WELLS =     1005616.5098              FARM WELLS =       32863.9139
    FARM  NET  RECH. =     5441472.2726        FARM  NET  RECH. =      173732.9247
```

Example Plan for MODFLOW Packages to be used for the Upper Klamath Basin Groundwater Flow Model



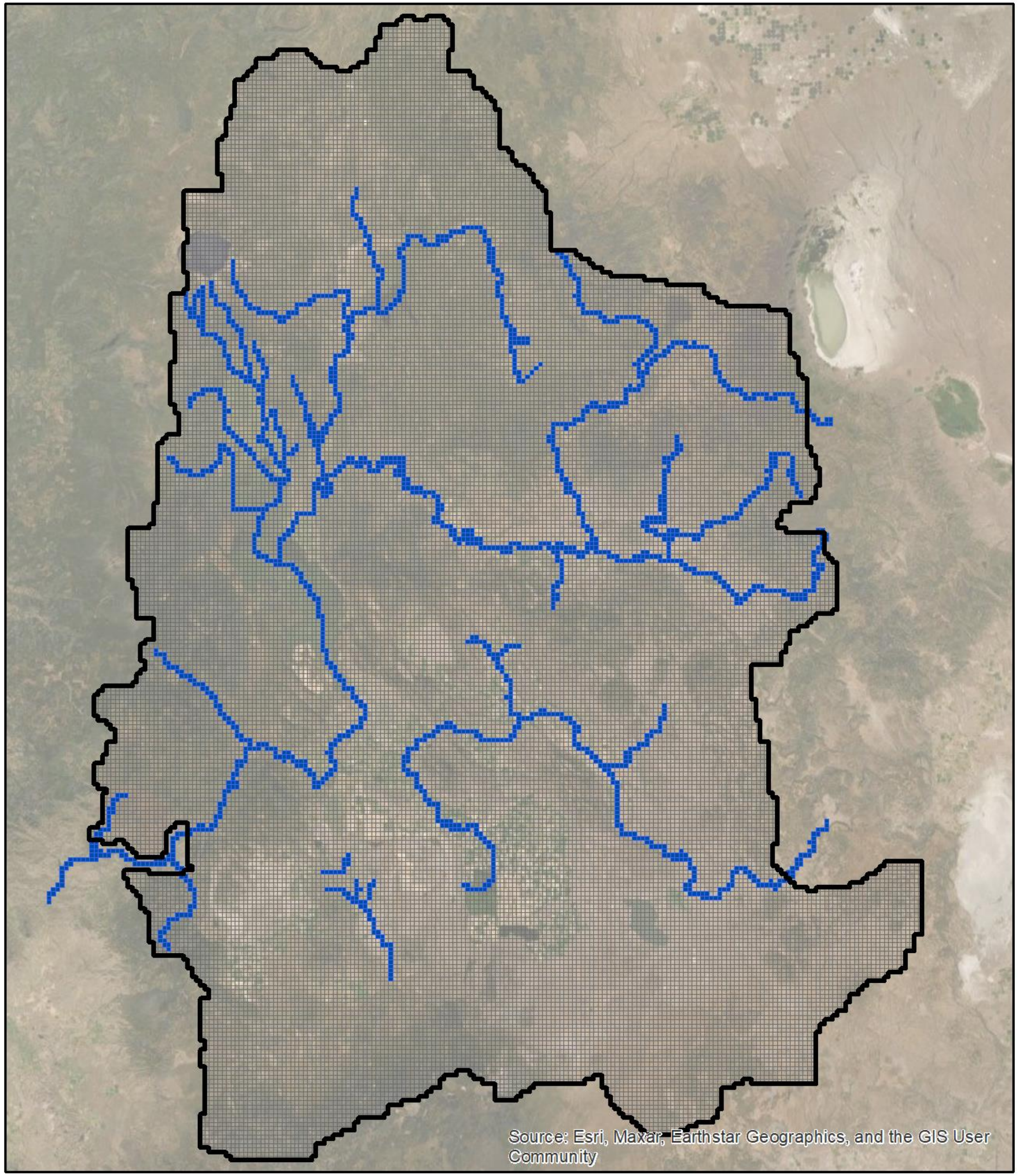
Interbasin groundwater Flow

- In the 2012 USGS study (Gannett and others, 2012), interbasin boundary flows simulated include:
  - Between the Deschutes Basin and the UKB (North End)
  - Between the Pit River Basin and the UKB (South End)
