ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

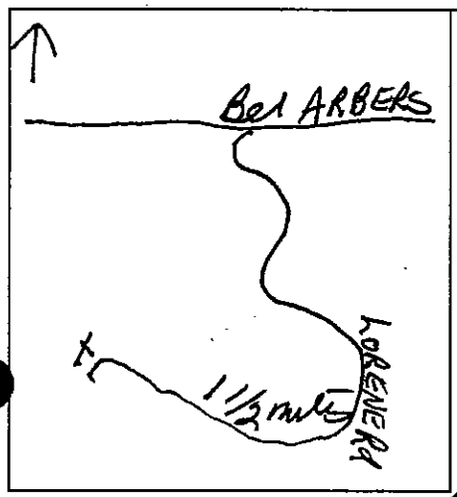
Do not fill in
No. 378252

Notice of Intent No. _____
Local Permit No. or Date 9002 May 2, 1991 #57 200 026

State Well No. _____
Other Well No. 16N12W18

(2) LOCATION OF WELL (See instructions):

County Mendocino Owner's Well Number _____
Well address if different from above 700 Lorene Rd. RV
Township 16 North Range 12 West Section 12
Distance from cities, roads, railroads, fences, etc. Off Bel Arbers to Lorne Road South to end of road 1 1/2 miles



WELL LOCATION SKETCH

(3) TYPE OF WORK:

New Well XX Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:

Domestic ☐
Irrigation ☐
Industrial ☐
Test Well XX
Municipal ☐
Other ☐
(Describe)

(5) EQUIPMENT:

Rotary XX Reverse ☐
Cable ☐ Air XX
Other ☐ Bucket ☐

(6) GRAVEL PACK:

Yes ☐ No XX Size
Diameter of bore 8 Inch
Packed from DRY ft. to _____ ft.

(7) CASING INSTALLED:

Steel ☐ Plastic ☐ Concrete ☐

(8) PERFORATIONS:

Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
	DRY	DRY	DRY			

(9) WELL SEAL:

Was surface sanitary seal provided? Yes ☐ No ☐ If yes, to depth DRY ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval DRY ft.
Method of sealing DRY

(10) WATER LEVELS:

Depth of first water, if known DRY ft.
Standing level after well completion DRY ft.

(11) WELL TESTS:

Was well test made? Yes ☐ No ☐ If yes, by whom? _____
Type of test Pump ☐ DRY Bailer ☐ Air lift ☐
Depth to water at start of test _____ ft. At end of test _____ ft.
Discharge _____ gal/min after _____ hours Water temperature _____
Chemical analysis made? Yes ☐ No ☐ If yes, by whom? _____
Was electric log made Yes ☐ No ☐ If yes, attach copy to this report

(12) WELL LOG:

Total depth 695 ft. Completed depth 0 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	55	Yellow Cement Gravel
55	100	Green Clay
100	120	Yellow Cement Gravel
120	140	Green Clay & Gravel
140	180	Yellow Cement Gravel
180	220	Gray Clay & Gravel
220	240	Yellow Clay
240	245	Brown Clay
245	300	Yellow Cement Gravel
300	350	Blue Cement Gravel
350	695	Yellow Cement Gravel with streaks of Blue Gravel & Clay
		DRY DRY DRY

Work started ??? 5/2 19 91 Completed 5/ 9 19 91

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signed John T Graves (Well Driller)
NAME R & B Drilling (Person, firm, or corporation) (Typed or printed)
Address 580 Milani Drive
City Ukiah, CA. ZIP 95482
License No. 482117 Date of this report 5/16/91

VOIDED NOT FOR PUBLIC USE WATER CODE SEC. 13752

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

DWR 188 (REV. 12-86) 86 96355

ORIGINAL
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Page X of 1

Owner's Well No. 92-2797

Date Work Began August 92, Ended August 92

Local Permit Agency Mendocino Cty

Permit No. 9113 Permit Date 7-8-92

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 398391

M N

DWR USE ONLY — DO NOT FILL IN

16N12W08 M

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	1	topsoil
1	23	gravel
23	150	blue clay
150	153	blue sand
153	200	brown clay
200	280	blue clay
280	285	coarse & loose sand
285	310	brown clay
310	320	birdseye gravel
320	330	clay
330	332	sand
332	340	clay

TOTAL DEPTH OF BORING 340 (Feet)

TOTAL DEPTH OF COMPLETED WELL X 340 (Feet)

WELL OWNER

Name Floyd Black

Mailing Address 7935 Uva Dr.

CITY Redwood Valley Ca. STATE 95470 ZIP

WELL LOCATION

Address 7935 Uva Dr.

City Redwood Valley Ca.

County Mendocino Ca.

APN Book 165 Page 010 Parcel 08

or Township ___ Range ___ Section ___

or Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY

X Domestic

___ Public

___ Irrigation

___ Industrial

___ "TEST WELL"

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD Rotary Mud FLUID Mud

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 15 (Ft.) & DATE MEASURED ___

ESTIMATED YIELD* 20+ (GPM) & TEST TYPE airlift

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN 200 (Ft.)

** May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL/ GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	200	10 5/8	X				F480 PVC	5	c200	
200	340	"		X			"	"	"	.032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	22	X			
22	340			X	fine pea

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME FISCH BROS DRILLING INC.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

5001 Gravenstein Hwy No. Sebastopol Ca. 95472
ADDRESS CITY STATE ZIP

Signed Brian Burnham By c.j.usher 8-10-92 399226
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

RECEIVED
JUL 22 1994
D.W.R.

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

Page 1 of 4
Owner's Well No.
Date Work Began 6/22/94 Ended 6/24/94
Local Permit Agency Mendocino County Environmental Health
Permit No. 9822 Permit Date 6/20/94

No. 405865

DWR USE ONLY — DO NOT FILL IN
16N12W04K M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER 87 (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	2	Top Soil
2	8	Clay & Rock
8	30	Yellow Clay
30	45	Yellow Cement Gravel
45	60	Blue Clay
60	85	Yellow Cement Gravel
85	87	Blue Clay (WATER)
87	99	Yellow Cement Gravel

TOTAL DEPTH OF BORING 99 (Feet)
TOTAL DEPTH OF COMPLETED WELL 100 (Feet)

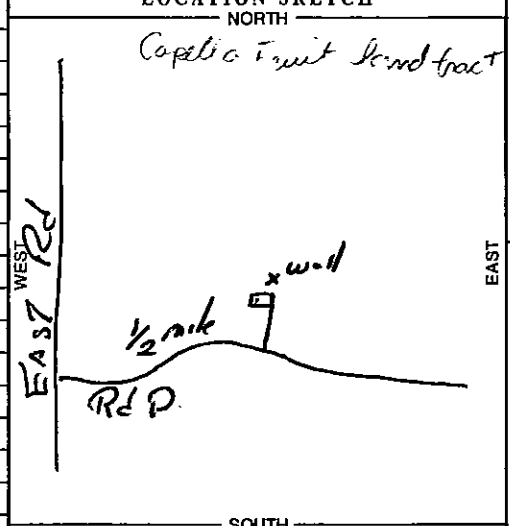
WELL OWNER

Name Charlotte Bergera
Mailing Address 1450 Road D
Redwood Valley, CA. 95470
CITY STATE ZIP

WELL LOCATION

Address 1450 Road D
City Redwood Valley, CA. 95470 23
County Mendocino
APN Book 163 Page 030 Parcel 22
or Township ___ Range ___ Section ___
or Latitude ___ DEG. MIN. SEC. NORTH Longitude ___ DEG. MIN. SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
X Domestic
___ Public
___ Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD Air Rotary FLUID

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 50 (Ft.) & DATE MEASURED 6/23/94
ESTIMATED YIELD* 5 (GPM) & TEST TYPE Air Lift
TEST LENGTH 1 (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	TILL PIPE	MATERIAL/GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	99	9"	Steel				12 gauge	6 5/8"	12 1/4x1"	

PERFORATIONS 60 feet to 98 feet

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	X			Pea Gravel

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME R & B DRILLING 380
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
580 Milani Drive, Ukiah, CA. 95482
ADDRESS CITY STATE ZIP
Signed [signature] 6/24/93 482117
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 7-90 IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

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Page 1 of 4

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SEP 08 1992
D.W.R.

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 485050

DWR USE ONLY — DO NOT FILL IN
16N12W02D M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No.
Date Work Began 8/13/92 Ended 8/27/92
Local Permit Agency Mendocino County Environmental Health
Permit No. 9453 Permit Date 8/13/92

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER 100 (Ft) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	3	Top Soil
3	10	Yellow Clay
10	15	Green Clay
15	92	Blue Rock
92	100	Green Stone Fractured
100	150	Green Stone
150	425	Gray Wacky & Green Stone
425	466	Black Serpetine

TOTAL DEPTH OF BORING 466 (Feet)
TOTAL DEPTH OF COMPLETED WELL 467 (Feet)

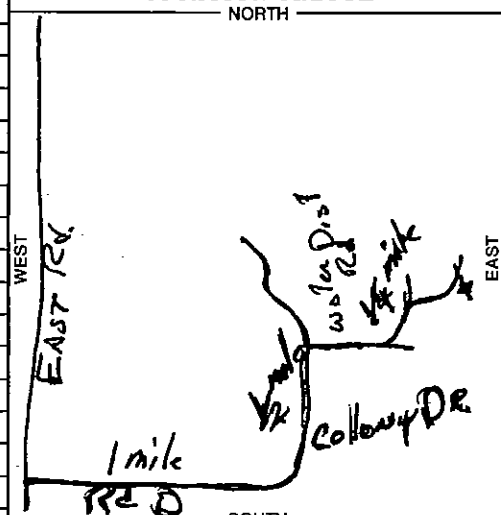
WELL OWNER

Name Henry Abshire
Mailing Address 8977 Colony Drive
Redwood Valley, CA. 95470
CITY STATE ZIP

WELL LOCATION

Address 8977 Colony Drive
City Redwood Valley, CA. 95470
County Mendocino
APN Book 176 Page 140 Parcel 07
or Township 16N Range 12W Section 02
or Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
X Domestic
___ Public
___ Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD Airy Rotary FLUID

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 90 (Ft.) & DATE MEASURED 4/27/92
ESTIMATED YIELD* 1 (GPM) & TEST TYPE Air Lift
TEST LENGTH 4 (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL/ GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
1 Plus	466	9"		Steel			12 gauge	6 5/8"	12	1/4x1"
							PERFORATIONS 80 ft. to 464 ft.			

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	X			pea gravel

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME R & B DRILLING 380
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS 580 Milani Drive, Ukiah, CA. 95482
CITY STATE ZIP

Signed John F Green
WELL DRILLER/AUTHORIZED REPRESENTATIVE
DATE SIGNED 8/27/92
C-57 LICENSE NUMBER 482117

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
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Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 548137

DWR USE ONLY — DO NOT FILL IN
16N12W08E M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 94-3216
Date Work Began Oct 94, Ended Oct 94
Local Permit Agency Mendocino Cty
Permit No. 9980 Permit Date

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER ___ (Ft) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	2	topsoil
2	80	brown clay w/gravel stringers
80	180	blue clay
180	260	blue clay w/cemented gravel

TOTAL DEPTH OF BORING 260 (Feet)
TOTAL DEPTH OF COMPLETED WELL 260 (Feet)

WELL OWNER

Name Doyle Sievers
Mailing Address 8150 Vineyard Oaks Dr.
Redwood Valley Ca. 95470
CITY STATE ZIP

WELL LOCATION

Address 8150 Vineyard Oaks Dr.
City Redwood Valley Ca.
County Mendocino Ca.
APN Book 162 Page 210 Parcel 37
or Township ___ Range ___ Section ___
or Latitude ___ DEG. MIN. SEC. NORTH Longitude ___ DEG. MIN. SEC. WEST

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
X Domestic
___ Public
___ Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD Rotary Mud FLUID Mud

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 60 (Ft.) & DATE MEASURED ___
ESTIMATED YIELD* 6 (GPM) & TEST TYPE airlift
TEST LENGTH 4 (Hrs.) TOTAL DRAWDOWN 250 (Ft.)
** May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL/GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	60	8.75	X				F480PVC	5	c200	
60	260	"		X			"	"	"	1/8

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20		X		
XXXXXXXXXX					
20	260			X	fine pea

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME FISCH BROS. DRILLING INC. 941
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

5001 GRAVENSTEIN HWY NO. SEBASTOPOL CA. 95472
ADDRESS CITY STATE ZIP

Signed Dale Theiss by c.j.usher 10-31-94 399226
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
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Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 775490

DWR USE ONLY --- DO NOT FILL IN
16N/12W
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. Well #1
Date Work Began 9/27/01, Ended 10/3/01
Local Permit Agency Mendocino Co Environ Health
Permit No. 11988 Permit Date 2/26/01

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD MUD ROTARY FLUID BENTONITE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Brown clay
5	9	Brown sand
9	15	Sandy clay
15	23	Clayee sand
23	35	Brown clay
35	45	Clayee coarse sand with small gravels
45	55	Big loose gravel with some clay
55	62	Brown clay with gravel
62	90	Brown clay
90	104	Blue clay with gravels
104	109	Loose gravels
109	118	Brown clay with gravel
118	136	Gravels with some clay
136	152	Gray clay

TOTAL DEPTH OF BORING 152 (Feet)
TOTAL DEPTH OF COMPLETED WELL 136 (Feet)

WELL OWNER
Name Oren Thompson
Mailing Address PO Box 559
Redwood Valley CA
CITY STATE ZIP

WELL LOCATION
Address 3355 Road E
City Redwood Valley CA
County Mendocino
APN Book 163 Page 020 Parcel 58
Township ___ Range ___ Section ___
Latitude ___ DEG. MIN. SEC. ___ DEG. MIN. SEC.

LOCATION SKETCH
NORTH / WEST / EAST / SOUTH
Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
Deepen
Other (Specify)
DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
✓ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING
TEST WELL
CATHODIC PROTECTION
HEAT EXCHANGE
DIRECT PUSH
INJECTION
VAPOR EXTRACTION
SPARGING
REMEDIATION
OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE 1
DEPTH OF STATIC WATER LEVEL 27 (Ft.) & DATE MEASURED 10/3/01
ESTIMATED YIELD 9 (GPM) & TEST TYPE BAILED
TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN 39 (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	152	11								
+2	136		✓				PVC	5	CL200	
36	56			✓						.032
96	136			✓						.032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	✓			
20	136			✓	8 x 16 sand

ATTACHMENTS (✓)
Geologic Log
Well Construction Diagram
Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Weeks Drilling and Pump Company, Inc.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 176 Sebastopol CA 95473
ADDRESS CITY STATE ZIP
Signed Melissa G Lopez 10/16/01
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
177681
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. e0082849

DWR USE ONLY — DO NOT FILL IN

1SN 12W 32

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. WELL #1

Date Work Began 11/7/2008, Ended 11/14/2008

Local Permit Agency Mendocino County Environmental

Permit No. WW21382 Permit Date 9/25/2008

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD Mud Rotary FLUID Bentonite

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 10	Gray clay with gravel
10 14	Gray clay w/fractured stone
14 20	Gray clay with gravel
20 35	Gravel with sand, little clay
35 40	Gravel with sand
40 55	Gray clay
55 60	Gravel
60 80	Coarse crushed fracture
80 85	Green clay
85 100	Sandstone
100 120	Sandstone with clay
120 125	Sandstone with clay
125 140	Clay

TOTAL DEPTH OF BORING 140 (Feet)

TOTAL DEPTH OF COMPLETED WELL 140 (Feet)

WELL OWNER

Name Jack & Linda Gardner

Mailing Address 2901 Briggs Lane

Ukiah CA

CITY STATE ZIP

WELL LOCATION

Address 100 Gobalet Lane

City Ukiah CA

County Mendocino

APN Book 184 Page 120 Parcel 18-00

Township — Range — Section —

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH

WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR

— Deepen

— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY

✓ Domestic — Public

— Irrigation — Industrial

— MONITORING

— TEST WELL

— CATHODIC PROTECTION

— HEAT EXCHANGE

— DIRECT PUSH

— INJECTION

— VAPOR EXTRACTION

— SPARGING

— REMEDIATION

— OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER N/A (Ft.) BELOW SURFACE 1

DEPTH OF STATIC WATER LEVEL 20 (Ft.) & DATE MEASURED 11/14/2008

ESTIMATED YIELD * 15+ (GPM) & TEST TYPE Air Developed

TEST LENGTH 1 (Hrs.) TOTAL DRAWDOWN 140 (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0 140	10"								
+2 140		✓				PVC	5	SDR21	
20 40			✓						.032
80 140			✓						.032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 2	✓			
2 20		✓		
20 140			✓	3/8 GRAVEL

ATTACHMENTS (✓)

— Geologic Log

— Well Construction Diagram

— Geophysical Log(s)

— Soil/Water Chemical Analysis

— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Weeks Drilling & Pump

(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

P.O. Box 176 Sebastopol CA 95473

ADDRESS CITY STATE ZIP

Signed Melissa G Lopez 11/18/08 177681

WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. e0096032

DWR USE ONLY — DO NOT FILL IN
15N12W10
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. DRY HOLE #2
Date Work Began 7/28/2009, Ended 7/30/2009
Local Permit Agency Mendocino County Environmental
Permit No. WW21536 Permit Date 6/3/2009

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD N/A FLUID N/A

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
		DRY HOLE
0	15	Tan clay
15	35	Tan clay with rock
35	90	Stiff gray clay
90	110	Hard rock
110	140	Stiff gray clay
140	150	Sandy gray clay
150	180	Stiff gray clay
180	210	Shale
210	280	Gray stiff clay
		Dry hole backfilled and abandoned per Mendocino County requirements

TOTAL DEPTH OF BORING 280 (Feet)
TOTAL DEPTH OF COMPLETED WELL N/A (Feet)

WELL OWNER

Name Sarah Kammer
Mailing Address 1491 Fawnwood Drive
Ukiah CA
CITY STATE ZIP

WELL LOCATION

Address 1491 Fawnwood Drive
City Ukiah CA
County Mendocino
APN Book 178 Page 140 Parcel 33
Township ____ Range ____ Section ____
Latitude ____ DEG. MIN. SEC. ____ DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
✓ Domestic — Public
— Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER N/A (Ft.) BELOW SURFACE 1
DEPTH OF STATIC WATER LEVEL N/A (Ft.) & DATE MEASURED ____
ESTIMATED YIELD * N/A (GPM) & TEST TYPE N/A
TEST LENGTH N/A (Hrs.) TOTAL DRAWDOWN N/A (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	20	11"								
20	280	8"								

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
-----	-----				----------

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other ____
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Weeks Drilling & Pump
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 176 Sebastopol CA 95473
ADDRESS CITY STATE ZIP
Signed Melissa G Lopez
WELL DRILLER/AUTHORIZED REPRESENTATIVE
08/05/09 DATE SIGNED
177681 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

STATE OF CALIFORNIA

WELL COMPLETION REPORT

No. e0124475

DWR USE ONLY --- DO NOT FILL IN

15N/12W-34

STATE WELL NO. STATION NO.

39 07 20 | 123 09 47

LATITUDE LONGITUDE

APN / TRS / OTHER

OWNER'S WELL No. 7264

Date Work Began 2/11/11 Ended 2/15/11

Local Permit Agency MENDOCINO

Permit No. WW21866 Permit Date 02-07-2011

GEOLOGIC LOG

ORIENTATION Vertical Degree of Angle ____

DEPTH TO FIRST WATER ____ (ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	Ft.	DESCRIPTION
0	1	topsoil
1	3	brown clay
3	50	brown clay with cemented gravel
50	55	brown clay
55	64	brown and blue clay
64	70	blue clay with gravel
70	90	cemented gravel with blue clay
90	95	brown clay
95	100	brown clay with gravel
100	110	brown clay
110	115	brown clay with gravel
115	122	blue clay
122	123	blue clay with gravel
123	125	blue clay
125	127	blue clay with gravel
127	154	blue clay
[illegible]4	157	blue clay with gravel
[illegible]7	165	blue clay
165	170	blue clay with fine gravel
170	231	gravel with blue clay
231	240	blue clay

TOTAL DEPTH OF BORING 240 (Feet)

TOTAL DEPTH OF COMPLETED WELL 240 (Feet)

WELL OWNER

LESLIE STURZBECHER

P.O. BOX 441

TALMAGE CA 95481

WELL LOCATION

Address 2860 OLD RIVER ROAD

City TALMAGE County MENDOCINO

Apn Book 182 Page 070 Parcel 35

or

Township ____ Range ____ Section ____ 1/4 ____ 1/4

or

Latitude ____ Deg. ____ Min. ____ Sec. NORTH Longitude ____ Deg. ____ Min. ____ Sec. WEST

LOCATION SKETCH

ACTIVITY NEW WELL PLANNED USE(S) DOMESTIC WATER

DRILLING METHOD ROTARY MUD FLUID

DEPTH OF STATIC WATER LEVEL 60 (Ft.) & DATE MEASURED Feb 15, 2011

ESTIMATED YIELD * 20 (G.P.M.) & TEST TYPE Airlift

TEST LENGTH. 2 (Hrs.) TOTAL DRAWDOWN 200 (FT.)

*May not be representative of a well's long-term yield.

CASING

DEPTH FROM SURFACE Ft.	To Ft.	BORE-HOLE DIA.	TYPE	Material / Grade	Dia.	Gauge	Slot size
0	120	10 5/8	Blank	F480 PVC	5	200	
120	240	10 5/8	Perfs	F480 PVC	5	200	032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	To Ft.	Seal Material	Filter Pack (Type / Size)
0	20	BENTONITE	
20	240		3 YDS 12/20 Sand

Attachments

no Geologic Log

Well Construction Diagram

no Geophysical Logs

no Soil Water Chemical Analyses

no Other

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME FISCH BROS. DRILLING, INC.

(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

5001 Gravenstein Hwy No. Sebastopol CA 95472

Signed Scot Unterseher 02/16/11 399226

WELL DRILLER / AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

STATE OF CALIFORNIA

WELL COMPLETION REPORT

No. e0158282

OWNER'S WELL No. 7745

Date Work Began 10/9/12 Ended 10/15/12

Local Permit Agency SONOMA

Permit No. WW22065 Permit Date 09-10-2012

DWR USE ONLY --- DO NOT FILL IN

1SN12W08

STATE WELL NO. STATION NO.

39 10 05 123 12 28

LATITUDE LONGITUDE

APN / TRS / OTHER

GEOLOGIC LOG

ORIENTATION Vertical Degree of Angle ____

DEPTH TO FIRST WATER ____ (ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	Ft.	DESCRIPTION
0	2	topsoil
2	12	brown clay
12	22	small gravel brown clay
22	35	brown clay
35	39	cemented gravel
39	55	blue clay
55	80	brown clay with cemented gravel
80	100	cemented gravel
100	160	brown and blue clay
160	220	cemented gravel
220	230	blue clay
230	300	cemented gravel

TOTAL DEPTH OF BORING 300 (Feet)

TOTAL DEPTH OF COMPLETED WELL 300 (Feet)

WELL OWNER

CPP UKIAH CROSSROADS LLC

429 SANTA MONICA BLVD. #600

UKIAH CA 95482

WELL LOCATION

Address 1315 NORTH STATE STREET

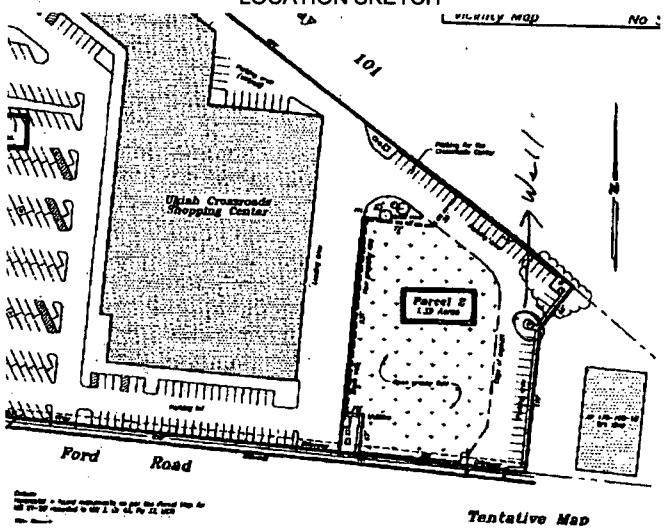
City UKIAH County MENDOCINO

Apn Book 170 Page 190 Parcel 19

or Township ____ Range ____ Section ____ 1/4 ____ 1/4

or Latitude ____ Deg. ____ Min. ____ Sec. NORTH Longitude ____ Deg. ____ Min. ____ Sec. WEST

LOCATION SKETCH



ACTIVITY NEW WELL PLANNED USE(S) PUBLIC WATER

DRILLING METHOD ROTARY MUD FLUID

DEPTH OF STATIC WATER LEVEL 60 (Ft.) & DATE MEASURED Oct 15, 2012

ESTIMATED YIELD * 75 (G.P.M.) & TEST TYPE Airlift

TEST LENGTH. 4 (Hrs.) TOTAL DRAWDOWN 220 (FT.)

*May not be representative of a well's long-term yield.

CASING

DEPTH FROM SURFACE Ft.	To Ft.	BORE-HOLE DIA.	TYPE	Material / Grade	Dia.	Gauge	Slot size
0	50	12.25	Blank	F480 PVC	5	200	
50	80	8 3/4	Blank	F480 PVC	5	200	
80	300	8 3/4	Perfs	F480 PVC	5	200	032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	To Ft.	Seal Material	Filter Pack (Type / Size)
0	50	BENTONITE	
50	300		12/20

Attachments

no Geologic Log

no Well Construction Diagram

no Geophysical Logs

no Soil Water Chemical Analyses

no Other

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME FISCH BROS DRILLING, INC

(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

5001 Gravenstein Hwy No Sebastopol CA 95472

Signed Dale Theiss 10-16-12 399226

WELL DRILLER / AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. e0209535

DWR USE ONLY — DO NOT FILL IN
15N/12W/08
STATE WELL NO./ STATION NO.
39 10 08 | 123 12 00
LATITUDE | LONGITUDE
APN/TRS/OTHER

Owner's Well No. WELL #2
Date Work Began 3/4/2014, Ended 3/12/2014
Local Permit Agency Mendocino County Environmental
Permit No. WW22350 Permit Date 3/4/2014

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD Mud Rotary FLUID Bentonite

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	3	Brown silty clayee sand
3	7	Brown silty gravel
7	25	Multi-colored sand and gravel
25	28	Larger diameter rocks, sand and gravels
28	54	Reddish brown clayee sand and gravel
54	58	Clayee sand and gravel, loose volcanic
58	73	Tighter sand and gravel
73	81	Loose sand and gravel
81	95	Tight multi-colored sand and gravel, brownish
95	103	Clayee sand and gravel
103	121	Becomes more clayeee
121	138	Brown clay, becomes grayish
138	144	Greenish gray clay
144	153	Greenish gray clay, sandy
153	170	Reddish brown sand and gravel
170	173	Larger diameter rocks
173	177	Clayee sand
177	185	Sand and gravel brown, multi
185	197	Sandy gravelly clay
197	202	Tight clayee sand and gravel
202	207	Blue green clay
207	213	Blue multi sand and gravel
213	220	Blue clay

TOTAL DEPTH OF BORING 220 (Feet)
TOTAL DEPTH OF COMPLETED WELL 220 (Feet)

WELL OWNER
Name Charles & Nancy Sawyer
Mailing Address 1305 Rafello Drive
Ukiah CA
CITY STATE ZIP

WELL LOCATION
Address 700 Ford Road
City Ukiah CA
County Mendocino
APN Book 170 Page 200 Parcel 14
Township ___ Range ___ Section ___
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH
NORTH / WEST / EAST / SOUTH
Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
✓ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL
DEPTH TO FIRST WATER N/A (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 23 (Ft.) & DATE MEASURED 3/12/2014
ESTIMATED YIELD * 90 (GPM) & TEST TYPE Air Devel/Pump
TEST LENGTH 5 (Hrs.) TOTAL DRAWDOWN 200 (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	220	8								
0	220	18								
+1	150		✓				PVC	10	SDR17	
150	210			✓			PVC	10	SDR17	.032
210	220		✓				PVC	10	SDR17	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	0	✓			CONCRETE
0	50	✓			
50	120		✓		
120	220			✓	1/8x1/4 Gravel

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Weeks Drilling & Pump
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 176 Sebastopol CA 95473
ADDRESS CITY STATE ZIP
Signed [signature] 04/16/14 177681
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. e0231794

DWR USE ONLY -- DO NOT FILL IN

STATE WELL NO./ STATION NO.: 15N12W32

LATITUDE: 39.6600 N LONGITUDE: 123.1222 W

APN/TRS/OTHER: 184-023-05

Owner's Well No. WELL #1

Date Work Began 8/4/2014, Ended 8/5/2014

Local Permit Agency Mendocino County Environmental

Permit No. WW22400 Permit Date 5/9/2014

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD Mud Rotary FLUID Bentonite

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	14	Sandy tan soil and gravel
14	22	Stiff tan clay
22	33	Clayee green serpentine
33	41	Gray shale
41	46	Serpentine
46	57	Gray shale
57	69	Black shale
69	73	Serpentine
73	82	Gray shale
82	87	Black shale
87	93	Sandy gray rock (damp)
93	140	Gray sandstone fractured and lots of water

TOTAL DEPTH OF BORING 140 (Feet)

TOTAL DEPTH OF COMPLETED WELL 127 (Feet)

WELL OWNER

Name Myra Drury

Mailing Address 298 Valley View Road

Ukiah CA

CITY STATE ZIP

WELL LOCATION

Address 298 Valley View Road

City Ukiah CA

County Mendocino

APN Book 184 Page 023 Parcel 05

Township ____ Range ____ Section ____

Latitude ____ DEG. ____ MIN. ____ SEC. ____ DEG. ____ MIN. ____ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
✓ Domestic — Public
— Irrigation — Industrial

— MONITORING
— TEST WELL
— CATHODIC PROTECTION
— HEAT EXCHANGE
— DIRECT PUSH
— INJECTION
— VAPOR EXTRACTION
— SPARGING
— REMEDIATION
— OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER N/A (Ft.) BELOW SURFACE 1

DEPTH OF STATIC WATER LEVEL 11 (Ft.) & DATE MEASURED 8/5/2014

ESTIMATED YIELD * 50+ (GPM) & TEST TYPE Air Developed

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN 105 (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	58	11								
58	140	8								
+2	87		✓				PVC	5	SDR21	
87	127			✓			PVC	5	SDR21	.032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	50		✓		
50	127			✓	3/8 Pea Gravel

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Weeks Drilling & Pump (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

P.O. Box 176 ADDRESS Sebastopol CITY CA STATE 95473 ZIP

Signed June Weeks Johnson WELL DRILLER/AUTHORIZED REPRESENTATIVE 09/12/14 DATE SIGNED 177681 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. e0236817

DWR USE ONLY — DO NOT FILL IN
17N12W33
STATE WELL NO./ STATION NO.
LATITUDE 39 16 47 N
LONGITUDE 123 11 36 W
APN/TRS/OTHER

Owner's Well No. DRY HOLE #1
Date Work Began 10/3/2014, Ended 10/6/2014
Local Permit Agency Mendocino County Environmental
Permit No. WW22480 Permit Date 8/12/2014

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD AIR FLUID N/A

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
		DRY HOLE
0	35	Brown clay with gravel
35	60	Tan clay
60	85	Blue clay with gravel
85	125	Stiff gray clay
125	145	Brown stiff clay
145	200	Gray clay / Shale
		Dry hole backfilled and abandoned per Mendocino County requirements

TOTAL DEPTH OF BORING 200 (Feet)
TOTAL DEPTH OF COMPLETED WELL N/A (Feet)

WELL OWNER

Name Charles Walker
Mailing Address 2730 Road E
CITY Redwood Valley STATE CA ZIP

WELL LOCATION

Address 2730 Road E
City Redwood Valley CA
County Mendocino
APN Book 161 Page 240 Parcel 02
Township — Range — Section —
Latitude — DEG. MIN. SEC. — DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
✓ Domestic — Public
✓ Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER N/A (Ft.) BELOW SURFACE 1
DEPTH OF STATIC WATER LEVEL NA (Ft.) & DATE MEASURED —
ESTIMATED YIELD * N/A (GPM) & TEST TYPE N/A
TEST LENGTH N/A (Hrs.) TOTAL DRAWDOWN N/A (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	25	11								
25	200	7 7/8								
-----	-----	----------					----------	----------	----------	----------

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
-----	-----				----------

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other —

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Weeks Drilling & Pump
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS P.O. Box 176 CITY Sebastopol STATE CA ZIP 95473
Signed June Boscolini
WELL DRILLER/AUTHORIZED REPRESENTATIVE
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Appendix 2-D Ukiah Valley Integrated Hydrologic Model Report

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Chapter 1

Background

This appendix documents the development and calibration of the Ukiah Valley Integrated Hydrologic Model (UVIHM).The model simulates groundwater and surface water processes for historical period and is used to project future Ukiah Valley Groundwater Basin (Basin) conditions. UVIHM is used in the development of the Ukiah Valley Basin Groundwater Sustainability Plan (Plan or GSP) including evaluation of Basin's historical and projected future water budgets, improve understanding of Basin conditions and long term trends in groundwater levels. It is also used to assess the impact of climate change, and projects and management actions on groundwater conditions. The UVIHM was developed to meet the requirements of the Sustainable Groundwater Management Act (SGMA) (Cal. Water Code, Division 6, Part 2.74).

Chapter 2

Model Software Summary

The UVIHM is a combination of multiple models interacting to simulate the entire Upper Russian River Watershed (Watershed; shown in **Figure ??**). Three models are used to estimate all of the flow components herein. USGS Precipitation-Runoff Modeling System (PRMS) (Markstrom et al., 2015; Regan & LaFontaine, 2017), and USGS Modular Groundwater Flow Model (MODFLOW) (Panday, Langevin, Niswonger, Ibaraki, & Hughes, 2013) are used in a coupled platform called Groundwater and Surface Water FLOW (GSFLOW) (Markstrom, Niswonger, Regan, Prudic, & Barlow, 2008) to simulate coupled surface water and groundwater processes. Department of Water Resources (DWR) Integrated Water Flow Model Demand Calculator (IDC) (Dogrul, Kadir, & Chung, 2011) is used to calculate agricultural demand and applied water within the Basin and its results are incorporated as input to GSFLOW.

The GSA consciously selected this model structure due to coordination with Sonoma Water and the USGS and their efforts to develop a watershed-wide integrated hydrological model for the Russian River Watershed (USGS Model). The USGS Model also uses GSFLOW as its main platform. Spatial discretization of the UVIHM is selected to fit within the structure of the USGS Model while providing a more refined representation of the Upper Russian River Watershed. The USGS model was not made available during the GSP development. However, the GSA plans to continue the coordination and cooperation with Sonoma Water and the USGS to harmonize and improve both models.

2.1 MODFLOW

MODFLOW is a finite difference groundwater model that simulates spatial and temporal groundwater (GW) conditions in the Basin. The MODFLOW model simulates the spatially and temporally variable dynamics of groundwater fluxes and groundwater elevations which are sufficient to characterize a water budget for the Basin and determine whether there will be significant changes in groundwater conditions that may impact groundwater users. UVIHM Uses USGS MODFLOW-NWT as part of its GSFLOW platform. The USGS MODFLOW-NWT is a Newton-Raphson formulation for MODFLOW-2005 to improve solution of unconfined groundwater-flow problems. MODFLOW-NWT uses different processes and packages to simulate fluxes and conditions within a groundwater Basin. UVIHM MODFLOW uses the packages outlined in **Table 2.1** to calculate relevant flows in the Basin. These packages were specifically selected to characterize the multiple aspects

Table 2.1: MODFLOW packages used in the UVIHM to calculate groundwater flows.

Package Name	Package Application
Basic (BAS)	Defines active cells and initial heads
Discretization (DIS)	Defines model discretization and layer elevations
Upstream Weighted Flows (UPW)	Defines aquifer parameters
Newton-Raphson Solver (NWT)	Defines numerical solver settings
Well (WEL)	Defines pumping rates
Stream Flow Routing (SFR)	Defines stream routing and stream-groundwater interaction
General Head Boundary (GHB)	Defines head dependent boundaries with specified conductance
Unsaturated Zone Flow (UZF)	Defines parameters from soil zone to groundwater
Output Control Option (OC)	Defines output structure for the model
Gage Package (GAGE)	Defines surface flow gages for SFR Package

of the hydrogeological conceptual model (HCM) of the Basin and to satisfy the key components necessary for GSFLOW model development.

