Numerical Model of Groundwater Flow in the southern portion of the Trinity Aquifer

Technical Progress Meeting
August 8, 2025

Thank you for signing in early.

The meeting will begin at 10:00 am, Central Daylight Time

Please stay muted during the meeting and use the chat box to submit questions

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What to Expect Today

- Draft model is ready
- Highly technical in nature
- Official public comment period TBD

Meeting information

- An audio and video recording of the meeting, presentation, and the report summarizing the meeting will be made available on the TWDB project webpage

http://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp

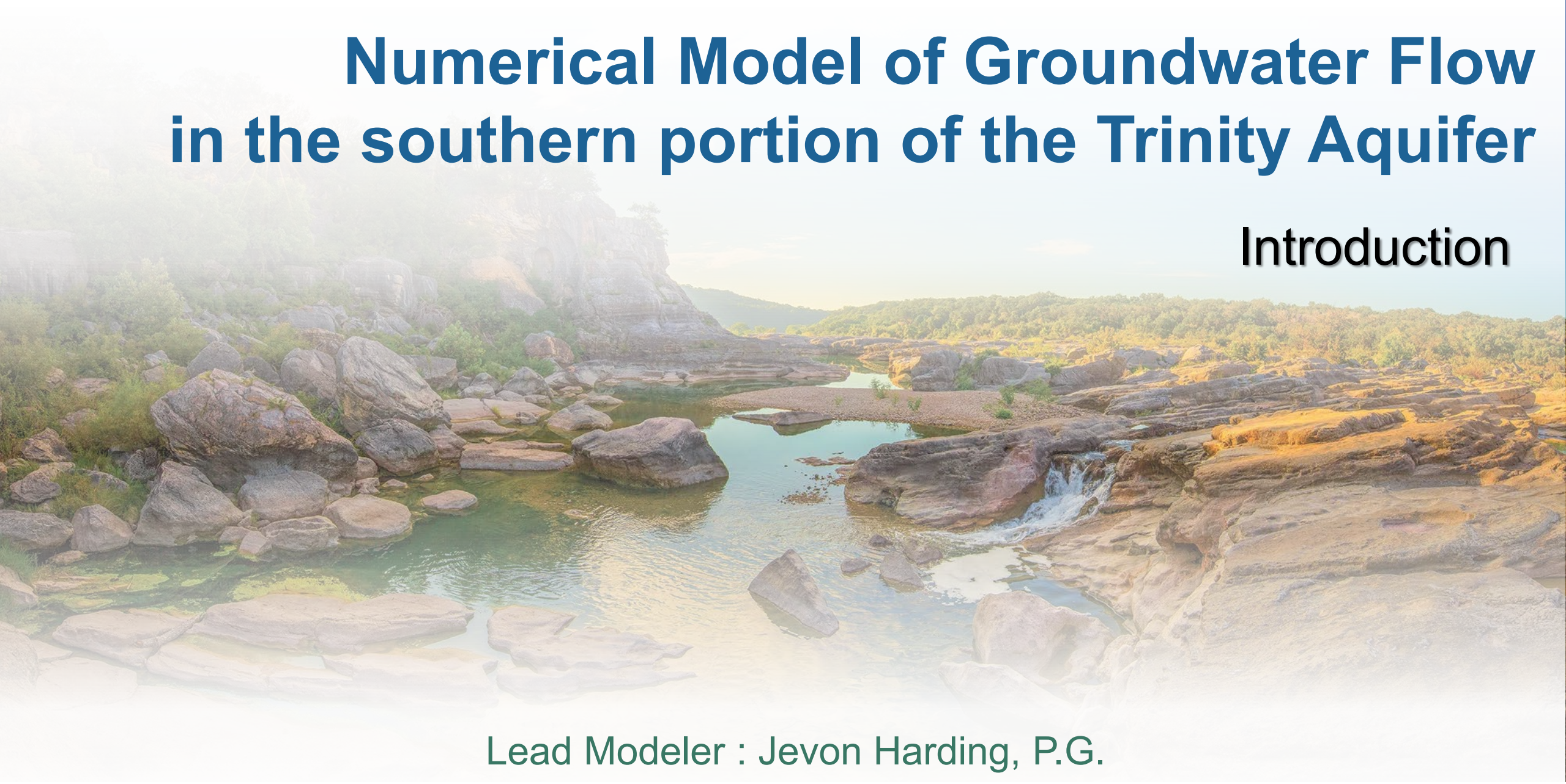
Agenda

Numerical Model for the southern portion of the Trinity Aquifer

Question and Answer

Numerical Model of Groundwater Flow in the southern portion of the Trinity Aquifer

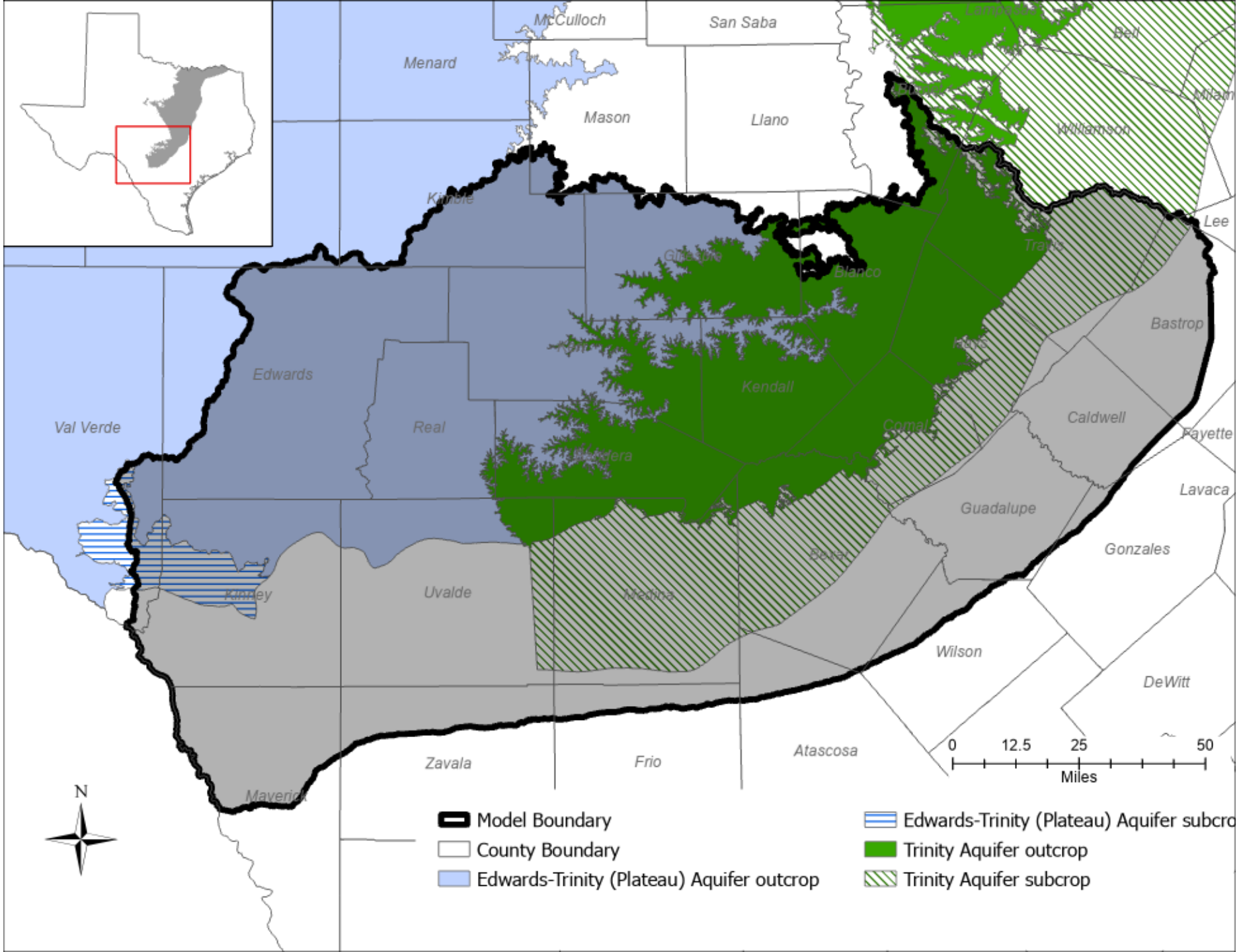
Introduction



Lead Modeler : Jevon Harding, P.G.

