Phase 6 WSM Prototype:

building sensitivities into the model …

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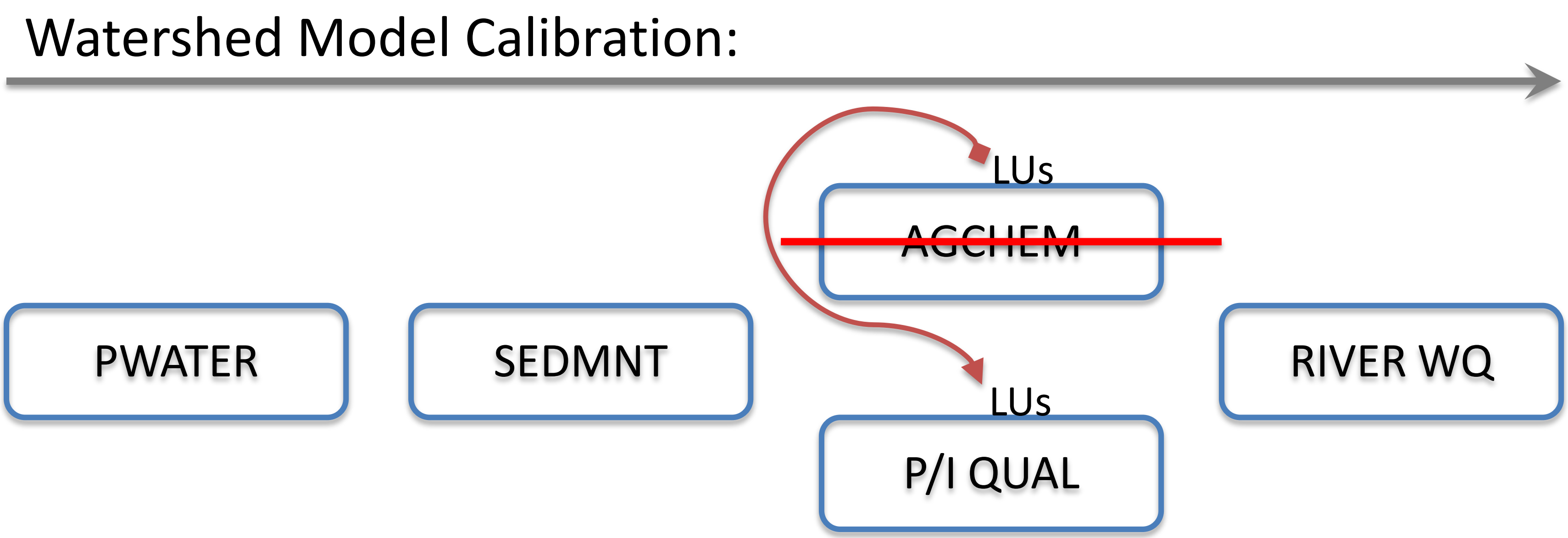
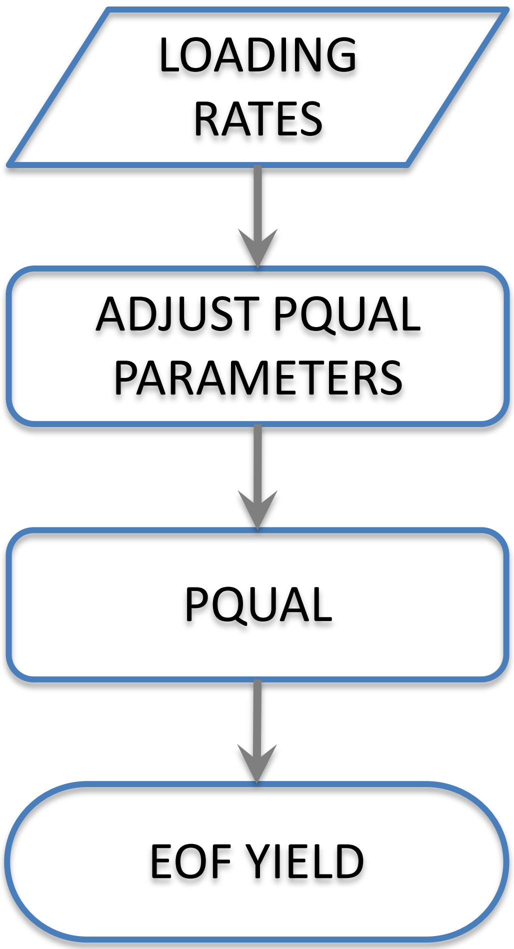
Phase 6 Watershed Model



We are able to calibrate watershed model with this new setup with model performance indices as par compared to P532.