2.2 PRMS

PRMS is a surface water hydrology model focused on simulating a watershed's response to climatic processes such as precipitation, evaporation, and evapotranspiration. The first iteration of PRMS was released by USGS in 1983 in the FORTRAN programming language where model inputs were incorporated with punch cards and outputs were summarized by line printers. USGS has released five iterations of the model with recent revisions focused on streamlining the integrating PRMS with other computational tools such as USGS' MODFLOW. The surface water component of USGS' coupled Groundwater and Surface Water FLOW (GSFLOW) model developed for the UVIHM is the most recent publicly available iteration of PRMS, PRMS-V or version 5, released in late May of 2019. PRMS is comprehensively documented and supported by USGS with a dedicated webpage, release notes, and installation instructions. The PRMS version 4 User's Manual (PRMS User's Manual)[1] is the most comprehensive resource outlining model parameters and processes. An overview of watershed processes modeled by PRMS and their integration with MODFLOW within the GSFLOW framework is presented in **Figure 6.2**.

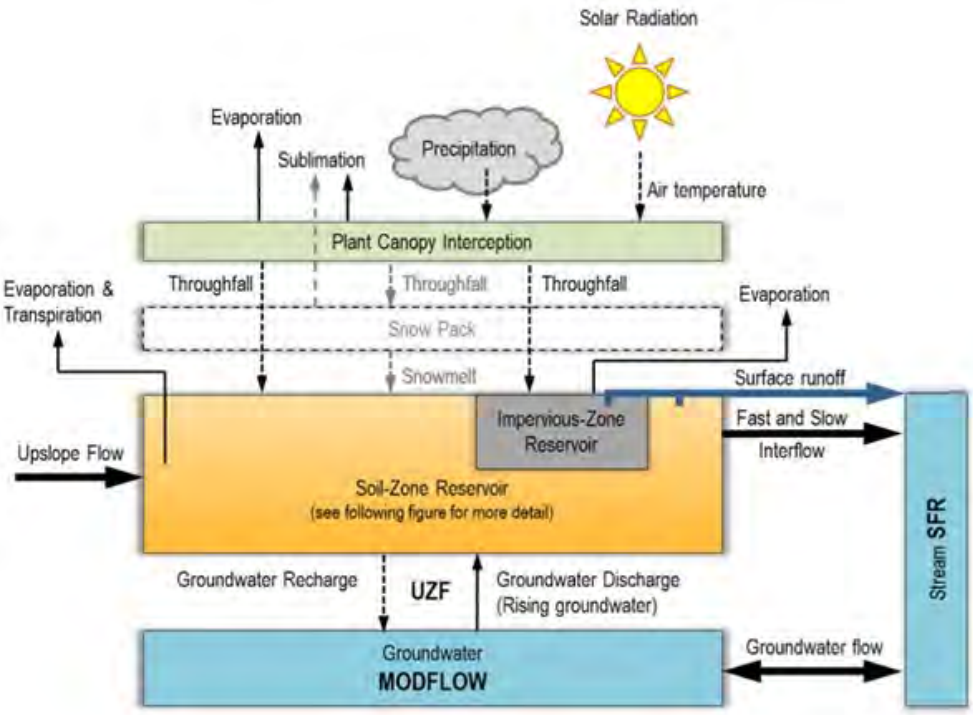

Figure 2.1: Conceptualization of fluxes of water into and out of GSFLOW.

[1]Markstrom, S.L., Regan, R.S., Hay, L.E., Viger, R.J., Webb, R.M.T., Payn, R.A., and LaFontaine, J.H., 2015, PRMS-IV, the precipitation-runoff modeling system, version 4: U.S. Geological Survey Techniques and Methods, book 6, chap. B7, 158 p., http://dx.doi.org/10.3133/tm6B7.

The UVIHM PRMS model simulates precipitation as the sole source of surface water within the domain.[2] Precipitation is then partitioned into evaporation, interception, evapotranspiration, soil moisture, or surface runoff based on the energy balance, a function of air temperature, solar radiation, and windspeed, of the modeled timestep.

Soil-zone reservoir processes, including inflows and outflows, within PRMS are summarized in **Figure 2.2**. At each modeled timestep, soil moisture is partitioned into surface runoff (either Dunnian or Hortonian runff), fast and slow interflow, fluxes into the capillary reservoir, and either direct groundwater recharge or gravity drainage to groundwater.

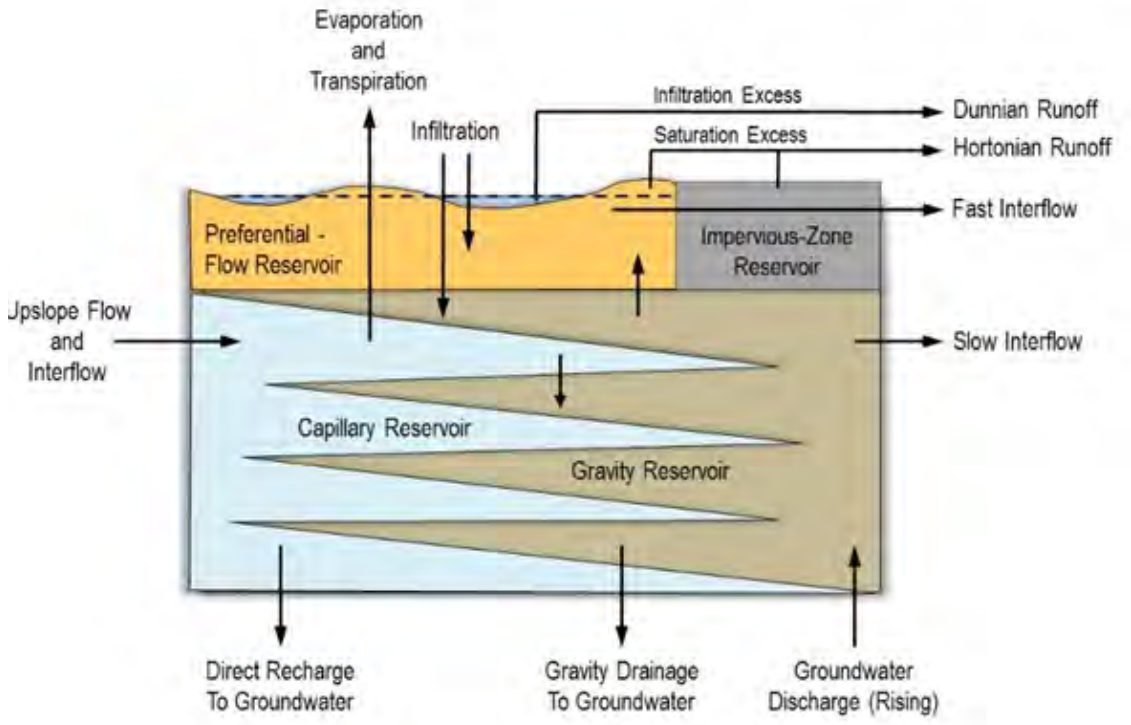

Figure 2.2: Soil-Zone reservoirs with inflows and outflows within GSFLOW.

PRMS uses different computational modules to simulate these hydrological processes. Often these modules provide the user with options that represent different physical equations to choose the best option according to physical conditions of the modeled area and the data available. Accordingly, UVIHM PRMS modules were selected based on the data at hand and how well the modules could represent the actual conditions of the Watershed. Moreover, modules with fewer non-physical parameters or physical parameters that were a source of data gap and uncertainty in the Watershed were prioritized in this selection. A list of the UVIHM PRMS modules are shown in **Table 2.1** and a comprehensive discussion of each of these model processes and modules can be found in the PRMS version 4 User's Manual.

[2] If watershed boundaries are not used, surface water inflows from outside the model boundary, imported water into the modeling area, and generated water within the modeling area (ex. recycled water) can be other sources of surface water

Table 2.2: PRMS modules used in the UVIHM to calculate watershed flows in the Upper Russian River Watershed.

Hydrologic or computational process	Available PRMS and/or GSFLOW Modules	Module Selected for UVIHM	Description of the Selected Module
Potential-evapotranspiration	climate_hru, potet_jh, potet_hamon, potet_hs, potet_pt, potet_pm, potet_pm_sta, or potet_pan	potet_hs	Computes the potential evapotranspiration by using the Hargreaves-Samani formulation
Precipitation	climate_hru, ide_dist, precip_1sta, precip_dist2, precip_laps, or xyz_dist	xyz_dist	Determines the form of precipitation and distributes precipitation to each HRU by using a multiple linear regression of measured data from a group of measurement stations or from atmospheric model simulation.
Soil zone	Either soilzone or deprecated modeules smbal_prms and ssflow_prms (soilzone or smbal_prms)	soilzone	Computes inflows to and outflows from soil zone of each HRU and includes inflows from infiltration, groundwater, and upslope HRUs, and outflows to gravity drainage, interflow, and surface runoff to downslope HRUs
Solar Radiation	ccsolrad or ddsolrad	ddsolrad	Distributes solar radiation to each HRU and estimates missing solar radiation data using a maximum temperature per degree-day relation.
Surface runoff and infiltration	srunoff_carea or srunoff_smidx	srunoff_smidx	Computes surface runoff and infiltration for each HRU by using a nonlinear variable-source-area method allowing for cascading flow.
Streamflow	strmflow, muskingum, strmflow_in_out, or muskingum_lake	muskingum	Computes flow in the stream network using the Muskingum routing method
Temperature	climate_hru, temp_1sta, temp_sta, temp_dist2, temp_laps, ide_dist, or xyz_dist	xyz_dist	Distributes temperatures to each HRU by using a multiple linear regression of measured data from a group of measurement stations or from atmospheric model simulation.

Transpiration	climate_hru, transp_frost, or transp_tindex	transp_frost	Determines whether the current time step is in a period of active transpiration by the killing frost method.
Basin	Required module utilized by PRMS in all models	basin	Defines shared watershed-wide and hydrologic response unit (HRU) physical parameters and variables.
cascade	Required module utilized by PRMS in all models	cascade	Determines computational order of the HRUs and groundwater reservoirs for routing flow downslope
Interception	Required module utilized by PRMS in all models	intcp	Computes volume of intercepted precipitation, evaporation from intercepted precipitation, and throughfall (net precipitation) that reaches the soil or snowpack.
Summary	Modules that control the output generated by the PRMS and GSFLOW	basin_summary; nhru_summary; nsegment_summary; prms_summary	Summary modules compute and convert model results into selected temporal and spatial options and write them into identified output files.

2.3 GSFLOW

The UVIHM uses USGS GSFLOW to assess historical, current, and projected conditions of the Basin and the Watershed. GSFLOW was developed to simulate coupled groundwater/surface-water flow in one or more watersheds by simultaneously simulating flow across the land surface, within subsurface saturated and unsaturated materials, and within streams and lakes. Climatic and hydrogeological data along with defined initial and boundary conditions are the driving factors for a GSFLOW simulation (Markstrom et al., 2008).

2.4 IDC

IDC is a component of the DWR Integrated Flow Model (IWFM) that can be used as an standalone program to calculate agricultural and urban water demands at a Basin or watershed. IDC was used in this GSP to calculate agricultural demands (applied water) based on land use and crop maps and crop water use information to fill the existing data gap for measured pumping and surface water diversions in the Basin. Most recent version of GSFLOW was updated to include a new MODFLOW-NWT package called AG Package (Niswonger, 2020) to similarly estimate agricultural demands. However, this package was not available at the time of development for the UVIHM. Therefore, IDC was substituted to estimate agricultural demands and its results were incorporated as input to the GSFLOW model. As mentioned in **Section 8**, future updates to the UVIHM can include adding AG Package and retiring IDC incorporation.

2.5 Model Integration

UVIHM consists of the fully-coupled PRMS and MODFLOW-NWT models through GSFLOW and offline integration of IDC by pushing surface water and groundwater pumping input data to corresponding MODFLOW-NWT packages. In GSFLOW, flow is exchanged among the three regions of GSFLOW based on interdependent equations that calculate flow and storage of water throughout the simulated hydrologic system (Markstrom et al., 2008). The first region includes the plant canopy, snowpack, impervious storage, and soil zone and is simulated by PRMS. Soil-moisture-dependent flow from this first region can be exchanged between PRMS soil zone and streams, lakes, and subsurface storage including unsaturated and saturated zones simulated by MODFLOW-NWT. Streams and lakes are defined as the second regions and subsurface storage is defined as region 3 in **Figure 2.3**. Region 2 is simulated using Streamflow Routing Package (SFR) and Lake (LAK) packages in MODFLOW-NWT. Region 3 is simulated using the Unsaturated Zone Flow (UZF) package. The dynamic integration of the three regions allows fluxes back and forth from PRMS and MODFLOW-NWT.

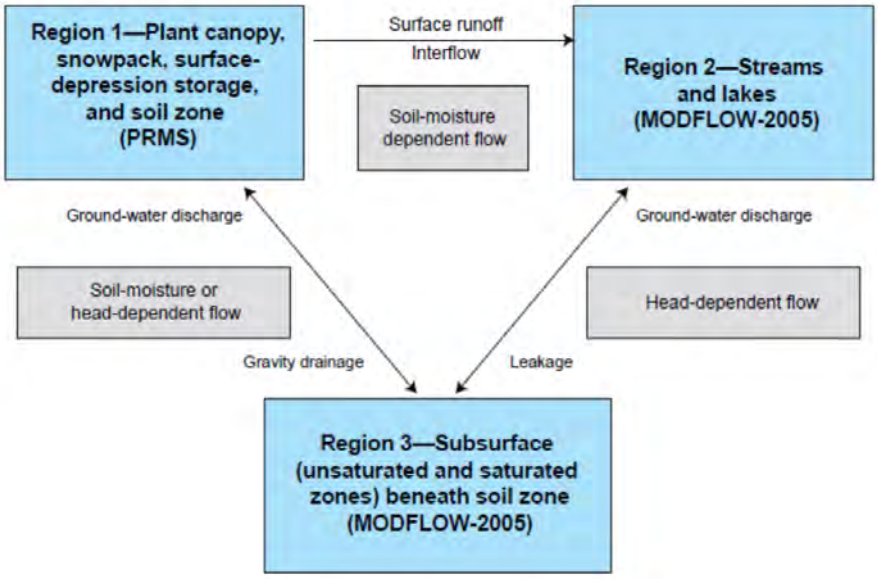

Figure 2.3: Schematic diagram of the exchange of flow among the three regions in GSFLOW, taken from GSFLOW Technical Manual.

Offline integration of IDC is executed through transferring calculated applied water to input data in the relevant packages used by MODFLOW-NWT. Applied surface water is simulated through surface water diversions in the SFR package and applied groundwater is included in the Well (WEL) package. Offline integration does not allow for iterative solutions of the UVIHM. Therefore, IDC and GSFLOW portions of the UVIHM need to be run separately and sequentially. As outlined in **Section 8**, UVIHM can be upgraded by transferring the IDC portion into the GSFLOW AG Package that has been recently added.

Chapter 3

Model Construction

The following section discusses the procedure used to develop the UVIHM including establishing the model extent, translation of that extent into modeled hydrologic response units (HRUs) and MODFLOW layers and cells, and the parameterization of the models with spatial and timeseries inputs.

3.1 Model Domain

The model domain, shown in **Figure 3.1**, covers the Watershed and Basin area. The Watershed domain modeled for both PRMS and MODFLOW is 238,940 acres. This area is simulated through the rectangular grid defined for both PRMS and MODFLOW that covers an area of 410,225 acres including active and inactive calculation units. The model domain is delineated further larger than the Basin limit to include the entire area and all tributaries that potentially contribute flow to the Basin. The modeling area is bounded by the Russian River Watershed boundary to the north, west and east, but is limited to the south to include the USGS Hopland streamflow gage (about 5 miles south of the Basin boundary) and the entire extent of the Basin. Southern limit is appropriately selected to include entire subwatersheds that contribute streamflow to the Russian River north of the USGS Hopland streamflow gage.

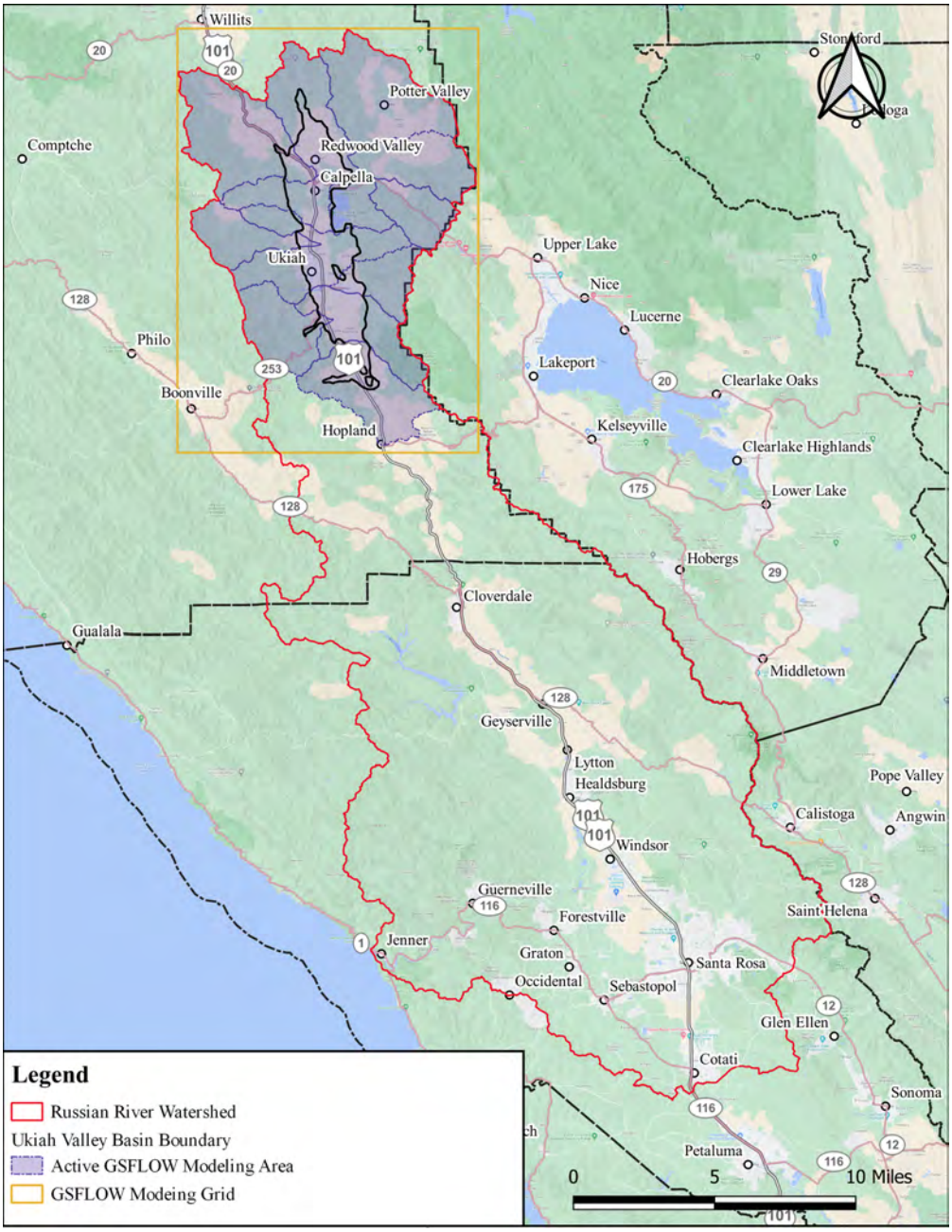

Figure 3.1: UVIHM model domain

3.2 Model Discretization

The process of translating physical characteristics such as elevation, land use or land cover, geology and hydrogeology, precipitation patterns, topography, water supply and use, and other hydrologic factors into a set of unique calculation units is often referred to as spatial discretization. The process of translating atmospheric and hydrogeologic conditions into time series that can drive a model is typically referred to as temporal discretization. All three models in UVIHM (PRMS, MODFLOW, and IDC) need to be spatially and temporally descritized. Spatial and temporal discretization of each model part is discussed below.

3.2.1 Spatial Discretization

MODFLOW and PRMS

PRMS model domain is discretized into HRUs based on land use, soil type, precipitation patterns, topography, stream segments or reaches, lakes, water supply and use, and other hydrologic factors. HRUs are assumed to be uniform in all categories of model inputs and how they respond to hydrological events. While PRMS is capable of integrating irregular or complex (non-rectangle) geometry HRUs, USGS strongly recommends that HRUs reflecting the discretization of the land surface align with the subsurface discretization represented in the coupled MODFLOW groundwater model. Following this recommendation PRMS HRUs and MODFLOW cells were aligned to cover the entire domain using 100 m by 100 m square cells. The UVIHM GSFLOW model is comprised of 165,669 square cells representing HRUs and MODFLOW cells arranged in 483 rows and 343 columns of a grid. Each HRU is assigned a unique set of land use/land cover and atmospheric inputs during spatial processing using an external geographic information system (GIS). The active simulation area for the UVIHM is limited to the Watershed boundary that includes the Basin. Active area consists of 70,102 HRUs and MODFLOW cells.

IDC

IDC is spatially discretized into HRUs based on land use and land cover, soil type (hydrologic soil types), precipitation gages, and the need for non-irrigation applications like frost and heat protection. Land use types were obtained from the 2010 Land Use Survey (DWR, 2019) and hydrologic soil types from the U.S. Department of Agriculture's (USDA) Soil Survey Geographical (SSURGO), as shown in **Table 3.1**.

Six Hydrologic soil groups included in IDC HRU analysis are soil groups A, B, C, and D as defined by SSURGO along with HRUs that are missing soil type data or are located within water bodies. For dual hydrologic soil groups (ex. A/D) the first soil type assignment is assumed. Nineteen land-use types were included in IDC HRU analysis including native vegetation and riparian vegetation. Urban demand was not simulated in IDC. Small water agencies and the City of Ukiah (City) supply the majority of urban demands in the Basin. Therefore, urban demands are incorporated using available water supply data.

Native and riparian vegetation are not effectively characterized in the Basin and were therefore grouped into two categories based on their assumed water demand. These native and riparian water demands can be re-evaluated, re-assessed, and incorporated into the UVIHM when these communities are more comprehensively understood. HRU properties represent the land use or soil type that covers the majority of the cell area. Frost and heat protection were only considered

Table 3.1: Land use and hydrologic soil types used in IDC HRU analysis.

Land Use Tyep	Hydrologic Soil Group
Alfalfa/Clover	A
Apples	B
Citrus/Subtropical	C
Field Crops	D
Fruits	Water
Grains	Unknown/no data
Grapes	
Grass	
Grazing	
Greens and Vegetables	
Idle	
Native Vegetation	
Not irrigated	
Pasture	
Peaches & Nectarines	
Pears	
Pistachios	
Riparian Vegetation	
Walnuts	

for grapes and pears in the Basin based on local agricultural input. Using this methodology, 252 HRUs were defined for IDC simulation that corresponded to the 165,669 HRUs and MODFLOW cells defined in GSFLOW.

3.2.2 Temporal Discretization

Both GSFLOW and IDC parts of the UVIHM produce daily outputs. MODFLOW is set up on monthly stress period and daily timesteps. Historical baseline is defined as WY1992-WY2018 for all models. Future baseline is defined as the repeat of the historical period from WY 1969 to WY 2018. A relatively short warmup period is built into the UVIHM for both historical and future baselines. As a result, all input data and modeling packages start prior to the baselines' starting date.

3.2.3 Boundary Conditions

The MODFLOW model has one General Head boundary that simulates groundwater flows between the Basin boundary and the Hopland Sub-Basin downstream. The stream network for the Watershed includes 208 stream segments divided into 4596 reaches[1] that form the dead dependent flux boundaries in the model. The two vertical boundary conditions are groundwater recharge simulated through PRMS integration and the UZF and SFR packages, and groundwater pumping that is incorporated through WEL package.

3.3 Model Layering and Zonation

The layering of the MODFLOW model was based on the Hydrogeological Conceptual Model (HCM) developed for this Basin(see **Section 2.2.1**) and the Initial Hydrogeologic Conceptual Model (IHCM) (LACO Associates, 2017). The Basin was divided into 3 model layers representing hydrogeologic units identified in the HCM (**Figure 3.2**). Model Layer 1 principally represents the Quaternary Alluvium Units. The extent of Layer 1 is mostly limited to the area along the Russian River mainstem and gets wider as it moves towards the south of the Basin. According to the HCM, the depth of the geologic formation increases when moving north to south, but there is currently limited understanding about how these depth changes occur across the Basin. Therefore, Layer 1 thickness is assumed 16m deep over the whole model domain. For pure modeling purposes and to facilitate the integration of MODFLOW and PRMS in GSFLOW and the simulation of stream and aquifer exchanges through the MODFLOW SFR package, Layer 1 is further extended outside its HCM boundaries to cover the entire active area of the Watershed. The depth of this extension is 5m and is parametric different than the actual boundary of Layer 1 to prevent additional recharge and flow to the aquifer.

Model Layer 2 primarily represents the Terrace Deposit Formation. Its thickness ranges from 16m to 108m and is bounded by the extent determined by the HCM in the Basin. Model Layer 3 mainly represents the Continental Basin Deposits Formation. Its extent matches the Basin extent and its thickness ranges from 12m to 300m.

[1] Each reach is the same as a MODFLOW cell

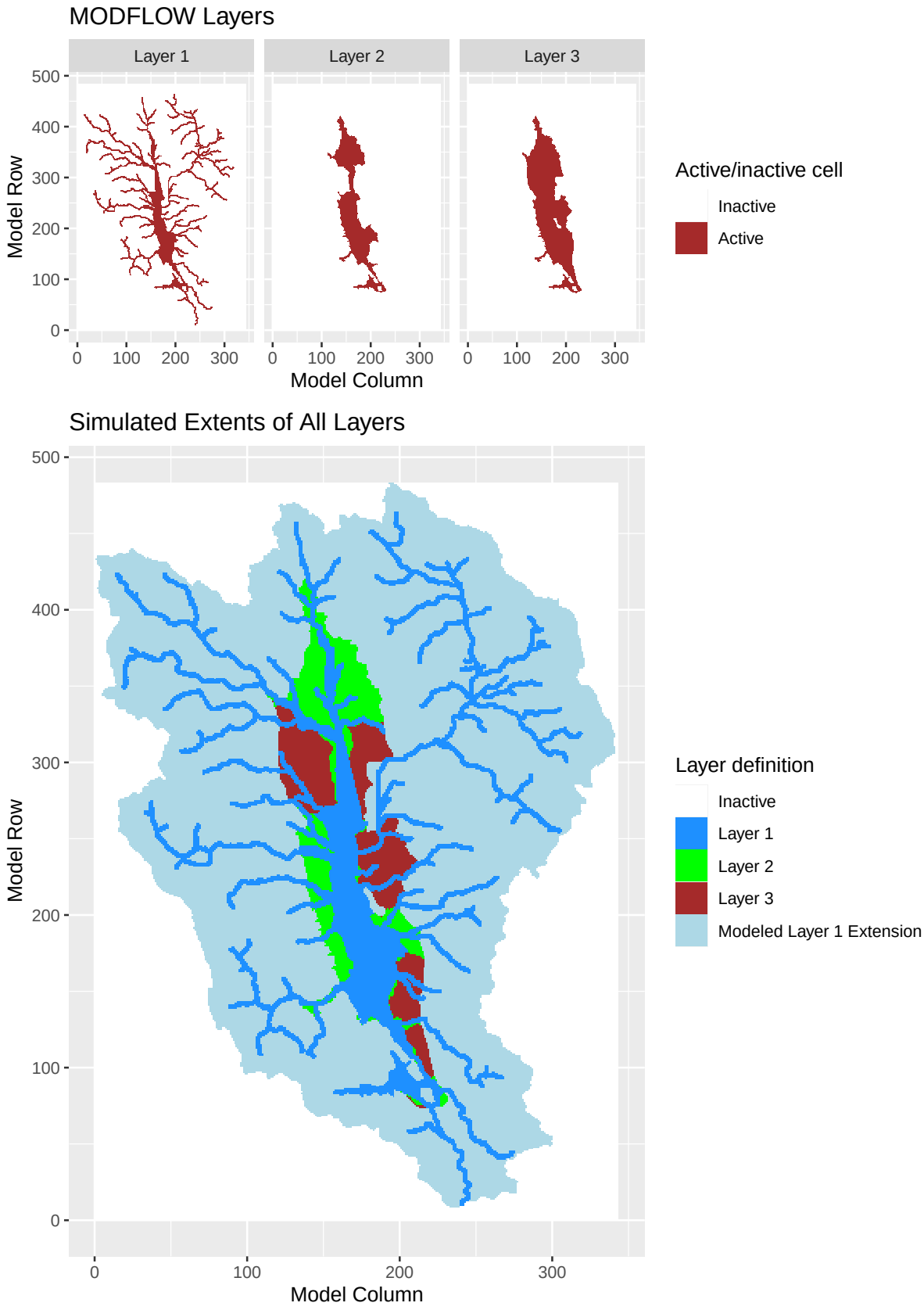

Figure 3.2: MODFLOW layer extents.

Chapter 4

Hydrologic System

In conjunction with the Potter Valley Project (PVP) and Lake Mendocino, the Russian River and its tributaries constitute the main surface water supply for the Watershed and the Basin. While surface water is the primary water supply for the Basin and the Watershed, groundwater supply, and as of late 2019, recycled water, are the other water supply sources in the Basin. PVP supplies water to Lake Mendocino through releases in the East Fork Russian River. Coyote Valley Dam (CVD) provides managed water releases from Lake Mendocino storage through the East Fork Russian River. East Fork Russian River merges with the West Fork Russian River north of the City, creating what is commonly referred to as the mainstem Russian River. The Russian River is currently fully appropriated from July through October and, with the exception of high winter stream flows, fully appropriated in the winter and spring (MCWA, 2010).

4.1 Potter Valley Project and Lake Mendocino

Pacific Gas and Electric Company's (PG&E) PVP was constructed in 1908 for power generation purposes. It collects water from the Eel river at Lake Pillsbury, a reservoir created by the Scott Dam. Natural flows of Eel River and water released from Lake Pillsbury storage are diverted 12 miles downstream from Scott Dam at Cape Horn Dam. It is then conveyed through a diversion tunnel and penstocks to the Potter Valley Powerhouse, which is located in the Russian River Watershed. A portion of the PVP discharge is diverted into canals from which the Potter Valley Irrigation District (PVID) receives irrigation supply under a water supply agreement with PG&E and its own appropriative water rights license. The remaining water discharged from the powerhouse not consumptively used by PVID flows down the East Fork Russian River into Lake Mendocino. The PVP has a maximum flow capacity of approximately 300 cubic feet per second (cfs). The PVID has a water supply contract with PG&E to receive up to 50 cfs of flows from the PVP (SCWA, 2016).

Lake Mendocino was created when the United States Army Corps of Engineers (USACE) constructed the Coyote Valley Dam in 1959. Coyote Dam is located on the East Fork of the Russian River, approximately one mile upstream from convergence with the West Fork and three miles north of Ukiah. Lake Mendocino is used for flood control, municipal and industrial water supply, recreation, and generating power (MCWA, 2010). Lake Mendocino's total current storage capacity is 116,500 acre-feet, with a water supply pool between 68,400 acre-feet and 111,000 acre-feet, depending on the time of year. Between 1922 and 1992, diversions from the Eel River through the

PVP averaged greater than 150,000 acre-feet annually. During this period, the SWRCB adopted water rights Decision 1610, which established a hydrologic index for the Russian River and Dry Creek minimum instream flow requirements based on cumulative inflows into Lake Pillsbury. The USACE manages water releases from Coyote Valley Dam and Lake Mendocino during flood management operations. It also operates Lake Mendocino recreational facilities, which include hiking trails, picnic areas, campgrounds, boat launches, and a disc golf course. These facilities also provide opportunities for boating, swimming, and hunting. Sonoma Water is the local sponsor for Lake Mendocino and is responsible for making water supply releases in compliance with its water right permits. Sonoma Water makes releases from Coyote Valley Dam to maintain the minimum instream flow requirements specified in its water right permits and for downstream beneficial uses along the Upper Russian River, including diversions for domestic, municipal, industrial and agricultural purposes.

PVP and Lake Mendocino provide a significant share of the surface water supply in the Watershed and the Basin, especially during the dry season, and are essential pieces of the hydrologic system. Accurate simulation of their storage and operation is critical for obtaining meaningful and representative results from the UVIHM. However, their operations have been modified during the period modeled as historical baseline in the UVIHM and have been the subject of debate in the Watershed. In 1998, PG&E applied for an amendment to its PVP license that requested changing the required minimum instream flows in the Eel River to benefit Eel River salmon listed as threatened species under the federal Endangered Species Act (ESA). Federal Energy Regulatory Commission (FERC) prepared an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA), which evaluated the potential environmental impacts of various PVP flow proposals on environmental conditions in the Eel River and Russian River Watersheds. In 2002, the National Marine Fisheries Service (NMFS) issued a Biological Opinion under the federal ESA for the proposed license amendment.

FERC amended PG&E's license in 2004 to require implementation of the "reasonable and prudent alternatives" and "reasonable and prudent measures" that the Biological Opinion stated were necessary to avoid jeopardizing the continued existence of the ESA-listed salmon species in the Eel River watershed. At the time, FERC believed that the differences between the Biological Opinion conditions and an earlier flow proposal by NMFS that had been evaluated in the EIS for the PVP were "modest differences… not likely to result in any material difference in the environmental effects" (FERC Order on Rehearing, 107 FERC Section 61,232, Para.22). PG&E began operation of the PVP following its amended FERC license in 2006, and these new operations substantially reduced the amounts of PVP diversions compared to historical levels. According to (SCWA, 2016) annual PVP diversions based on the new requirements averaged about 72,000 acre-feet, less than half the 1922-1992 average. These reductions have resulted in much lower inflows into Lake Mendocino from the East Fork Russian River than analyzed by the Biological Opinion or the EIS. Changes in the seasonal timings of PVP diversions have also affected Lake Mendocino water storage reliability.

4.2 Incorporation of PVP and Lake Mendocino Operations in the UVIHM

There are two stream discharge gages located right after the PVP and CVD that measure their respective releases. USGS 11471000 measures the PVP releases into the Russian River East Fork

that runs through the northeast of the Watershed and flows into Lake Mendocino. USGS 11461500, located almost 2 miles to the northwest of Lake Mendocino, measures the streamflow entering the Lake and stored in the reservoir. Similarly, CDEC gage CDM (historically, USGS 11462000) located on the East Fork Russian River, less than half a mile from the CVD, measures the streamflow released into the East Fork Russian River. streamflow data from the USGS 11471000 and CDEC CDM gauges are input as measured headwater for stream segments starting at the PVP and CVD. They are used for simulations that mirror the historical period, including the historical and future baseline simulations.

The above approach cannot be used when hydroclimatic conditions do not mirror the historical period. Suppose any changes are made to the historical hydroclimatic conditions of the Watershed, such as simulating climate change scenarios. In that case, operations of PVP and CVD need to be simulated considering those changes and the resulting releases to be incorporated into the UVIHM. Sonoma Water has developed HEC-ResSim[1] models that simulate the operations of the PVP and the CVD. These models use the water system's losses and gains calculated through different analyses as simulated and incorporated into the UVIHM. Therefore, the results of these HEC-ResSim models are not directly importable into the UVIHM unless appropriate adjustments are made to harmonize the system's losses and gains among the models. The ideal approach to supplement the UVIHM with reservoir operation simulation is to couple its GSFLOW with the reservoir operation models developed by Sonoma Water. However, this coupling needs the models to be modified to use similar input data and iteratively run to generate equal gain and losses in the system. The coupling is a significant undertaking and out of the GSP development scope. As mentioned in **Section 8**, developing a component for the UVIHM capable of simulating reservoir operations is a recommended action to be considered by the GSA during the implementation period given its scope and required budget.

For the purposes of GSP development, streamflow measurements provide an accurate account of releases for the historical and future baseline scenarios and water budgets. For climate change scenarios, the GSA assumes that releases would be similar to those of the historical period, although precipitation and evapotranspiration are changed. The GSA understands the uncertainty and inaccuracy that this simplifying assumption imposes on the model but determined that it was the best available approach to analyze the extent of impacts from climate change. As outlined in **Chapter 4** of the GSP, the GSA developed a project and management action (PMA) to expand its assessment of the impacts of climate change in the Basin, including improvements to the UVIHM and additional climate change simulations. This PMA will be considered for implementation for the 5-year update of the GSP.

4.3 Incision of the mainstem Russian River and major tributaries

A number of factors historically have kept the Russian River from maintaining a channel in equilibrium not experiencing significant incision or aggradation. Key among these are the retention of sediment supply behind Coyote Dam and the mining of the channel for gravel. Consequently, the river has eroded down into its alluvial floodplain and is significantly entrenched, in some places up to 20 ft. According to the (ISRP, 2015), the entrenchment of the mainstem river prevents floodplain inundation resulting in higher velocity flows in the channel causing channel erosion, loss of

[1] https://www.hec.usace.army.mil/software/hec-ressim/

instream fish habitat, bank erosion, loss of riparian forest and creation of channel geometry that does not support regeneration of the riparian and aquatic ecosystem.