Model Boundary

Model Boundary



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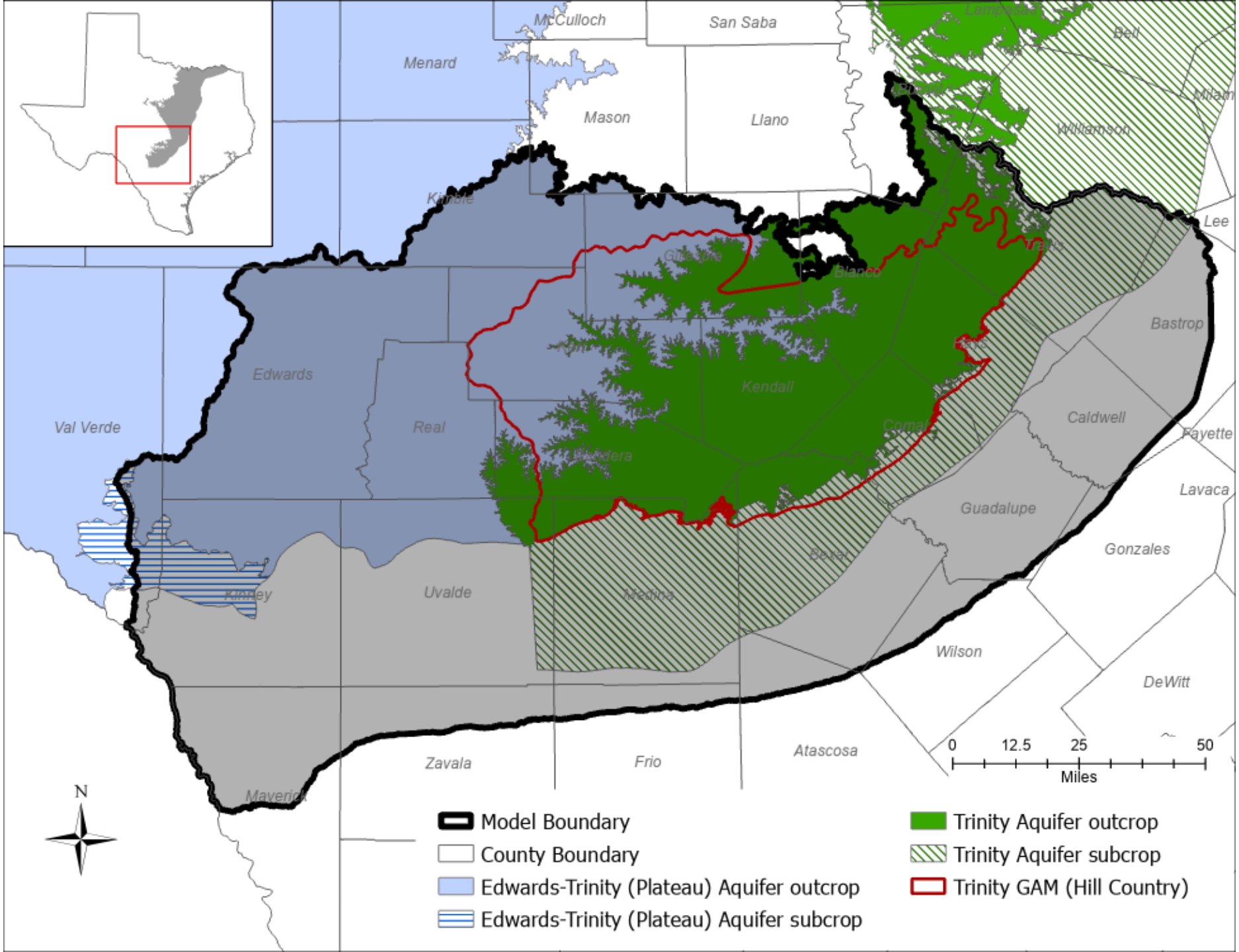
Model Boundary



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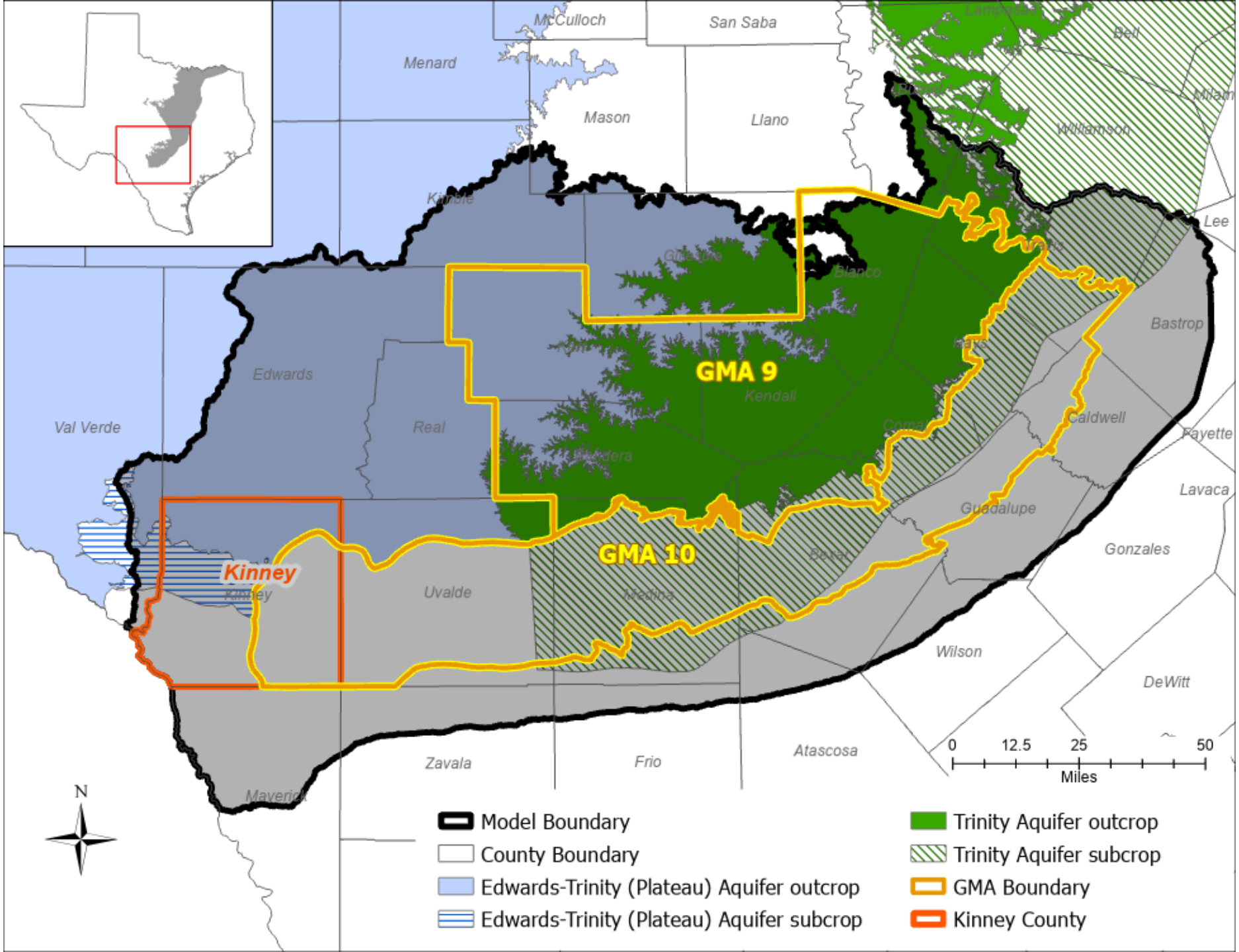
Planning Boundaries