Phase 6 Watershed Model

Calibration Scenario

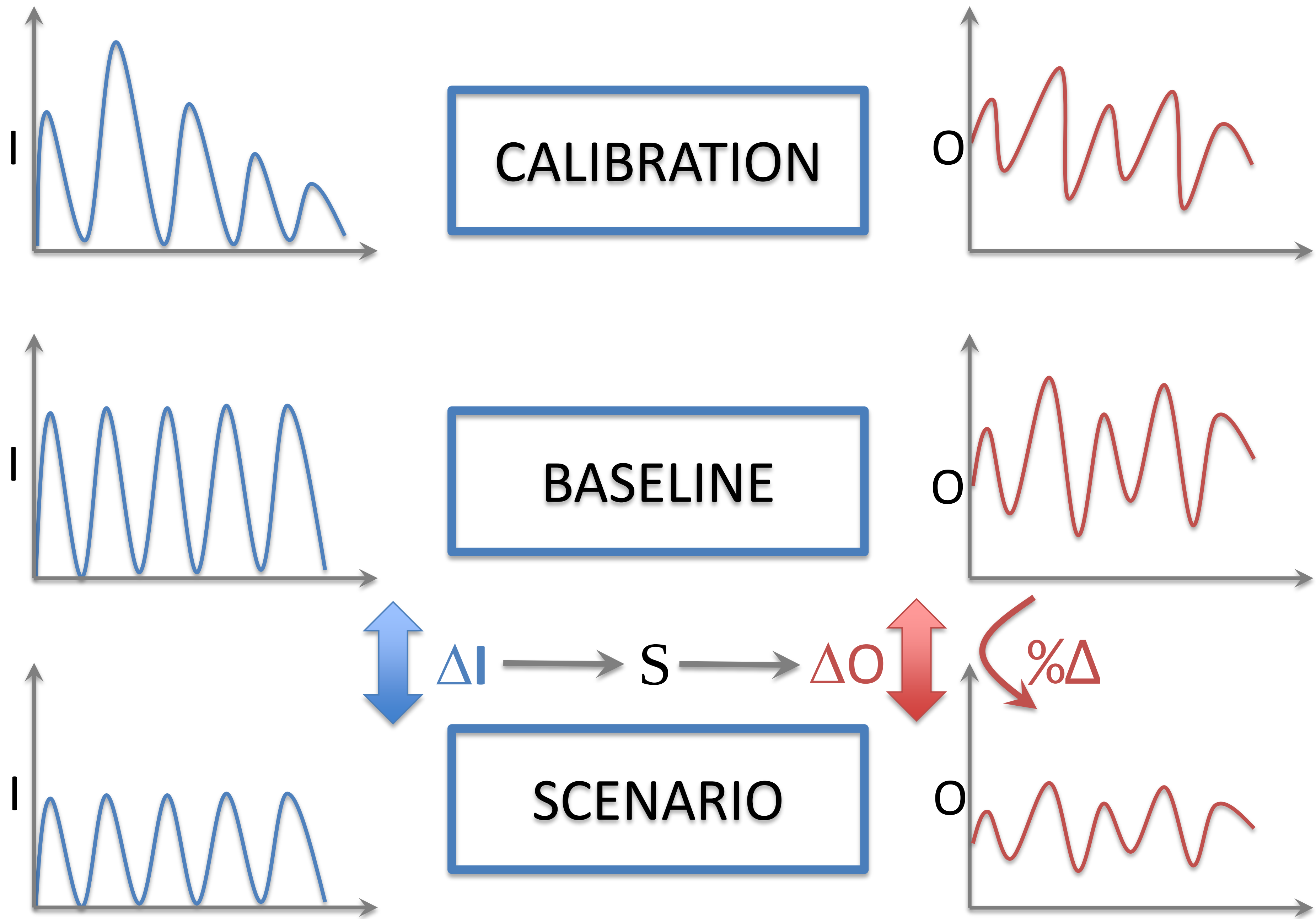


Running Management Scenarios: **Challenges**?