- Interbasin groundwater flow is simulated using the general head boundary package (GHB) (Harbaugh and others, 2000)
- Other boundaries are no-flow



Stream Base Flow

- Streams simulated in the 2012 USGS study area are shown (Gannett and others, 2012)
- Streams are simulated using the stream package (STR) (Prudic, 1989)
- 2012 USGS study assumes that streamflow loss to the groundwater system is generally small and does not represent a significant source of recharge
- STR package was setup to only allow base flow to streams



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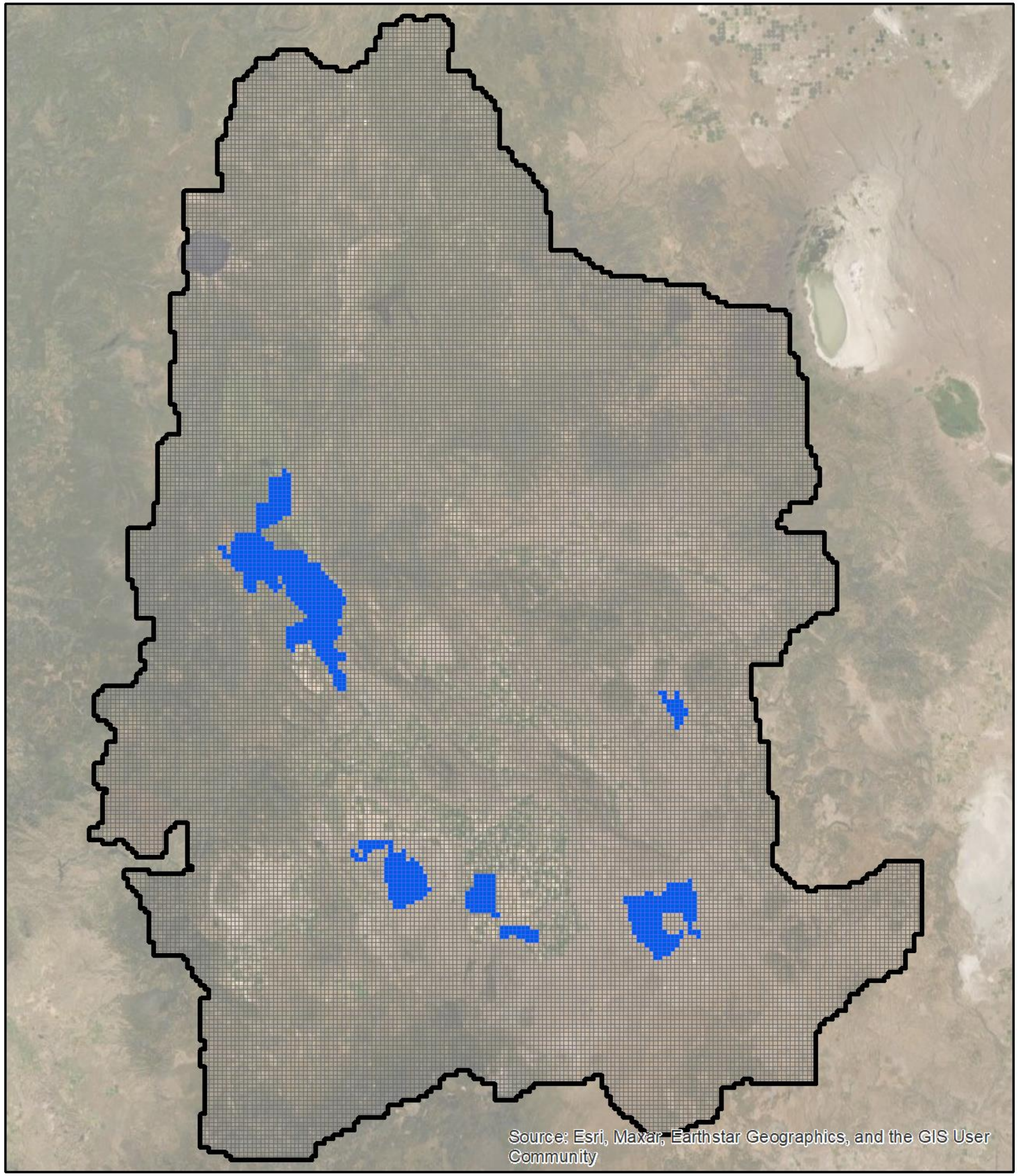
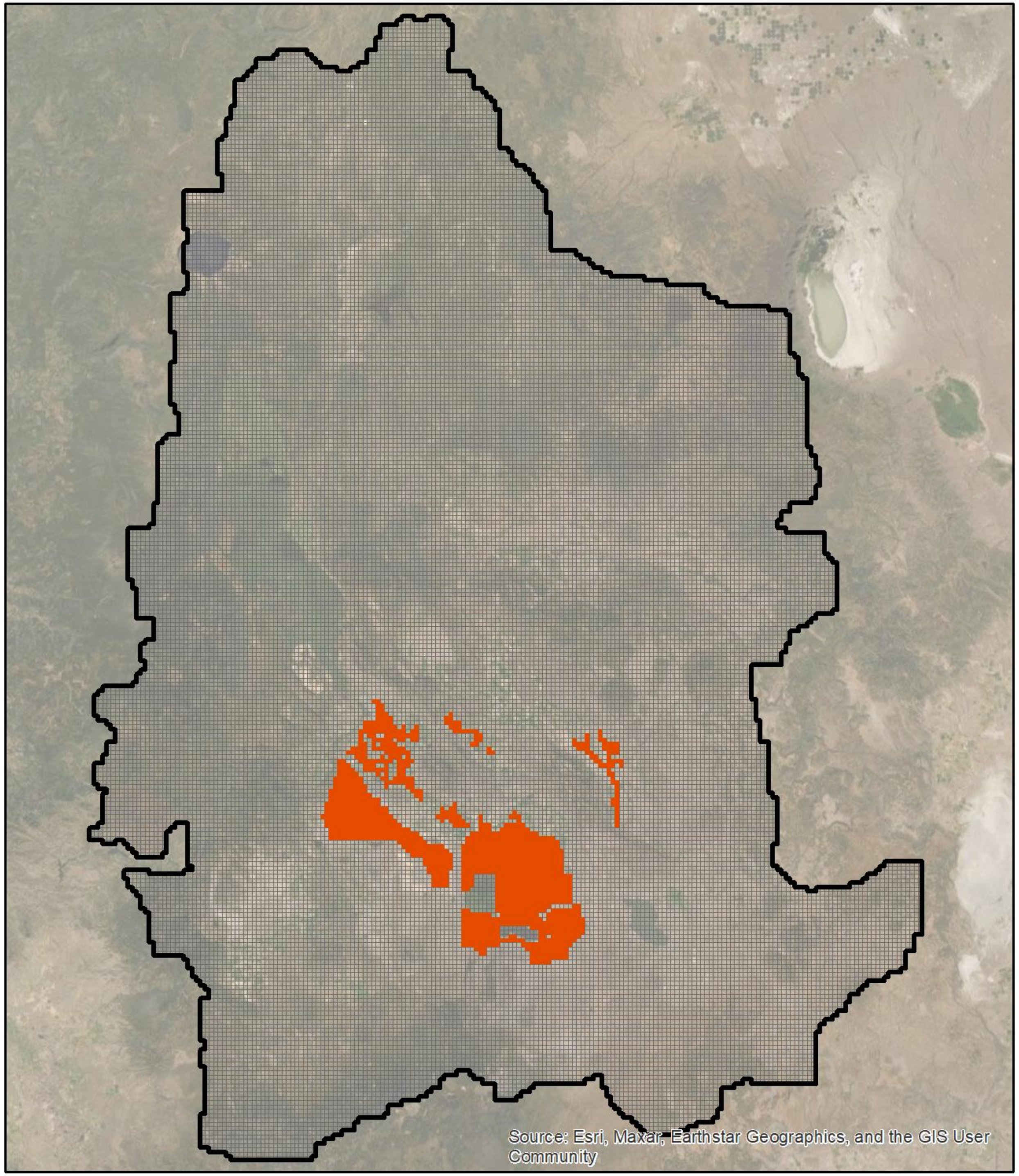
Lake and Reservoir Seepage

- Lakes and reservoirs simulated in the 2012 USGS study (Gannet and others, 2012) include:
  - Upper and Lower Klamath Lakes
  - Tule Lake sumps
  - Gerber Reservoir
  - Clear Lake
- Lakes are simulated using the reservoir package (RES) (Fenske and others, 1996)
- Lake stages can be estimated from the Mass Balance Model being developed as part of the KNFS using RiverWare (Zagona and others, 2001)



Tile Drains