The entrenchment of the Russian River mainstem and its alluvial tributaries contributes to lowering groundwater levels in the Basin and aquifers adjacent to the river. This can impact connectivity and flow in streams and aquifer-stream interaction in the Basin. It drops the base level of the stream network, causing tributaries to go subsurface before reaching the river (ISRP, 2015).

Detailed profile or bathymetry of the Russian River mainstem or its tributaries was unavailable for GSP and model development. Therefore, the spatial distribution of entrenchment could not be established in the stream network. Due to the significance of its impacts and the importance of surface water and groundwater interaction in the Basin, entrenchment depth was considered a calibration parameter in the UVIHM with a range of zero to 20 feet. Entrenchment is assumed to exist only south of Lake Mendocino.

Chapter 5

Model Input Data

PRMS, MODFLOW, and IDC require various input datasets based on the computational modules and packages selected for UVIHM. To maintain consistency and validity within all parts of the UVIHM, the data sources used for each input category are the same for all models. For example, all three models use land use data directly or to estimate relevant parameters. Therefore, land use data used for all models and how it was processed was made intentionally consistent. This section describes the hydroclimatic and geologic data used in different parts and stages of the UVIHM development and calibration.

5.1 Land Surface Inputs

A number of spatial datasets were used to establish a model representation of land surfaces that drive the relationship between precipitation, runoff, and other elements of the hydrologic cycle such as evapotranspiration, infiltration, and interflow.

5.1.1 Elevation

A one-meter resolution Light Detection and Ranging (LiDAR) digital elevation model (DEM) produced on behalf of Mendocino County was obtained and adapted to represent topography within the Ukiah PRMS model domain. A representation of elevation within the Ukiah watershed and model domain is presented in **Figure 5.1**.

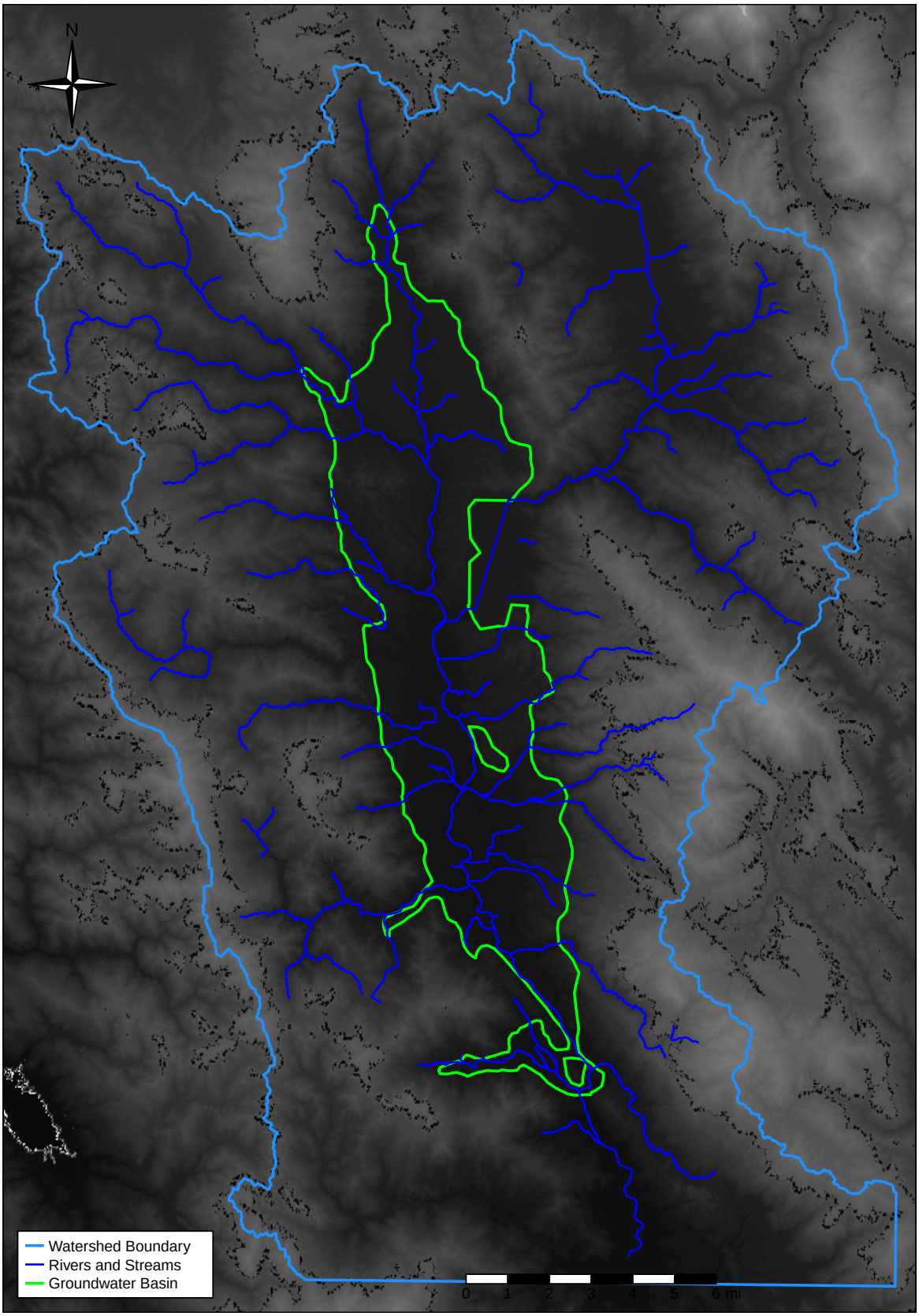

Figure 5.1: Topography of the Upper Russian River Watershed shown using the DEM data used in the UVIHM.

Table 5.1: Acreage and percentage of Upper Russian River Watershed covered by each land use category according to 2010 Land Use Survey

Reclassified Land Use Description	Percentage of Watershed (%)	Area (acre) in Watershed	Percentage of Basin (%)	Area (acre) in Basin
Alfalfa/Clover	0.0	87	0.0	59
Almonds	0.0	1	0.0	0
Apples	0.3	2,745	0.0	1
Citrus/Subtropical	0.0	457	0.0	6
Field Crops	0.1	531	0.0	7
Fruits	0.0	353	0.0	80
Grains	0.6	5,244	0.0	201
Grapes	6.3	59,836	0.8	8,153
Grass	0.2	1,447	0.0	94
Grazing	1.0	9,607	0.1	861
Greens and Vegetables	0.1	917	0.0	31
Idle	0.2	1,685	0.1	519
Native Vegetation	81.0	767,011	97.8	1,000,460
Not irrigated	0.0	40	0.0	0
Pasture	0.6	5,905	0.0	121
Peaches & Nectarines	0.0	1	0.0	0
Pears	0.1	1,405	0.1	1,062
Pistachios	0.0	11	0.0	11
Plums	0.0	14	0.0	0
Prunes	0.0	6	0.0	0
Riparian Vegetation	0.9	8,769	0.1	643
Urban	7.5	71,105	0.8	7,968
Walnuts	0.0	269	0.0	60
Water	1.0	9,800	0.2	2,366

5.1.2 Land Use and Land Cover

A 2010 Mendocino County land use and land cover survey serves as the best available representation of conditions within the UVIHM domain. These land uses were translated into each HRU through spatial processing. This land use data is used to discretize models spatially, inform crop types in IDC, assign hydrologic properties, and determine groundwater pumping and surface water diversions in GSFLOW. Land use types were reclassified to fewer categories for UVIHM. A summary of the distribution of the reclassified land use for the Upper Russian River Watershed is presented in **Table 5.1** and **Figure 5.2**.

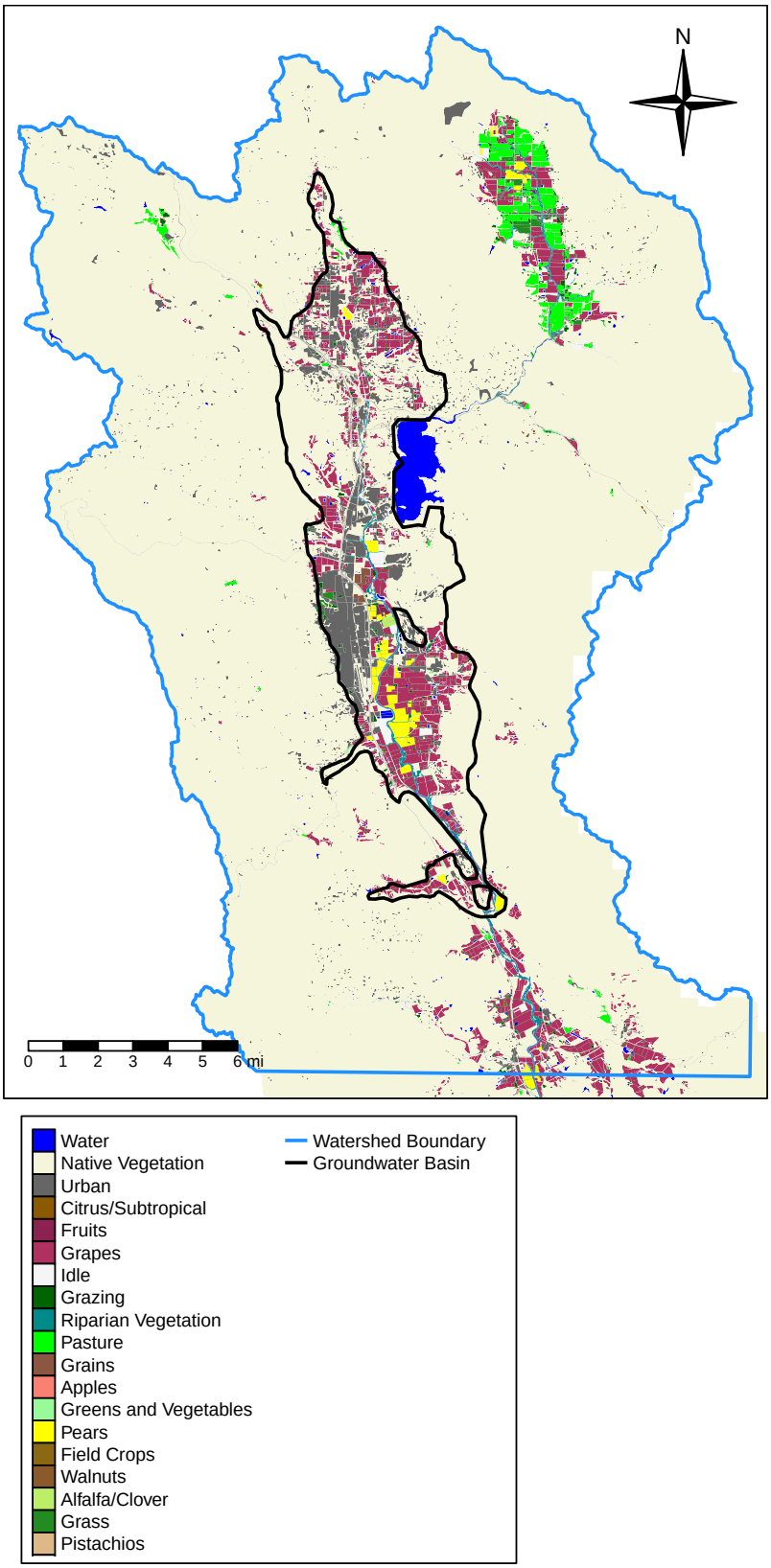

Figure 5.2: Land use distribution in the Upper Russian River Watershed.

5.1.3 Hydrography

Hydrography within the Ukiah watershed was established using a series of terrain processing tools to establish surface drainage patterns, flow directions, and flow paths using the high-resolution one-meter LiDAR-derived DEM. This Ukiah Watershed hydrography was compared to the USGS National Hydrography Dataset (NHD),[1] and stakeholders were consulted to resolve inconsistencies or disagreements between datasets. The revised and validated representation of hydrography within the Ukiah watershed is presented in **Figure 5.1**.

The resulting hydrography is implemented into the UVIHM through a stream network comprised of 208 stream segments and 4574 MODFLOW cells that also reflect the extent of PRMS HRUs. Stream segments are numbered from north to south generally and according to the flow direction. Flow direction and cell by cell cascade for the stream network are calculated similarly to the general cascade calculation based on the mean cell elevations extracted from the DEM. **Figure 5.3** shows the hydrography along with the HRU and MODFLOW cell representation that is built into the UVIHM.

[1] https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset?qt-science_support_page_related_con=0#qt-science_support_page_related_con

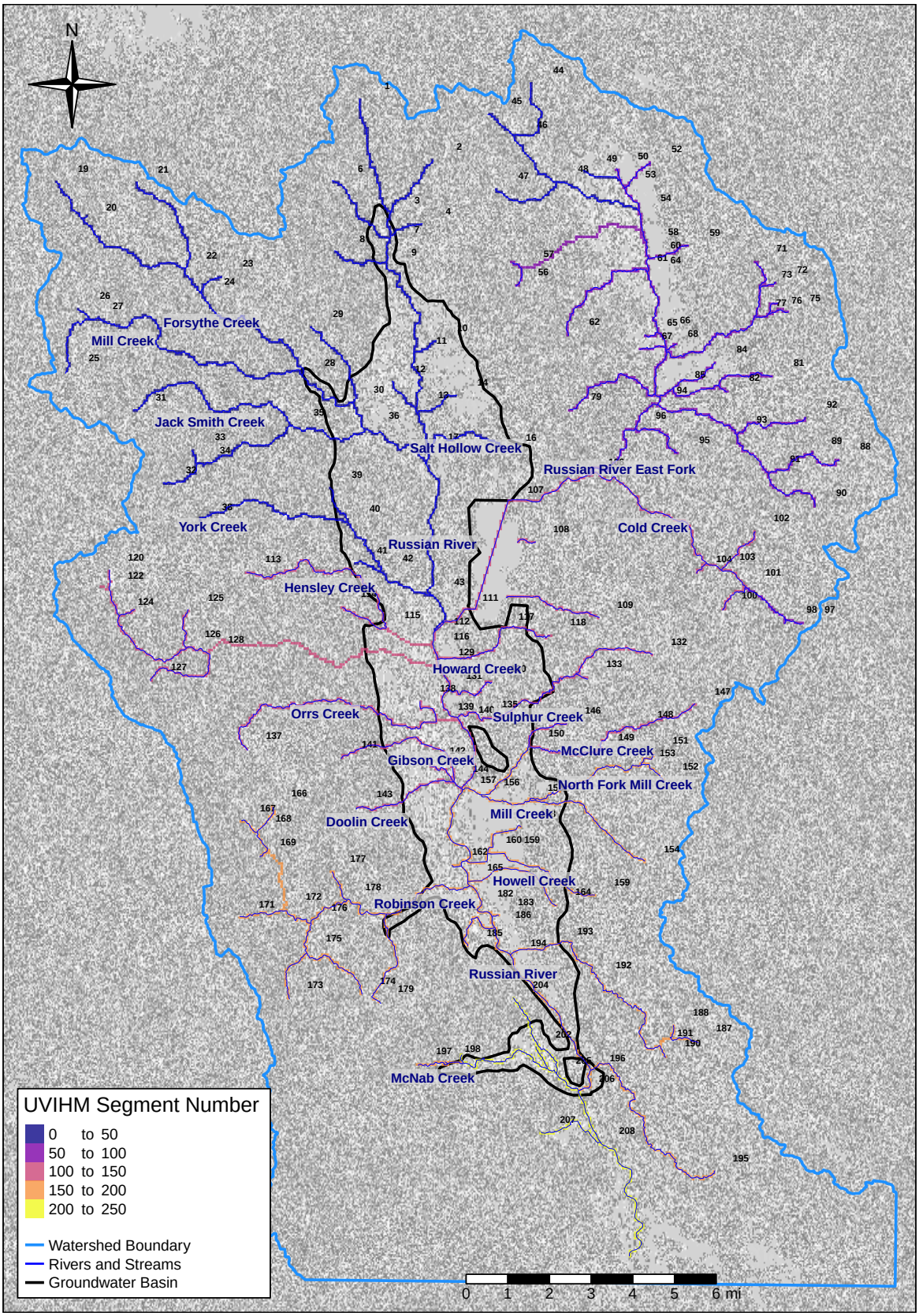

Figure 5.3: Calculated and refined stream network and its representation in the UVIHM.

5.1.4 Soil Parameters

Physical properties and hydraulic parameters of soils were adapted from the SSURGO dataset. Soil types were extracted for each HRU and MODFLOW Cell based on the first hydrologic soil type assigned to that cell/HRU. A summary of the distribution of soil classes within the Watershed as incorporated into UVIHM is presented in **Figure 5.4**.

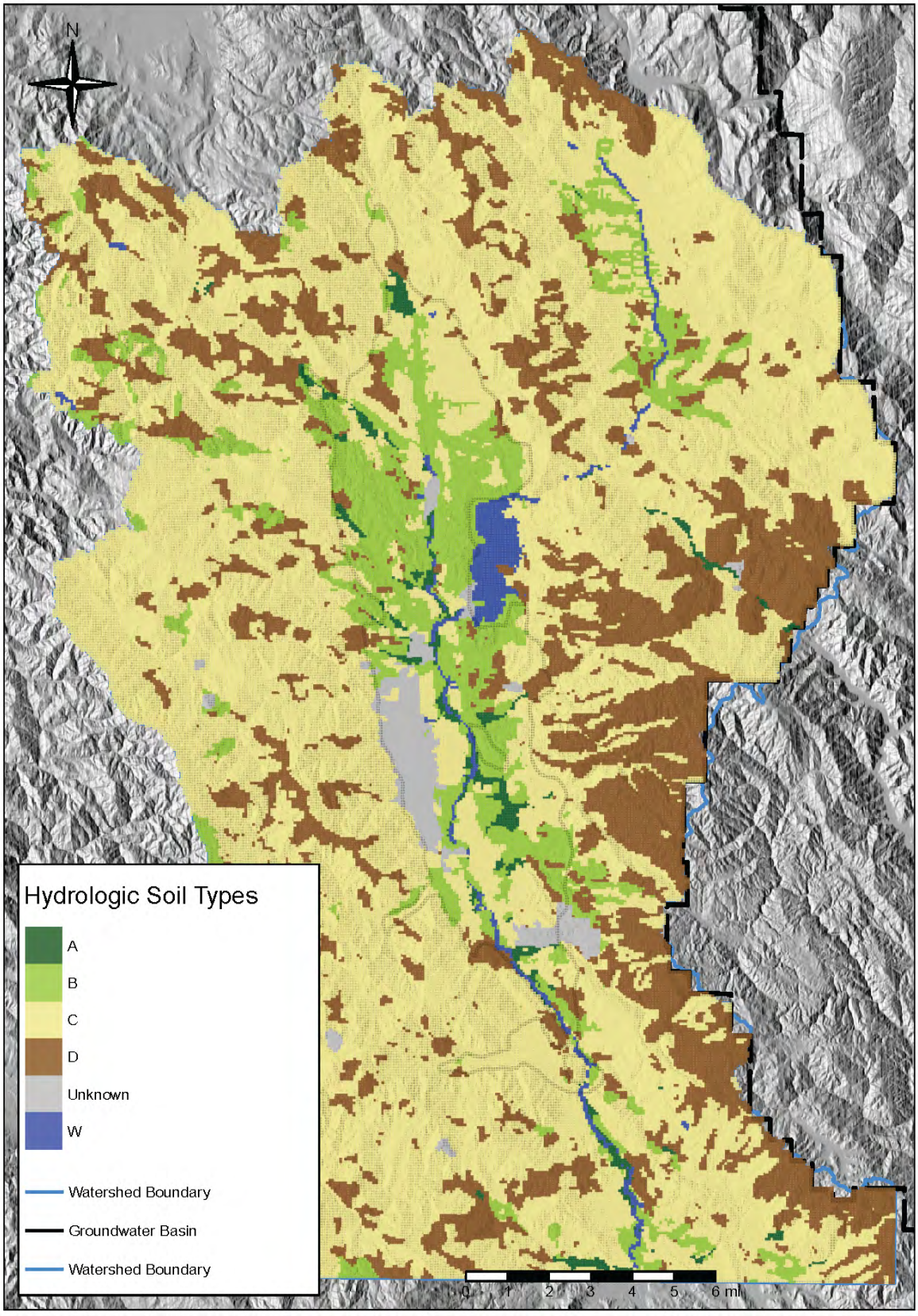

Figure 5.4: Hydrologic soil types as incorporated into the UVIHM.

Table 5.2: Initial aquifer hydraulic properties and parameter ranges set for the UVIHM.

Aquifer Parameters	Parameters Ranges	Initial Values
Hydraulic conductivity (Kx,y):		
Layer 1: Channel Alluvium	5 – 60 m/d	60 m/d
Layer 2: Terrace Deposit	0.03 – 4.5 m/d	3 m/d
Layer 3: Continental Deposit	0.003 – 0.2 m/d	0.15 m/d
Specific Storage (SS)		
Layers 1&2	0.00001 - 0.1	1E-3
Layer 3	0.00001 - 0.01	1E-4

5.1.5 Vegetation Type

There are 5 types of vegetation cover within PRMS: bare soil, grasses, shrubs, trees, and coniferous correlating to 0 through 4, respectively. The vegetation types are generalized and interact with other variables to account for native vegetation water consumption and use. Distribution of vegetation type was done based on the Land Use and Crop Map data shown in **Table 5.1** and **Figure 5.2** above.

5.1.6 Hydrofacies Hydraulic Properties (Aquifer Properties)

Initial values for model layer hydraulic properties were set, assuming each layer to be homogenous and representing a vertical anisotropy estimated at 10% of the horizontal hydraulic conductivity. Each model layer's initial specific storage values are based on the properties outlined in **Chapter 2** of the GSP. **Table 5.2** lists the initial values and ranges considered for aquifer parameters.

5.2 Climate Data

5.2.1 Precipitation and Temperature

PRMS is capable of interpolation, scaling, and assigning precipitation totals by HRU using a number of methods and modules. The UVIHM uses the xyz_dist combined climate module driving a process where precipitation and temperature are distributed to each HRU using a multiple linear regression of observed data from a series or array of precipitation gages based on the elevation and distance of the gages and the respective HRUs.

Daily precipitation and temperature datasets were obtained from the California Data Exchange Center (CDEC) and the National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center Climate Data Online portal, reformatted, and incorporated into the PRMS model. A summary of the attributes of precipitation and temperature gages are summarized in **Table 5.3** and **Table 5.4**, respectively. The distribution of precipitation and temperature gages calculated as the annual average over the entire active modeling area is presented in **Figure 5.6** and **Figure 5.7**, respectively. The distribution of precipitation and temperature gages is presented in **Figure 5.5**.

Table 5.3: Precipitation gage summary as incorporated into the UVIHM.

Station Name	Source of Data	Start Date as Implemented in UVIHM	End Date as Implemented in UVIHM	Latitude	Longtitude	Gage Elevation
CDW	CDEC	2010-02-08	2018-12-31	39.2031	-123.1853	670
LYO	CDEC	2010-12-23	2017-04-09	39.1250	-123.0710	3200
POTTER VALLEY POWERHOUSE, CA US	NOAA	1965-01-01	2018-12-31	39.3619	-123.1286	1018
UKIAH 4 WSW, CA US	NOAA	1965-01-01	2018-11-30	39.1266	-123.2719	1328
UKIAH MUNICIPAL AIRPORT, CA US	NOAA	2001-01-01	2018-12-31	39.1258	-123.2008	601
UKIAH, CA US	NOAA	1965-01-01	2013-05-24	39.1466	-123.2102	636
WIL	CDEC	1991-01-01	2018-12-31	39.3506	-123.3217	1925
WILLITS 1 NE, CA US	NOAA	1965-01-01	2012-09-27	39.4194	-123.3425	1353

Table 5.4: Temperature gage summary as incorporated into the UVIHM.

Station Name	Source of Data	Start Date as Implemented in UVIHM	End Date as Implemented in UVIHM	Latitude	Longtitude	Gage Elevation
BOONVILLE CALIFORNIA, CA US	NOAA	1991-01-01	2018-12-31	38.9875	-123.3486	644
CDW	CDEC	2010-02-08	2018-12-31	39.2031	-123.1853	670
HOPLAND CALIFORNIA, CA US	NOAA	2001-10-04	2018-12-31	39.0308	-123.0806	2682
LYO	CDEC	1991-06-01	2018-12-31	39.1250	-123.0710	3200
POTTER VALLEY POWERHOUSE, CA US	NOAA	1965-01-01	2018-12-31	39.3619	-123.1286	1018
Q03	CDEC	2014-01-10	2016-03-21	39.3771	-123.3280	1447
UKIAH MUNICIPAL AIRPORT, CA US	NOAA	2001-01-01	2018-12-31	39.1258	-123.2008	601
UKIAH, CA US	NOAA	1965-01-01	2013-05-24	39.1466	-123.2102	636
WIL	CDEC	2009-10-27	2013-06-12	39.3506	-123.3217	1925
WILLITS 1 NE, CA US	NOAA	1965-01-01	2012-09-27	39.4194	-123.3425	1353

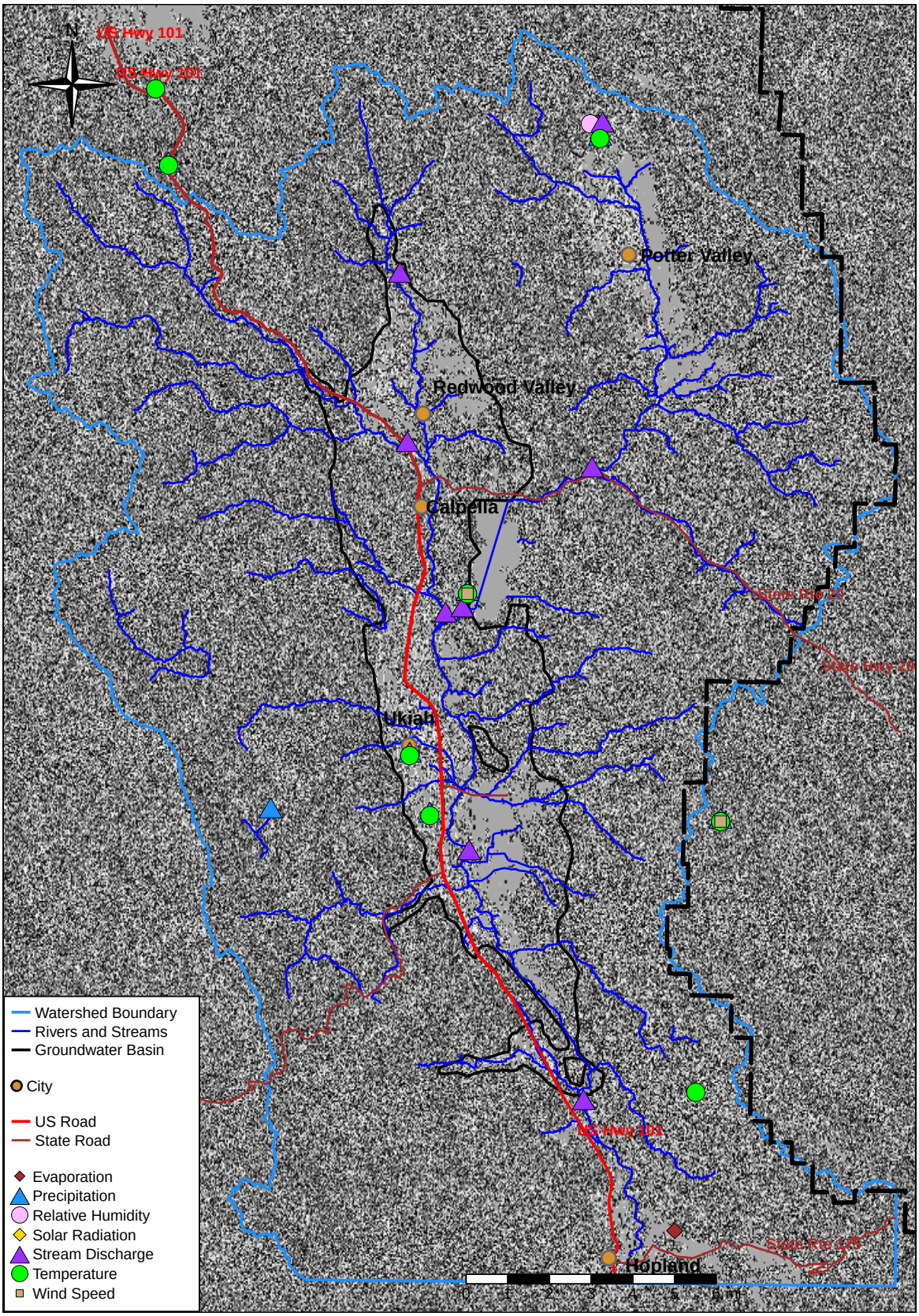

Figure 5.5: UVIHM representations of hydrgraphy and atmospheric gage locations.

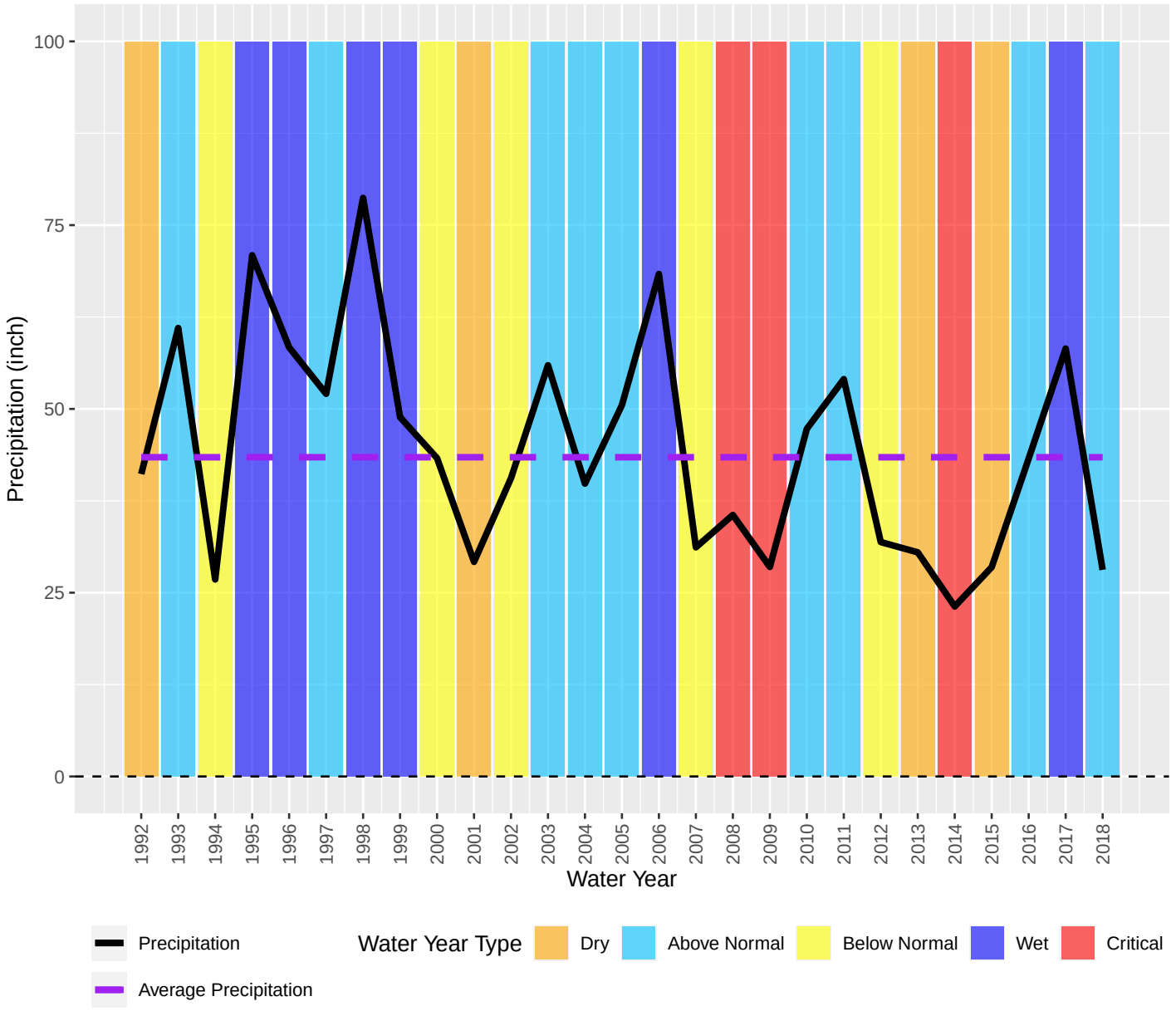

Figure 5.6: Historical precipitation and water year types for the upper Russian River watershed calculated by the UVIHM.

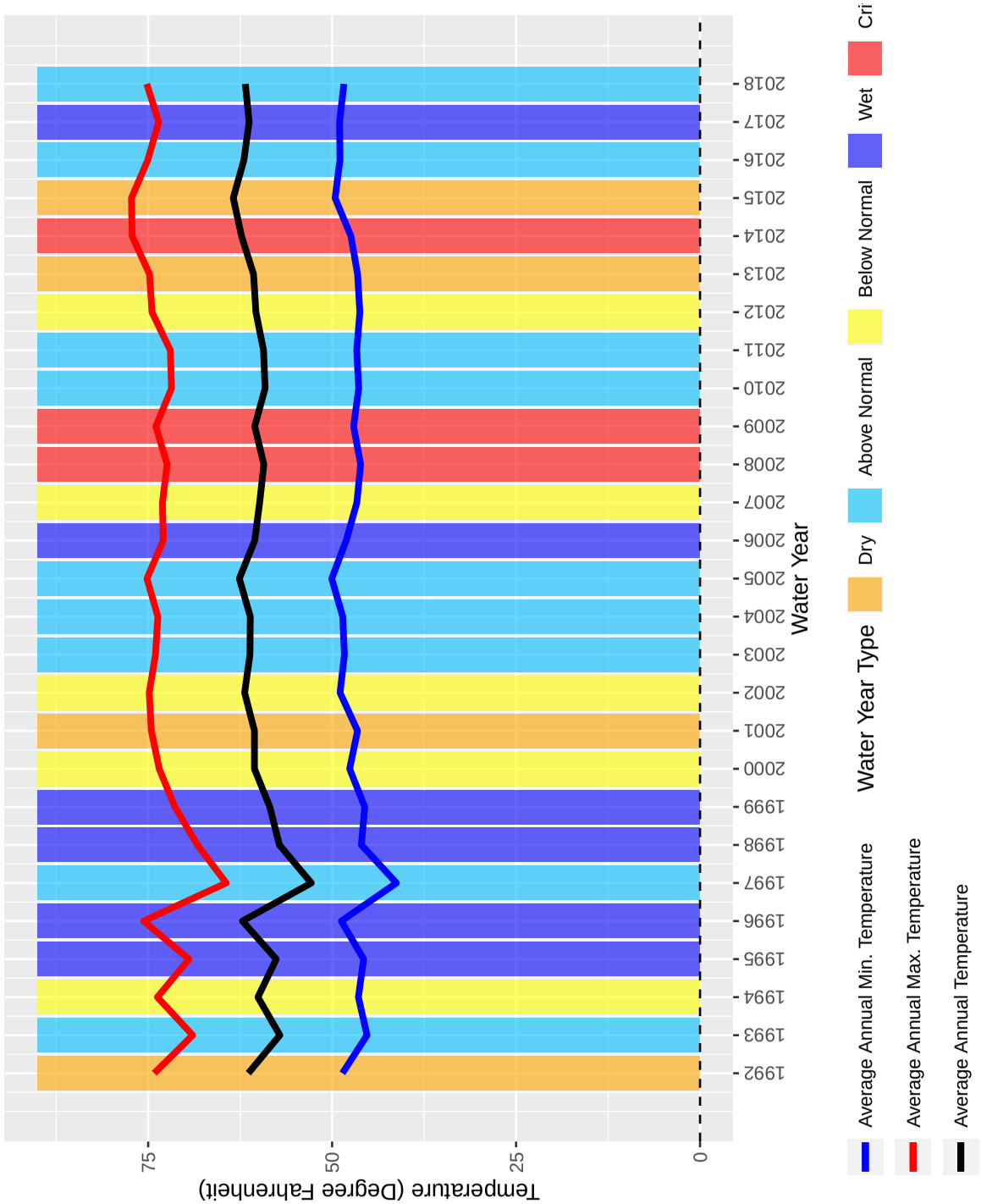

Figure 5.7: Historical temperature and water year types for the Upper Russian River Watershed calculated by the UVIHM.

Table 5.5: Solar radiation gage summary as incorporated into the UVIHM.

Station Name	Source of Data	Start Date as Implemented in UVIHM	End Date as Implemented in UVIHM	Latitude	Longtitude	Gage Elevation
CDW	CDEC	2010-12-23	2018-12-31	39.2031	-123.1853	670
LYO	CDEC	2010-12-23	2014-04-26	39.1250	-123.0710	3200

5.2.2 Potential Evapotranspiration

Daily potential evapotranspiration was computed for HRU by the *potet_hs* module within PRMS as a function of daily air temperature and solar radiation using the Hargreaves-Samani method. A comprehensive discussion of the Hargreaves-Samani method can be found on page 90 of the Appendix 1 of the PRMS model documentation.