Strategy: Adjust EOF yield time series based on the ***sensitivity*** of an application source at a given land use and land segment.

Step 1: We need to remove background loading signals from calibration EOF load time series. Note, management scenarios have fixed annual application rates.

Step 2: We need to develop a new tool to grab sensitivities to application sources, apply to changes in input loadings, and apply changes in output yields to previously adjusted calibration EOF yield.


I
CALIBRATION
O
I
BASELINE
O
ΔI
S
ΔO
%Δ
I
SCENARIO
O

Step 1: We need to remove background loading signals from calibration EOF load time series. Note, management scenarios have fixed annual application rates.

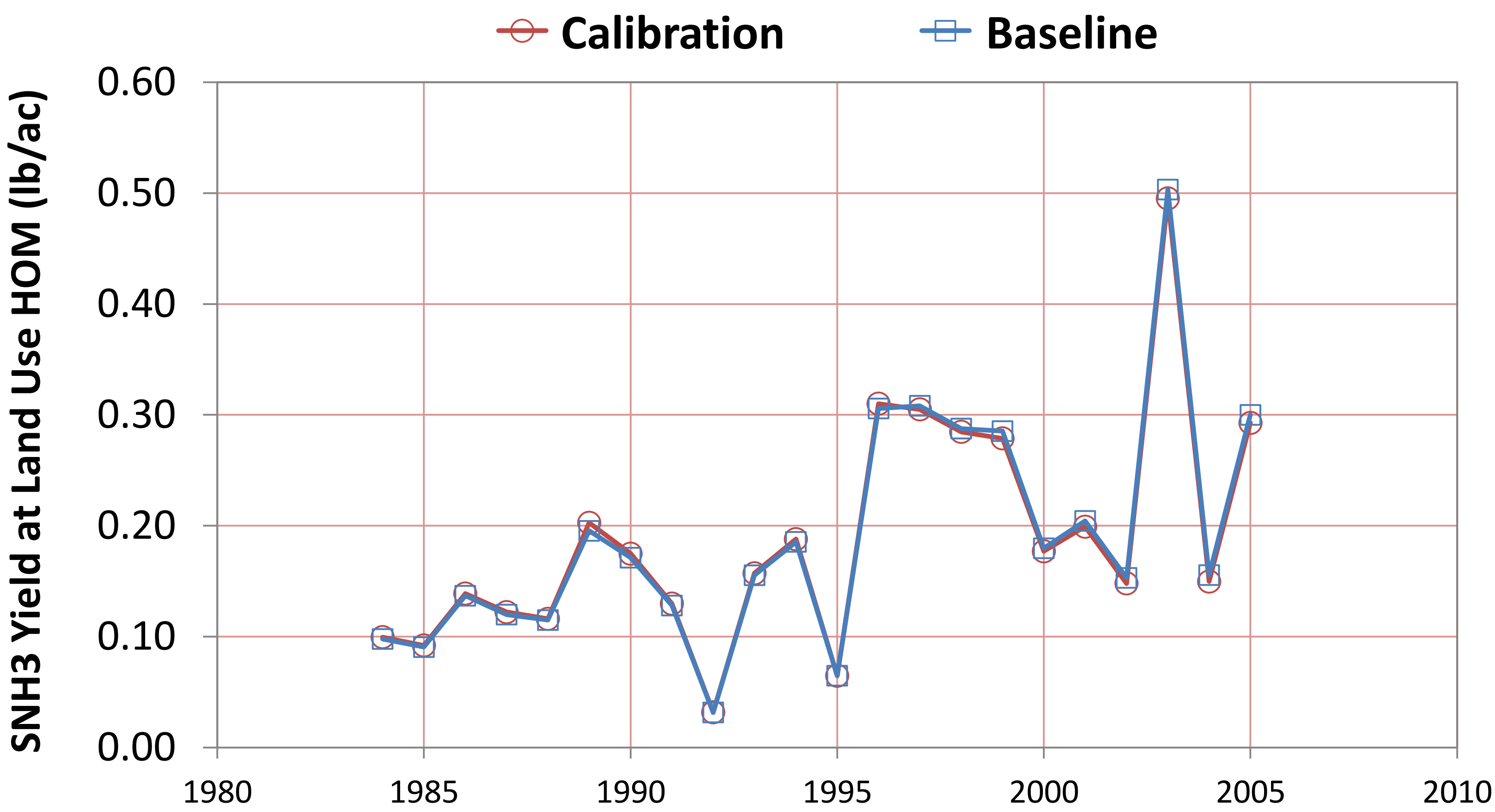
Creating a Baseline Scenario

- **Calibration Scenario** with time (annual) variable PQUAL parameters.
  - Underlying objective is to fine tune PQUAL parameters to mimic temporal variability in input loading rates that is eventually reflected in the EOF yields.
  - Here, average PQUAL parameter value is scaled linearly based on the annual loading rates.

- **Baseline Scenario** was created by muting the temporal (annual) variability in the PQUAL parameters (SQO, ACQOP). In other words, as if inputs were fixed.

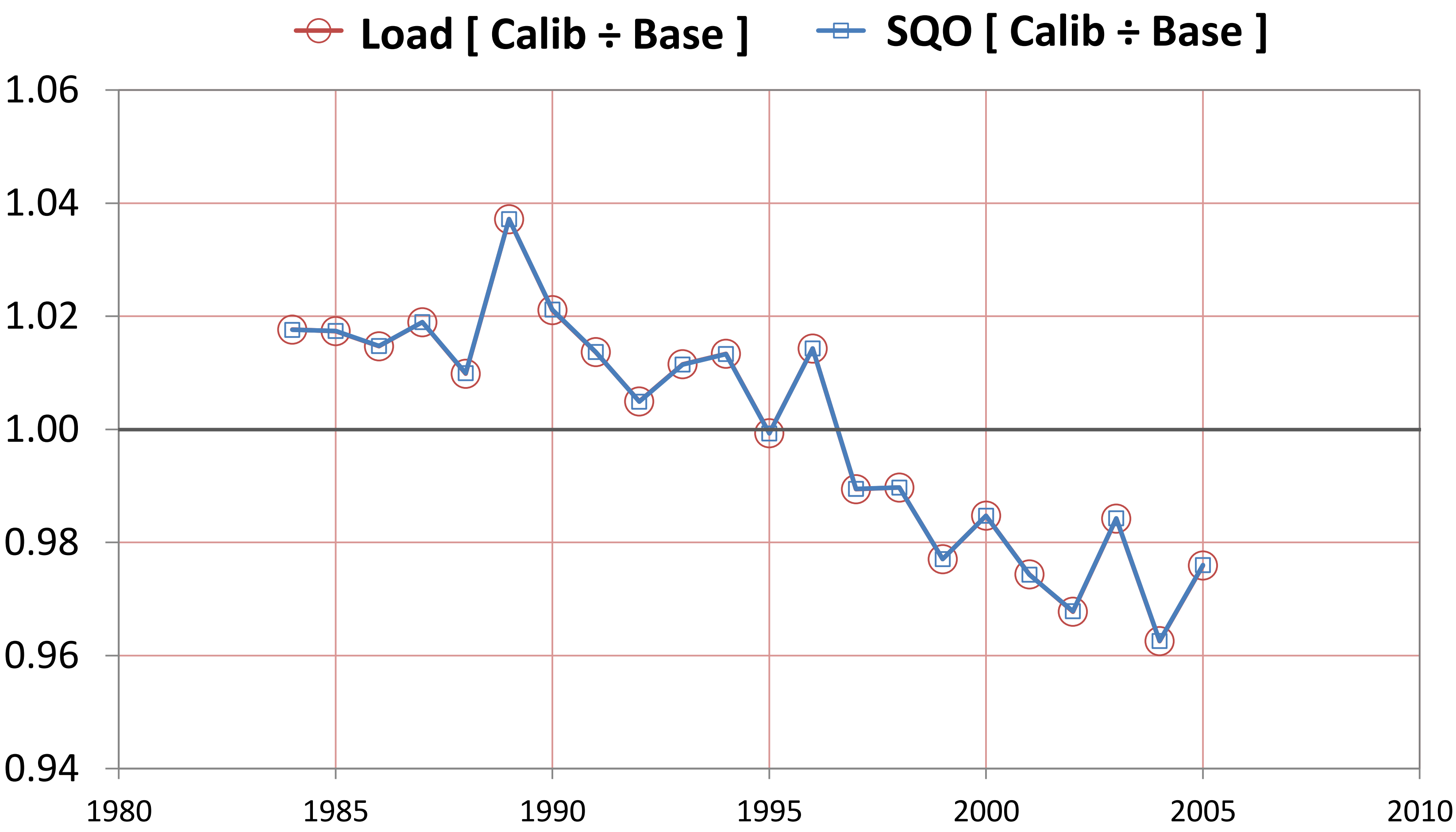
- Testing was done on segment **A10001** and land use ‘**hom**’.