- Distribution of drains is based on the 2012 USGS Study (Gannet and others, 2012)
- Drain bottoms are assumed to be 10 feet below ground surface
- Groundwater discharge to drains is simulated using the drain package (DRN) (Harbaugh and others, 2000)



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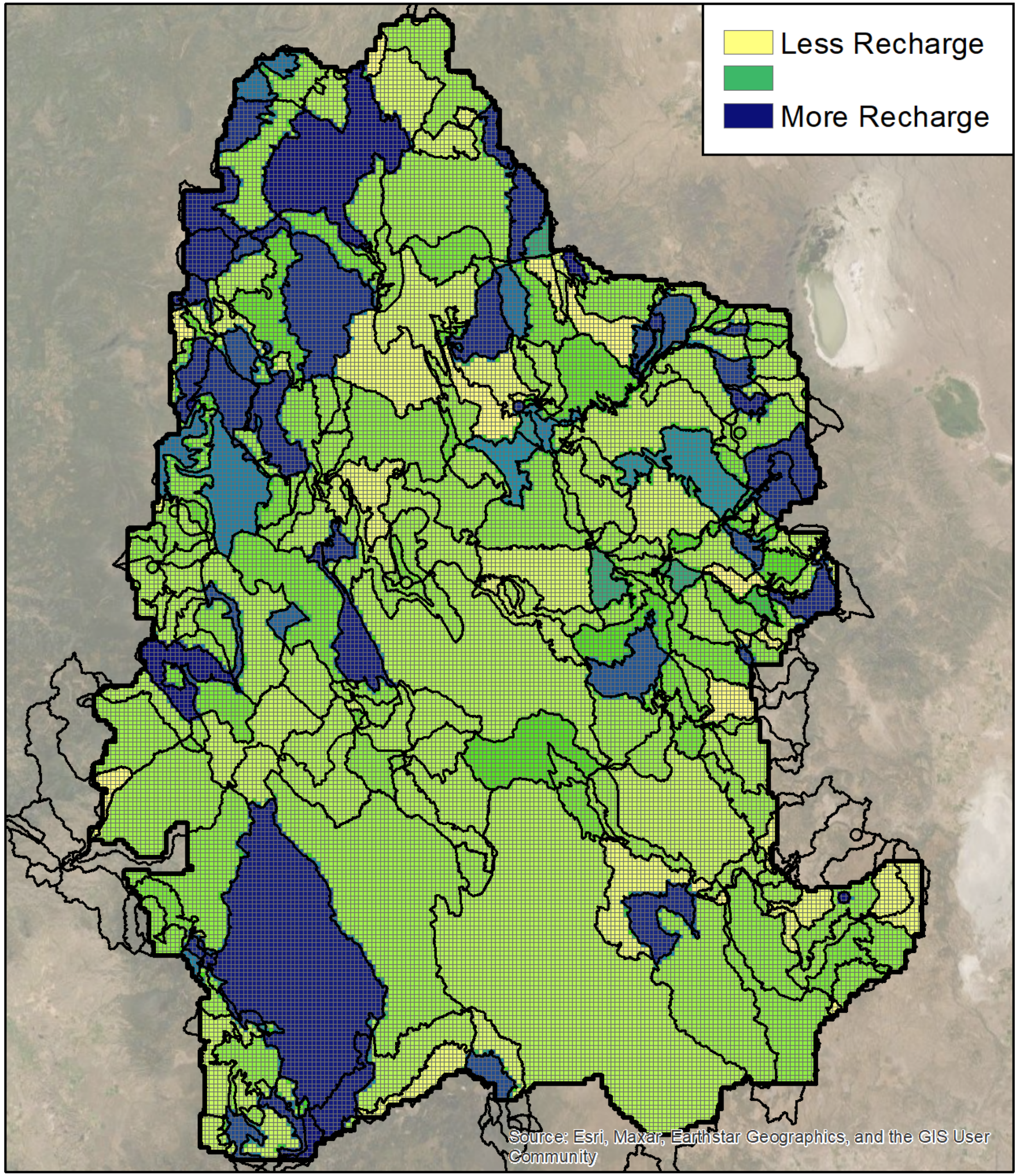
Recharge from Precipitation

- Recharge of precipitation can be simulated using output from a surface hydrology model that is being developed as part of the KNFS using the Precipitation-Runoff Modeling System (PRMS) (Regan and others, 2018)