Daily solar radiation records were obtained from two CDEC gages and incorporated into PRMS. The *ddsolrad* module was used to distribute daily solar radiation estimates using a relationship between maximum temperature and degree-day. A summary of solar radiation time series by gage is presented in **Table 5.5**. The distribution of climatic gages is presented in **Figure 5.5**.

5.3 Stream Network Data

The stream network implemented in the UVIHM is explained in **Section 5.1.3**. Stream network propertied are needed for both PRMS and MODFLOW parts of the GSLFOW and the UVIHM. MODFLOW SFR package requires stream lengths, stream thickness, hydraulic conductivity of the streambed, and stream slope within each stream cell. Cascading order of the stream segments, headwater flow or diversion flow at each stress period, and method and properties needed to calculate stream depth are needed to be defined. Cascading order is also defined separately in PRMS. In addition, PRMS requires Muskingum routing parameters, storage coefficient and routing weighting factor, to be defined for each segment.

The UVIHM MODFLOW-NWT uses Manning's equation to calculate stream depth in stream segments. This option assumes a rectangular channel for the streams. Therefore, stream and reach profile dimensions were estimated as input for the UVIHM. Reach lengths were estimated through spatial processing of stream network line features within each MODFLOW cell. To calculate stream widths absent measured data and mapping, one-meter resolution LiDAR DEM was used. Cell elevations were mapped at specific cross-sections of stream segments to build an approximate river profile. Stream widths were manually estimated at each profile and incorporated into the SFR for each segment's beginning and end. For the purpose of this estimation, the depth of the profile is considered to be the length from the point where a change in the side slope is observed to the bottom of the profile. stream width is calculated as the median width of this profile. **Figure 5.8** shows one sample of the streambed profiles produced for the stream network. Cell elevations were also used to estimate stream slope within each reach cell.

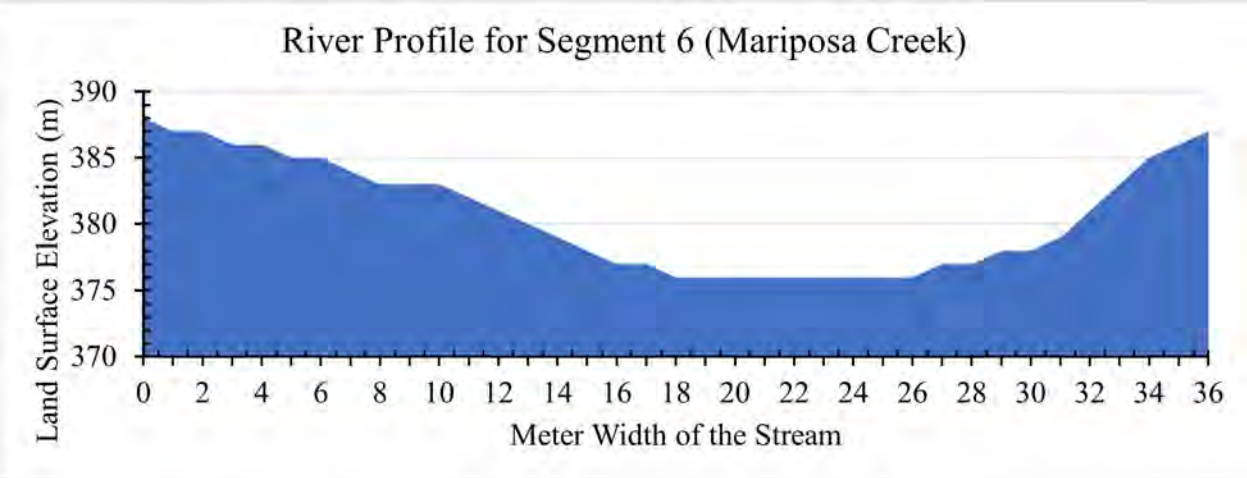

Figure 5.8: A sample streambed profile built from DEM for segment 6.

Table 5.6: Initial streambed properties and parameter ranges set in the UVIHM.

Stream Parameters	Parameters Ranges	Initial Values
Streambed Thickness		
Alluvial West Fork Russian River	1.5 – 2 m	2 m
Regulated Russian River Mainstem	1 – 1.5 m	1 m
Unconfined Alluvial Channels	0.4 – 0.6 m	0.4 m
Bedrock and Confined Alluvial	0.2 – 0.4 m	0.2 m
Streambed Hydraulic Conductivity		
Alluvial West Fork Russian River	0.006 - 0.01 m/d	0.006 m/d
Regulated Russian River Mainstem	0.003 - 0.006 m/d	0.003 m/d
Unconfined Alluvial Channels	0.01- 0.1 m/d	0.01 m/d
Bedrock and Confined Alluvial	0.1 - 0.2m/d	0.2m/d

ISRP (2015) provides a conceptual stream typology for the Russian River Watershed. It characterizes the streams into seven different channel types based on the depth and type of alluvial deposits and the degree of natural channel confinement. Bedrock canyon streams, confined alluvial channels, semiconfined alluvial channels, dissected alluvium channels, alluvial fan channels, unconfined alluvial channels, and regulated channels are the seven stream types identified for the Russian River Watershed. Following this characterization, four different categories of stream segments were defined in UVIHM. Mainstem Russian River is divided into two categories: 1) Alluvial West Fork Russian River, which includes the length of the river in Redwood Valley and up to the confluence with the East Fork Russian River, and 2) Regulated Russian River Mainstem that extends from the confluence to the drainage of the Basin and represents the incised portion of the River. Russian River tributaries are divided into categories following ISRP (2015) categories: 1) unconfined alluvial channels that include dissected alluvium channels and unconfined alluvial channels, and 2) bedrock and confined alluvial that includes confined and semi-confined alluvial channels ad bedrock canyon streams. Initial streambed properties and their respective calibration ranges were set based on the defined four categories, as shown in **Table 5.6**. The spatial distribution of these categories as incorporated into the UVIHM grid is shown in **Figure 5.9**.

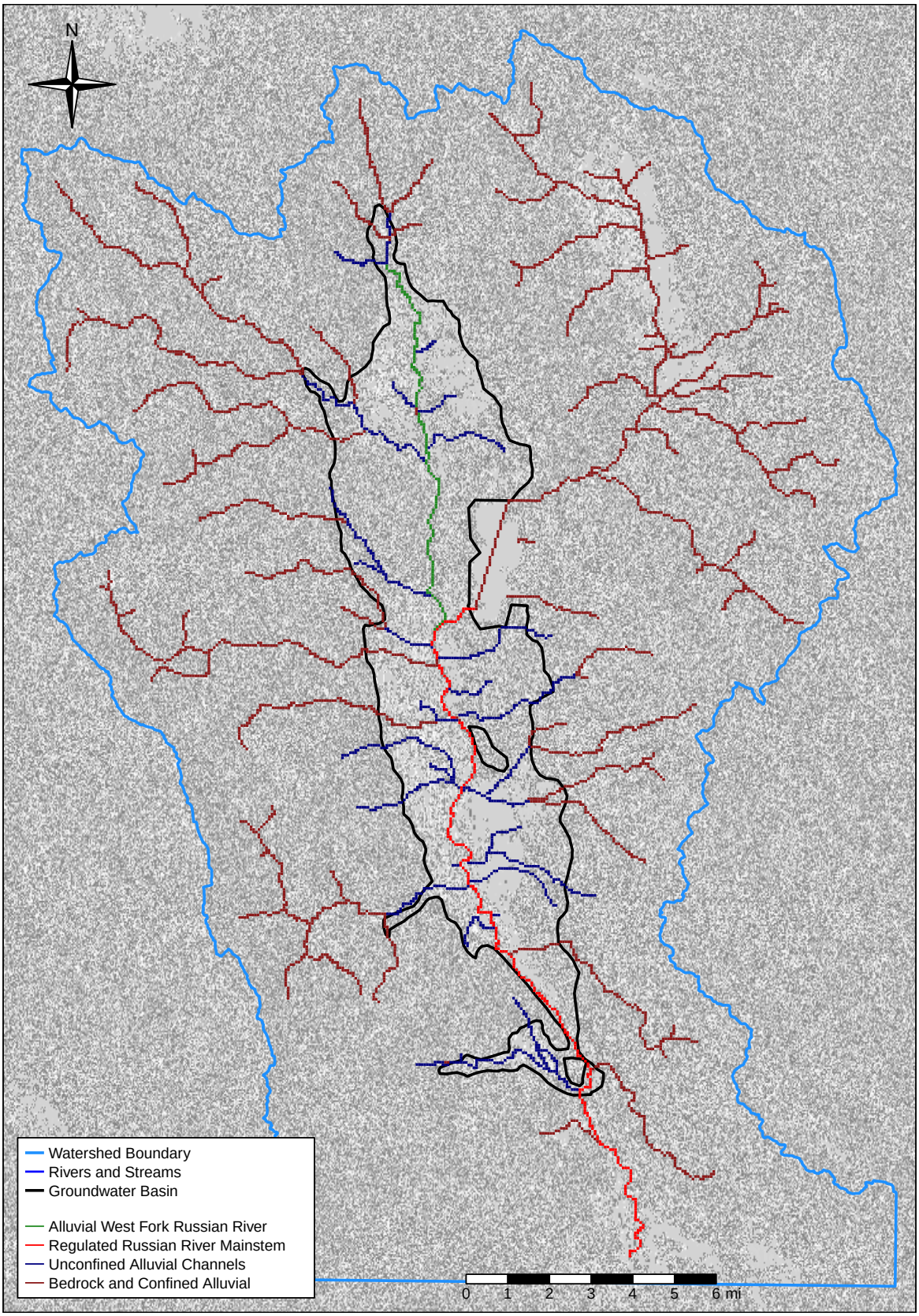

Figure 5.9: Stream typology used in the UVIHM to assign streambed properties.

5.4 Water Use

Water use in the Basin is divided into three major categories: municipal use, non-municipal domestic use, and agricultural use. All three categories have historically utilized surface water and groundwater as their supply. Municipal use in the Basin is limited to the City. Non-municipal domestic use is supplied through the small water agencies and purveyors in the Basin. The City and the small water agencies may supply water to non-urban users such as industrial, commercial, and agricultural.[2]

Agricultural water use includes irrigation and applied water used in the Basin. Agricultural parcels in the Basin commonly use groundwater wells for both their irrigation and domestic use. De minimis users of water and domestic users outside the service areas of water agencies and water purveyors are not incorporated into this analysis and this stage of GSP development due to insufficient data to assess their demand and water use. This data gap will be addressed during the GSP implementation and at the discretion of the GSA through the implementation of PMAs in **Chapter 4** of the GSP.

5.4.1 Municipal Water Use

The City's supply portfolio includes surface water, groundwater, recycled water, and supplies purchased from other agencies (Carollo Engineers, 2011). The City has a pre-1914 appropriative right, and additional water right permits to divert water from the mainstem Russian River. The City also draws groundwater from the Basin through multiple wells distributed across its footprint. The City also collects wastewater from its collection system and the Ukiah Valley Sanitation District's collection system at its Ukiah Wastewater Treatment Plant (UWWTP). The UWWTP discharges disinfected secondary and tertiary effluent to three percolation/evaporation ponds on a year-round basis, and discharges disinfected tertiary effluent to the Russian River as needed during wet weather months. The UWWTP is permitted to discharge disinfected tertiary wastewater to the Russian River from October 1 through May 14 at a discharge rate of up to one percent of the total Russian River flow. The City has started delivering recycled water to agricultural customers along the Russian River through its Purple Pipe Project in late 2019. Treated water stored at UWWTP ponds that is not delivered to recycled water users infiltrates and recharges the groundwater Basin and contributes to the Russian River streamflow.

Historical water use, including groundwater pumping and surface water diversions, was obtained from the City of Ukiah from 1991-2015. The data was used in the UVIHM and water budget analysis for the GSP, as shown in **Figure 5.10**. The period of 2016-2018 is considered a data gap. For GSP and model development purposes, the City's water use during this period is assumed to be equal to the 2015 calendar year.

[2] the City supplies recycled water to agricultural users outside the Basin

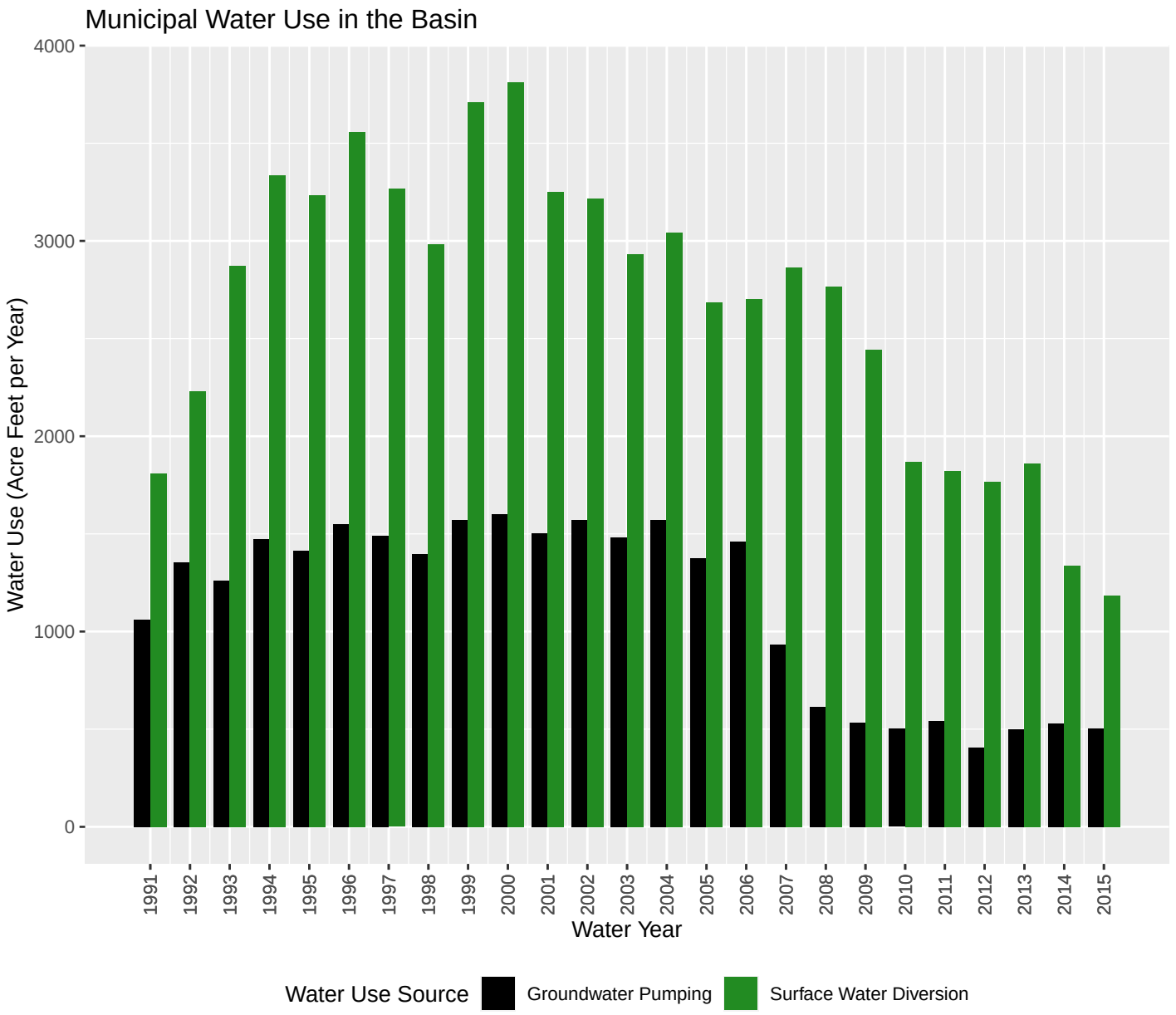

Figure 5.10: Municipal water use in the Basin.

5.4.2 Non-municipal Domestic Water Use

Non-municipal domestic water use refers to water supplied by small water agencies and water purveyors in the Basin including the Russian River Flood Control and Water Conservation Improvement District (RRFC), Calpella County Water District (CWD), Millview CWD, Redwood Valley CWD, Rogina Water Company Inc, Willow CWD, Yokayo tribe, and the City of 10,000 Buddhas. Surface water from the Russian River and its tributaries and groundwater are the primary sources of supply for these water suppliers. However, not all of them use groundwater as a supply source.

Water use estimates for this category were generated using the data supplied by these agencies. Similar to the City's water use, data provided by the agencies covered period from 1991 to 2015 and was extended to the end of 2018, assuming a constant supply equal to 2015. Surface water diversion and groundwater use data was received from all the water suppliers mentioned above except for the Yokayo tribe and the City of 10,000 Buddhas. In addition, Rogina Water Company's groundwater use data was not obtained and is not included in the UVIHM. RRFC supplied surface water supply through 2020. Its data was fully applied to water use estimates and incorporated in the UVIHM.

In addition to water use, Millview CWD, Calpella CWD, and Rogina Water Company conduct limited spreading recharge in their supply practices. The details of these recharge practices were not made clear to the GSA for the GSP development. However, Calpella CWD shared its recharge rates with the GSA. Calpella CWD net water use was considered as the subtraction of their recharge from their water use. This assumption was applied to both water use calculations here and water use data incorporated in the UVIHM. Yearly non-domestic water use divided into surface water diversions and groundwater pumping is shown in **Figure 5.11**.

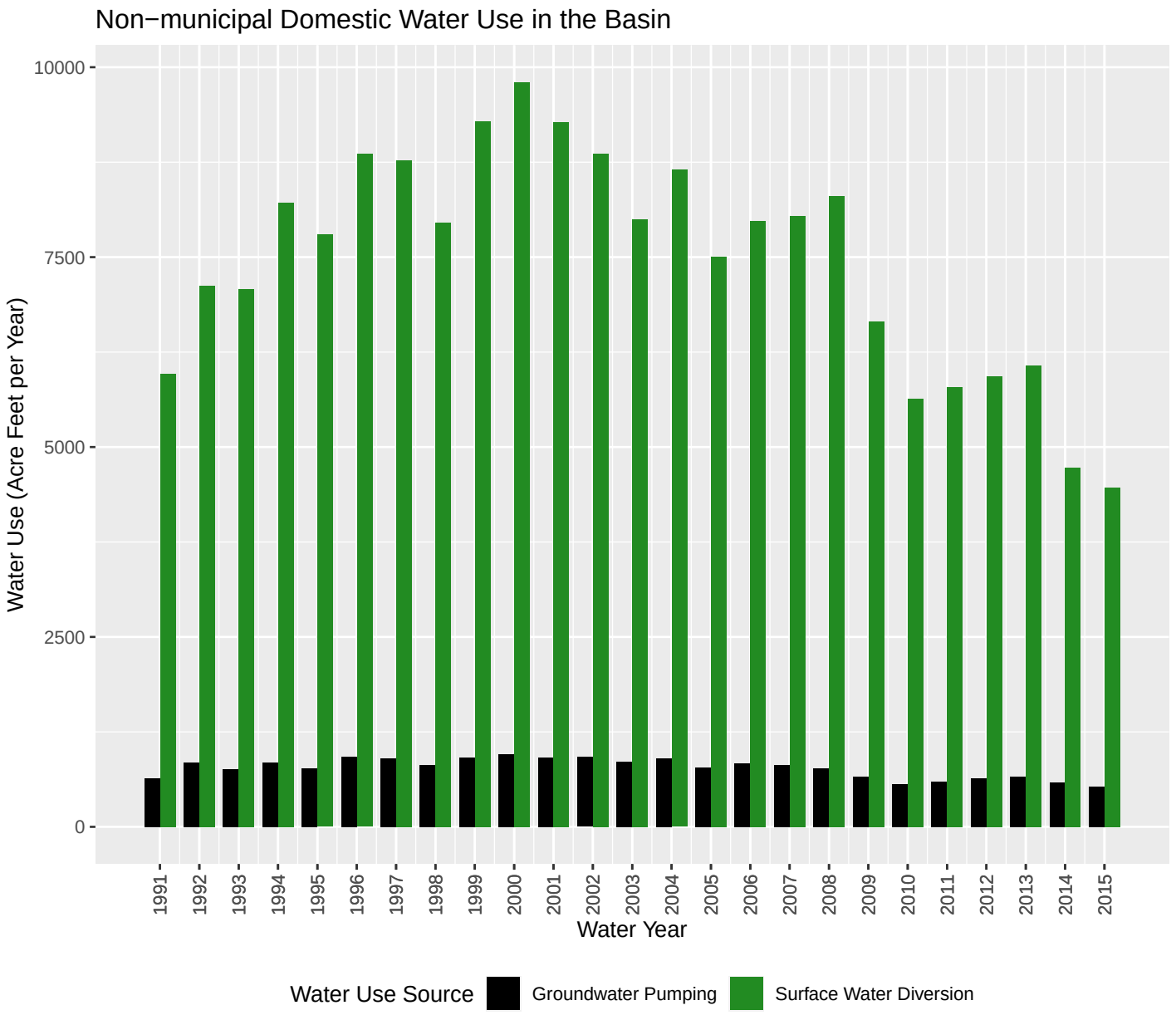

Figure 5.11: Non-municipal domestic water use in the Basin.

5.4.3 Agricultural Water Use

Agricultural water use in the Basin is primarily focused on crop irrigation for grapes, pears, and pasture along with small acreages of other crops as outlined in **Section 5.1.2**. This use may also include frost, heat, and post-harvest irrigation for grapes and pears. Cannabis cultivation has grown in recent years in Mendocino County and to some extent in the Basin. At the time of development of the GSP and the UVIHM, reliable data regarding the cannabis cultivation extents, their respective irrigation practices, and their water use did not exist. This is a data gap that will be addressed during GSP implementation and for the 5-year review of the GSP upon availability of better data and further model calibration.

Groundwater use in the Basin for agricultural and domestic users is not metered and no data was made available to the GSA for agricultural groundwater pumping. Surface water diversions for agricultural uses may be extracted from water rights reports and water agencies' allocations. However, these avenues are cumbersome and were not pursued by the GSA due to their complexity and scope. In order to estimate the agricultural water use in the Basin and cover this important data gap, the GSA implemented IDC simulation into the UVIHM. The IDC model setup, including its discretization and input data is discussed in sections above.

5.5 Aritificial Recharge and Additional Water Supplies

Artificial or managed aquifer recharge is not currently conducted in the Basin except for the recharge practices undertaken by the Calpella CWD, Millview CWD, and Rogina Water Company. The only other significant source of recharge in the Basin is the UWWTP percolation ponds. UWWTP also discharges to the mainstem Russian River on an as-needed basis which may lead to streambed recharge and improve streamflow conditions in the Basin. Recharge from percolation ponds was simulated in the UVIHM through surface depression storages in PRMS. River discharges made by the UWWTP were simulated through direct injection to appropriate stream segments using MODFLOW's SFR package. Data for the quantity of water transferred to the percolation ponds and discharged into the river were obtained from the City of Ukiah and the California Integrated Water Quality System Project (CIWQS).

The City started delivering recycled water through its purple pipe project in late 2019. Recycled water users are primarily agricultural users along the mainstem Russian River north of the UWWTP that supplement their irrigation and frost control water with recycled water. While recycled water deliveries are outside the historical and current periods considered for the GSP and the UVIHM, they are implemented for future baseline period and projected scenarios. Recycled water deliveries help reduce pumping and surface water diversion near the Russian River, increasing groundwater levels and reducing surface water depletion in those areas. The quantity of the recycled water delivered is also obtained from the CIWQS. UWWTP percolation ponds, river discharges, and recycled water deliveries are shown in **Figure 5.12**.

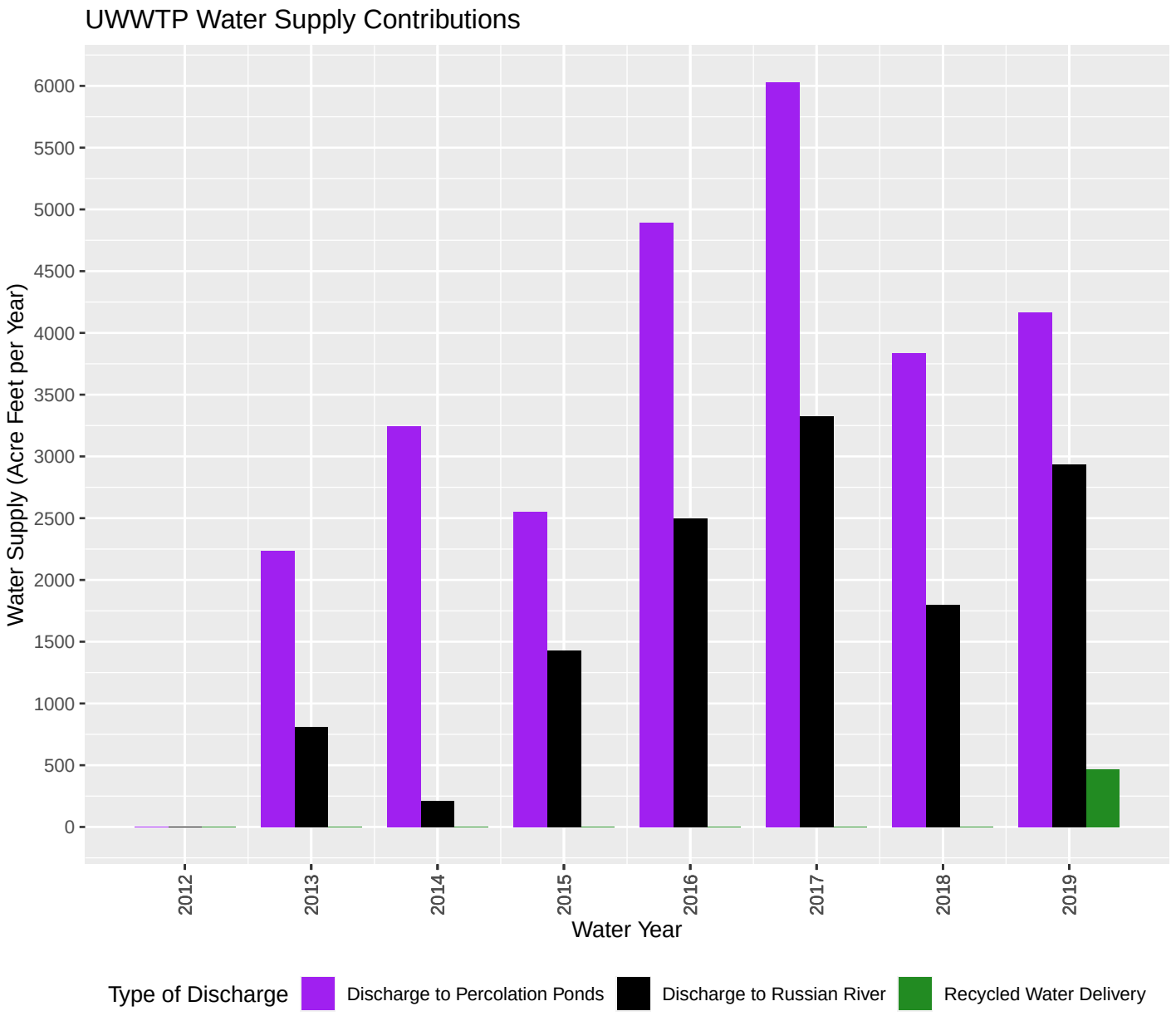

Figure 5.12: City of Ukiah Wastewater Treatment Plant recycled water delivery and discharges to the river and percolation ponds.

Chapter 6

UVIHM Sensitivity Analysis and Calibration

The UVIHM GSFLOW transient model, which ran from WY1991-2018, was calibrated with the groundwater elevation and streamflow targets described in this section. The calibration period was limited to 2014-2018 due to data limitations regarding available groundwater elevation data in the Basin. The sensitivity analysis and calibration software UCODE2014[1] was applied to the UVIHM. UCODE2014 uses the sum of square weighted residuals as the objective function for determining the model's ability to match observations. Preliminary calibration was conducted on the groundwater flow system, but due to data gaps and data limitations, additional calibrations will be done in the next rounds of GSP 5-year reviews upon collection of additional data and information to update and enhance the model.

MODFLOW and PRMS were initially calibrated independently of the GSFLOW to maximize the efficiency of the calibration process. The calibrated parameter set was then used for subsequent coupled calibration of GSFLOW. A preliminary calibration of solar radiation estimations was done for PRMS prior to the three levels of calibrations using streamflow and groundwater level data. Solar radiation data outlined in **Section 5.2.2** was used to calibrate the ddsolrad module of the UVIHM PRMS.

6.1 PRMS-only Calibration

6.1.1 Calibration Targets and Objective Function

A combination of calibration targets were chosen to capture runoff and streamflow dynamics in the Russian River mainstem and contributing tributaries in the Ukiah Valley Basin. Calibration was conducted by minimizing a set of objective functions for simulated and observed values using an automated procedure with the UCODE calibration software.

Russian River High, Mid and Low-Streamflow Calibration Targets

[1] 6https://igwmc.mines.edu/wp-content/uploads/sites/117/2018/11/UCODE_2014_User_Manual-version02.pdf

A subset of daily streamflow data from the USGS Hopland gage (11462500) at the outlet of the Russian River[2] from the Basin were used as calibration targets during a 5–year period (1/1/2014–12/31/2018). A subset of high, mid, and low-flow calibration targets were developed from the 5-year dataset to reduce the total number of calibration targets specified (**Figure 6.1**). High, mid, and low-flow calibration targets were chosen by visual inspection, with the high-flow targets (n[3]=65) coinciding with peak flow conditions, mid-flow targets (n[4]=147) coinciding with rising and falling limbs of the hydrograph when flows are changing rapidly, and low-flow targets (n[5] =53) corresponding typically with low-flow periods during the dry season.

In addition to select daily average streamflow observations, two other statistics were chosen as calibration targets to capture the “shape” of the simulated and observed streamflow hydrograph. These statistics, the auto-regressive lag-1 correlation (AR-1) and Coefficient of Variation of daily flow (CV) represent the day-to-day timing of flow and the “flashiness”[6] of flow, respectively. These statistics were calculated for all daily streamflow observations during the 5–year calibration period.

[2]The USGS Hopland Gage (11462500) is not located at the outlet of the Basin. However, due to its proximity, it is assumed to represent the flows at the outlet of the Basin in the UVIHM

[3]n: number of observation points]

[4]n: number of observation points]

[5]n: number of observation points]

[6]Flashiness reflects the frequency and rapidity of short term changes in stream flow in response to storm events. Streams that rise and fall quickly are considered flashy.

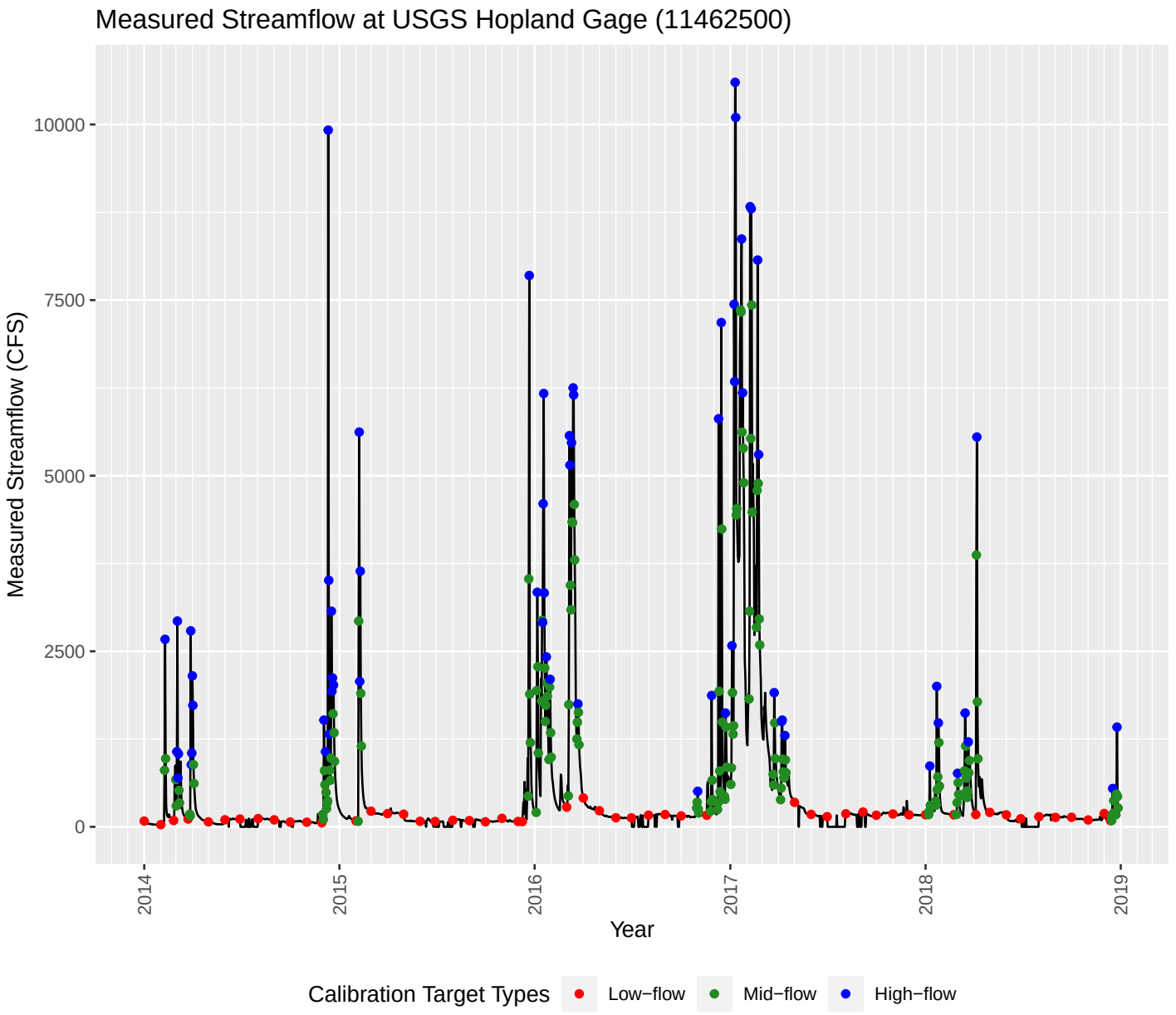

Figure 6.1: Daily measured streamflow from the USGS Hopland gage, along with high, mid, and low-flow calibration targets.

Table 6.1: Tributary gages used as additional streamflow calibration points.

Tributary Name	Coordinates (meters, UTM NAD83 zone 10S)	Period of Record	Operating Entity
McNab Creek #1	484794 E, 4321364 N	3/2016-12/2018	CLSI
McNab Creek #2	483538 E, 4321244 N	1/2014-12/2018	CLSI
Salt Hollow Creek #1	482689 E, 4345261 N	1/2018-12/2018	CLSI
Salt Hollow Creek #2	484393 E, 4345042 N	1/2018-12/2018	CLSI
Hensley Creek	481268 E, 4339766 N	1/2018-12/2018	CLSI
McClure Creek	486225 E, 4333187 N	3/2014-12/2018	CLSI
Mill Creek	473728 E, 4348037 N	9/2017- 12/2018	CW3E

Tributary Streamflow Calibration Targets

In addition to calibration targets selected for the Russian River at the Basin outlet, streamflow data that have been collected for several contributing tributaries were chosen as additional calibration targets. Because daily streamflow observations for these tributaries are statisticaly noisy and uncertain, monthly average streamflows were chosen as calibration targets for these tributaries. **Table 6.1** shows the tributary names, locations and periods of record chosen for calibration.

6.1.2 Model Parameters Included in the Calibration Procedure

Selection of model parameters to be included in the calibration process followed guidance provided by Douglas-Mankin and Moeser (2019) , which specified that 34 of 108 total parameters for PRMS should be included in the PRMS calibration process. **Figure 6.2** shows the 34 calibrated parameters, their description, PRMS module, and acceptable ranges for each. Because the UVIHM PRMS model does not simulate snow-related processes, the total number of adjustable parameters included in the calibration process was further reduced to 25. The remaining parameters were not varied during the calibration. Initial values were specified as the default values in PRMS.