EOF SNH3 Yield – Calibration vs. Baseline

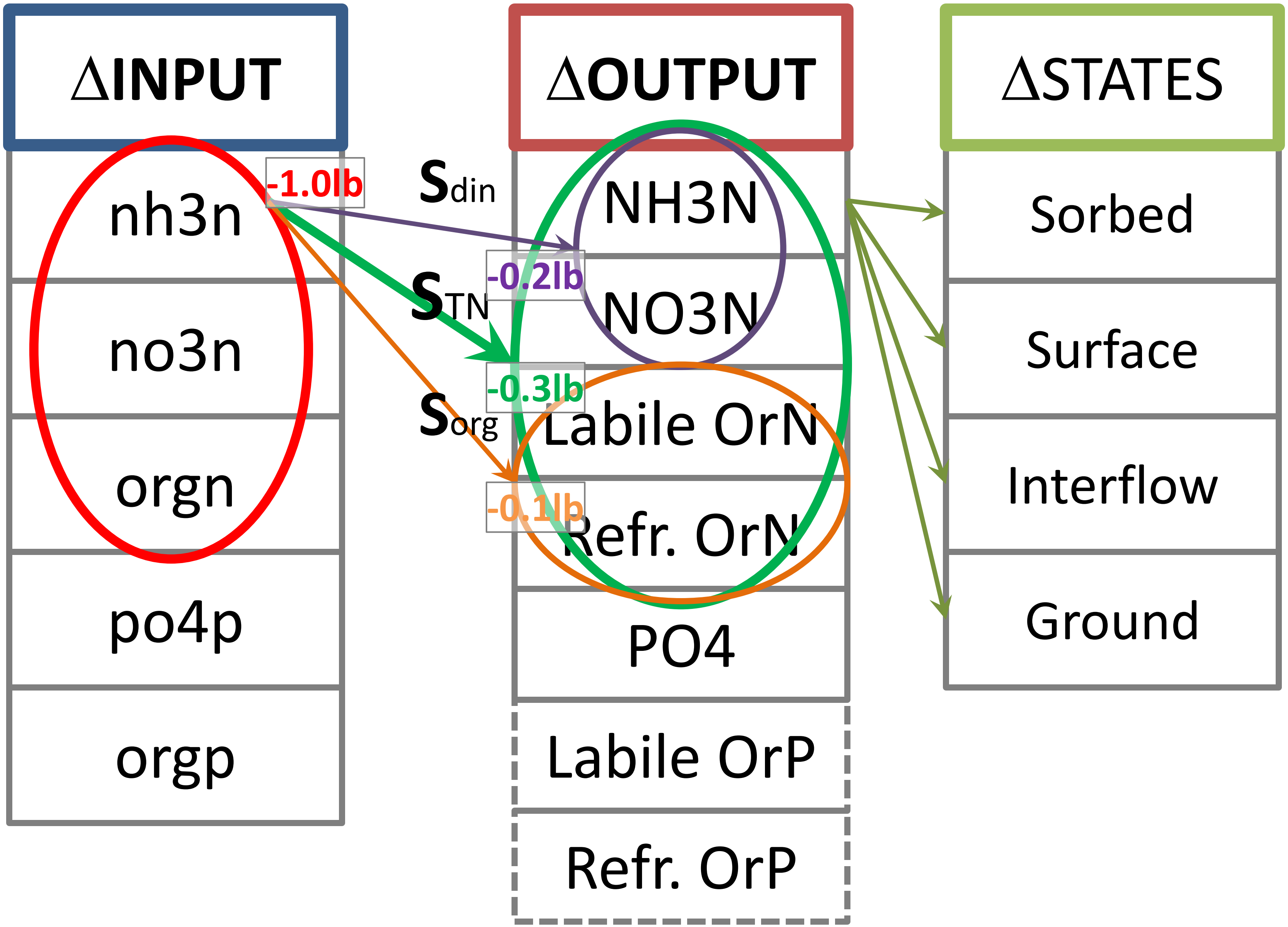


Here, the major driver of inter-annual differences in yield was flow. The differences in annual loads between the two scenario are due to adjustments to the PQUAL parameters.

How does scaling of PQUAL parameters affect the EOF yield?



Step 2: We need to develop a new tool to grab sensitivities to application sources, apply to changes in input loadings, and apply changes in output yields to previously adjusted calibration EOF yield.


ΔINPUT
nh3n
no3n
orgn
po4p
orgp
-1.0lb
Sdin
STN
Sorg
ΔOUTPUT
NH3N
-0.2lb
NO3N
-0.3lb
Labile OrN
-0.1lb
Refr. OrN
PO4
Labile OrP
Refr. OrP
ΔSTATES
Sorbed
Surface
Interflow
Ground

Generalized Sensitivity Formulation

$$SENSITIVITY = S_{SRC,CON}$$

$where,$

$$SRC : SOURCE\left(AtDep, Manure, Fertilizer, Legume, Uptake, ...\right)$$

$$CON : CONSTITUENTS\left(NH3, NO3, LON, RON, PO4, LOP, ROP\right)$$

$$OUT_{CON}^{SCEN} - OUT_{CON}^{CALIB} =$$

$$\sum_{J}^{SRC} f\left(S_{J,CON}, IN_{J,CON}^{SCEN}, IN_{J,CON}^{CALIB}, OUT_{CON}^{CALIB}, Others\right)$$

A New Subroutine for Simple Sensitivity