- Example recharge data from Fall 2019 is shown
- Recharge is simulated using the recharge package (RCH) (Harbaugh and others, 2000)



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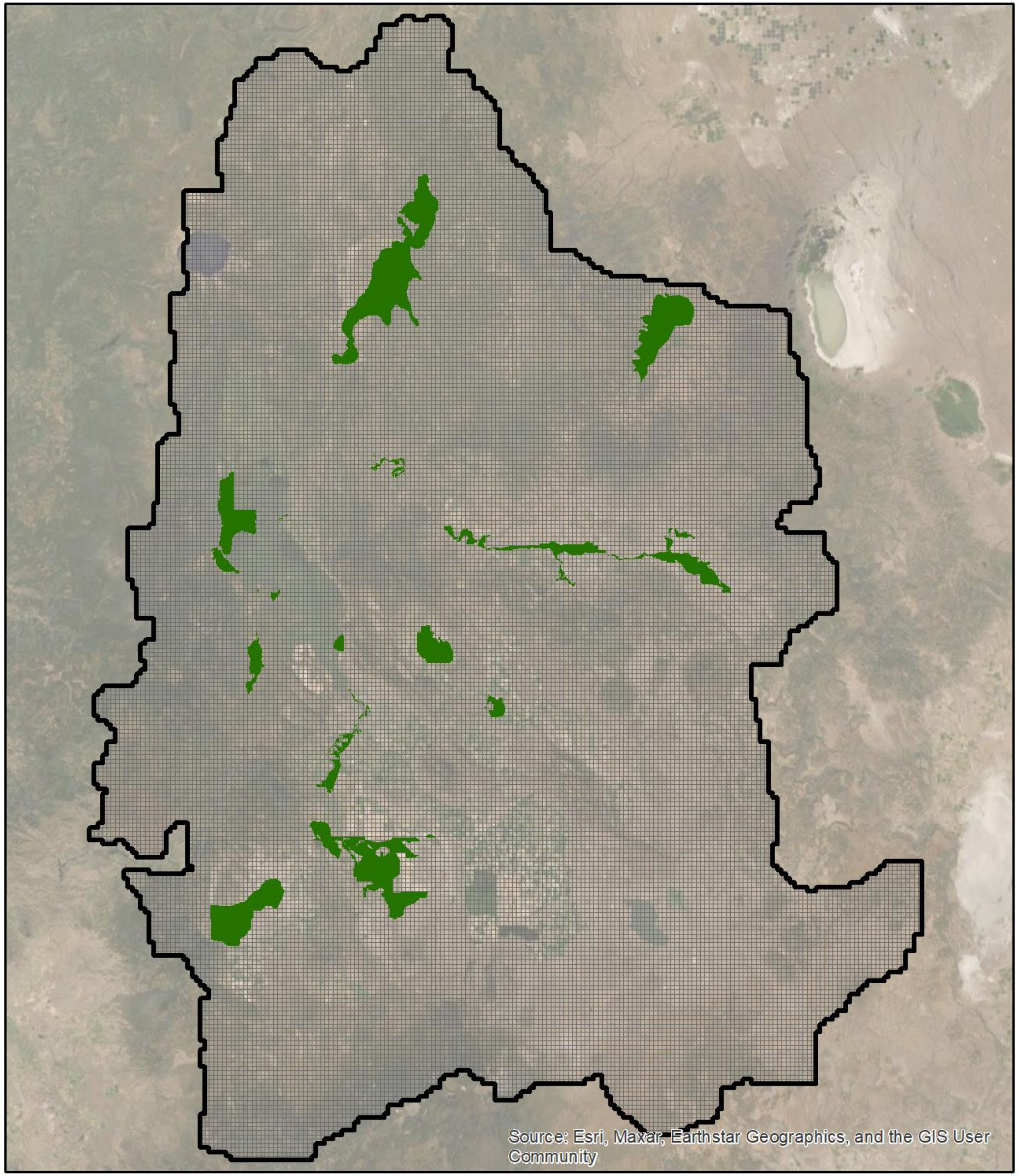
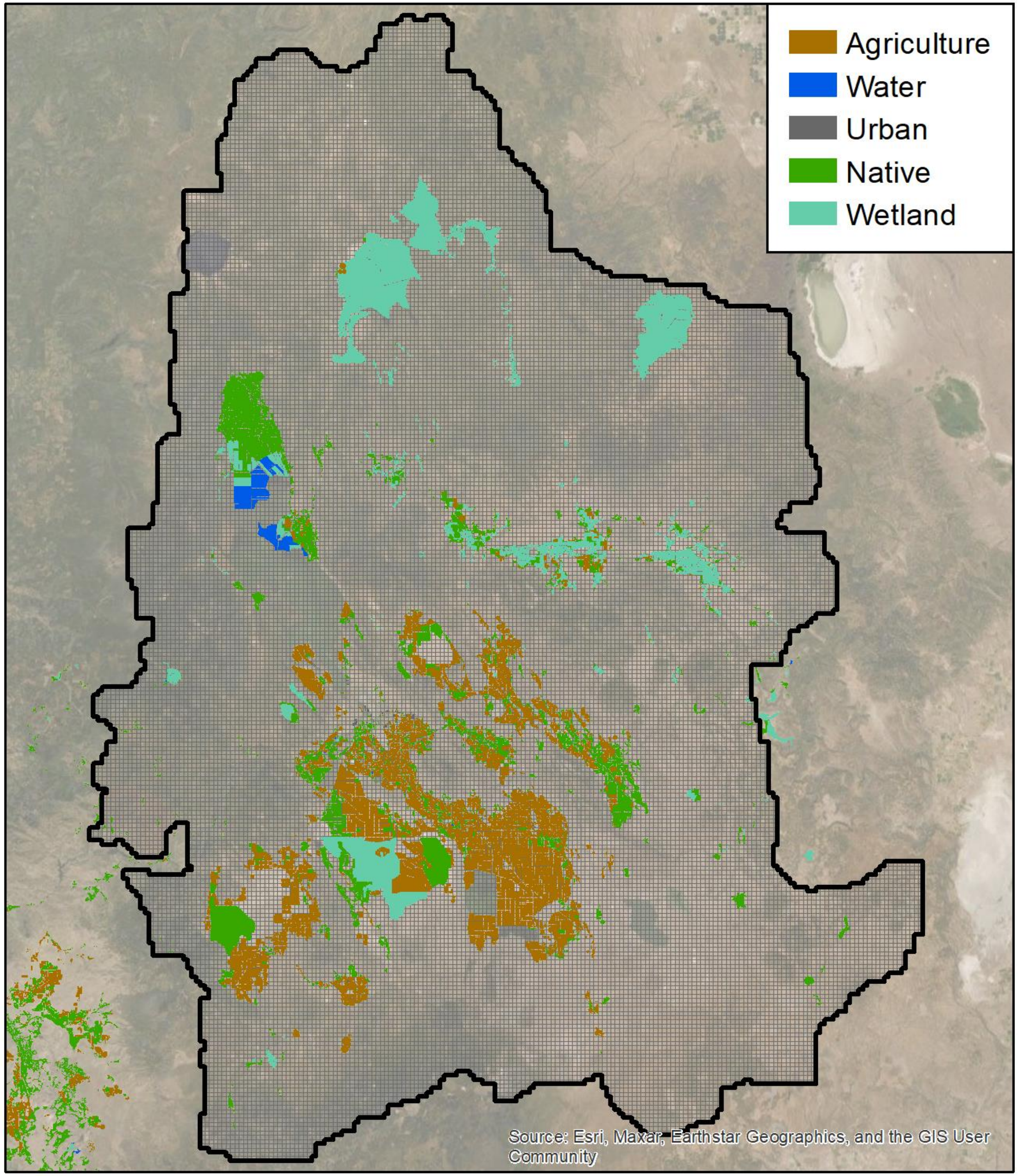
Evapotranspiration of Groundwater

- For undeveloped land, groundwater evapotranspiration (ET) can be simulated using datasets calculated by the Desert Research Institute (DRI) being developed as part of the KNFS