- GMAs 9 & 10
- Kinney County



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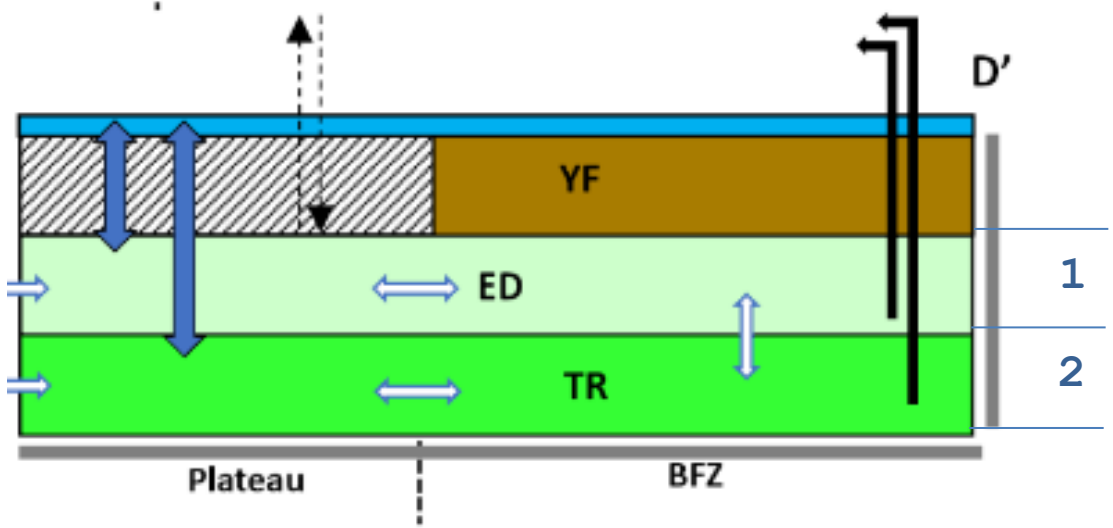
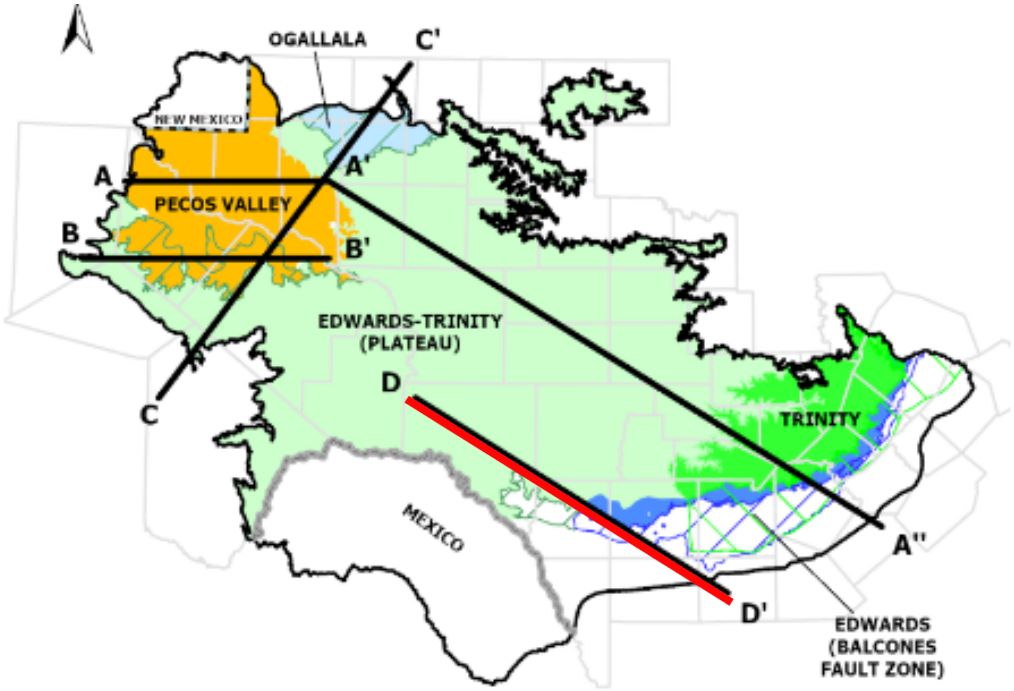
Model Layers

Stratigraphy

(Southern Trinity GAM)