$$OUT_{CON}^{SCEN} - OUT_{CON}^{CALIB} = \sum_{J}^{SRC}\left[S_{J,CON} \times \left(IN_{J,CON}^{SCEN} - IN_{J,CON}^{CALIB}\right)\right]$$

SENSITIVITES											
ATDEP	lsegmt	NO3	NH3	LON	RON	PO4	mNH3	mNO3	mLON	mRON	mPO4
	A10001	1x0.43	1x0.43	2x0.012	2x0.012	3x0.1	D1	D1	D1	D1	D1
FERTILIZER	lsegmt	NO3	NH3	LON	RON	PO4	mNH3	mNO3	mLON	mRON	mPO4
	A10001	1x0.23	1x0.23	2x0.005	2x0.005	3x0.1	D1	D1	D1	D1	D1
LEGUME	lsegmt	NO3	NH3	LON	RON	PO4	mNH3	mNO3	mLON	mRON	mPO4
	A10001	1x0.41	1x0.41	2x0.009	2x0.009	3x0.1	D1	D1	D1	D1	D1
UPTAKE	lsegmt	NO3	NH3	LON	RON	PO4	mNH3	mNO3	mLON	mRON	mPO4
	A10001	1x-0.05	1x-0.05	2x0.006	2x0.006	3x0.1	D1	D1	D1	D1	D1

∆INPUT (SCENARIO – CALIBRATION)					
apptyp	no3n	nh3n	orgn	po4p	orgp
atdep	-2.16E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
coverc	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
plow	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
fert	-3.27E+01	-9.82E+01	0.00E+00	1.23E+00	0.00E+00
manure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
legume	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
uptake	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
muptak	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
reforg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