- ET can be simulated using the evapotranspiration package (EVT) (Harbaugh and others, 2000) or the farm process (FMP) (Boyce and others, 2020)
- Example of areas with groundwater ET is shown
- Simulation of ET for Developed Land is TBD



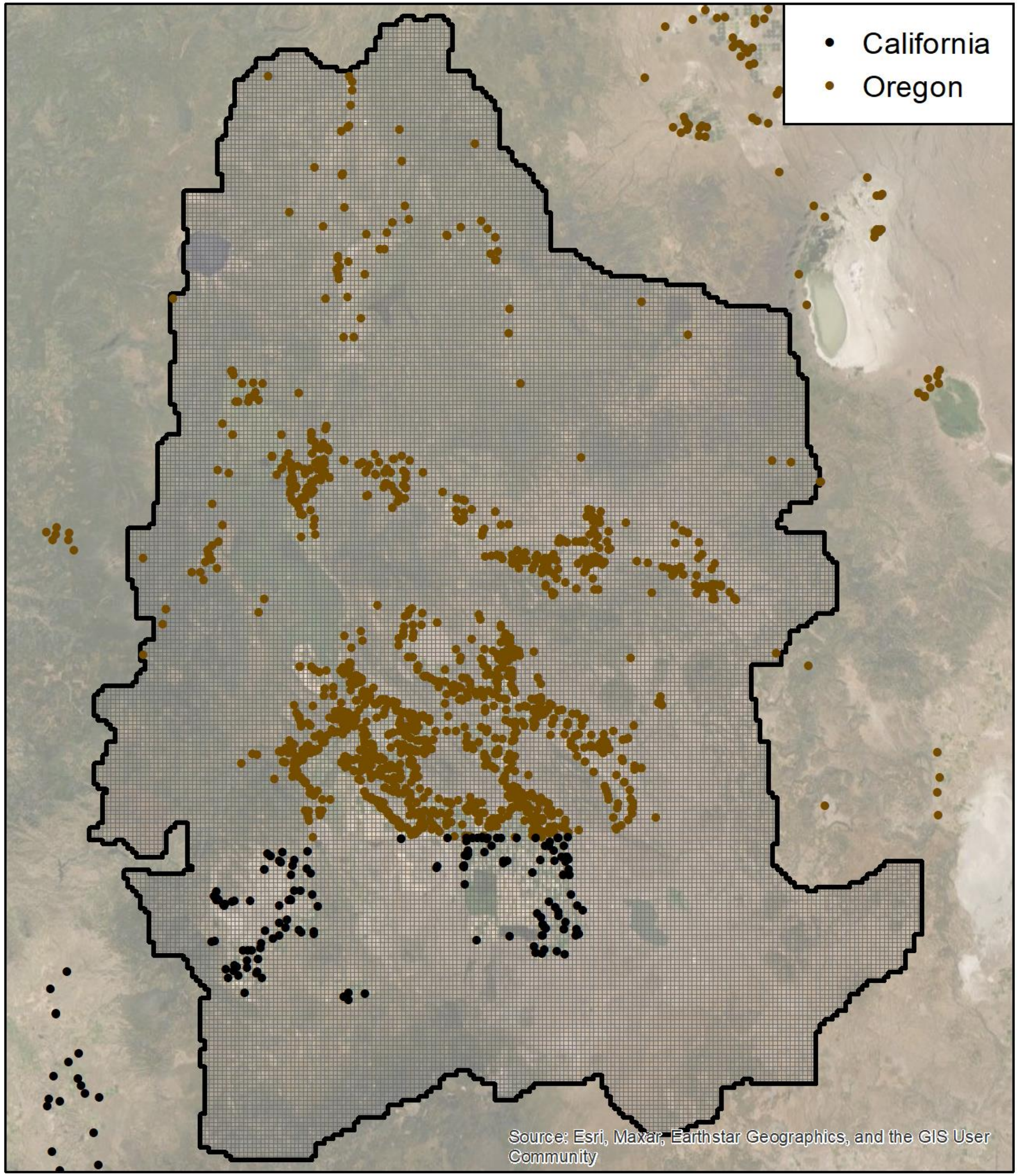
Developed Land Use

- Groundwater fluxes based on developed land use that can be updated in the UKBGFM include:
  - Groundwater pumping for irrigation
  - Recharge of irrigation (deep percolation)
  - Groundwater pumping for other urban uses
  - Canal seepage
- Land Use data from US Department of Agriculture (USDA, 2021).