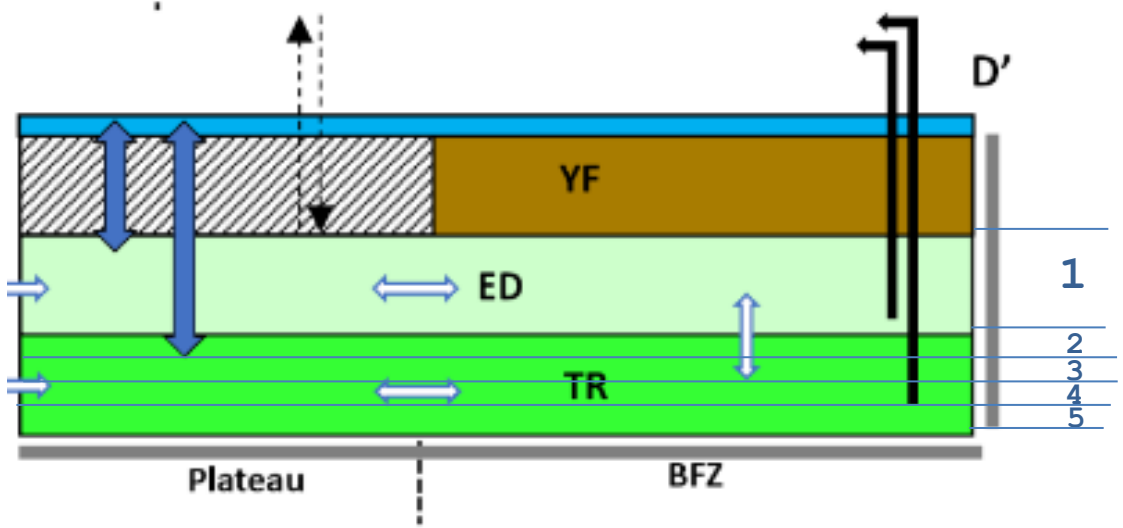


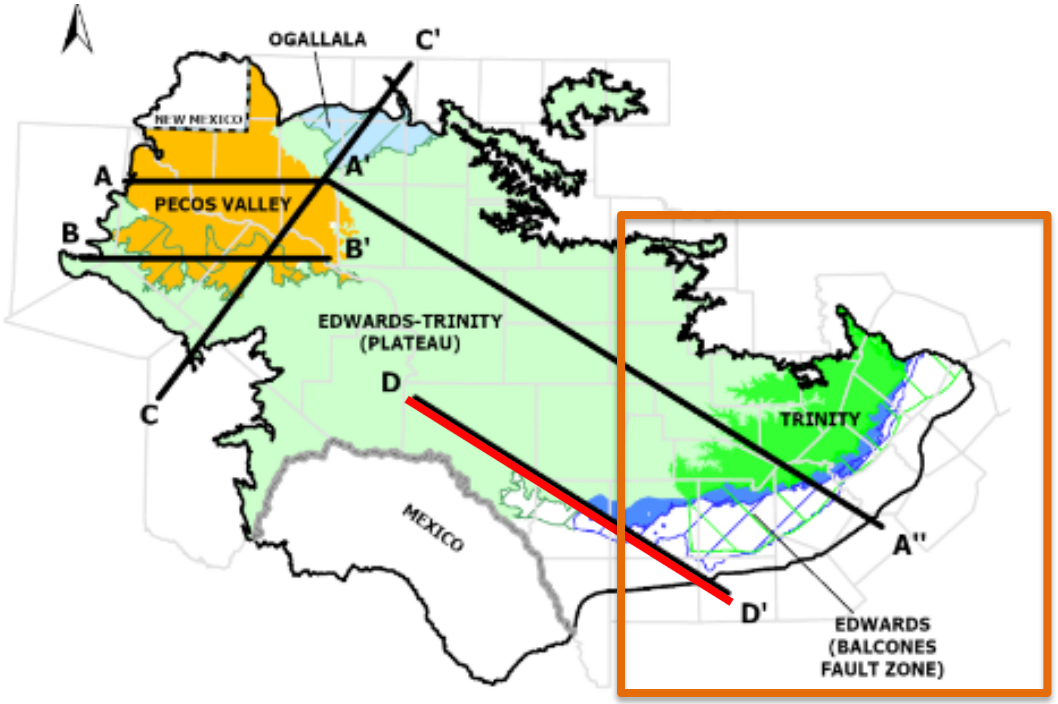


Plateau (West)	Model Layer
Edwards	1
Trinity	2

Stratigraphy

(Southern Trinity GAM)





Plateau (West)	Hill Country (Central)	Edwards BFZ (Southeast)	Model Layer
Edwards	--	Edwards	1
Upper Trinity	Upper Trinity	Upper Trinity	2
Middle Trinity	Middle Trinity	Middle Trinity	3
Hammett Shale	Hammett Shale	Hammett Shale	4
Lower Trinity	Lower Trinity	Lower Trinity	5

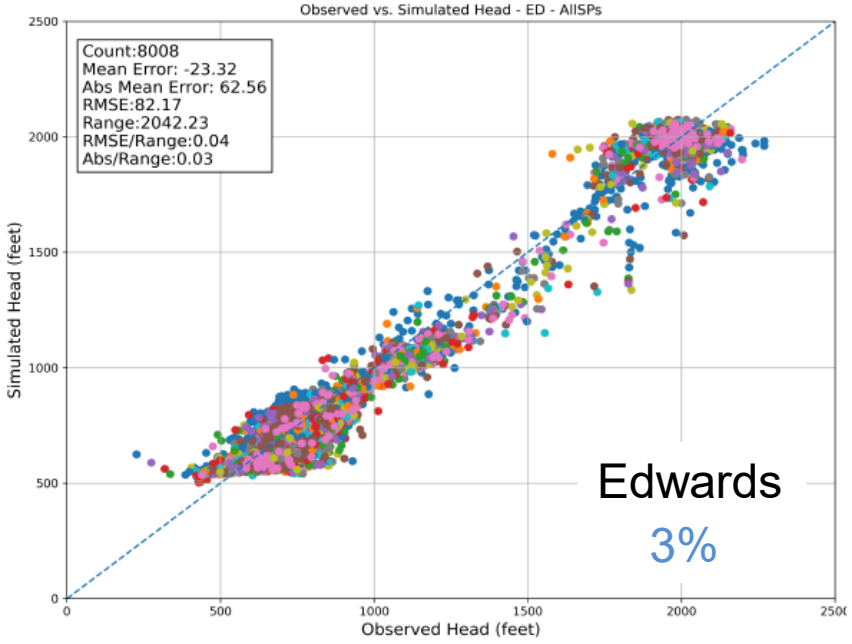
Model Summary

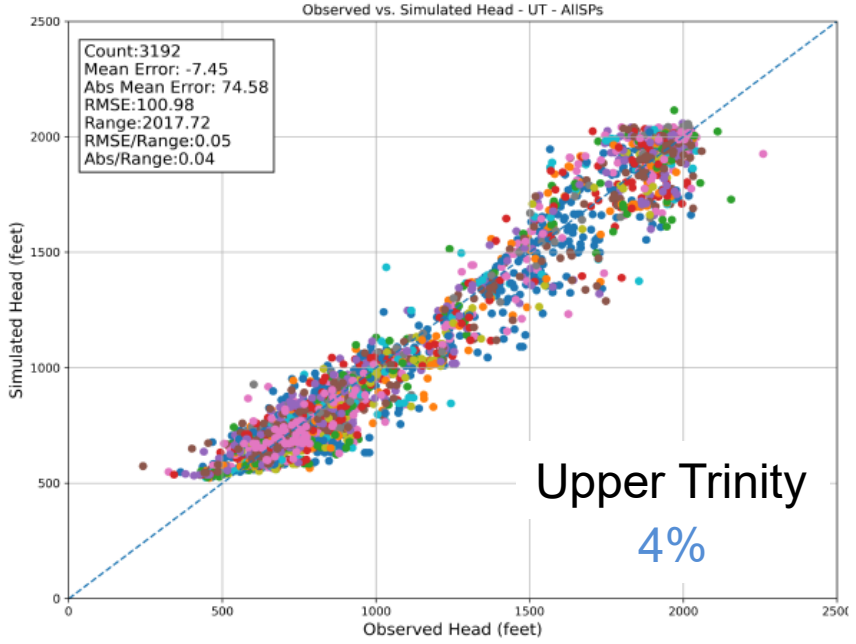
Model Summary

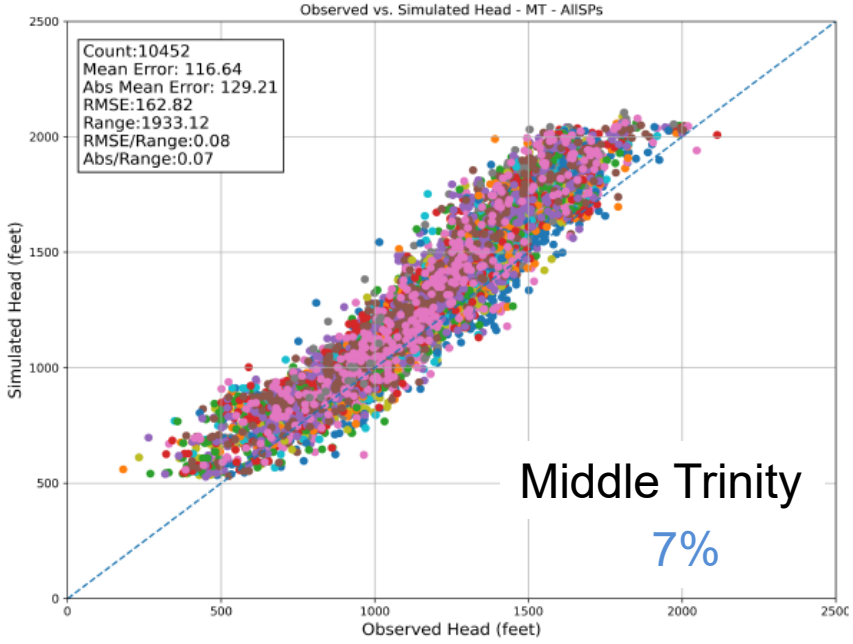
- MODFLOW 6
- 5 layers *(Edwards, Upper Trinity, Middle Trinity, Hammett, Lower Trinity)*
- 341,249 active cells *(443,425 total)*
- Time Period: 1980-2020
- 41 stress periods *(1 Steady-state & 40 annual transient)*
- Average run time : 17-19 minutes
- Steady-state model calibration using pestpp-ies