Parameter name	Description	PRMS module	Range
adjmix_rain	Factor to adjust rain proportion in a mixed rain/snow event	Climate	0.6–1.4
tmax_allrain	Maximum air temperature above which precipitation is rain	Climate	−8.0–60.0
tmax_allsnow	Maximum air temperature below which precipitation is snow	Climate	−10.0–40.0
dday_intcp	Intercept in degree–day equation	Solar radiation	−60.0–10.0
dday_slope	Slope in degree–day equation	Solar radiation	0.2–0.9
ppt_rad_adj	Solar radiation adjustment threshold for precipitation days	Solar radiation	0.0–0.5
radj_sppt	Solar radiation adjustment on summer precipitation days	Solar radiation	0.0–1.0
radj_wppt	Solar radiation adjustment on winter precipitation days	Solar radiation	0.0–1.0
radmax	Maximum solar radiation caused by atmospheric effects	Solar radiation	0.1–1.0
tmax_index	Temperature to determine precipitation adjustments to solar radiation	Solar radiation	−10.0–110.0
jh_coef	Coefficient used in Jensen–Haise potential ET computations	Potential ET	0.005–0.06
jh_coef_hru	Coefficient used in Jensen–Haise potential ET computations	Potential ET	5.0–25.0
srain_intcp	Summer rain interception storage capacity	Interception	0.0–1.0
wrain_intcp	Winter rain interception storage capacity	Interception	0.0–1.0
cecn_coef	Convection condensation energy coefficient	Snow	2.0–10.0
emis_noppt	Average emissivity of air on days without precipitation	Snow	0.757–1.0
freeh2o_cap	Free-water holding capacity of snowpack	Snow	0.01–0.2
potet_sublim	Snow sublimation fraction of potential ET	Snow	0.1–0.75
carea_max	Maximum area contributing to surface runoff	Surface runoff	0.0–1.0
smidx_coef	Nonlinear contributing area coefficient	Surface runoff	0.001–0.06
smidx_exp	Exponent in nonlinear contributing area coefficient	Surface runoff	0.1–0.5
fastcoef_lin	Linear coefficient in equation to route preferential flow	Soil zone	0.001–0.8
fastcoef_sq	Nonlinear coefficient in equation to route preferential flow	Soil zone	0.001–1.0
pref_flow_den	Fraction of the soil zone in which preferential flow occurs	Soil zone	0.0–0.1
sat_threshold	Water capacity between field capacity and total saturation	Soil zone	1.0–999.0
slowcoef_lin	Linear coefficient for interflow routing	Soil zone	0.001–0.5
slowcoef_sq	Nonlinear coefficient for interflow routing	Soil zone	0.001–1.0
soil2gw_max	Maximum soil-water excess that is routed directly to groundwater	Soil zone	0.0–0.5
soil_moist_max	Maximum available water-holding capacity of soil zone	Soil zone	0.001–10.0
soil_rechr_max	Maximum available water-holding capacity of recharge zone	Soil zone	0.001–5.0
ssr2gw_exp	Nonlinear coefficient in equation used to route soil-zone water to groundwater	Soil zone	0.0–3.0
ssr2gw_rate	Linear coefficient in equation used to route soil-zone water to groundwater	Soil zone	0.05–0.8
transp_tmax	Temperature that determines start of the transpiration period	Soil zone	0.0–1000.0
gwflow_coef	Linear groundwater discharge coefficient	Groundwater	0.001–0.5

Figure 6.2: Parameters used during model calibration (Douglas-Mankin and Moser,2019).

6.1.3 Sensitivity Analyses

Composite Scaled Sensitivity (CSS) results for the 25 adjustable parameters selected for the calibration procedure are shown in **Figure 6.3**. CSS results describe the relative importance (i.e., the sensitivity) of each parameter with respect to each of the model output observations. CSS results are further ranked according to each contributing model output observation group. As shown in **Figure 6.3**, the tributary flow group was the most important of all the observation groups by a substantial margin. The highest CSS value was for soil_moist_max, which describes the water-holding capacity of the soil zone. Of the 25 parameters, 7 had CSS values equal to zero, indicating no sensitivity. Nine of the 25 parameters had CSS values greater than 2 orders-of-magnitudes less than the CSS value for soil_moist_max. Using the 2 order-of-magnitude threshold, these 9 parameters were included the subsequent model calibration.

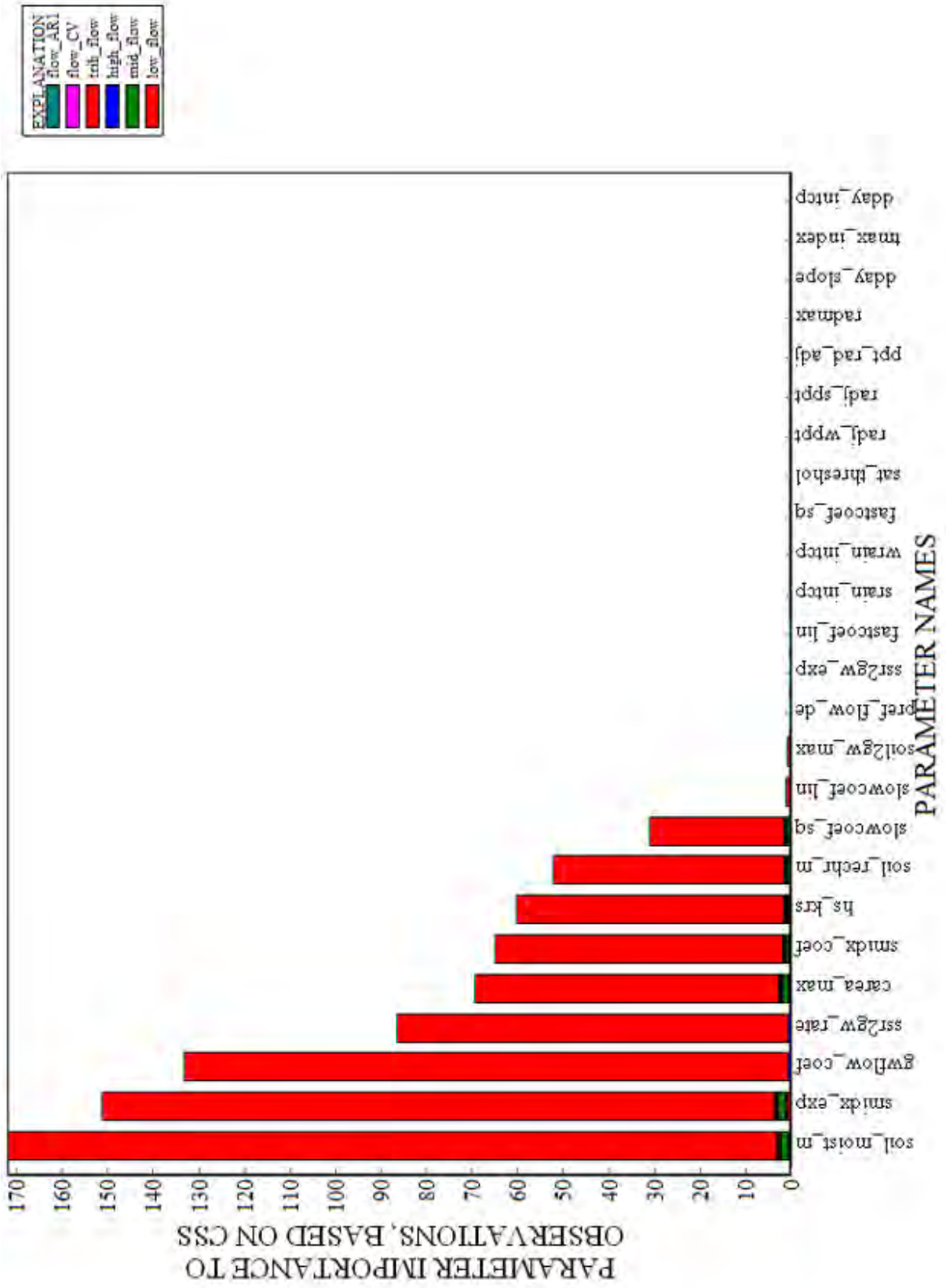

Figure 6.3: Composite-Scaled Sensitivity (CSS) for the 25 parameters included in the sensitivity analysis procedure.

6.1.4 Calibration Results

Calbirated Parameters

The final calibrated parameter set for the 25 adjustable parameters is shown in **Table 6.2**.

Streamflow Hydrographs

Nash-Sutcliffe Efficiency (NSE) for simulated vs. observed daily streamflow for 2014–2018 for the Basin outlet at the Russian River Hopland stream gage was 0.62, indicating fairly robust agreement between simulate and observed streamflow. Simulated and observed streamflow are shown in **Figure 6.4**. Importantly, model agreement was especially robust during low-flow periods that are important for water management. Simulated and observed monthly average streamflow for the seven gaged tributaries are shown in **Figure 6.5**. Because the rating curves for these gages typically incorporate very few measurements, observed streamflow measurement can be assumed to be fairly uncertain. Thus, the agreement between simulated and observed streamflow for these streams were not treated with the same importance as for those at the outlet of the Basin at the Hopland gage. Importantly, the timing of low-flows and high-flow periods for simulated and observed flows were generally consistent for most of the streams.

Table 6.2: Final calibrated parameter values for PRMS-only calibration along with the parameter groups and parameter ranges.

Parameter Name	Parameter Group Name	Final Calibrated Value	Lower Value Range	Upper Value Range
dday_intcp	Solar Radiation	-4.000e+01	-6e+01	10.00
dday_slope	Solar Radiation	4.000e-01	2e-01	0.90
ppt_rad_adj	Solar Radiation	2.000e-02	0e+00	0.50
radj_sppt	Solar Radiation	4.400e-01	0e+00	1.00
radj_wppt	Solar Radiation	5.000e-01	0e+00	1.00
radmax	Solar Radiation	8.000e-01	1e-01	1.00
tmax_index	Solar Radiation	5.000e+01	-1e+01	110.00
hs_krs	Potential ET	3.340e-02	5e-03	1.00
srain_intcp	Interception	1.066e-01	0e+00	1.00
wrain_intcp	Interception	1.870e-04	0e+00	1.00
carea_max	Surface runoff	6.014e-01	0e+00	1.00
smidx_coef	Surface runoff	2.440e-02	1e-03	0.06
smidx_exp	Surface runoff	4.035e-01	1e-01	0.50
fastcoef_lin	Soil Zone	1.899e-01	1e-03	0.80
fastcoef_sq	Soil Zone	1.237e+01	1e-03	1.00
pref_flow_den	Soil Zone	1.410e-03	0e+00	0.10
sat_threshold	Soil Zone	1.996e+03	1e+00	999.00
slowcoef_lin	Soil Zone	1.370e-03	1e-03	0.50
slowcoef_sq	Soil Zone	1.720e-02	1e-03	1.00
soil2gw_max	Soil Zone	9.540e-04	0e+00	0.50
soil_moist_max	Soil Zone	3.258e+00	1e-03	10.00
soil_rechr_max	Soil Zone	1.372e+00	1e-03	5.00
ssr2gw_exp	Soil Zone	8.030e-04	0e+00	3.00
ssr2gw_rate	Soil Zone	5.120e-02	5e-02	0.80
gwflow_coef	Groundwater	2.730e-03	1e-03	0.50

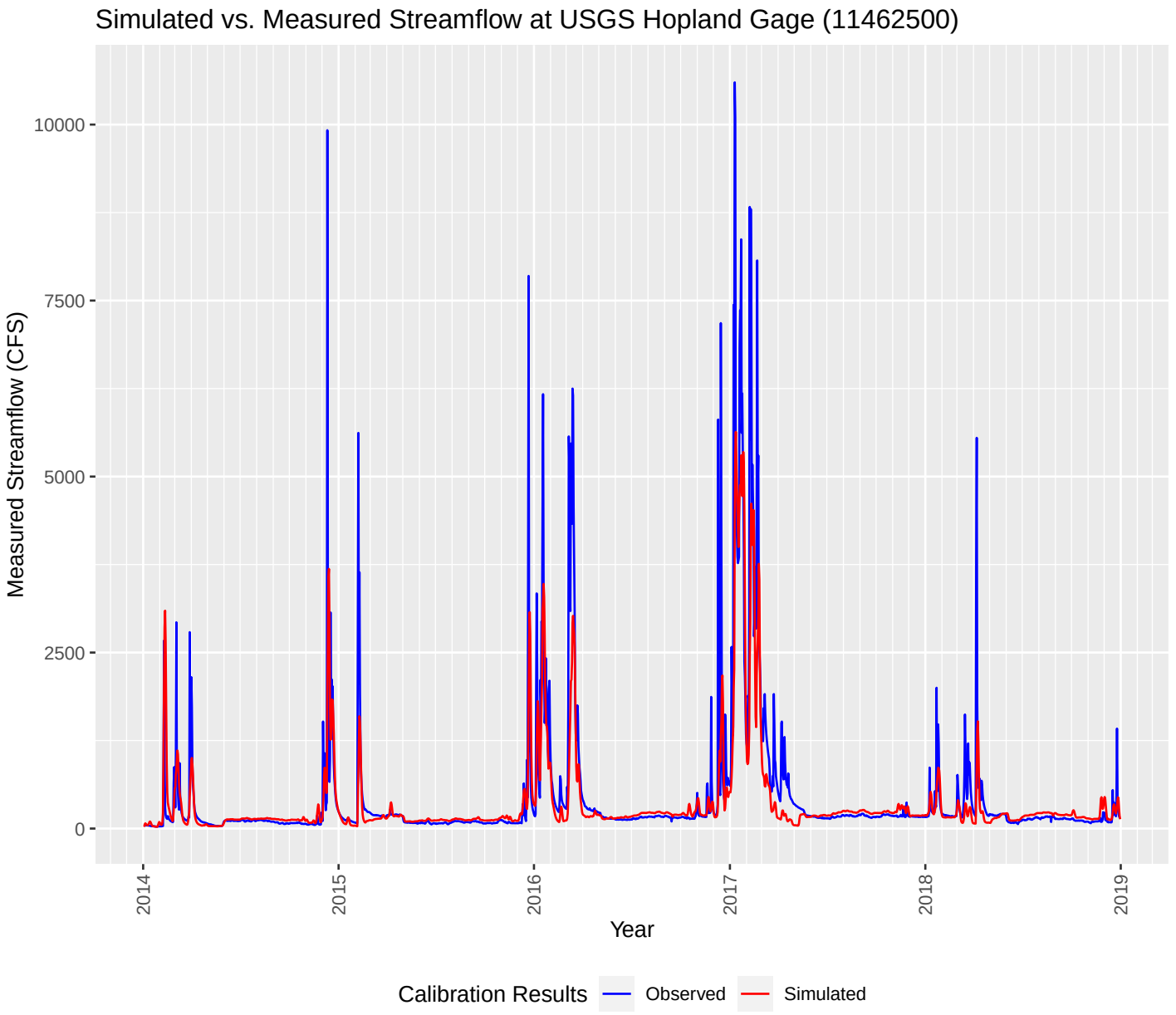

Figure 6.4: Simulated vs. observed daily streamflow for 2014–2018 for the watershed outlet at the Russian River Hopland stream gage (Log scale).

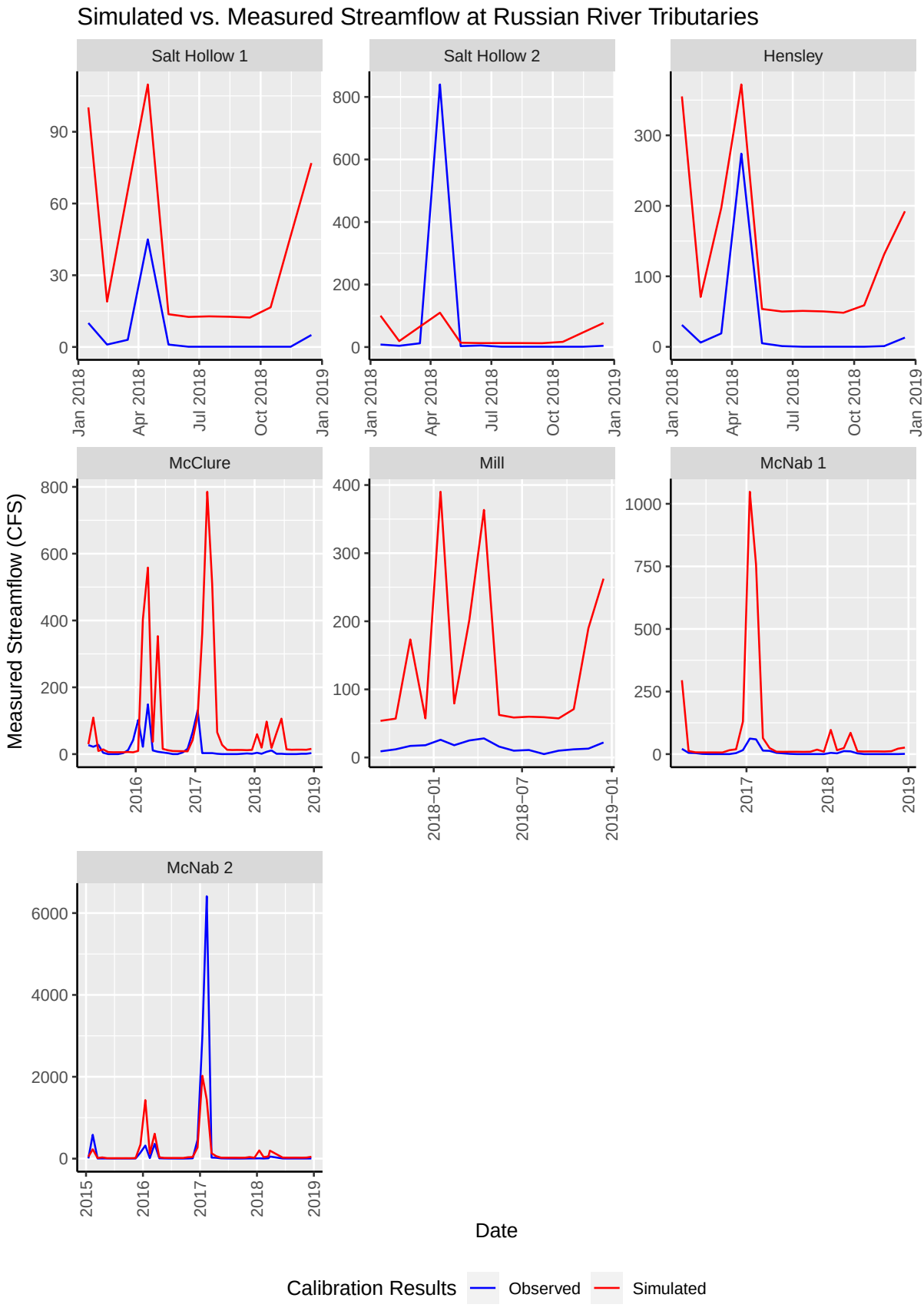

Figure 6.5: Simulated vs. observed monthly streamflow for measure tributaries to the Russian River.

6.2 MODFLOW-only calibration

6.2.1 Calibration Targets and Objective Function

A combination of calibration targets were chosen to capture groundwater head and streamflow dynamics in the Russian River mainstem in the Basin. Calibration was conducted by minimizing a set of objective functions for simulated and observed values using an automated procedure with the UCODE calibration software.

1.1.1. CASGEM groundwater head calibration targets

A combination of 252 groundwater head observations collected at 28 CASGEM well locations within the Basin area were used as calibration targets during a 5–year simulation period (1/1/2014–12/31/2018).

Streamflow Calibration Targets

In addition to CASGEM observations, average monthly streamflows measured at the USGS Hopland stream gage (11462500) at the outlet of the Basin during 2014–2018 were used at calibration targets.

6.2.2 Model Parameters Included in the Calibration Procedure

Model parameters used for the calibration process include horizontal and vertical hydraulic conductivities and specific storage of the three model layers that correspond to the geolgoical formations outlined in the Hydrogelogic Conceptual Model (GSP **Section 2.2.1**). Stream conductance for upper tributaries and the main Russian River channels are also included as calibration parameters.

6.2.3 Sensitivity Analyses

Composite Scaled Sensitivity (CSS) results for the 16 adjustable parameters selected for the calibration are shown in **Figure 6.6**. As shown in **Figure 6.6**, pumping and recharge were the most important parameters, followed by the hydraulic conductivity parameters. Vertical anisotropy of K was shown to be relatively unimportant for all model layers. Since pumping and recharge are calculated dynamically in GSFLOW, and because vertical anisotropy was shown to be relatively unimportant, these parameters are not included in subsequent calibration procedures for the coupled GSFLOW.

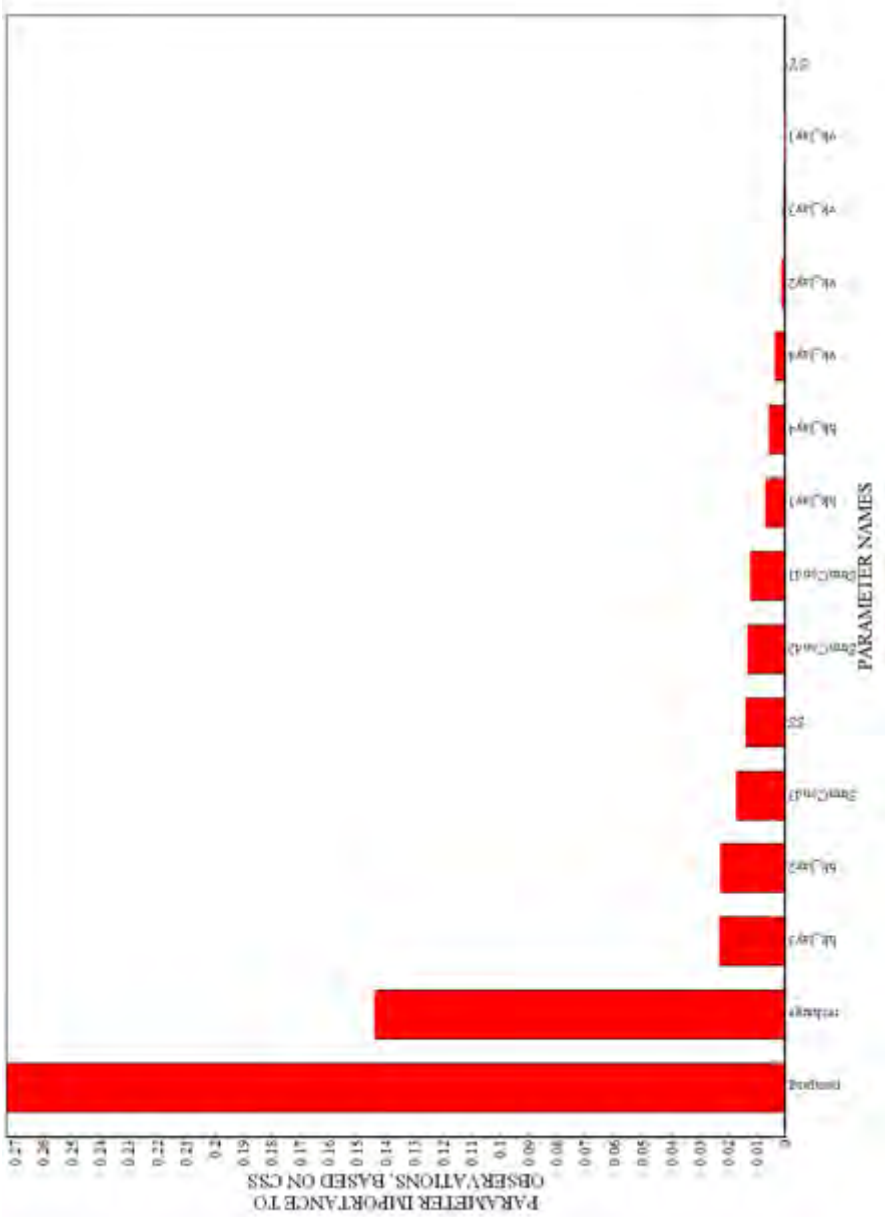

Figure 6.6: Composite-Scaled Sensitivity (CSS) for the 16 parameters included in the initial sensitivity analysis procedure.

Table 6.3: Final calibrated parameter values for MODFLOW-only calibration along with the parameter groups and parameter ranges.

Parameter	Initial value	Calibrated value
Horizontal Hydraulic Conductivity layer 1 (m/d)	6e+01	6.49e+01
Horizontal Hydraulic Conductivity layer 2 (m/d)	3e+00	2.90e-01
Horizontal Hydraulic Conductivity layer 3 (m/d)	5e-01	1.80e-02
Specific Storage layer 1	1e-04	2.00e-05
Specific Storage layer 2	1e-04	2.00e-05
Specific Storage layer 3	1e-05	6.00e-06
UplandStream Conductance (m/d)	1e-02	3.00e-03
Lowland Stream Conductance (m/d)	3e-03	9.40e-01
Recharge adjustment factor	1e+00	4.00e-01

6.2.4 Calibration Results

Calbirated Parameters

The calibrated parameter set for the 25 adjustable parameters is shown in **Table 6.3**.

Groundwater Heads

Uncalibrated and calibrated groundwater heads are shown in a 1:1 plot in **Figure 6.7**, where each point is shown as the average of total number of observations at each well location. Calibration showed significant improvement in model agreement between simulated and observed heads, with uncalibrated and calibrated root mean square errors (RMSE) of 54 ft and 28 ft, respectively. Results show that heads are substantially over-predicted with the initial calibration in areas along the southern portion of the GSA area. Subsequent analyses described herein were conducted to determine whether these results could be improved by including river entrenchment effects on the mainstem Russian River in the model.

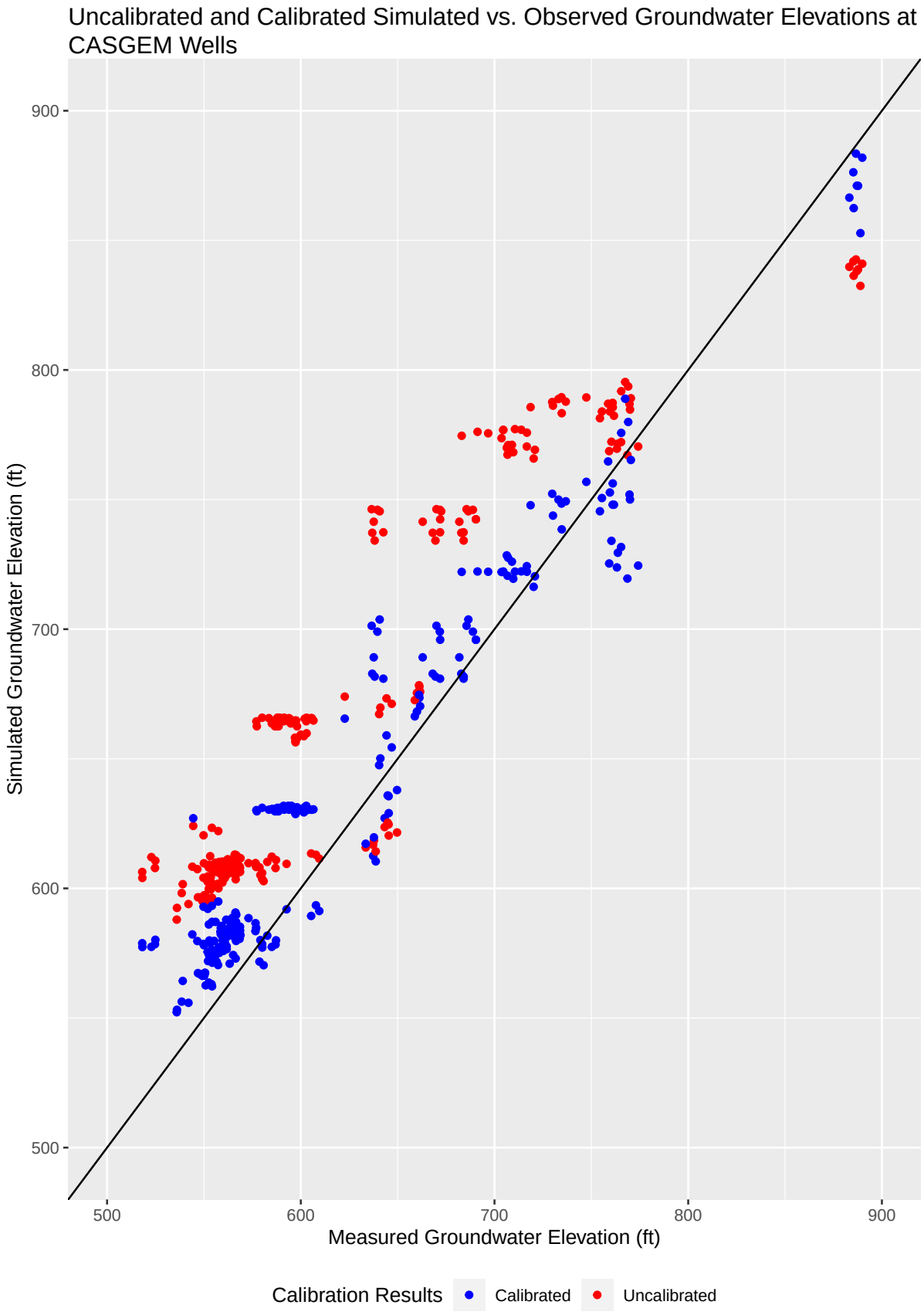

Figure 6.7: Uncalibrated and calibrated simulated vs. observed average groundwater heads for each CASGEM well location during the 2014–2018 calibration period.

Streamflow Hydrographs

Uncalibrated and calibrated monthly-average streamflow hydrographs in **Figure 6.8**. Calibration results show little change between uncalibrated and calibrated versions of the model, with good agreement between simulated and observed flows during the low-flow periods that are important for water management, and less agreement for high-flow periods.

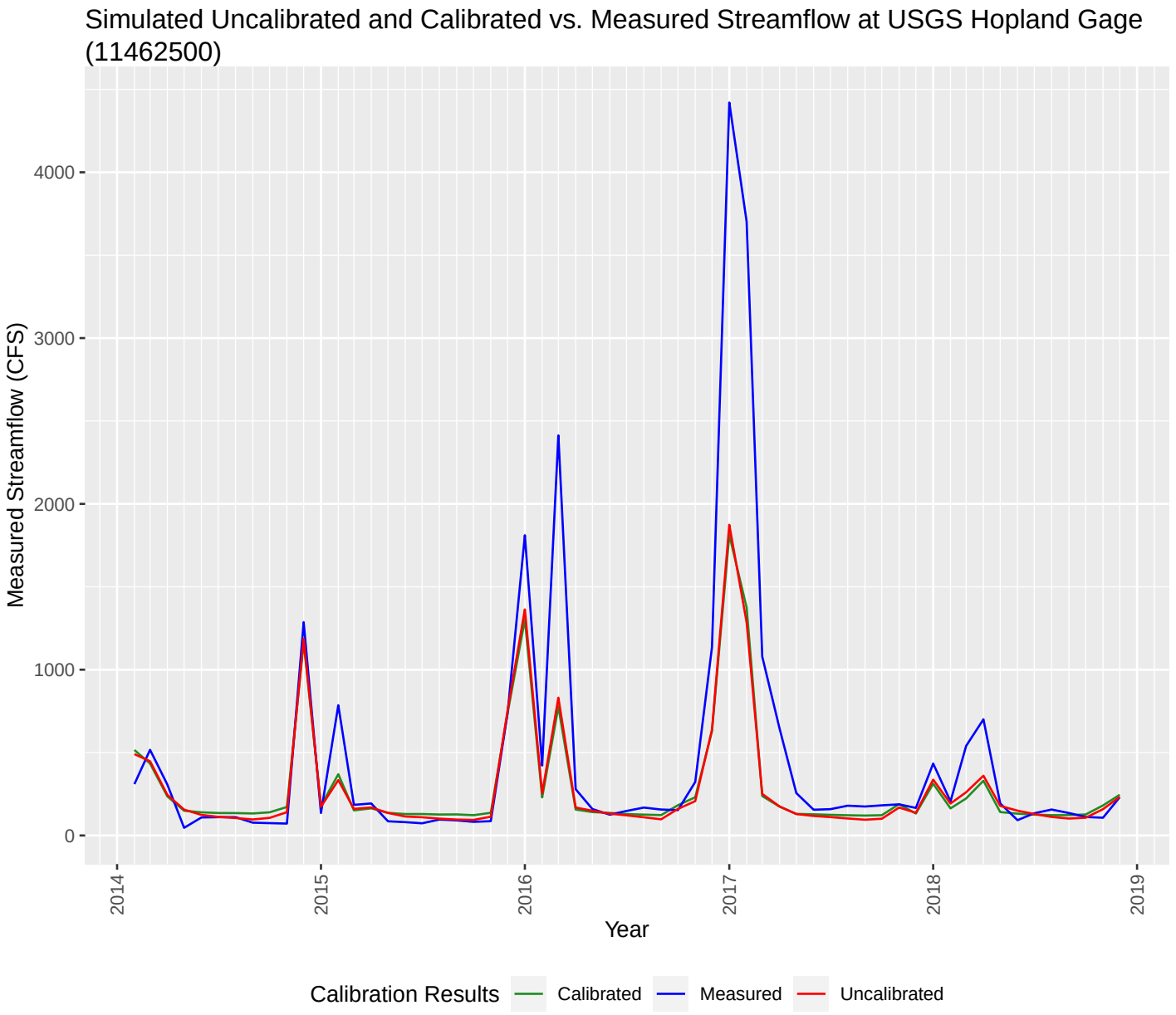

Figure 6.8: Uncalibrated and calibrated simulated vs. observed monthly streamflow averages for 2014–2018 for the Basin outlet at the Russian River Hopland stream gage.

6.2.5 Stream Entrenchment Analysis

Additional adjustments were made to the stream network to assess the effect of Russian River channel entrenchment on groundwater heads in the southern portion of the Basin. For this analysis, streambed elevation was reduced by 20 feet (6.096 m) for 20 stream segments that comprise the main Russian River downstream of the confluence of the East Fork and West Fork Russian River. Results suggest that groundwater heads are sensitive to this adjustment (**Figure 6.9**). However, additional adjustments are required to improve results further.

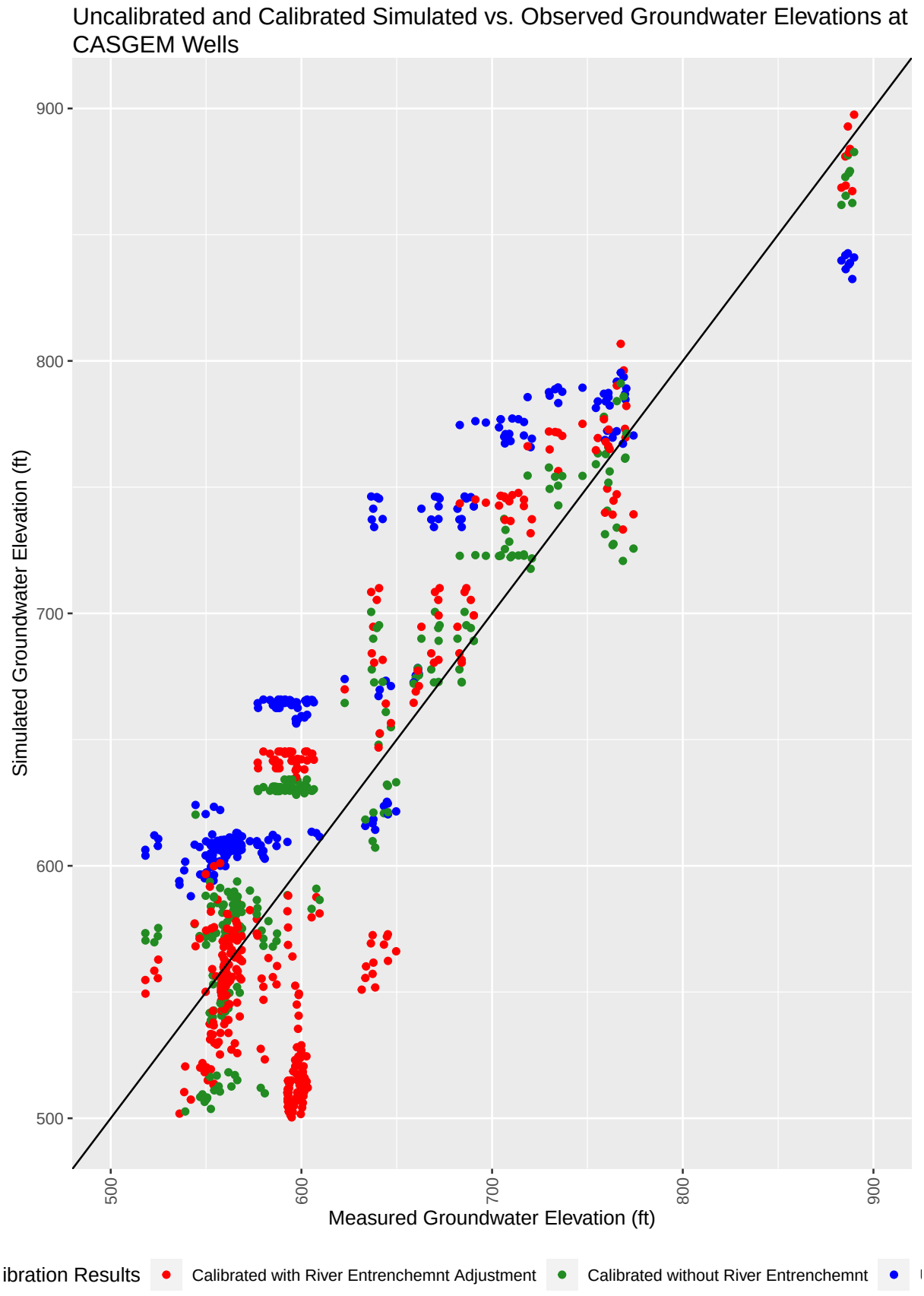

Figure 6.9: Uncalibrated and calibrated simulated vs. observed monthly streamflow averages for 2014–2018 for the Basin outlet at the Russian River Hopland stream gage, along with results from the calibrated version of the model that includes the effect of incision.