  - May be modified based ground-truthing or other analysis



Model Calibration

- UKBGFM can be calibrated to archive a best fit between simulated outputs and calibration targets
  - Groundwater levels at observation wells (shown on map)
  - Estimated base-flow component of gaged streamflow
- Calibration is performed using a combination of conceptual knowledge and automated methods
- Adjusted model parameters can include
  - Aquifer properties
  - Steam and lakebed conductance
  - Land-use properties



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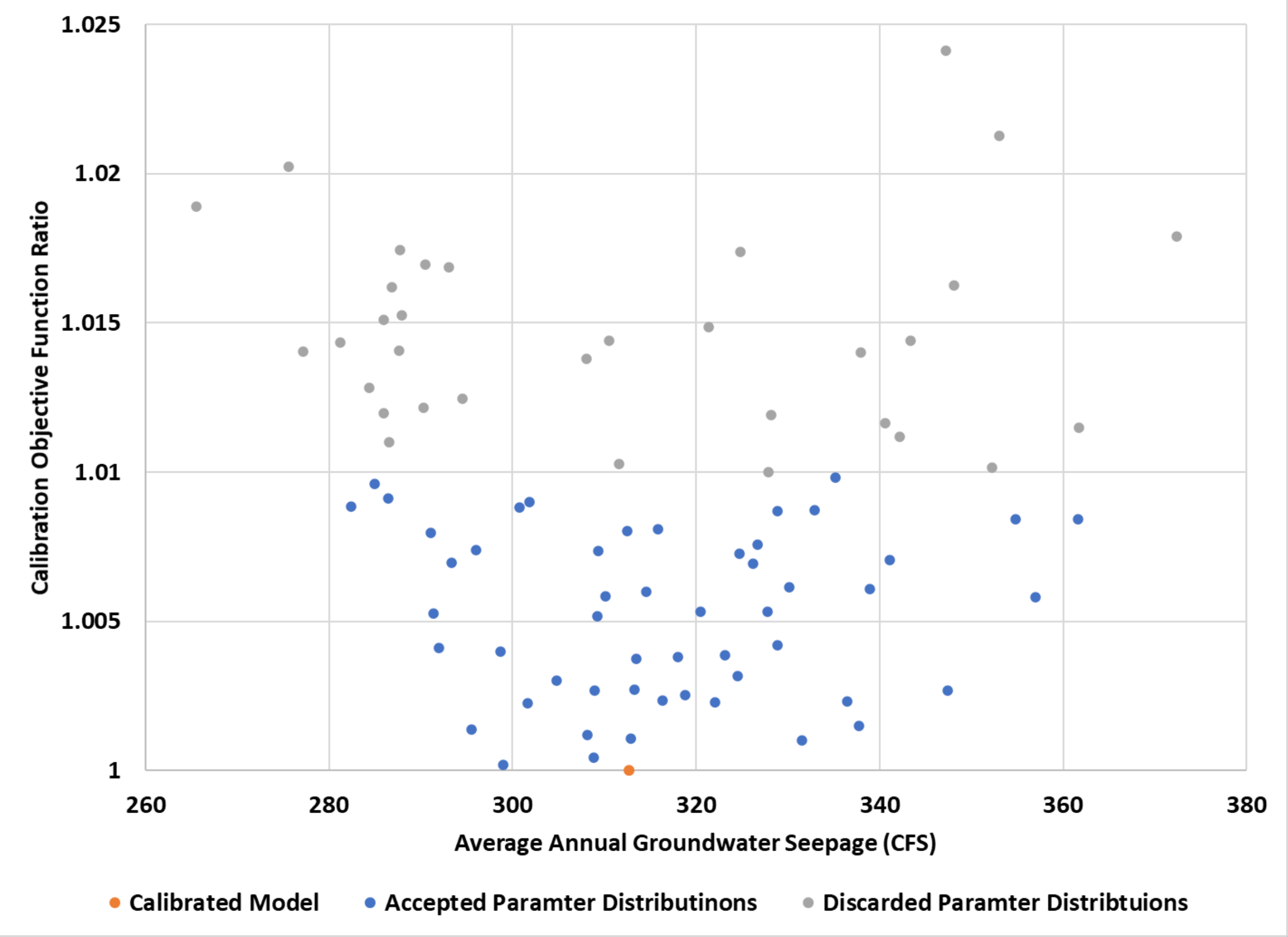
Sensitivity and Uncertainty Analysis

- A sensitivity analysis can be performed to determine the range over which parameters can be modified, while still ensuring a reasonable fit between simulated and observed
- An uncertainty analysis can be performed using this range of parameter values to determine a distribution of reasonable outputs such as base flow

Example of Uncertainty Analysis from a different study (Not UKB)



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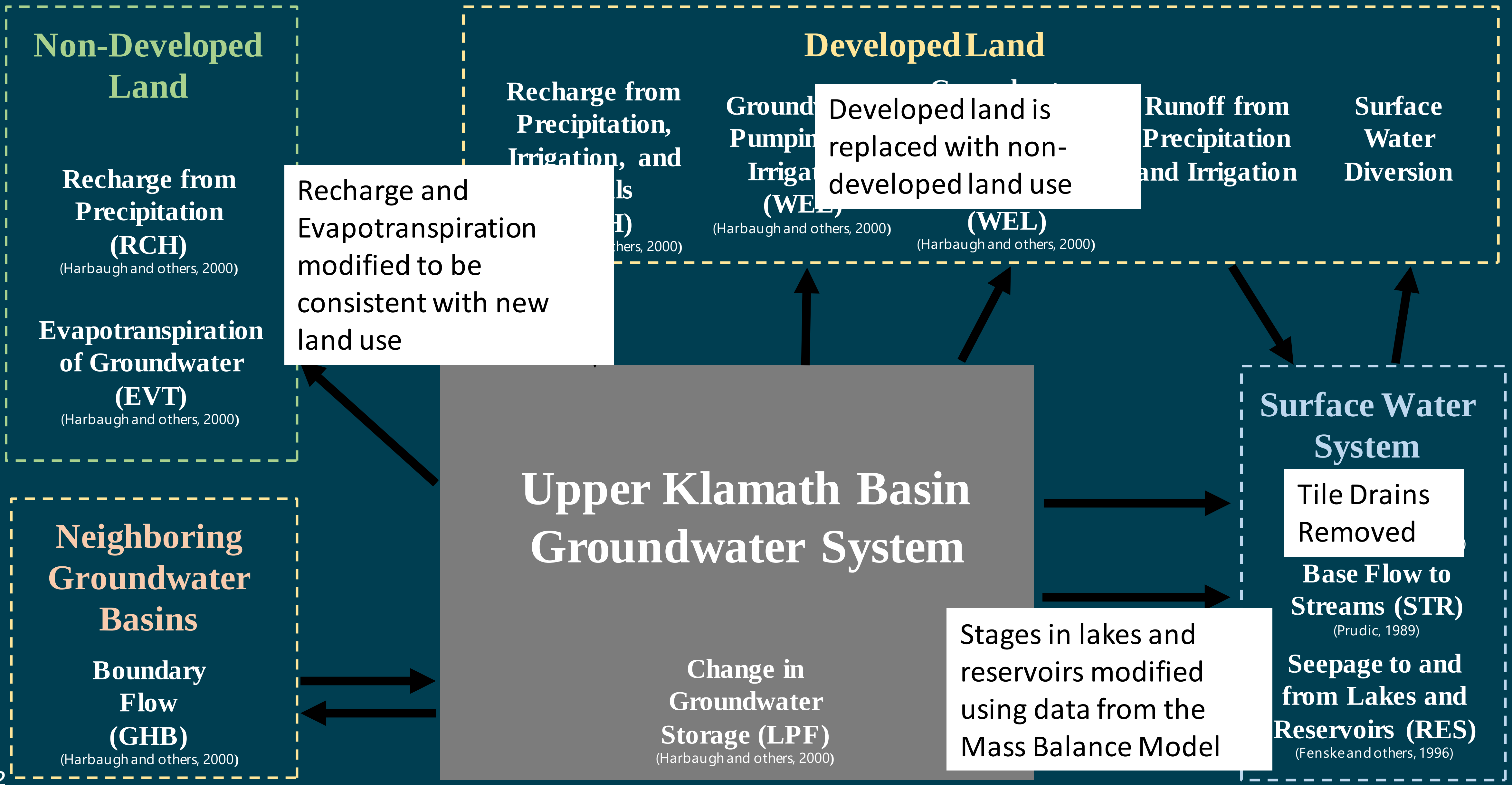
Example Plan for Natural Flow Representation



Comparison to 2005 Natural Flow Study

- 2005 Study (Perry and others, 2005)
  - Groundwater accrual in streams between measured gages and UKL were estimated from various sources (measured springs, comparison of nearby streams, previous studies, etc.)
  - In UKL, groundwater interaction was calculated as the residual in an analytical mass balance equation

- Current Study
  - The UKBGFM, a physically based model, is being developed to simulates a groundwater water table that changes spatially and temporally
  - Groundwater dependent fluxes, such as groundwater and surface water exchange, can be calculated using the UKBGFM

Summary

- The UKBGFM is being developed to simulate groundwater conditions during current (WY1981 – WY2020) and pre-development conditions
- The UKBGFM is based on a 2012 USGS Study
- The model code is being updated from MODFLOW 2000 to MODFLOW-OWHM
- Recharge from precipitation can be simulated using output from the PRMS model being developed as part of the KNFS
- Evapotranspiration can be simulated using datasets being developed by DRI as part of the KNFS
- UKBGFM outputs can be used in the RiverWare Mass Balance Model being developed as part of the KNFS
  - Base flow to streams
  - Seepage between the lakes/reservoirs and the groundwater system
  - Flow to tile drains
- Groundwater/surface water exchange is more refined using physically based model instead of previous analytical approach

References

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Questions and Additional Discussion

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