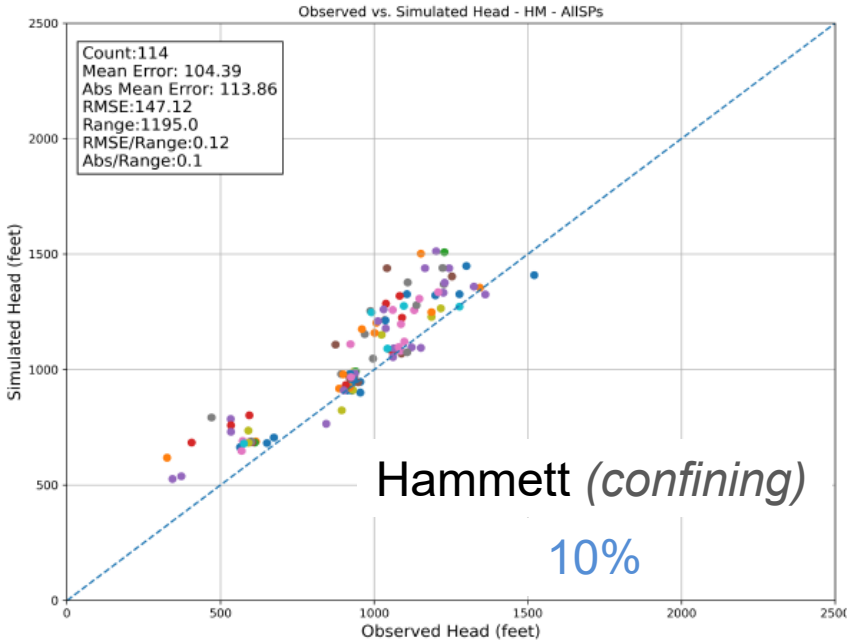
Model Standards

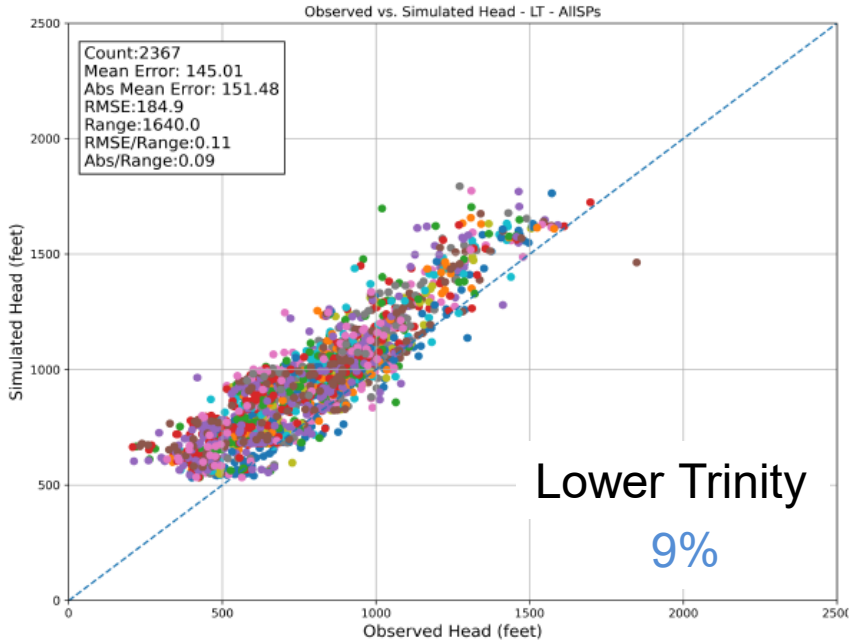
- “The range of hydraulic head fluctuations in the observation wells must be matched **as closely as possible**”
- “The **mean absolute error** or **root mean squared error** between measured hydraulic head and simulated hydraulic head must be **less than 10 percent** of the measured hydraulic head drop across the model area **for each model layer**.”
- “Any error must **not** be spatially biased”