6.3 GSFLOW Calibration

GSLFOW calibration was conducted after individual calibration of MODFLOW and PRMS and their coupling into GSFLOW. GSFLOW calibration was done in several rounds with modifications and adjustments based on input from GSA technical committee. Initially, all parameters considered for the individual calibrations of MODFLOW and PRMS were considered for GSFLOW calibration except for MODFLOW recharge adjustment factor and river entrenchment. Due to the computational expense of the calibration process considering the significant runtime for GSFLOW, the number of parameters was reduced to 38 parameters through multiple rounds of sensitivity analysis and calibration. These parameters are shown in **Table 6.4**. The period for calibration was 2014-2018, similar to the individual calibration periods for PRMS and MODFLOW. The number of parameters were further reduced for GSFLOW calibration. The latest round of sensitivity analysis included 24 parameters.

Table 6.4: Parameters included initially in the GSFLOW calibration process.

Parameter Name	Group/Module	Description	Lower Bound	Upper Bound
dday_intcp	PRMS - Solar Radiation	Monthly (January to December) intercept in degree-day equation for each HRU	-6.0e+01	10.00
dday_slope	PRMS - Solar Radiation	Monthly (January to December) slope in degree-day equation for each HRU	2.0e-01	0.90
ppt_rad_adj	PRMS - Solar Radiation	Monthly minimum precipitation, if HRU precipitation exceeds this value, radiation is multiplied by radj_sppt or radj_wppt precipitation adjustment factor	0.0e+00	0.50
radj_sppt	PRMS - Solar Radiation	Adjustment factor for computed solar radiation for summer day with greater than ppt_rad_adj inches precipitation for each HRU	0.0e+00	1.00
radj_wppt	PRMS - Solar Radiation	Adjustment factor for computed solar radiation for winter day with greater than ppt_rad_adj inches precipitation for each HRU	0.0e+00	1.00
radmax	PRMS - Solar Radiation	Monthly (January to December maximum fraction of the potential solar radiation that may reach the ground due to haze, dust, smog, and so forth, for each HRU	1.0e-01	1.00
tmax_index	PRMS - Solar Radiation	Monthly (January to December) index temperature used to determine precipitation adjustments to solar radiation for each HRU	-1.0e+01	110.00
hs_krs	PRMS - Potential Evapotranspiration	Monthly (January to December) adjustment factor used in Hargreaves-Samani potential ET computations for each HRU	5.0e-03	1.00
srain_intcp	PRMS - Interception	Summer rain interception storage capacity for the major vegetation type in each HRU	0.0e+00	1.00
wrain_intcp	PRMS - Interception	Winter rain interception storage capacity for the major vegetation type in each HRU	0.0e+00	1.00
carea_max	PRMS - Surface Runoff	Maximum possible area contributing to surface runoff expressed as a portion of the HRU area	0.0e+00	1.00

smidx_coef	PRMS - Surface Runoff	Coefficient in non-linear contributing area algorithm for each HRU	1.0e-03	0.06
smidx_exp	PRMS - Surface Runoff	Exponent in non-linear contributing area algorithm for each HRU	1.0e-01	0.50
fastcoef_lin	PRMS - Soil Zone	Linear coefficient in equation to route preferential-flow storage downslope for each HRU	1.0e-03	0.80
fastcoef_sq	PRMS - Soil Zone	Non-linear coefficient in equation to route preferential- flow storage downslope for each HRU	1.0e-03	1.00
pref_flow_den	PRMS - Soil Zone	Fraction of the soil zone in which preferential flow occurs for each HRU	0.0e+00	0.10
sat_threshold	PRMS - Soil Zone	Water holding capacity of the gravity and preferential- flow reservoirs; difference between field capacity and total soil saturation for each HRU	1.0e+00	999.00
slowcoef_lin	PRMS - Soil Zone	Linear coefficient in equation to route gravity-reservoir storage downslope for each HRU	1.0e-03	0.50
slowcoef_sq	PRMS - Soil Zone	Non-linear coefficient in equation to route gravity- reservoir storage downslope for each HRU	1.0e-03	1.00
soil2gw_max	PRMS - Soil Zone	Maximum amount of the capillary reservoir excess that is routed directly to the GWR for each HRU	0.0e+00	0.50
soil_moist_max	PRMS - Soil Zone	Maximum available water holding capacity of capillary reservoir from land surface to rooting depth of the major vegetation type of each HRU	1.0e-03	10.00
soil_rechr_max	PRMS - Soil Zone	Maximum storage for soil recharge zone (upper portion of capillary reservoir where losses occur as both evaporation and transpiration) of must be less than or equal to soil_moist_max	1.0e-03	5.00
ssr2gw_exp	PRMS - Soil Zone	Non-linear coefficient in equation used to route water from the gravity reservoirs to the GWR for each HRU	0.0e+00	3.00

ssr2gw_rate	PRMS - Soil Zone	Linear coefficient in equation used to route water from the gravity reservoir to the GWR for each HRU	5.0e-02	0.80
gwflow_coef	PRMS - Groundwater Discharge	Linear coefficient in the equation to compute groundwater discharge for each GWR	1.0e-03	0.50
hk1	MODFLOW - UPW	Horizontal hydraulic conductivity for Layer 1	2.0e+01	70.00
hk2	MODFLOW - UPW	Horizontal hydraulic conductivity for Layer 2	3.3e-02	5.00
hk3	MODFLOW - UPW/UZF	Horizontal hydraulic conductivity for Layer 3	3.3e-03	0.60
vk1	MODFLOW - UPW/UZF	Vertical hydraulic conductivity for Layer 1	2.0e+00	7.00
vk2	MODFLOW - UPW/UZF	Vertical hydraulic conductivity for Layer 2	3.3e-03	0.50
vk3	MODFLOW - UPW	Vertical hydraulic conductivity for Layer 3	3.3e-04	0.06
ss1	MODFLOW - UPW	Specific storage for Layer 1	1.0e-04	0.50
ss2	MODFLOW - UPW	Specific storage for Layer 2	1.0e-04	0.50
ss3	MODFLOW - UPW	Specific storage for Layer 3	1.0e-05	0.01
strhc1	MODFLOW - SFR	Hydraulic conductivity of the streambed for bedrock and confined alluvial streams	6.0e-05	2.00
strhc2	MODFLOW - SFR	Hydraulic conductivity of the streambed for unconfined alluvial channels	6.0e-05	2.00
strhc3	MODFLOW - SFR	Hydraulic conductivity of the streambed for regulated Russian River mainstem	6.0e-04	2.00
strhc4	MODFLOW - SFR	Hydraulic conductivity of the streambed for alluvial West Fork Srussian River	6.0e-04	2.00

6.3.1 Calibration Methodology and Targets

As mentioned above, GSFLOW calibration was done in several rounds of adjustments and updates after calibrating PRMS and MODFLOW individually. Prior to each round, a sensitivity analysis was conducted to limit the number of calibrated parameters. Measured streamflow and groundwater elevations were the targets for all rounds of calibration. However, different sets of wells and streamgages were used depending on the objective of the calibration. Initially, calibration was done for CASGEM groundwater elevation measurements and monthly streamflow from the three mainstem Russian River gages and available tributary measurements. Upon acceptable calibration of monthly streamflow, GSFLOW was further calibrated based on CASGEM groundwater elevation measurements and a selected subset of daily streamflow measurements at the mainstem Russian River stream gages. CASGEM groundwater elevations used are the same as observations that were used for MODFLOW calibration discussed in Section 6.2.2. Monthly tributary streamflow targets were the same as what were used for PRMS calibration and discussed in Section 6.1.2 and shown in **Table 6.1** and **Figure 6.5**. Monthly and daily streamflow data from mainstem Russian River gages used as calibration targets are shown in **Figure 6.11** and **Figure 6.11**, respectively. USGS 11461000 represents West Fork Russian River flow prior to the confluence with East Fork Russian River. USGS 11462080 represents flow near Talmage and adjacent to UWWTP. USGS 11462500 measures streamflow at the outlet of the Basin.

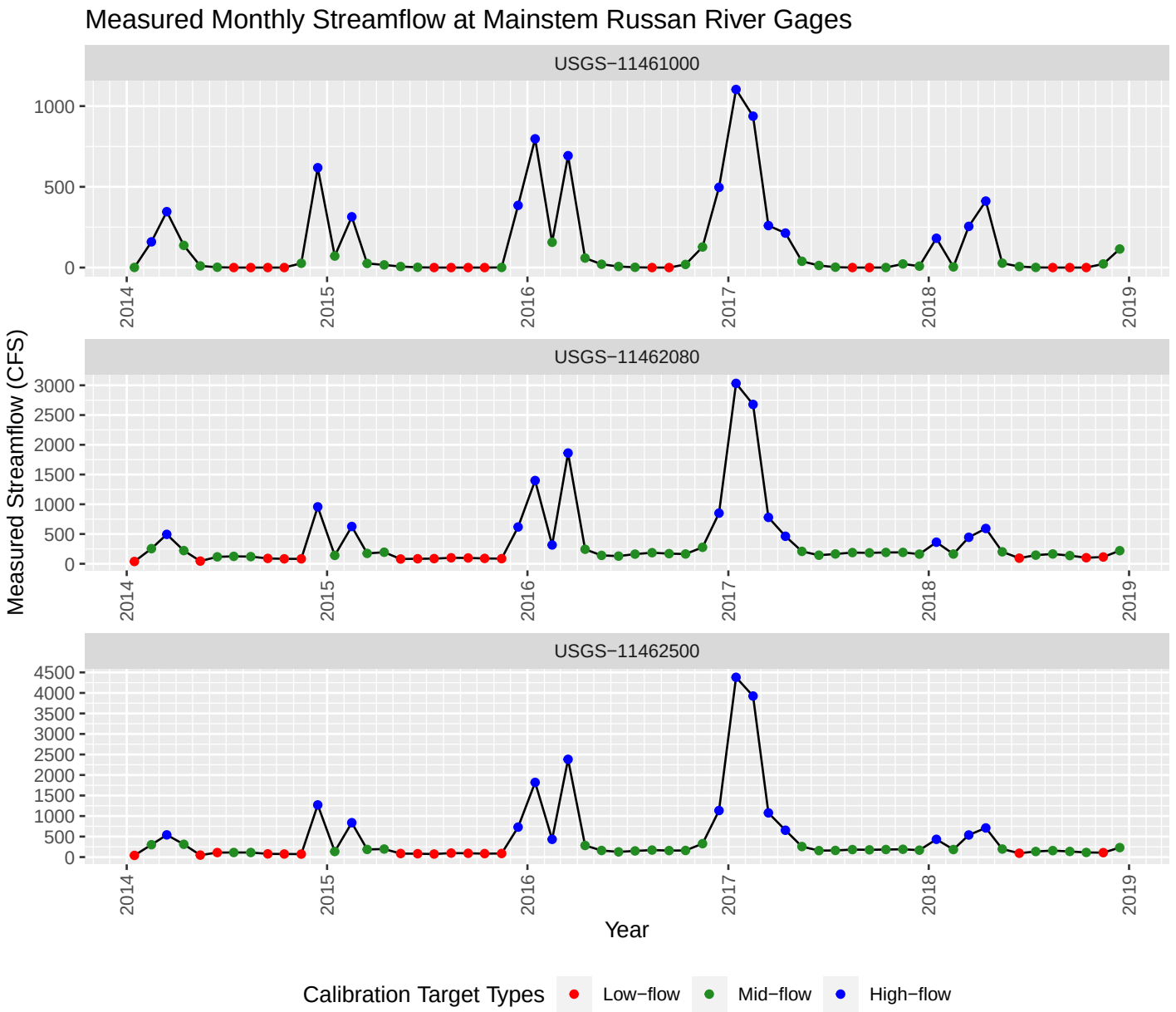

Figure 6.10: Monthly measured streamflow from the mainstem Russian River gages, along with high, mid, and low-flow calibration targets.

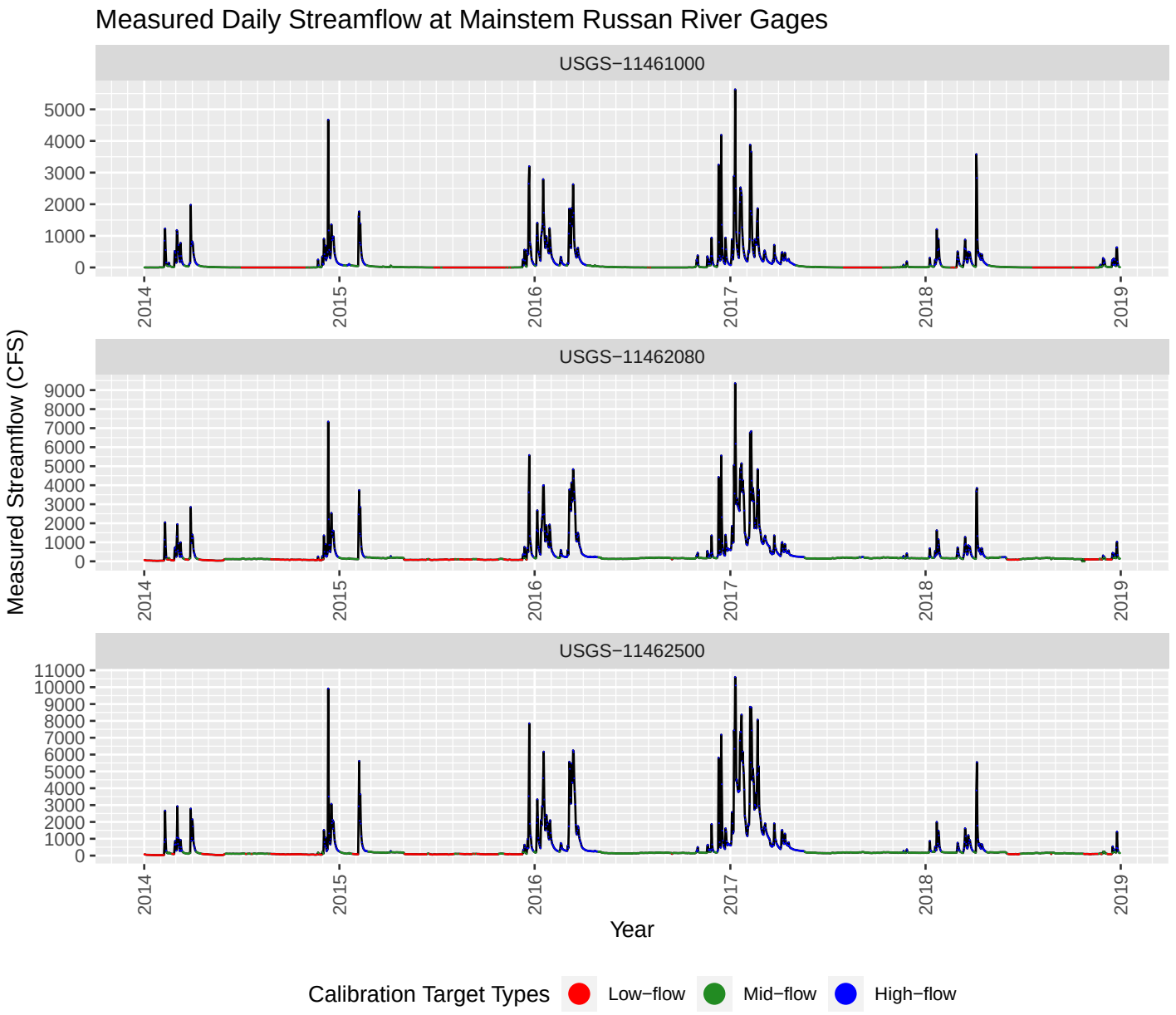

Figure 6.11: Daily measured streamflow from the mainstem Russian River gages, along with high-, mid-, and low-flow calibration targets.

6.3.2 6.3.2 Sensitivity Analysis

CSS results for the latest round of UCODE-2014 calibration with 24 adjustable parameters selected for the calibration are shown in **Figure 6.12**. Aquifer properties, streambed conductivity, soil zone, and surface runoff parameters were the most important parameters to the calibration.

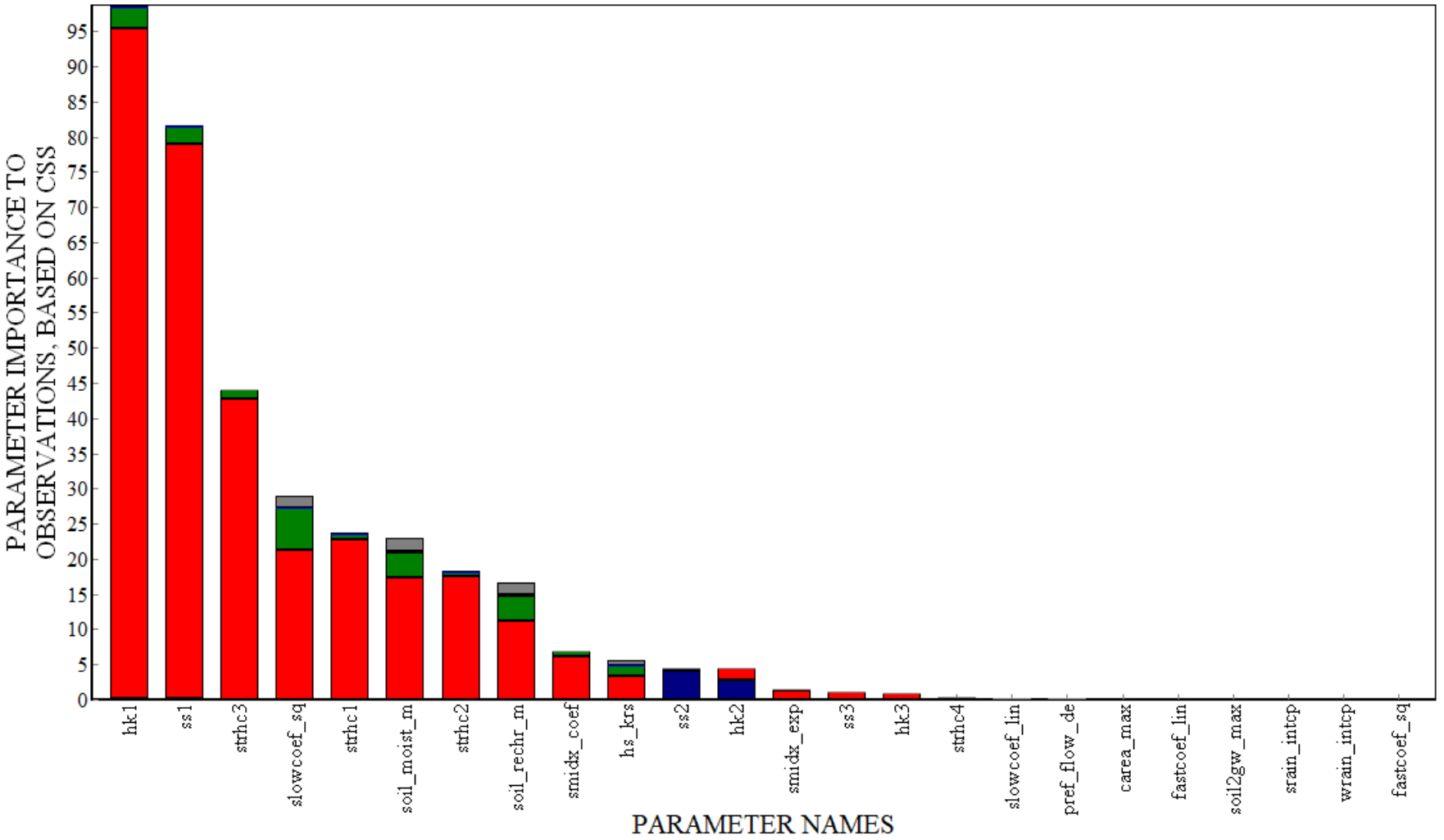

Figure 6.12: Composite-Scaled Sensitivity (CSS) for the 24 parameters included in the final UCODE-2014 sensitivity analysis procedure.

6.3.3 Calibration Results

Following the completion of UCODE-2014 calibration of GSFLOW for the 16 most sensitive parameters, as shown in **Figure 6.12**, manual adjustments and tuning were conducted based on best professional judgment and local and expert input from the GSA technical committee. Final calibration results for the 16 parameters are shown in **Table 6.5**. Comparison of simulated and observed groundwater elevations at CASGEM wells are shown in **Figure 6.13**. A similar comparison for monthly and daily streamflows at the three Russian River mainstem gages are shown in **Figure 6.14** and **Figure 6.15**, respectively. Results confirm that the UVIHM produces a very good fit and can sufficiently simulate the overall conditions of the Basin. Due to existing data gaps, assumptions and inherent uncertainty in the model must be considered in the translation of its results.

Table 6.5: Final calibrated parameter values from the GSFLOW calibration.

Parameter Name	Group/Module	Description	Calibrated Value	Lower Bound	Upper Bound
hs_krs	PRMS - Potential Evapotranspiration	Monthly (January to December) adjustment factor used in Hargreaves-Samani potential ET computations for each HRU	0.3560	5.0e-03	1.00
smidx_coef	PRMS - Surface Runoff	Coefficient in non-linear contributing area algorithm for each HRU	0.0020	1.0e-03	0.06
smidx_exp	PRMS - Surface Runoff	Exponent in non-linear contributing area algorithm for each HRU	0.0500	1.0e-01	0.50
slowcoef_sq	PRMS - Soil Zone	Non-linear coefficient in equation to route gravity- reservoir storage downslope for each HRU	0.0015	1.0e-03	1.00
soil_moist_max	PRMS - Soil Zone	Maximum available water holding capacity of capillary reservoir from land surface to rooting depth of the major vegetation type of each HRU	0.9560	1.0e-03	10.00
soil_rechr_max	PRMS - Soil Zone	Maximum storage for soil recharge zone (upper portion of capillary reservoir where losses occur as both evaporation and transpiration) of must be less than or equal to soil_moist_max	0.7000	1.0e-03	5.00
hk1	MODFLOW - UPW	Horizontal hydraulic conductivity for Layer 1 (m/d)	30.0000	2.0e+01	70.00
hk2	MODFLOW - UPW	Horizontal hydraulic conductivity for Layer 2 (m/d)	0.3000	3.3e-02	5.00
hk3	MODFLOW - UPW/UZF	Horizontal hydraulic conductivity for Layer 3 (m/d)	0.0500	3.3e-03	0.60
ss1	MODFLOW - UPW	Specific storage for Layer 1	0.0010	1.0e-04	0.50
ss2	MODFLOW - UPW	Specific storage for Layer 2	0.0010	1.0e-04	0.50
ss3	MODFLOW - UPW	Specific storage for Layer 3	0.0040	1.0e-05	0.01

strhc1	MODFLOW - SFR	Hydraulic conductivity of the streambed for bedrock and confined alluvial streams (m/d)	0.0100	6.0e-05	2.00
strhc2	MODFLOW - SFR	Hydraulic conductivity of the streambed for unconfined alluvial channels (m/d)	0.0300	6.0e-05	2.00
strhc3	MODFLOW - SFR	Hydraulic conductivity of the streambed for regulated Russian River mainstem (m/d)	0.1000	6.0e-04	2.00
strhc4	MODFLOW - SFR	Hydraulic conductivity of the streambed for alluvial West Fork Srussian River (m/d)	0.3000	6.0e-04	2.00

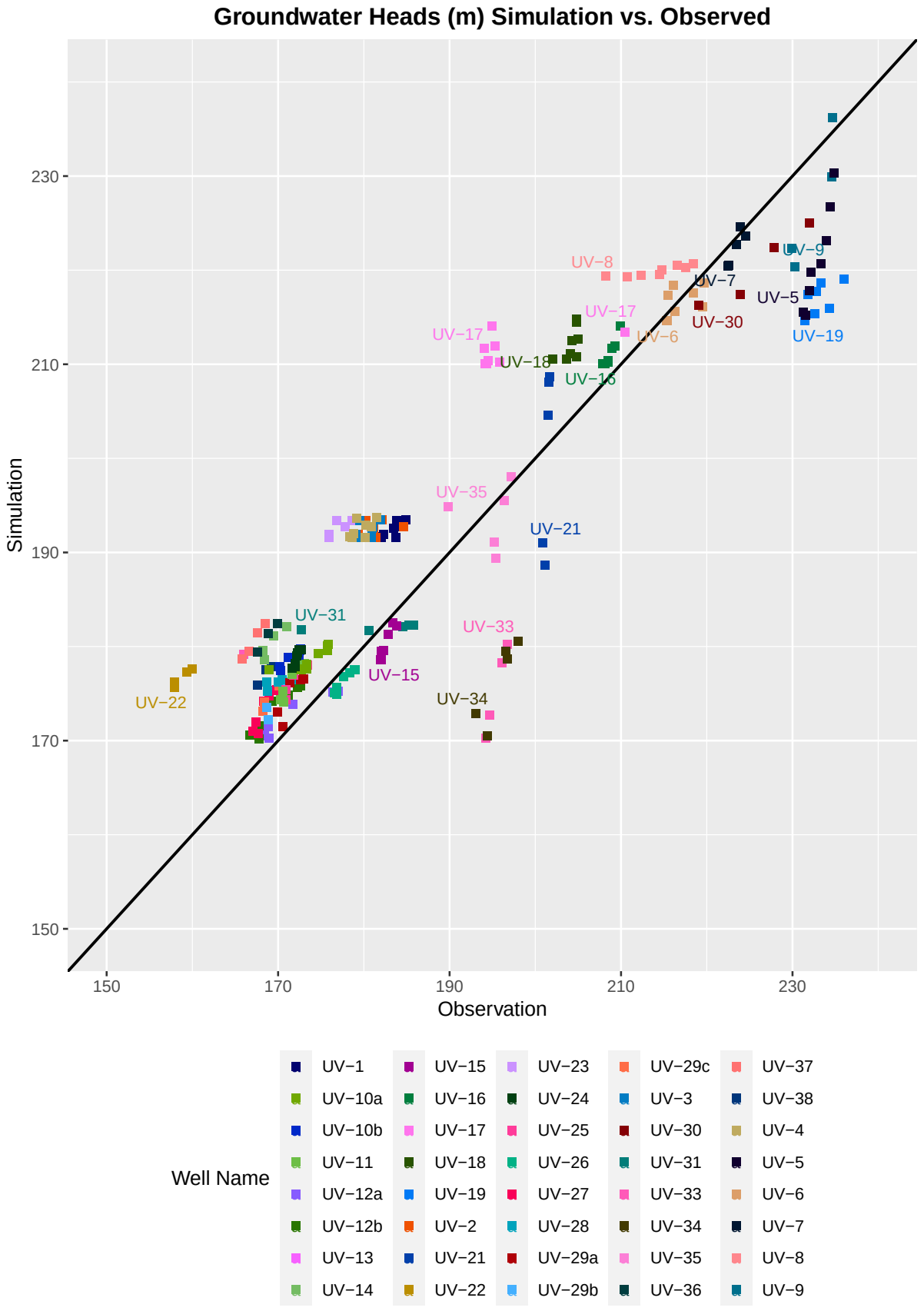

Figure 6.13: Simulated vs. observed CASGEM groundwater elevations.

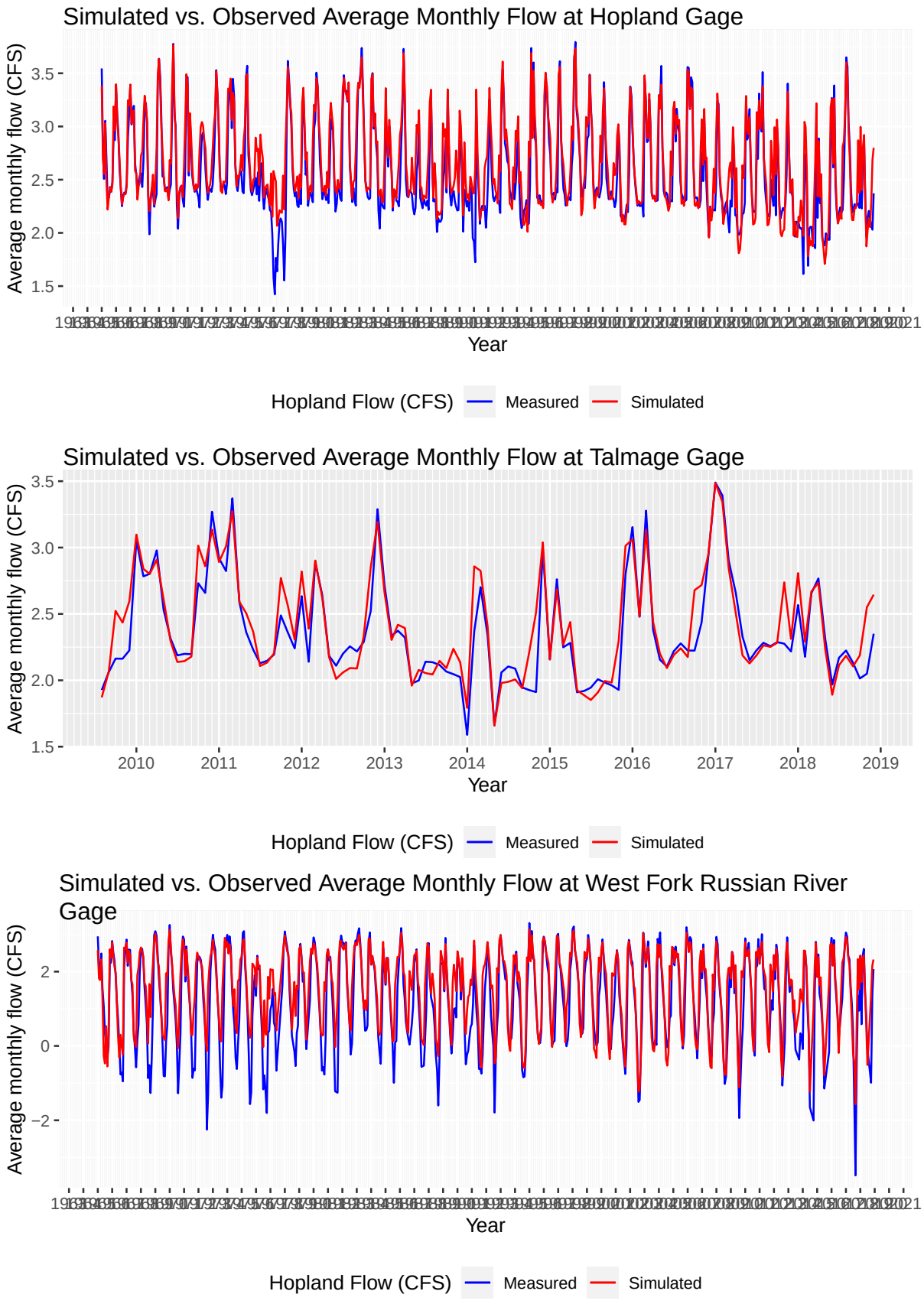

Figure 6.14: Simulated vs. observed monthly streamflow at Russian River mainstem gages.

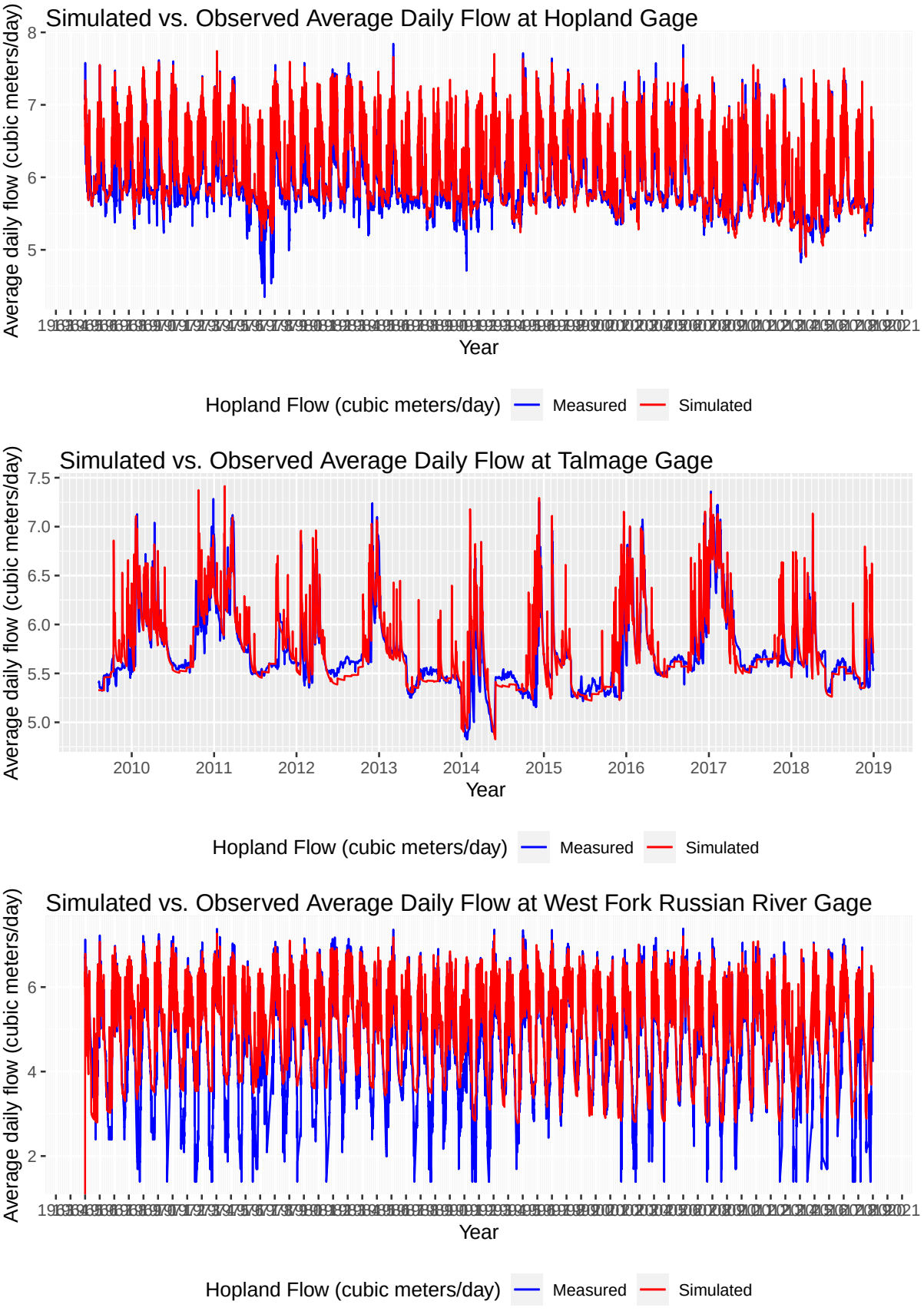

Figure 6.15: Simulated vs. observed daily streamflow at Russian River mainstem gages.

Chapter 7

Calibrated Model Results

The results produced by the calibrated UVIHM are presented below. These results were used to establish a better understanding of the conditions of the Basin and set sustainable management criteria. However, it is important to consider existing data gaps and sources of uncertainty in the UVIHM when using its results. The GSA has cautiously used these results for GSP development and has outlined where more data and improvement of the UVIHM were needed for it to be reliably utilized. Chapters 2 and 3 of the GSP, this appendix, and Appendix 2E discuss the major data gaps, how they will be covered, and why some of the UVIHM results are not yet considered in the decision making process. These include but are not limited to:

- generating simulated groundwater elevation contours to use for GDE and ISW identification due to lack of sufficient groundwater elevation measurements for calibration;
- evaluating river connectivity, surface water and groundwater interactions, and estimating surface water depletion volumes due to pumping because of insufficient groundwater elevation, streamflow measurements, and streambed characteristic information available for calibration; and,
- estimating boundary inflow and outflow to the Basin due to lack of measurements and boundary groundwater elevation monitoring.

Per SGMA requirements and according to GSA technical committee recommendations, results are categorized into water year types developed by DWR.[1] Water budget results are presented based on appropriate baselines and then summarized into different water year type statistics. Other results, such as groundwater elevation contours and stream connectivity, are only shown for a selected subset of recent years representing the different water year types. Water years 2012, 2014, 2015, 2016, and 2017 are selected to represent below normal, critical, dry, above normal, and wet water year types, respectively.