HAND CALCULATION		TOTAL_N	TOTAL_P
	ATDEP	-9.55E-01	0.00E+00
	FERTILIZER	-3.08E+01	1.23E-01
	TOTAL	**-31.72**	**0.12**

TOTAL N	**-31.72**
TOTAL P	**0.12**

OUTPUT							
qual1	state1	out_calib	2.87E+00	delta_out	-2.46E-01	pcent_delta	-0.0855
qual1	state2	out_calib	1.93E+00	delta_out	-1.65E-01	pcent_delta	-0.0855
qual1	state3	out_calib	1.19E+01	delta_out	-1.02E+00	pcent_delta	-0.0855
qual1	state4	out_calib	1.19E+01	delta_out	-1.02E+00	pcent_delta	-0.0855
qual2	state2	out_calib	6.42E+00	delta_out	-5.49E-01	pcent_delta	-0.0855
qual2	state3	out_calib	7.87E+01	delta_out	-6.73E+00	pcent_delta	-0.0855
qual2	state4	out_calib	2.49E+02	delta_out	-2.13E+01	pcent_delta	-0.0855
qual3	state1	out_calib	6.26E-01	delta_out	-5.95E-03	pcent_delta	-0.0095
qual3	state2	out_calib	2.06E-02	delta_out	-1.95E-04	pcent_delta	-0.0095
qual3	state3	out_calib	2.64E+00	delta_out	-2.50E-02	pcent_delta	-0.0095
qual3	state4	out_calib	3.25E+00	delta_out	-3.09E-02	pcent_delta	-0.0095
qual4	state1	out_calib	5.95E+00	delta_out	-5.65E-02	pcent_delta	-0.0095
qual4	state2	out_calib	1.95E+00	delta_out	-1.85E-02	pcent_delta	-0.0095
qual4	state3	out_calib	2.47E+01	delta_out	-2.35E-01	pcent_delta	-0.0095
qual4	state4	out_calib	3.25E+01	delta_out	-3.09E-01	pcent_delta	-0.0095
qual5	state1	out_calib	3.86E+00	delta_out	2.29E-02	pcent_delta	0.0059
qual5	state2	out_calib	7.99E-01	delta_out	4.74E-03	pcent_delta	0.0059
qual5	state3	out_calib	1.60E+01	delta_out	9.47E-02	pcent_delta	0.0059
qual5	state4	out_calib	2.01E-01	delta_out	1.19E-03	pcent_delta	0.0059

Conclusions: Sensitivity Prototype

- Calibration run was de-trended to create a baseline scenario to be used for running management scenarios.
- Load responds proportionately to changes in PQUAL parameters.
- Sensitivity algorithm was developed to offer maximum flexibility.
- Sensitivity code was verified.
- Code offers ability to incorporate multiple sensitivity functions.

Appendix: Expanded Formulation …

A →
$$OUT_{CON}^{SCEN} - OUT_{CON}^{CALIB} = \sum_{J}^{SRC} \left[S_{J,CON} \times \left(IN_{J,CON}^{SCEN} - IN_{J,CON}^{CALIB} \right) \right]$$

B →
$$OUT_{CON}^{SCEN} - OUT_{CON}^{CALIB} = \sum_{J}^{SRC} \left[S_{J,CON} \times IN_{J,CON}^{SCEN} \right] - OUT_{CON}^{CALIB}$$

C → …

SRC (J) ϵ [A,V,P,F,M,L,T,U,R]

- Above methods that are **exclusive** to each other.
- A method switch will be assigned a-priori

> *For a constituent compute percentage change in yield.*
>
> *At time = t, apply the percent change to baseline yield.*

E.g. **hom_atdep_sensitivity.csv**

```
lsegmt,NO3,NH3,LON,RON,PO4,mNH3,mNO3,mLON,mRON,mPO4
A10001,1x0.43,1x0.43,2x0.012,2x0.012,3x0.1,D1,D1,D1,D1,D1
A10003,1x0.43,1x0.43,2x0.012,2x0.012,3x0.1,D1,D1,D1,D1,D1
…
```