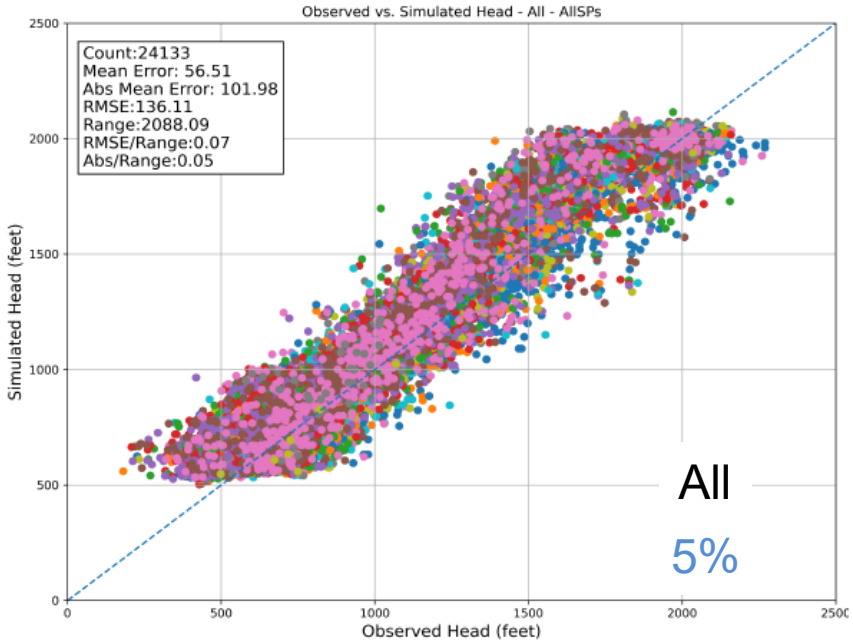






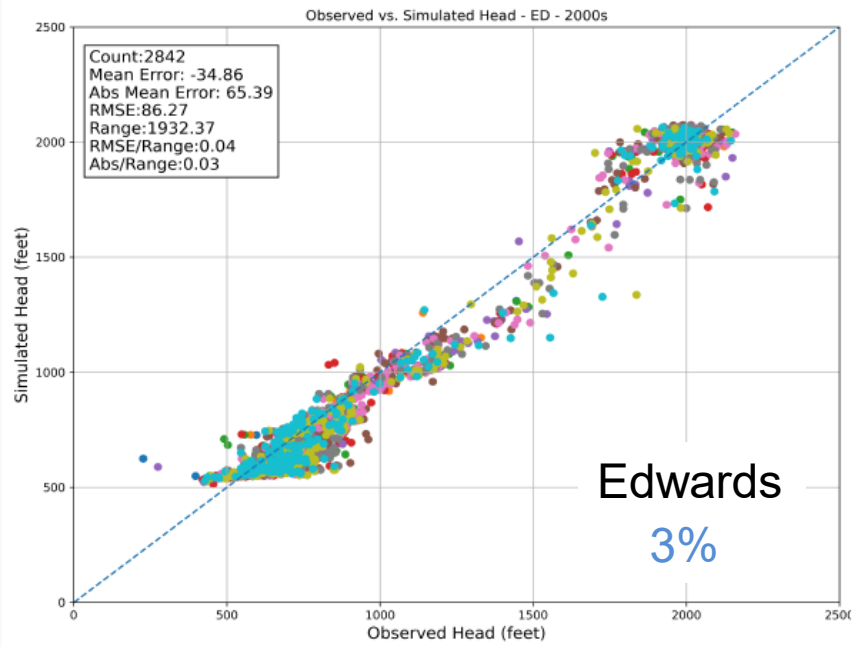


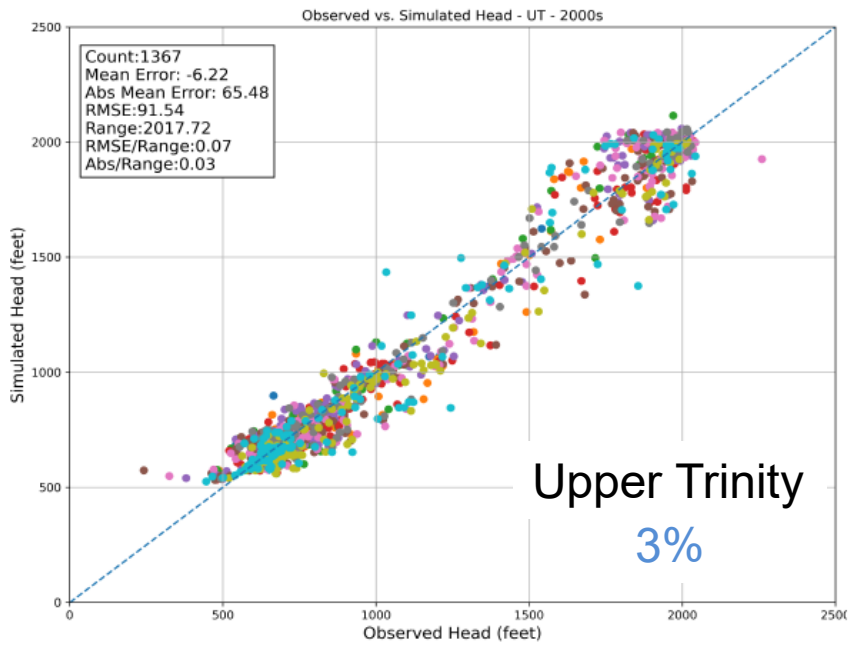


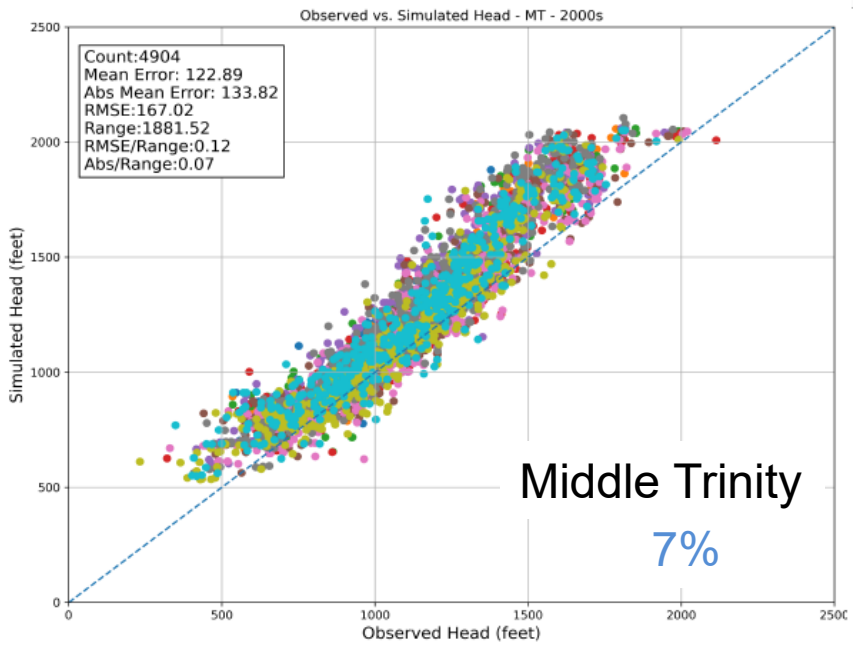


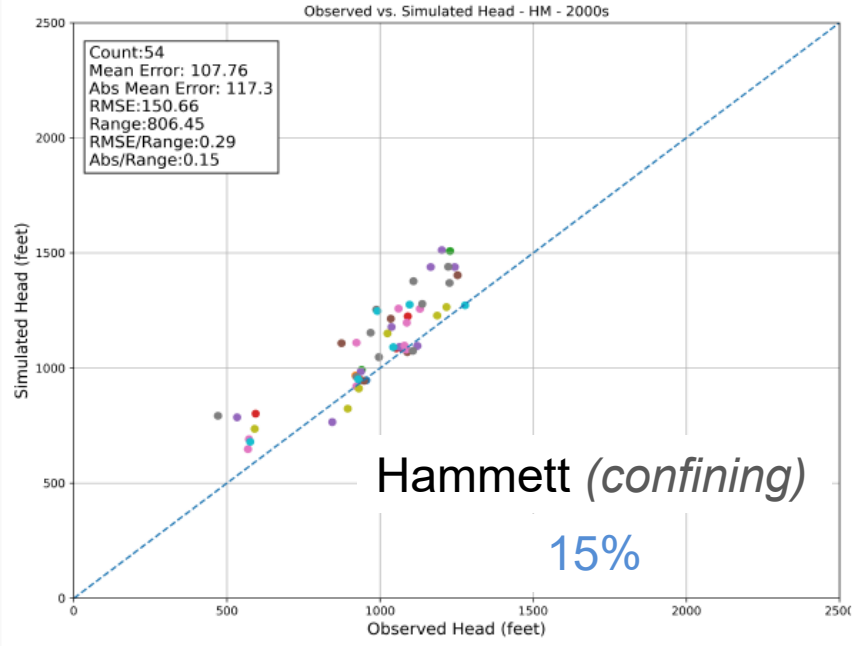
TEXAS WATER DEVELOPMENT BOARD

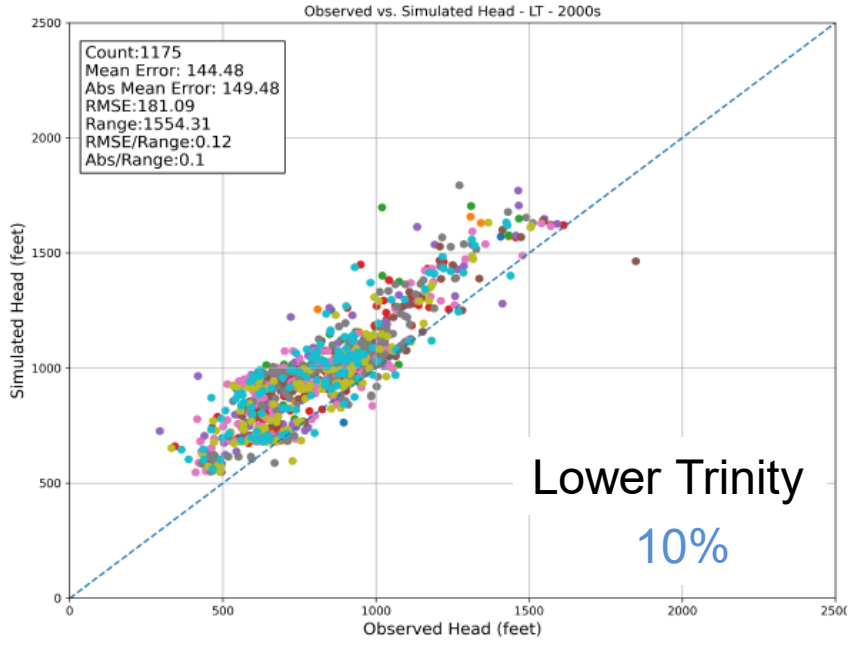
Colors represent different stress periods