7.1 Groundwater Elevation Contours

Figures 7.1 through **7.5** show groundwater elevation contours generated by the UVIHM for water years 2012, 2014, 2015, 2016, and 2017 representing below normal, critical, dry, above normal,

[1] https://data.cnra.ca.gov/dataset/806ce291-645b-4646-8e15-9295b7740f5a/resource/79c7b9c1-1203-4203-b956-844554fcec79/download/sgma_wyt_dataset_developmentreport.pdf

and wet water year types, respectively. Each figure and year include groundwater elevation contours for March, July, September, and December, representing Spring, Summer, Fall, and Winter seasons, respectively. Results confirm that water year types and seasonality impact groundwater levels in the Basin. In addition, contour figures show that areas near the boundary of the Basin can be improved in further calibration using additional measurement and data.

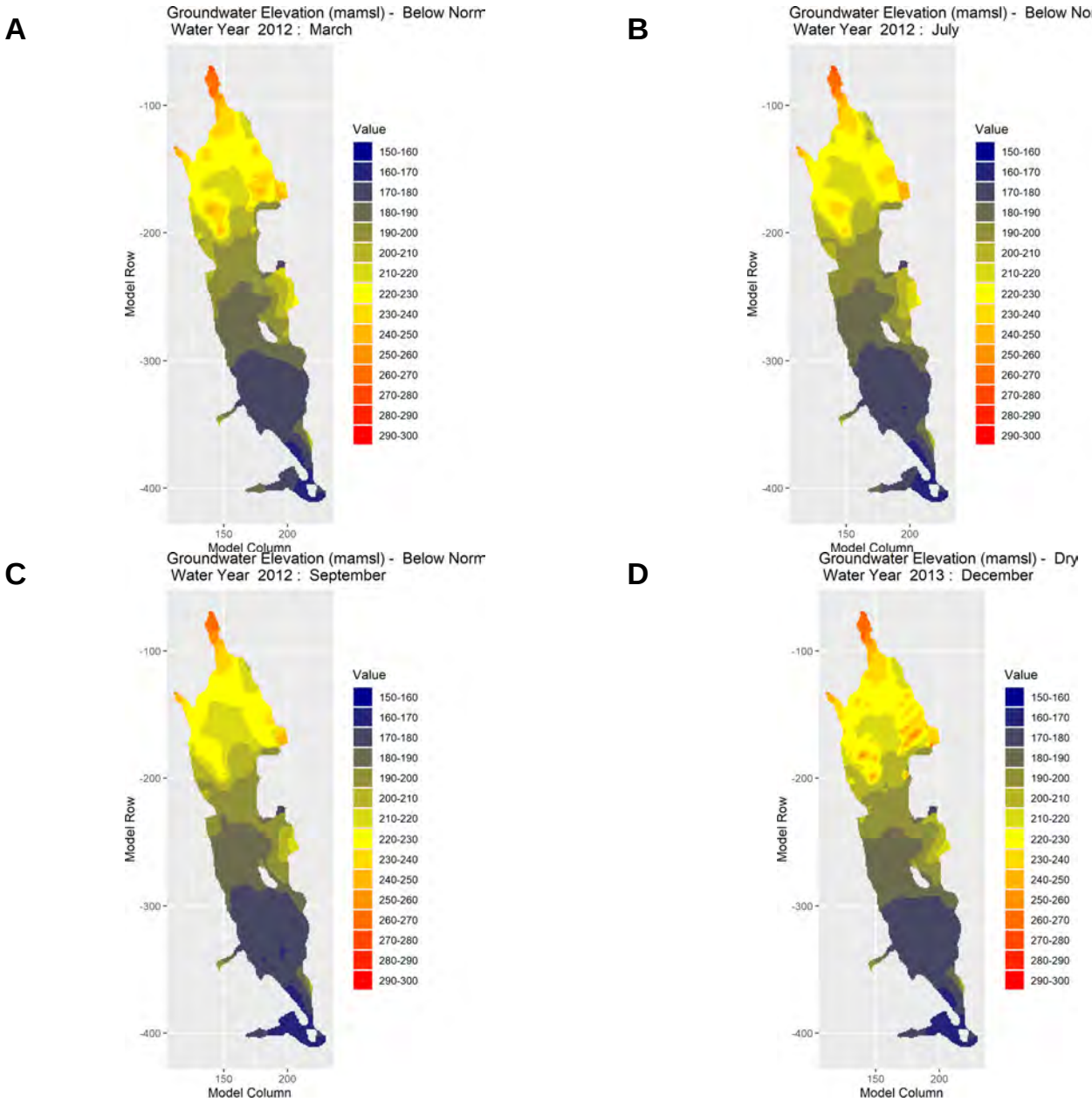

Figure 7.1: Simulated groundwater elevation contours in a below normal water year (2012) for (A) March, (B) July, (C) September, and (D) December.

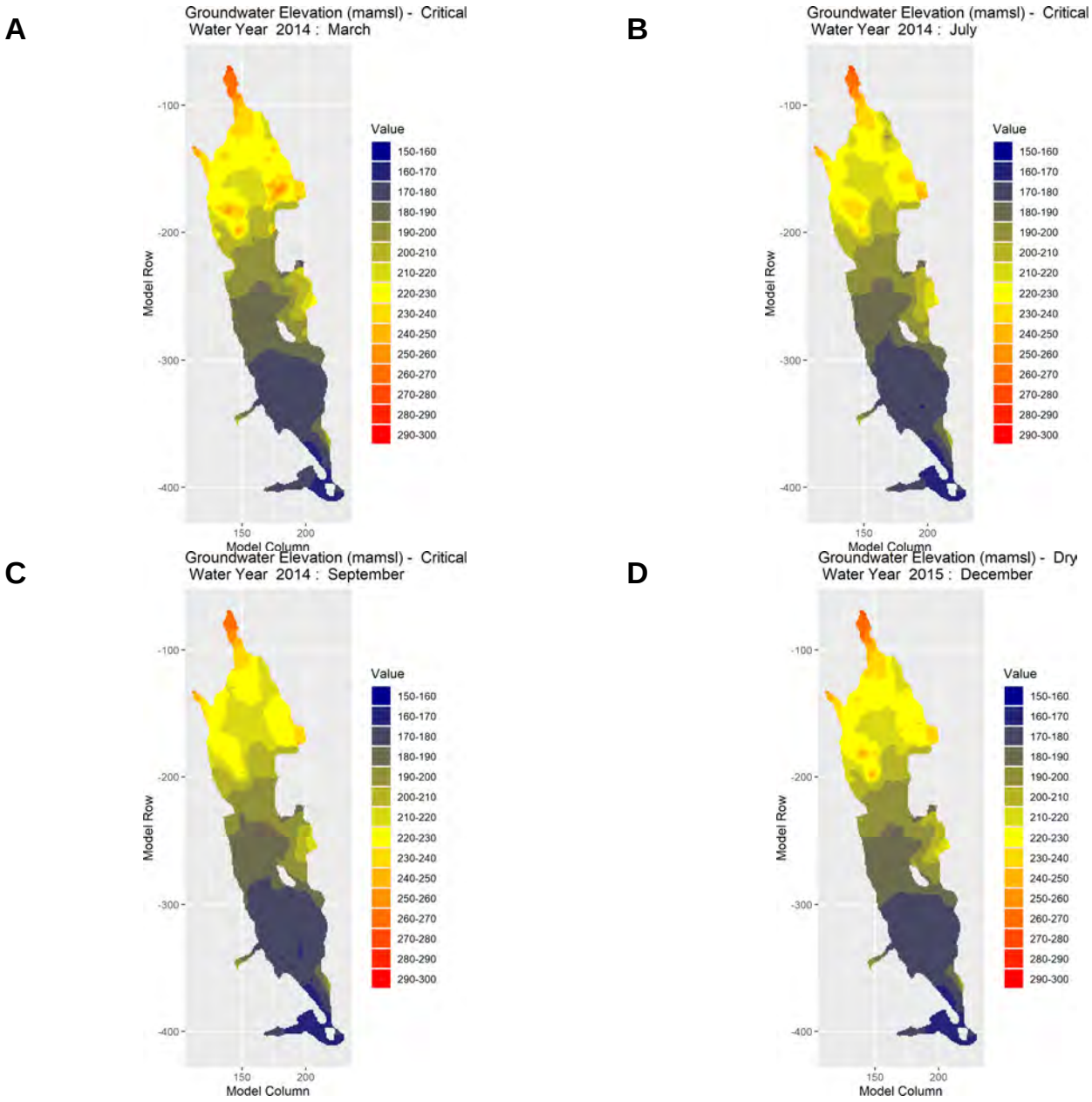

Figure 7.2: Simulated groundwater elevation contours in a critical water year (2014) for (A) March, (B) July, (C) September, and (D) December.

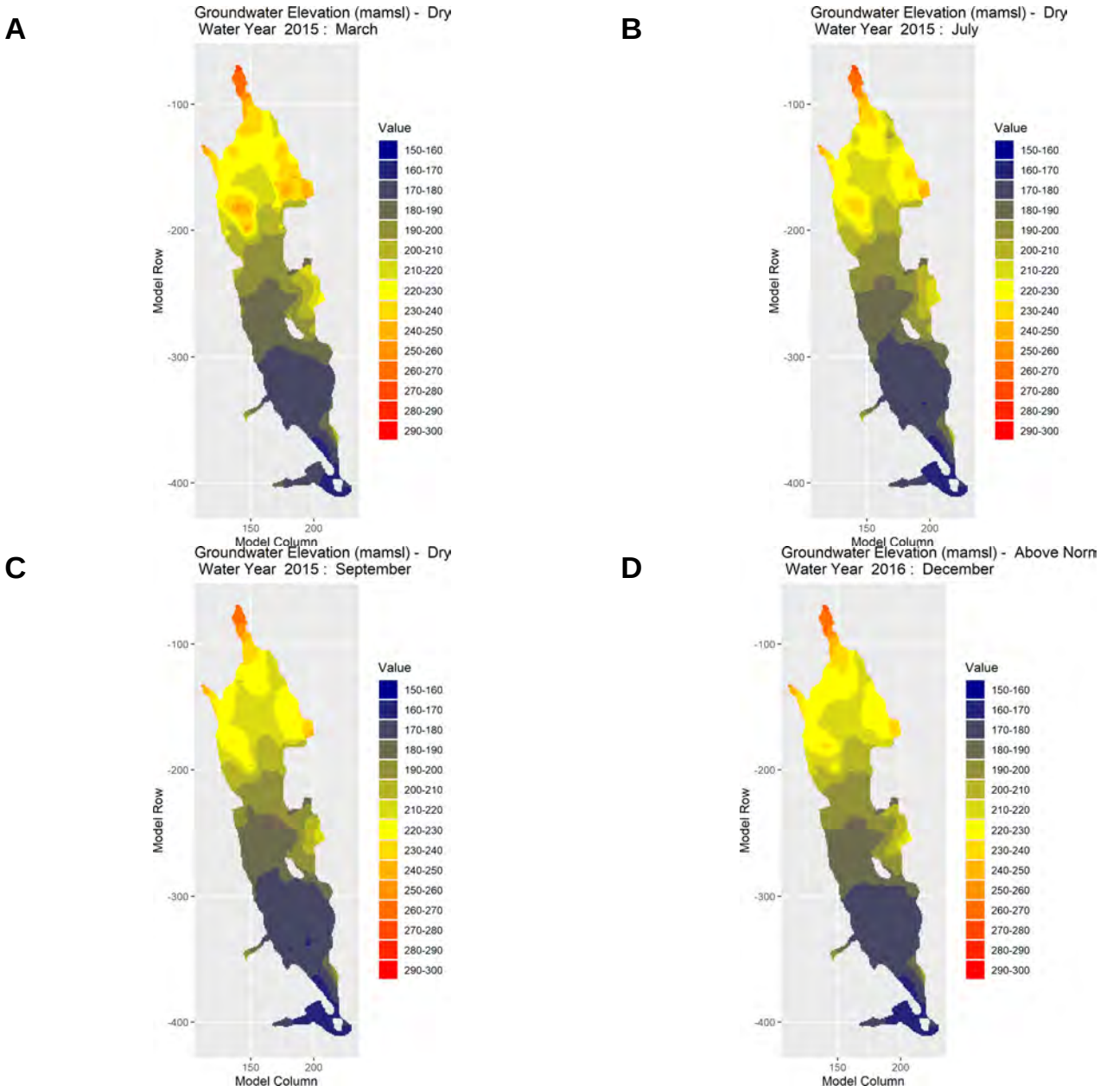

Figure 7.3: Simulated groundwater elevation contours in a dry water year (2015) for (A) March, (B) July, (C) September, and (D) December.

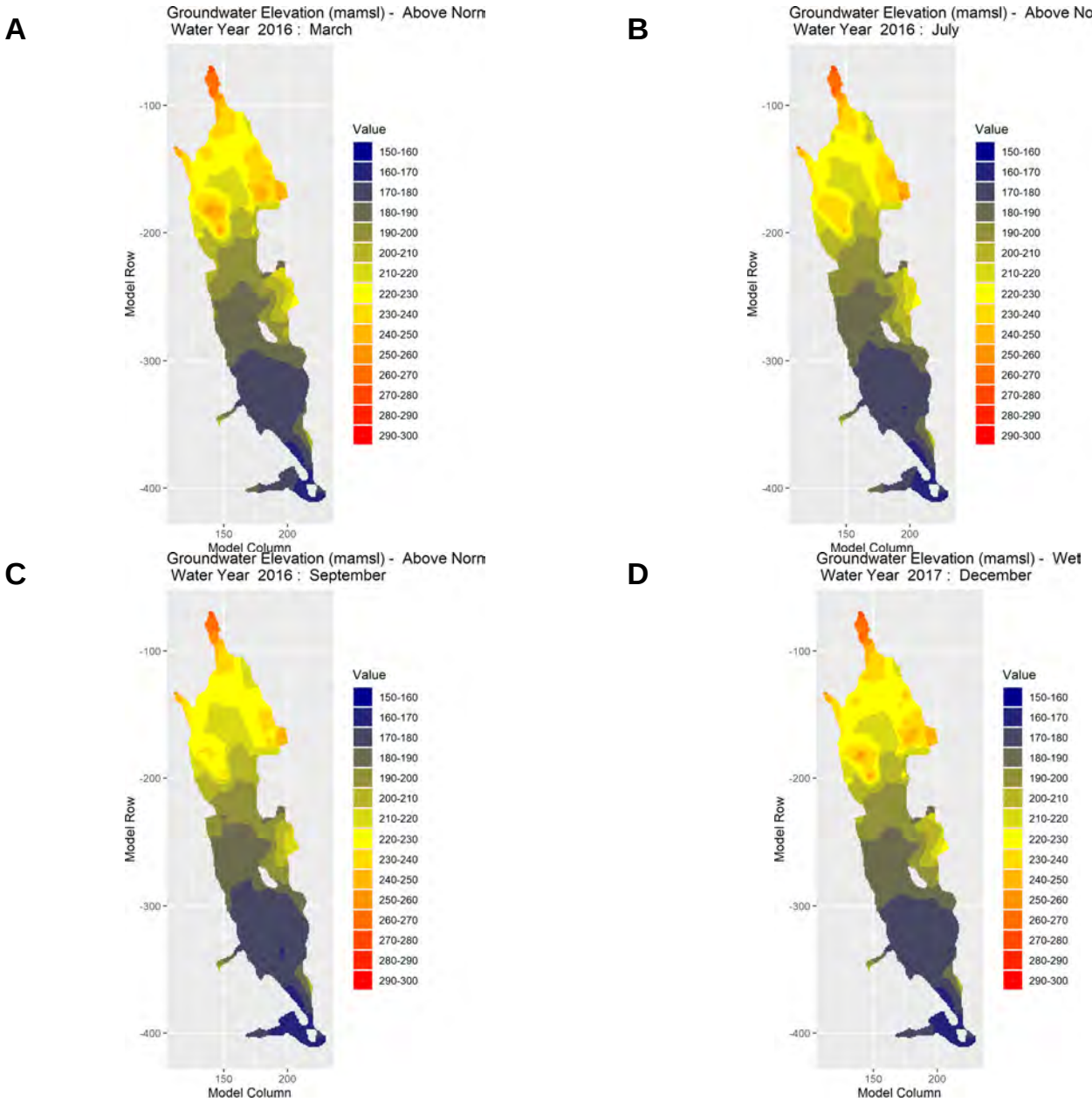

Figure 7.4: Simulated groundwater elevation contours in a above normal water year (2016) for (A) March, (B) July, (C) September, and (D) December.

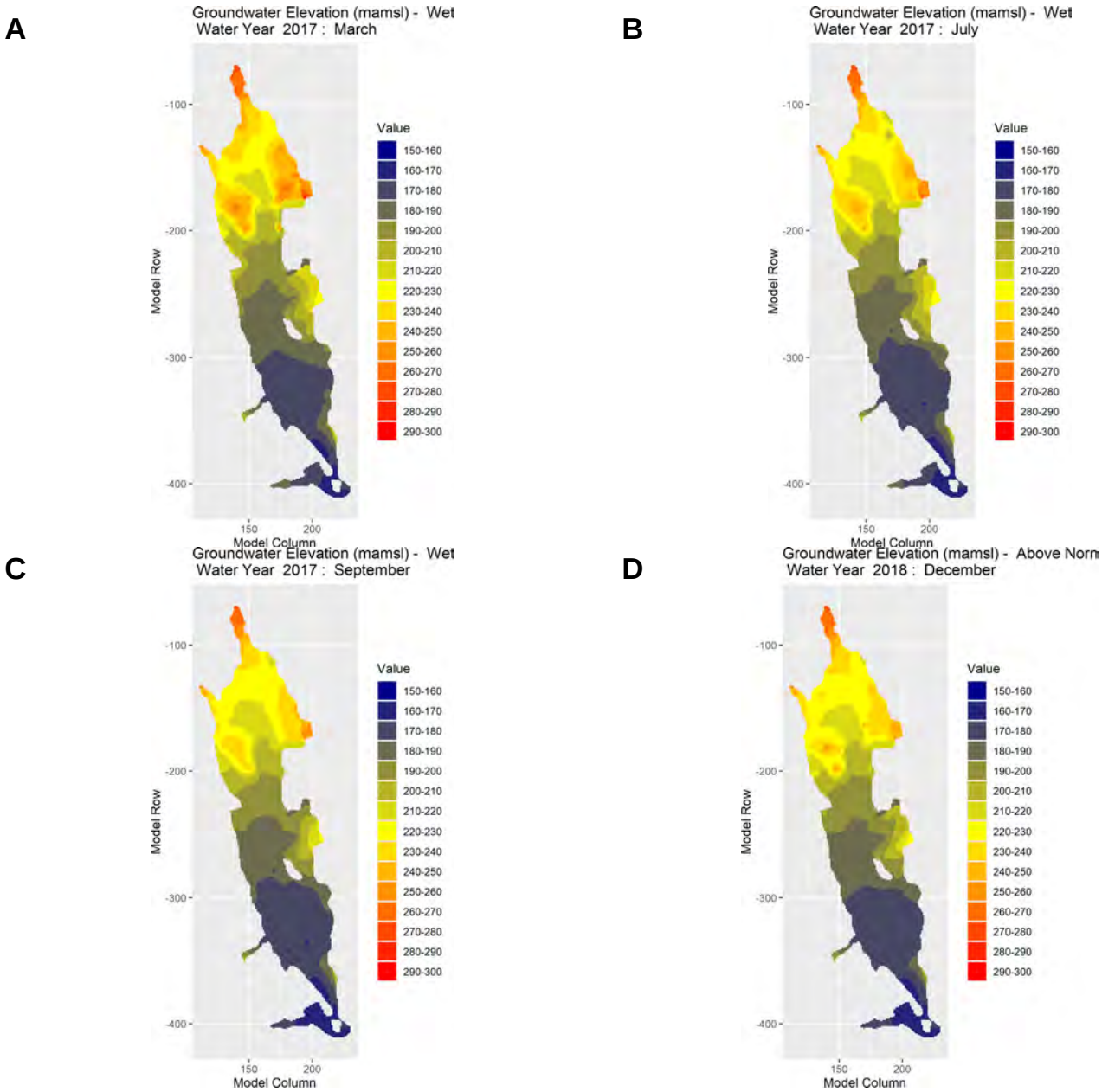

Figure 7.5: Simulated groundwater elevation contours in a wet water year (2017) for (A) March, (B) July, (C) September, and (D) December.

7.2 Groundwater Hydrographs

Figures 7.7 and 7.7 show groundwater elevation hydrographs at observation wells in the Basin (CASGEM wells). Results show a good fit overall for the Basin and do not present a specific pattern of overestimation or underestimation of groundwater elevations. Similarly, results show that seasonal variation in the Basin is captured sufficiently by the model. Furthermore, the UVIHM results show similar trends as observed and do not hint at any chronic decline of groundwater levels in the Basin. Upon additional data and information collection, further improvement and calibration of the model can be made to provide a better fit for both the average groundwater level and seasonal changes.

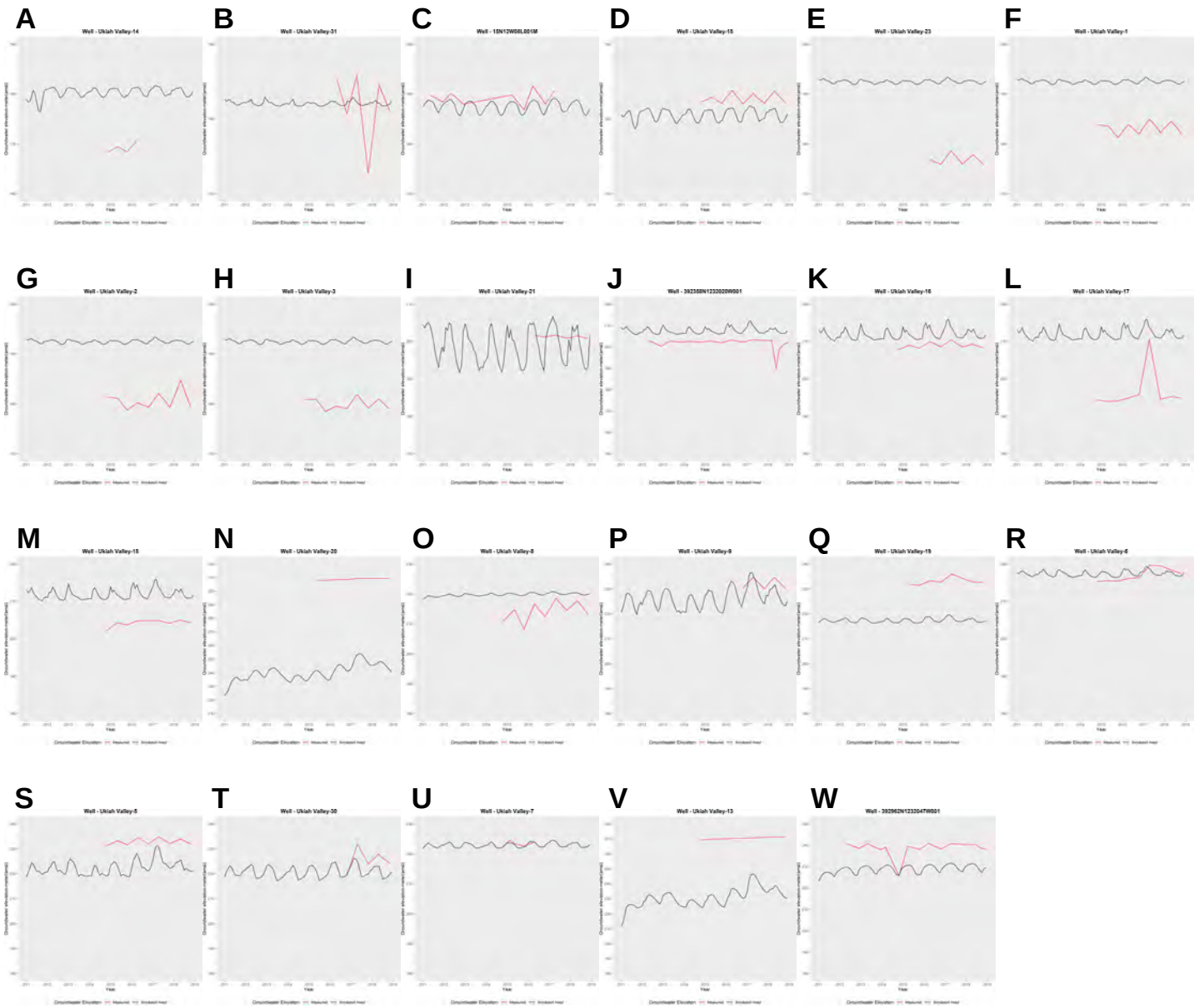

Figure 7.6: Simulated vs. observed groundwater elevation hydrographs at wells in northern and central Basin.

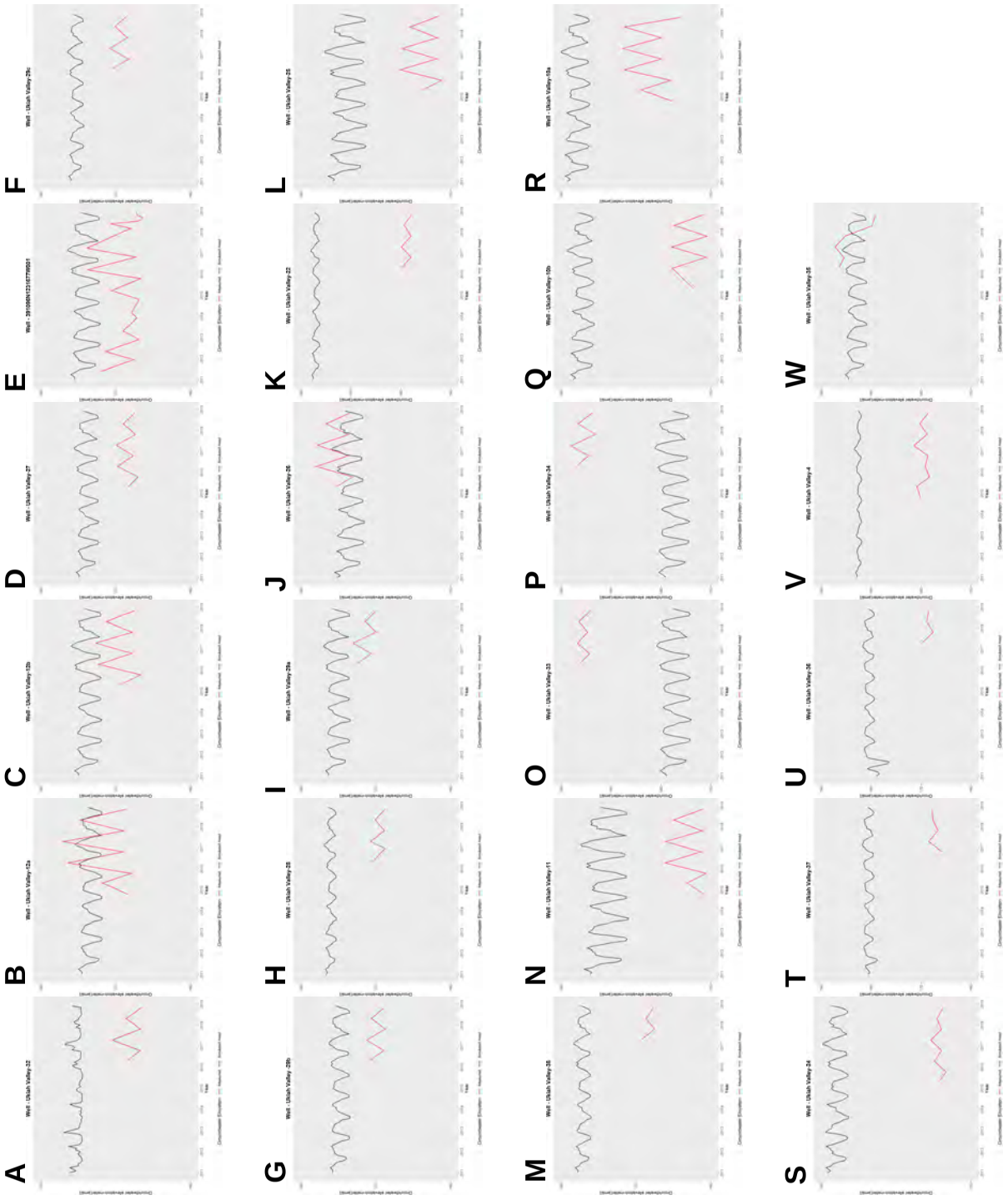

Figure 7.7: Simulated vs. observed groundwater elevation hydrographs at wells in central and southern Basin.

7.3 Stream-Aquifer Interactions

Stream-aquifer interactions are very difficult to measure and highly variable in both space and time, and model estimates of stream-aquifer interactions are subject to large uncertainty. At one snapshot in time, a single tributary can be both gaining and losing at different reaches at the same time, while at another snapshot in time, that behavior can be entirely switched. These factors require thoughtful characterization and reporting.

The UVIHM estimates the water gained by the stream network from groundwater or lost to the aquifers as streambed recharge. These estimations are provided for each stream cell of the model and can be summarized for each segment of the stream network. Although these estimations carry significant uncertainties due to data gaps, they can provide an understanding of the water system and stream-aquifer interaction. These estimations are aggregated basin-wide and shown in water budget figures in **Section 7.4**. Upon collecting additional information and data and enhancing the UVIHM, gaining and losing estimations of streams can be used to revise and track the depletion of ISWs due to groundwater pumping sustainable management criteria (SMC).

The gaining/losing characteristics of the stream network can be presented as snapshots of groundwater interconnection throughout the stream network during Spring and Fall to identify when streams are most and least interconnected. A particular stream reach or segment can be individually characterized by the percentage of time it is interconnected throughout a particular year. While further calibration and improvement of the UVIHM are needed to use its results for identifying ISWs reliably, such snapshots are provided based on its current results for informational purposes. **Figures 7.8** through **7.12** shown simulated gaining and losing streams generated by the UVIHM for water years 2012, 2014, 2015, 2016, and 2017 representing below normal, critical, dry, above normal, and wet water year types, respectively. Each figure and year include groundwater elevation contours for March, July, September, and December, representing Spring, Summer, Fall, and Winter seasons, respectively. The north-eastern portion of the Upper Russian River Watershed corresponding to the area from the Potter Valley Project (PVP) to the Lake Mendocino was not simulated for the historical period. Therefore, it is shown as dry in **Figures 7.8** through **7.12** but it should be noted that this categorization does not correspond to an actual estimation from the UVIHM.

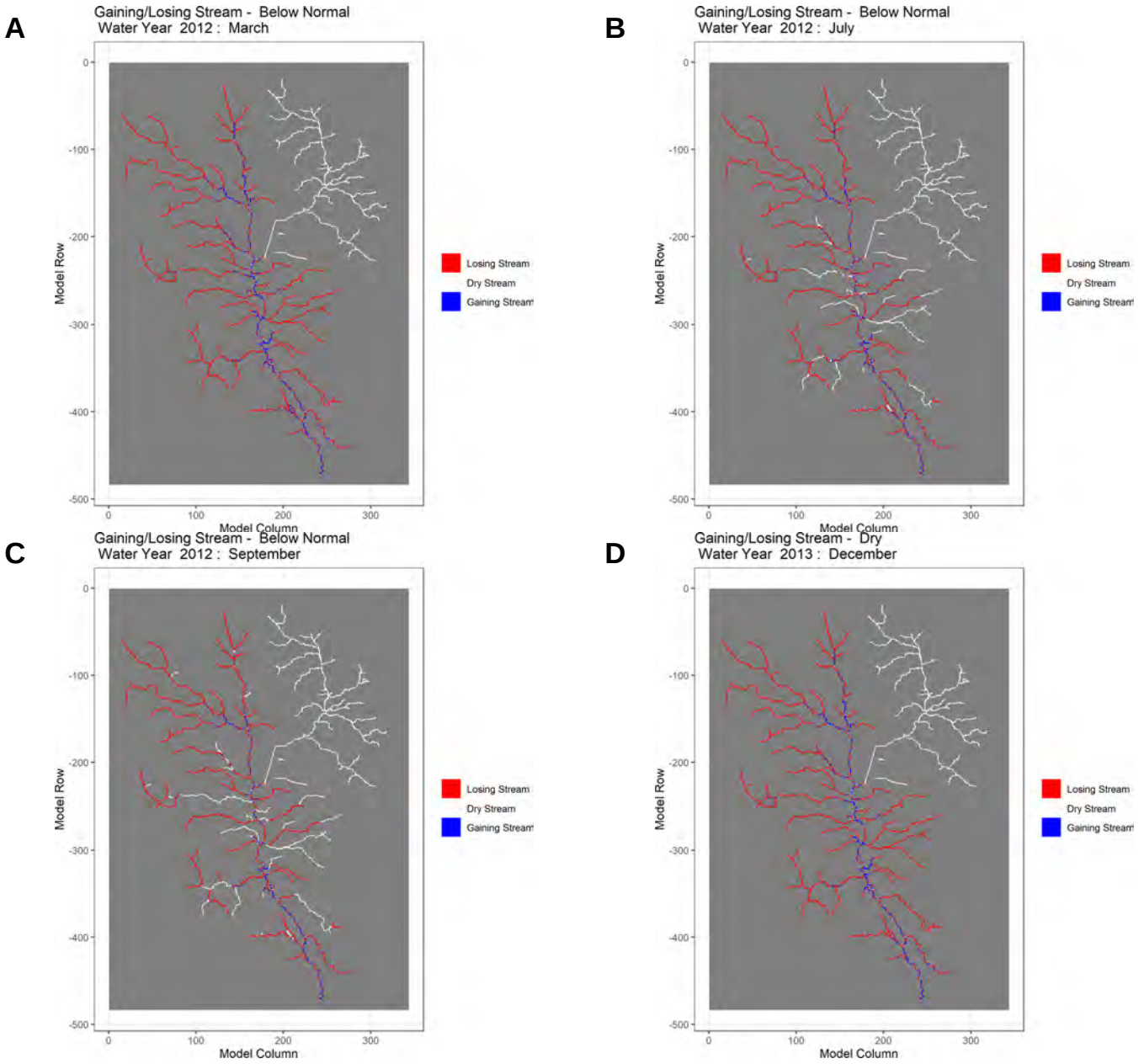

Figure 7.8: Simulated stream losing/gaining status in a below normal water year (2012) for (A) March, (B) July, (C) September, and (D) December.

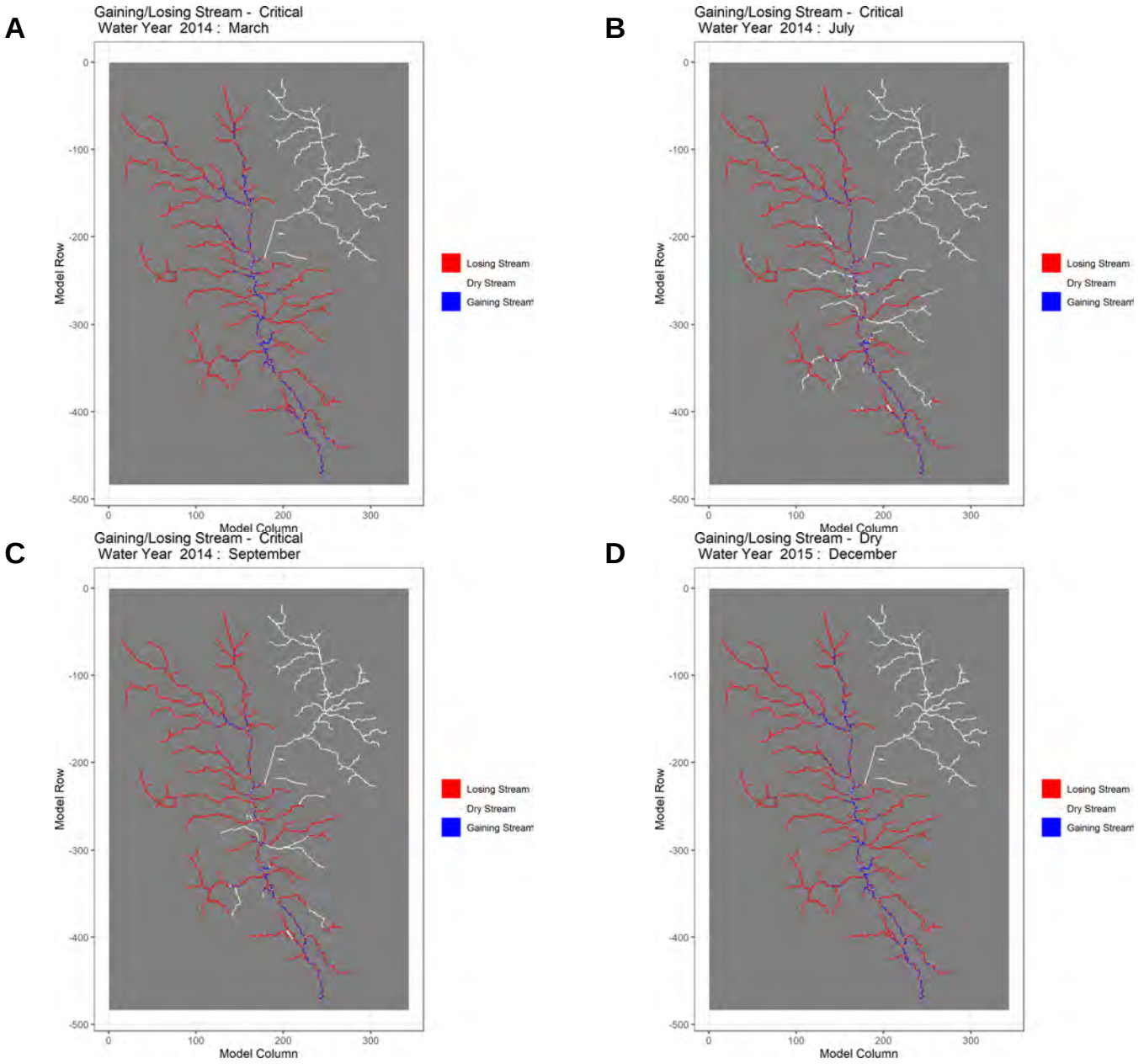

Figure 7.9: Simulated stream losing/gaining status in a critical water year (2014) for (A) March, (B) July, (C) September, and (D) December.