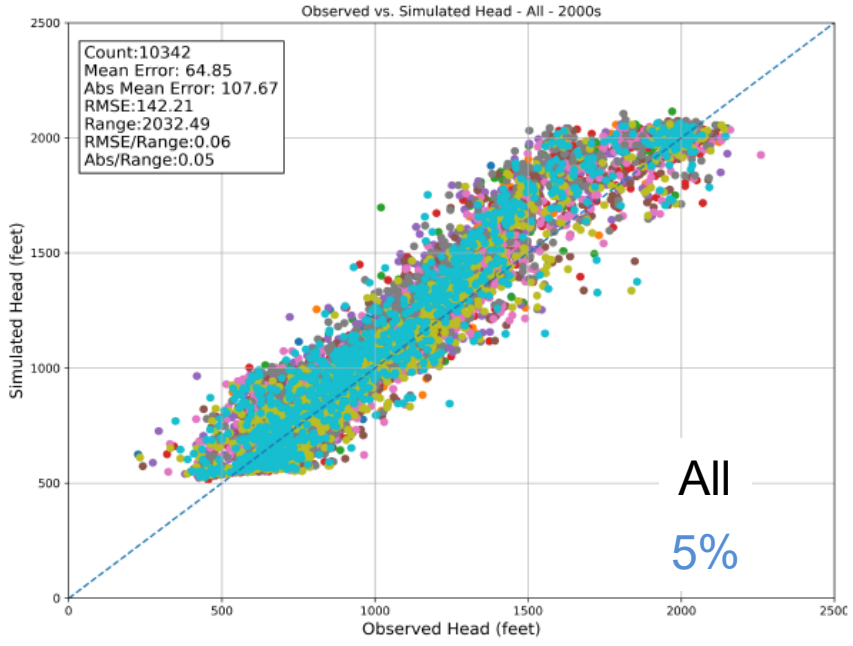








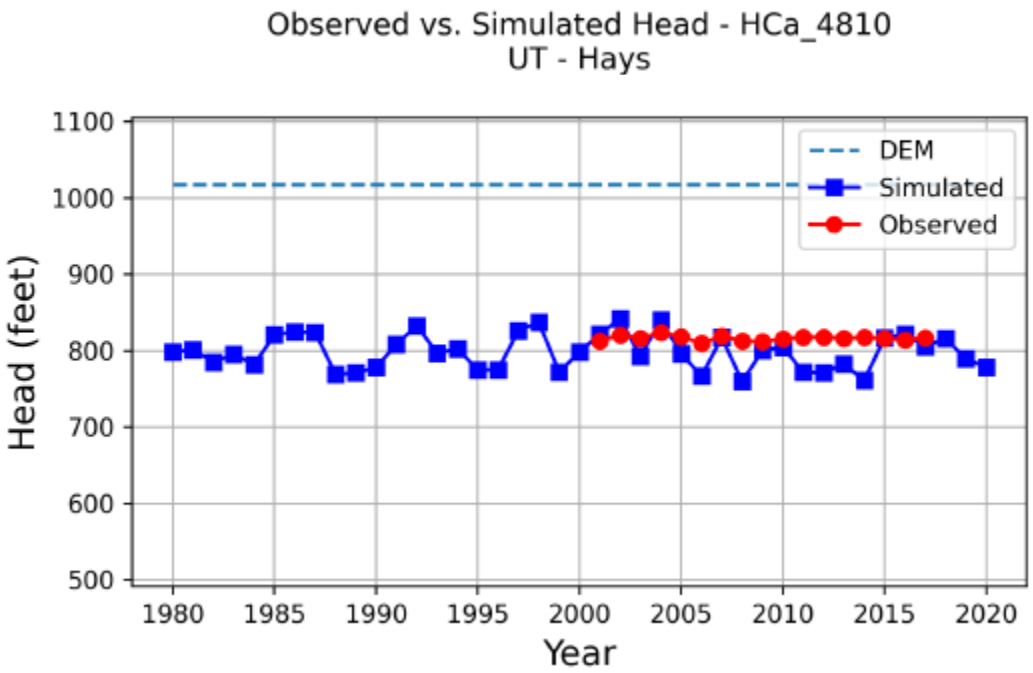




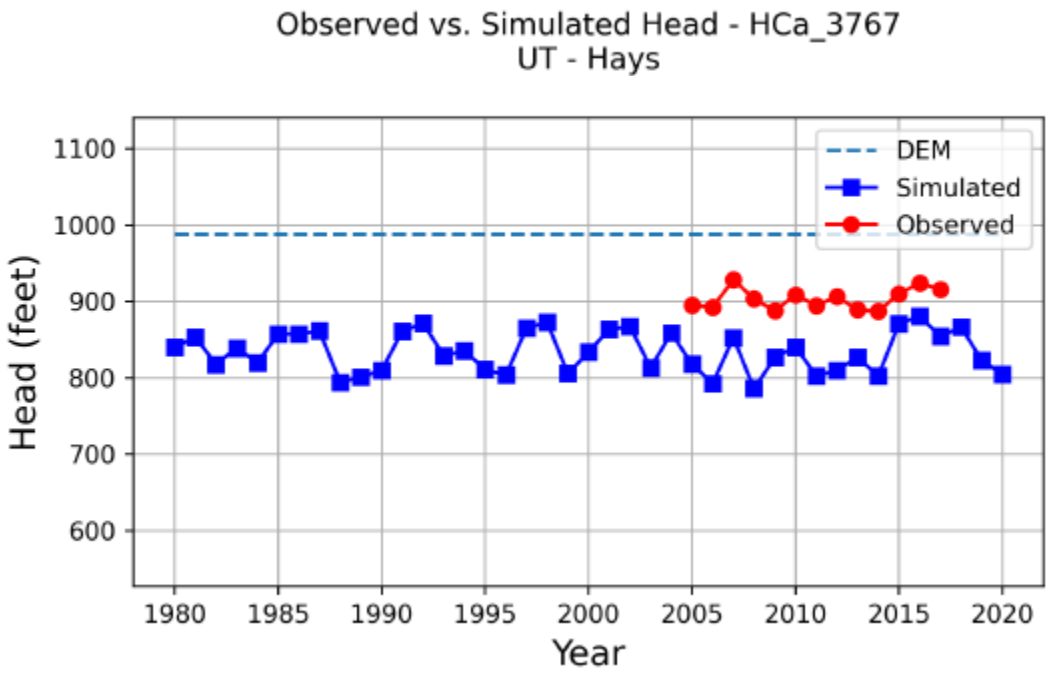
TEXAS WATER DEVELOPMENT BOARD

Colors represent different stress periods

History Matching - Hydrographs

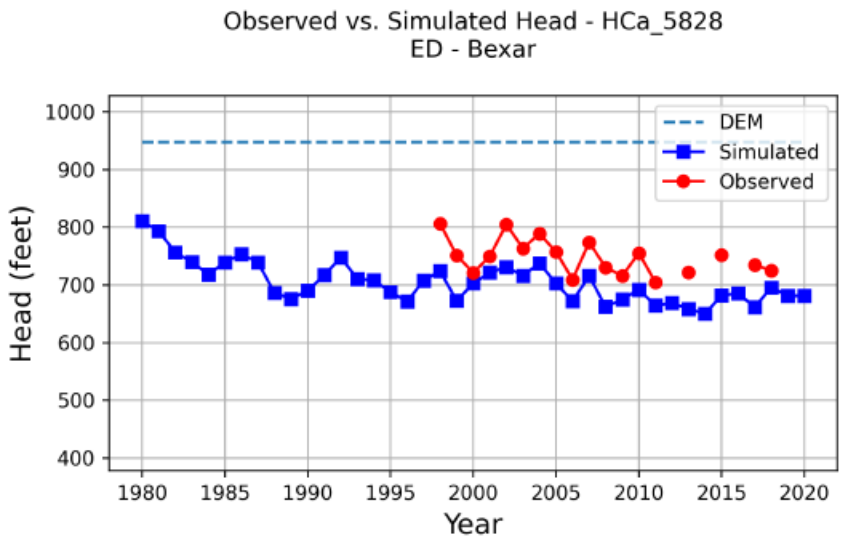