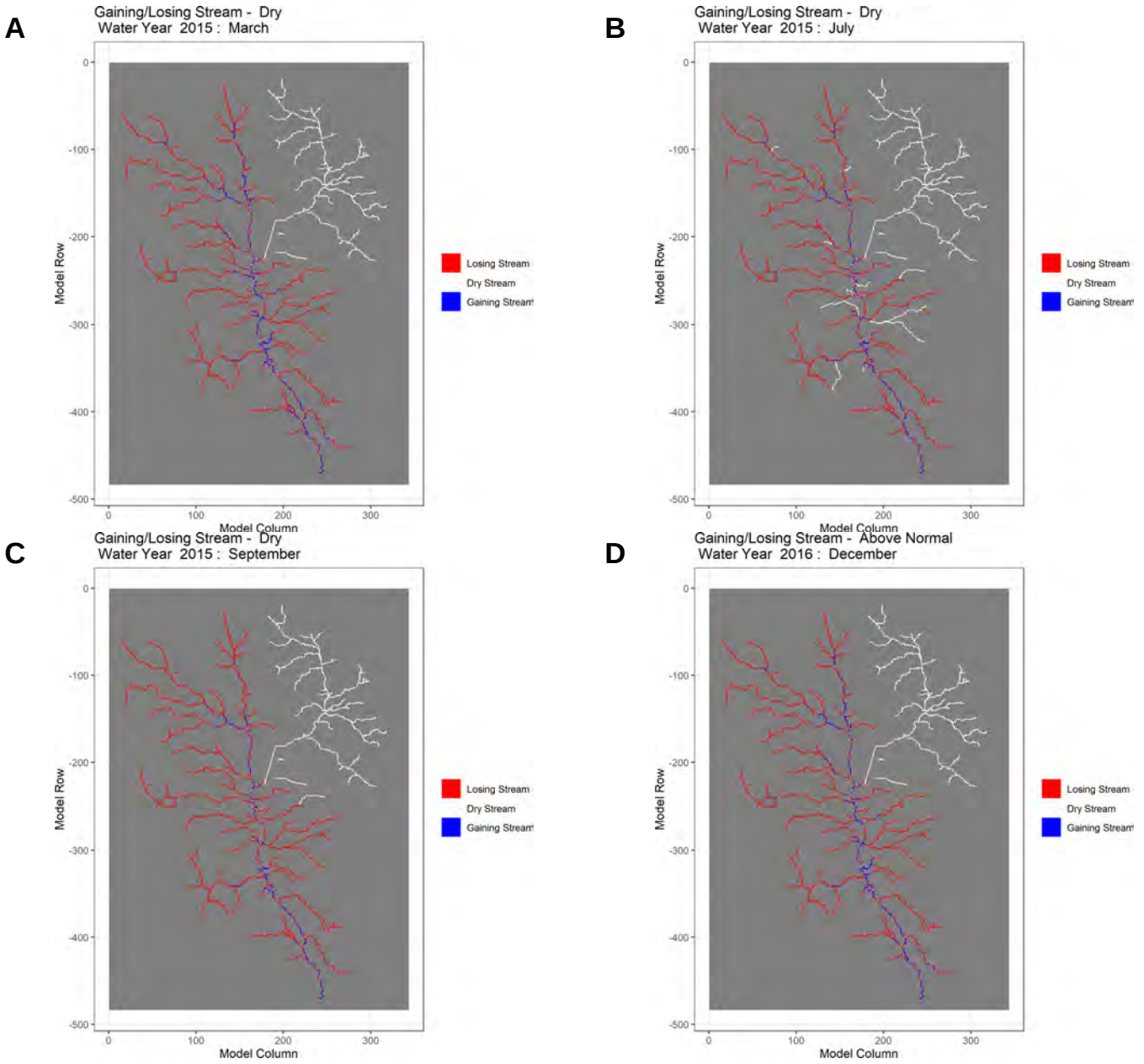

Figure 7.10: Simulated stream losing/gaining status in a dry water year (2015) for (A) March, (B) July, (C) September, and (D) December.

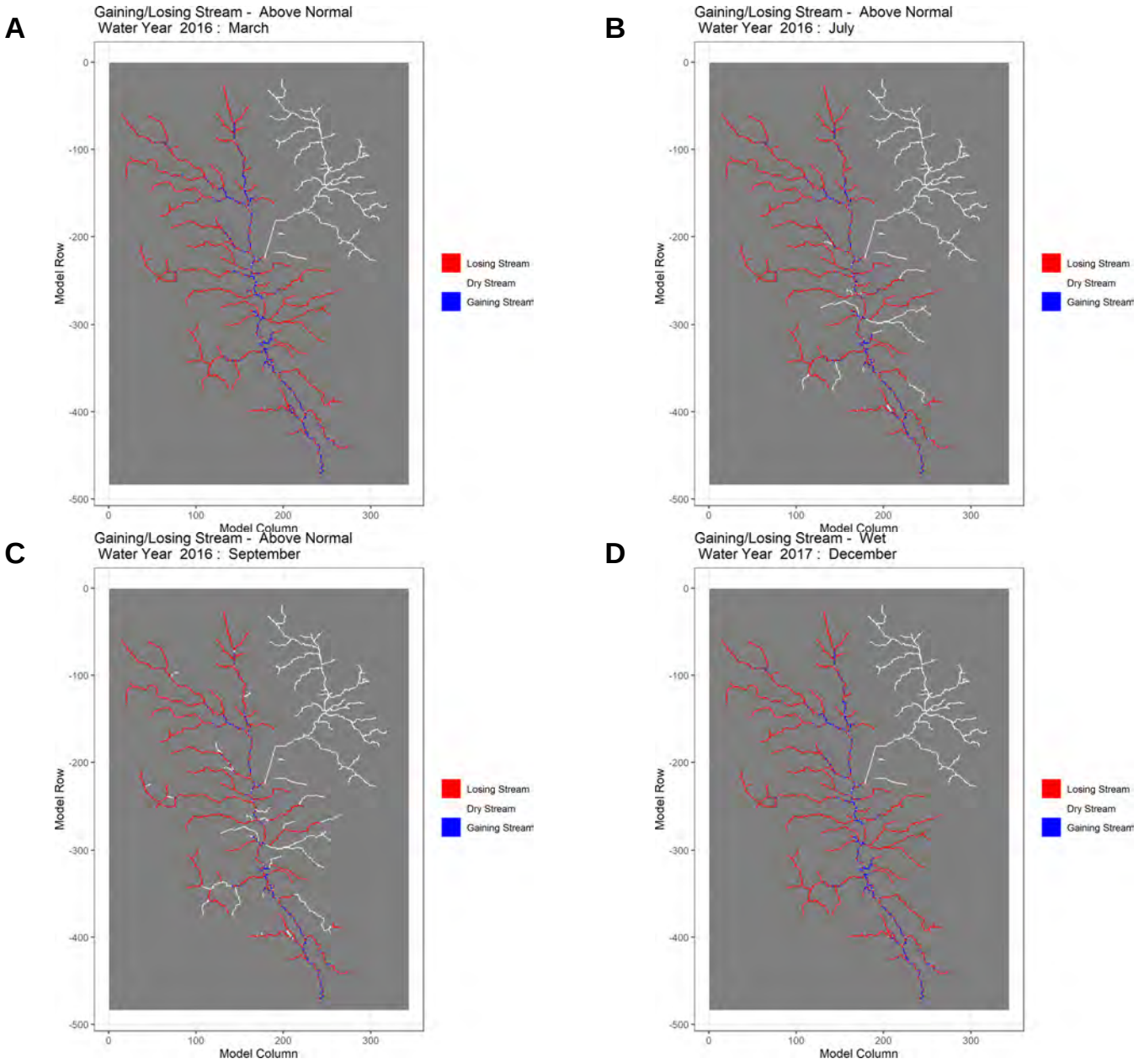

Figure 7.11: Simulated stream losing/gaining status in a above normal water year (2016) for (A) March, (B) July, (C) September, and (D) December.

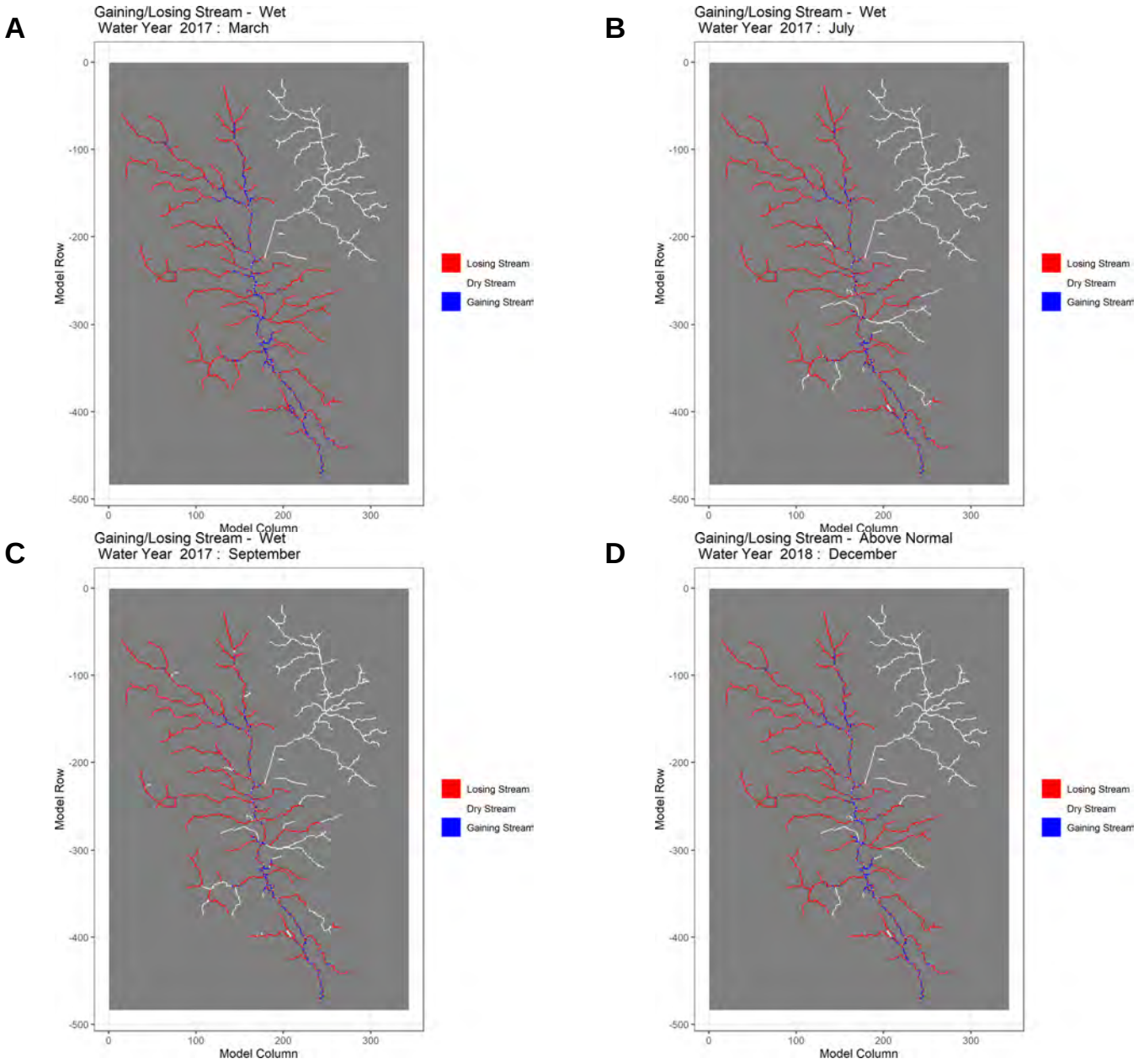

Figure 7.12: Simulated stream losing/gaining status in a wet water year (2017) for (A) March, (B) July, (C) September, and (D) December.

7.4 Water Budget Estimations

The UVIHM was used to generate water budgets for the Upper Russian River Watershed, the Basin, and the soil zone for specific agricultural crops. Water budget components and its definitions are provided in **Table 7.1**. The UVIHM estimates historical, current, and projected future water budgets. These baselines are defined below.

Table 7.1: Water budget components estimated by UVIHM and their associated limitations

Water Budget Component	Model Input or Model Result	Source of Data	Limitations
Precipitation	Input Data	Measured precipitation from weather gages spatially distributed by PRMS precipitation distribution module. Similar precipitation and distribution method is used for historical and future budget. Climate change scenarios use spatially distributed precipitation multiplied by change factors produced for DWR climate change scenarios.	Spatial precipitation distribution may change with changing climate. Distribution method imposes uncertainties onto the model. Inherent measurement errors from gages and gaps in their measurement impose further uncertainties.
Managed Streamflow Releases	Input Data	Simulated using measured streamflow at East Fork Russian River USGS gage.	Dam Releases from Coyote Valley Dam. Area discharging surface water to the Mendocino Lake is skipped in the simulations since the output to the basin is simulated using the streamflow gage at East Fork Russian River.
Surface Water Diversions (Agricultural and Municipal)	Input Data (Agricultural pumping is estimated by the IDC)	Based on available data from municipalities. Most data used were up to 2015 and considered constant afterwards. Agricultural demands are estimated using IDC model.	Municipal data is mostly up to 2015 and considered constant and the same as 2015 afterwards. Future municipal use is also considered equal to 2015. Agricultural demand for future is estimated using IDC for future similar to the historical period. Land use and soil types are considered constant and the same as 2010 land use map.

Table 7.1: Water budget components estimated by UVIHM and their associated limitations *(continued)*

Water Budget Component	Model Input or Model Result	Source of Data	Limitations
Groundwater Pumping: Municipal Pumping and Agricultural Pumping	Input Data (Agricultural pumping is estimated by the IDC)	Metered for historical municipal pumping and some small water systems data was used for municipal pumping. Agricultural pumping was estimated using IDC model, climatic data, crop type, and land and soil data.	Municipal data is mostly up to 2015 and considered constant and the same as 2015 afterwards. Future municipal use is also considered equal to 2015. Agricultural demand for future is estimated using IDC for future similar to the historical period. Land use and soil types are considered constant and the same as 2010 land use map.
Land Surface Infiltration	Model Result	Simulated by the model.	Infiltration to the soil zone of the model simulated by the PRMS.
Inflow from Upper Watershed Tributaries	Model Result	Flow from Area Upstream of Basin, simulated from calibrated model for all creeks.	Tributaries do not have data for calibration.
Overland Runoff	Model Result	Simulated from calibrated model. Impervious and pervious areas are determined using 2010 Land Use map for the County.	Based on calibration of streamflow to available data from gauged streams. Land use is considered constant for the entire period.
Groundwater Boundary Inflow	Model Result	Simulated from calibrated model. Impervious and pervious areas are determined using 2010 Land Use map for the County.	Groundwater inflow from Basin boundaries simulated by the model. Due to definition of boundary conditions, this term is negligible.

Table 7.1: Water budget components estimated by UVIHM and their associated limitations *(continued)*

Water Budget Component	Model Input or Model Result	Source of Data	Limitations
Evapotranspiration (ET)	Model Result	Measured and gaged temperature is spatially distributed by PRMS temperature distribution module. Potential ET is simulated by PRMS using temperature and solar radiation. Solar radiation is calculated by PRMS and calibrated based on measured and gaged date. Actual ET is modeled by the model. For agricultural fields, soil zone ET is simulated using same data, reference evaporation from CIMIS gage, and appropriate crop coefficients by the IDC model. ET for climate change scenarios uses the historical and future simulations and multiplies them by change factors provided for DWR climate change scenarios.	Not simulated from surface water bodies. Distribution method imposes uncertainties onto the model. Inherent measurement errors from gages and gaps in their measurement impose further uncertainties. Crop coefficients are based on best available literature and considered constant through out the modeling area for each crop type. Available solar radiation data was limited and constrained solar radiation calibration.
Direct Percolation/Recharge	Model Result	Deep percolation of distributed precipitation from measured gages is simulated by the calibrated model.	Assumes percolation applies directly as recharge to water table without delay through unsaturated-zone flow (UZF) package option. Uses soil parameters from NRCS SSURGO dataset and 2010 DWR land use map for surficial permeability. These data along with aquifer characteristics are considered constant throughout the simulation.

Table 7.1: Water budget components estimated by UVIHM and their associated limitations *(continued)*

Water Budget Component	Model Input or Model Result	Source of Data	Limitations
Stream Loss to Groundwater	Model Result	Simulated from calibrated model.	Calibration was done to streamflow and groundwater levels and no seepage estimations, streambed characterization, or measured data was available for enhancing calibration observations.
Stream Gain from Groundwater	Model Result	Simulated from calibrated model.	Calibration was done to streamflow and no seepage estimations, streambed characterization, or measured data was available for enhancing calibration observations.
Groundwater Outflow from Basin	Model Result	Simulated outflow from Basin boundaries from calibrated model.	Subsurface outflow to adjacent basins was estimated to be very small.
Russian River Outflow from Upper Watershed	Model Result	Simulated from calibrated model.	Streamflow leaving the Basin area through mainstem Russian River.
Boundary Inflow to Upper Watershed	Model Result	Simulated from calibrated model.	Flows and fluxes entering the Upper Russian River Watershed from outside. This term is negligible.
Stream Exchange to(+)/from(-) Aquifer	Model Result	Simulated from calibrated model.	Streamflow lost to groundwater (+) or water gained from the aquifer (-). Signs are defined with reference to aquifers' water balances.

Historical Baseline

Historical baseline is defined as the period starting from October 1992 through September 2018. This corresponds to a period from water year (WY) 1992 to WY 2018. Historical simulation baseline of the UVIHM starts from January 1991 and ends in December 2018. However, the first year is used as model warmup period and discarded. The 27-year historical baseline includes water years ranging from critical (e.g., 2008 and 2009) to wet (e.g., 2017) and multiple cyclical changes in wet and dry periods, as shown in **Figure 5.6**.

Current Baseline

The current period for the Basin is defined as WY 2015 through WY 2018. Although this period includes an end-of-drought year and a very wet year, it reflects the best historical period available to assess conditions of the Basin considering the availability of data and other relevant information. For current conditions, municipal demands, including groundwater pumping and surface water diversions, were implemented based on the most recent data available.

Future Baseline

Future baseline is defined as WY 2019 to WY 2070, providing a period of more than 50 years as required by SGMA. The future baseline is set up using climatic and hydrologic data and input from water years 1965-2018. The first few years of the period are used to allow the model to spin up and function effectively but are not incorporated into outputs. The 50-year baseline used for the water budget is equal to water years from 1969 to 2018. The Future Baseline projection represents a hypothetical future period in which climate conditions are the same as historical conditions.

During future baseline, all water demands are considered constant and equal to that of the water year 2018. For all other categories of input data, the latest and most recent version of data available was used and held constant for the entire period of the future baseline. This includes but is not limited to land use, soil types, irrigation practices, and supply wells.

7.4.1 Watershed/Landscape Water Budget

The Upper Russian River watershed budget for historical and future baselines is provided in **Figures 7.13** and **Figures 7.14**, respectively. Watershed and landscape water budgets illustrate the impacts of precipitation and evapotranspiration on the Basin and the watershed and present the water budget for natural landscape portions of the model domain.

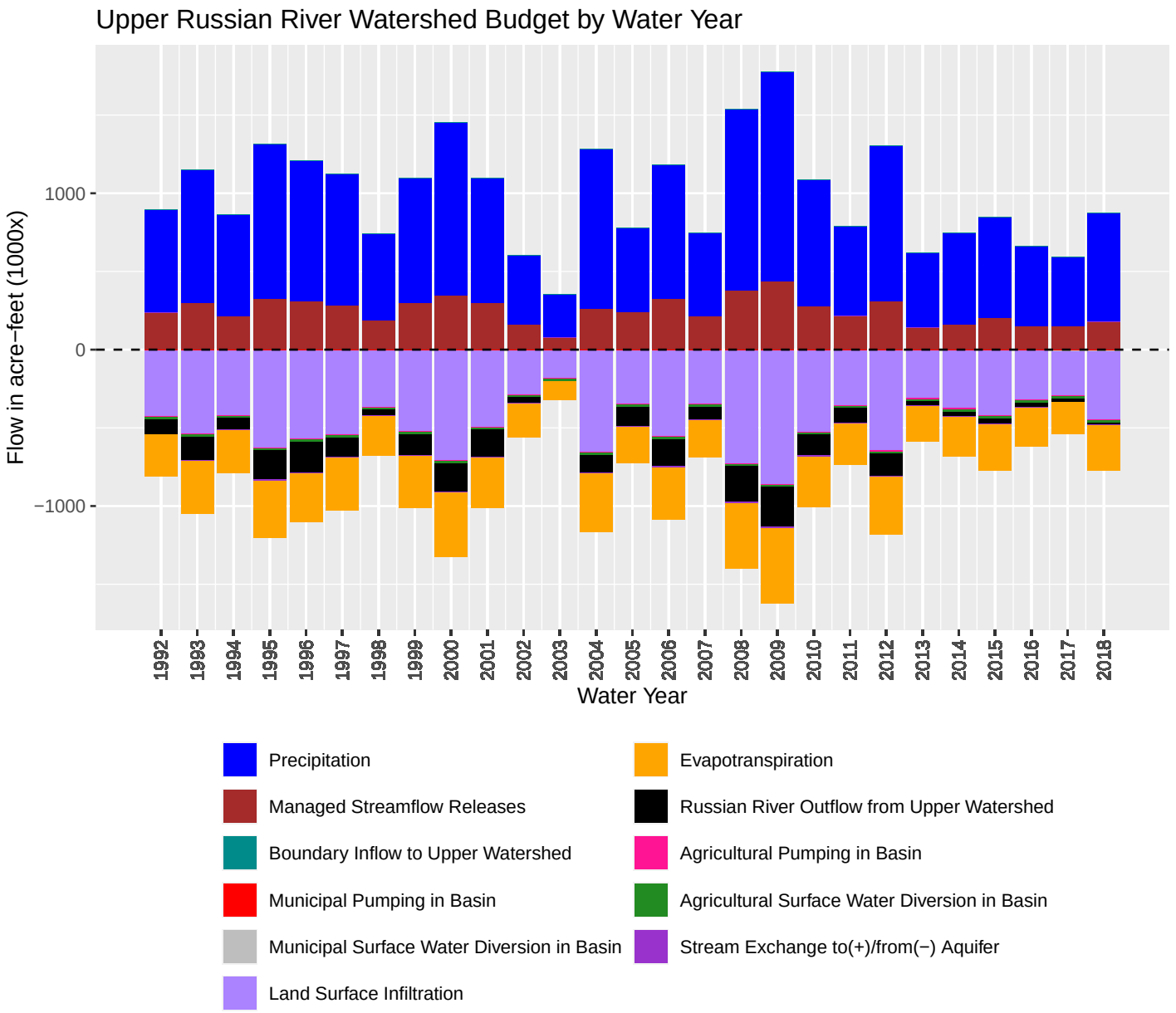

Figure 7.13: Estimated historical annual water budget for the Upper Russian River Watershed.

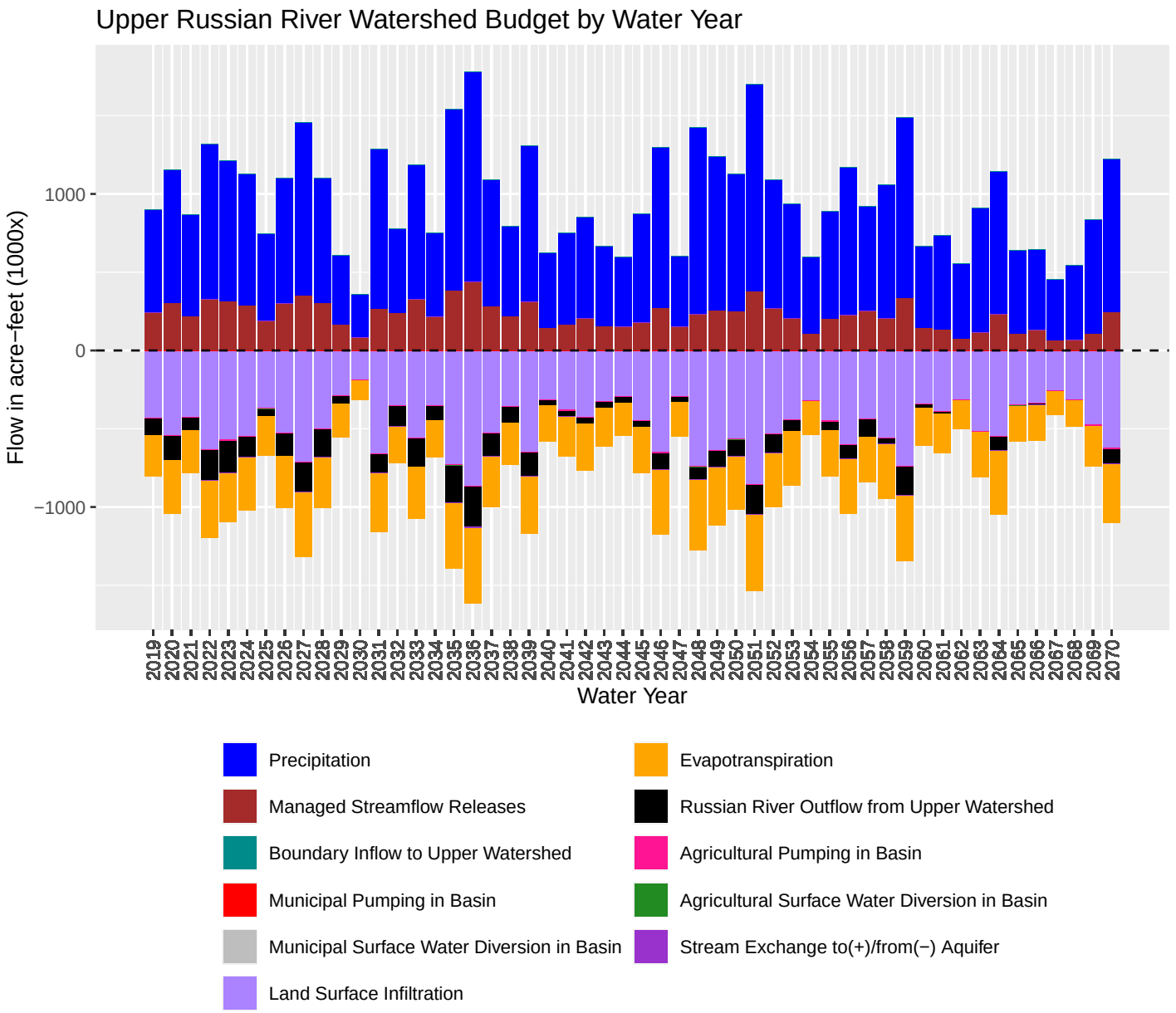

Figure 7.14: Estimated projected annual water budget for the Upper Russian River Watershed.

7.4.2 Soil Zone Water Budget

Soil zone water budgets are generated using the UVIHM IDC results for the Basin and individual crops. Although the UVIHM IDC results are transferred into the UVIHM GSFLOW as input data for agricultural surface water and groundwater demands, these budgets provide information about IDC results, soil-zone water budget, and native and riparian vegetation water needs in the Basin. Soil zone water budgets are estimated and shown as average rates per crop for the entire Basin in inches and feet per month instead of volumetric units. This is due to the request from the agricultural community to facilitate easier understanding and comparison to their normal practice. Total acreage corresponding to each water budget is provided on top of the figure and can be used to estimate volumes. **Figures 7.15** shows the soil zone budget for the entire Basin. **Figures 7.16** through **Figures 7.20** show soil zone water budgets for grapes, pears, pasture, native vegetation, and riparian vegetation in the Basin. Applied water estimated for riparian vegetation represents riparian demands by the vegetation supplied by streams or shallow groundwater. Riparian applied water demand was not transferred to the UVIHM GSFLOW due to existing uncertainties and data gaps. Furter re-evaluations are needed to prevent double-counting of its water demand and improve its applied water estimation by additional data regarding vegetation type, streambed profiles, groundwater elevations, and evapotranspiration demands.

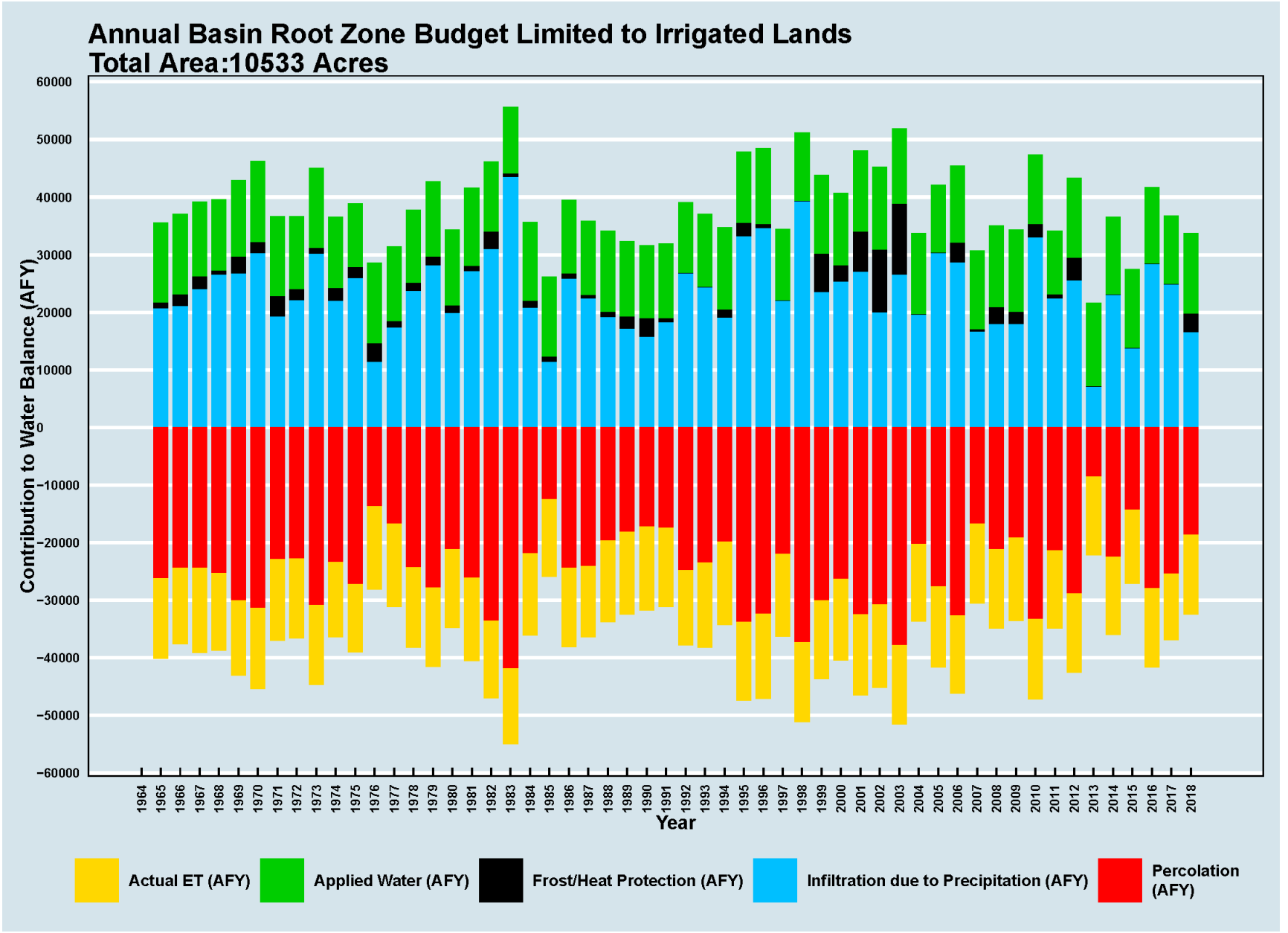

Figure 7.15: Annual historical Soil-zone water budegt for the Basin estimated by the UVIHM IDC.

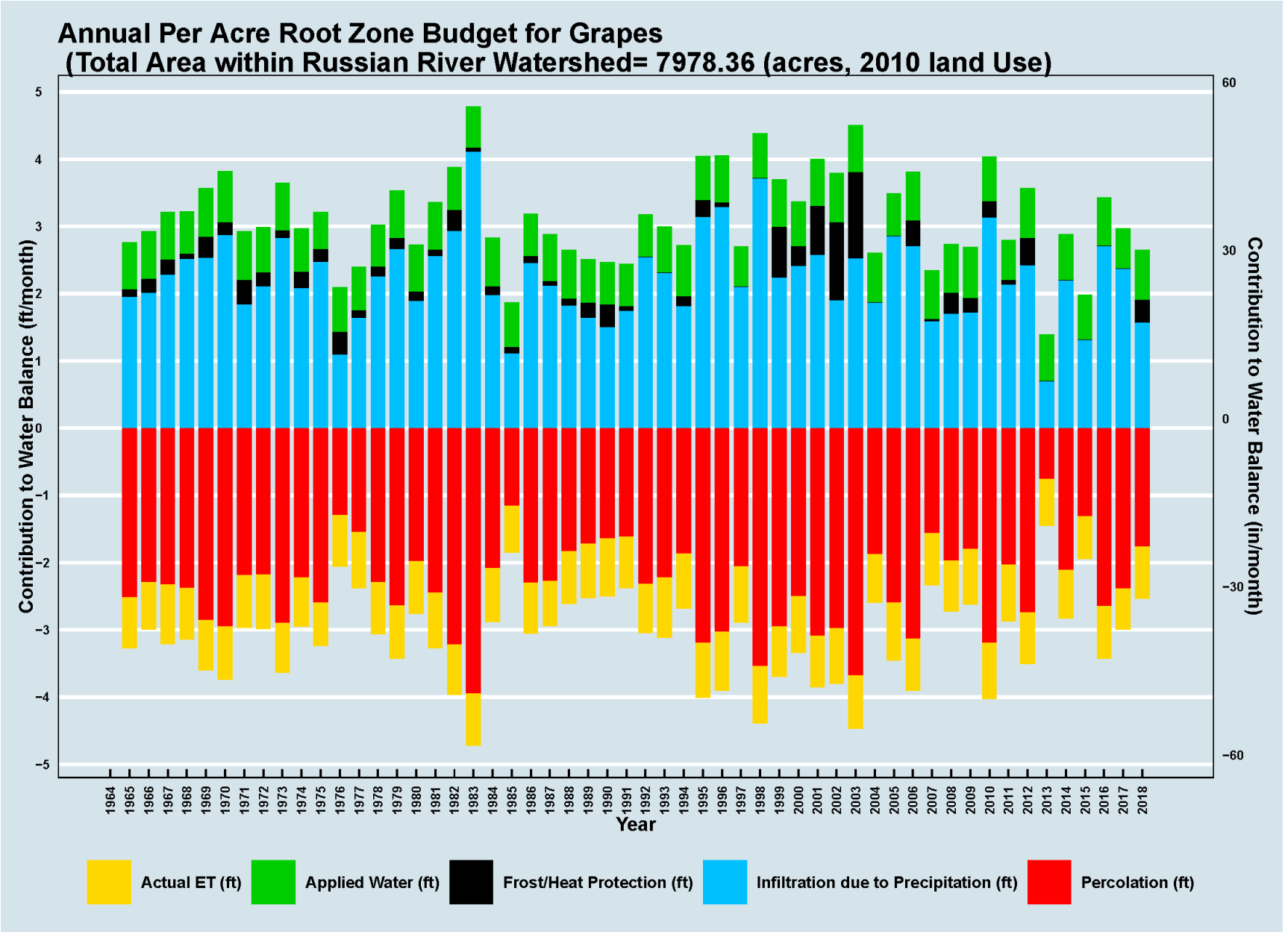

Figure 7.16: Annual historical Soil-zone water budegt for grape irrigation estimated by the UVIHM IDC.