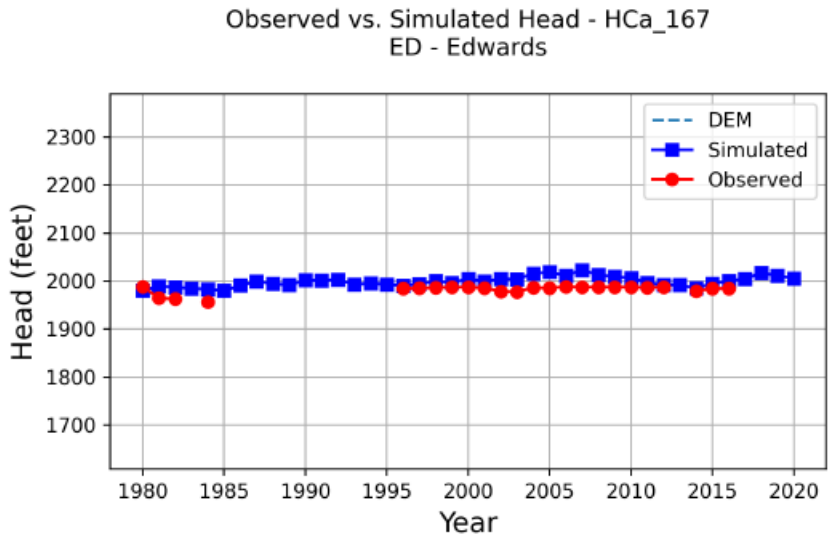
GOOD – matches Elevation Range

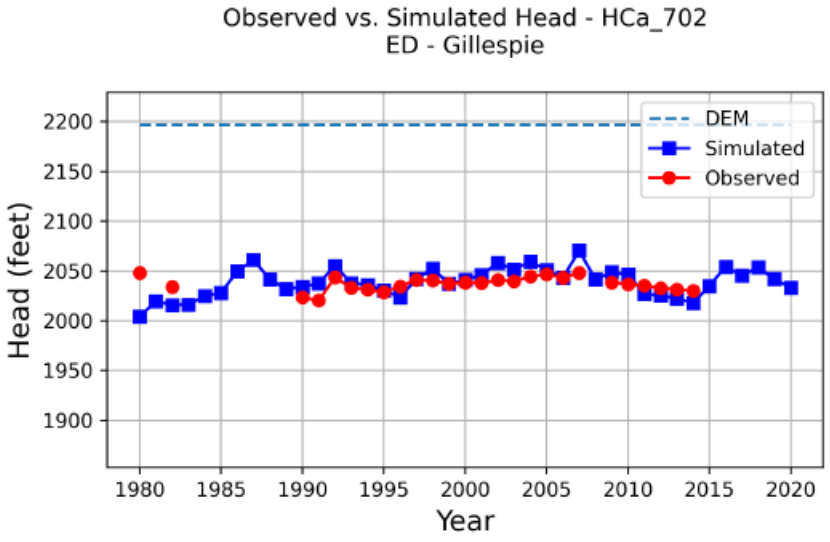


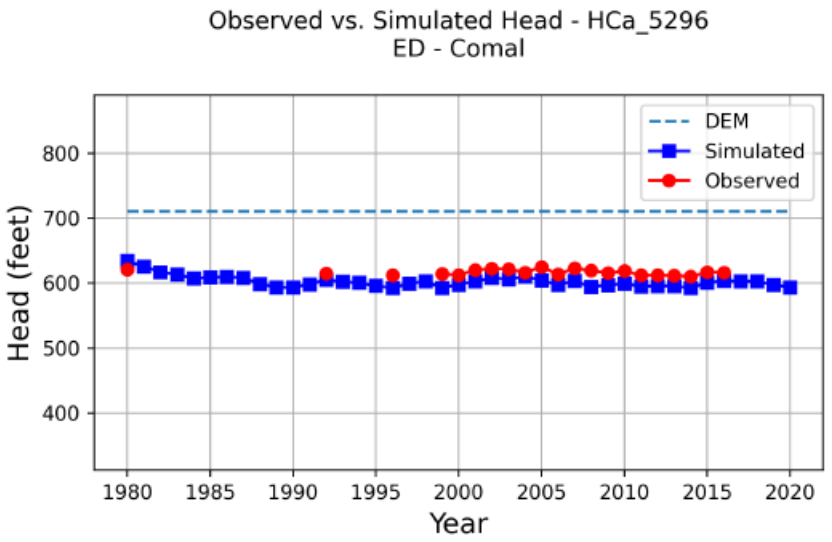
GOOD – matches Trend

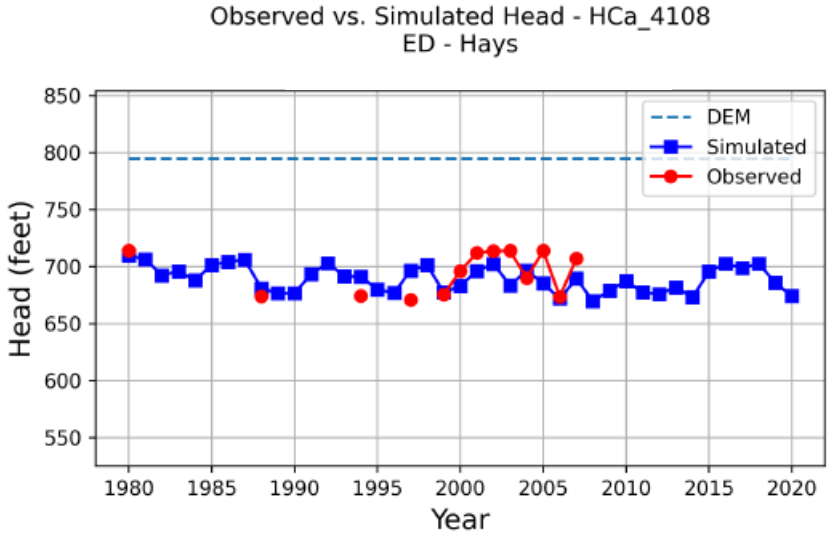
History Matching – Edwards

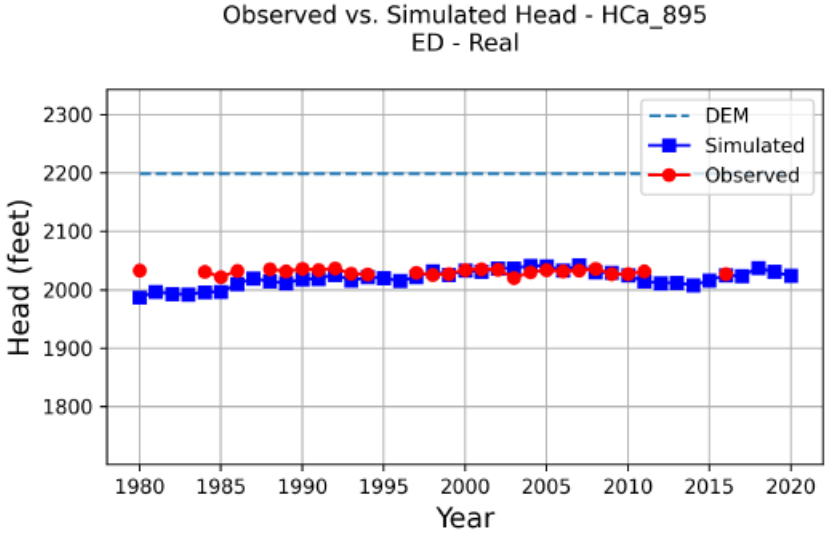




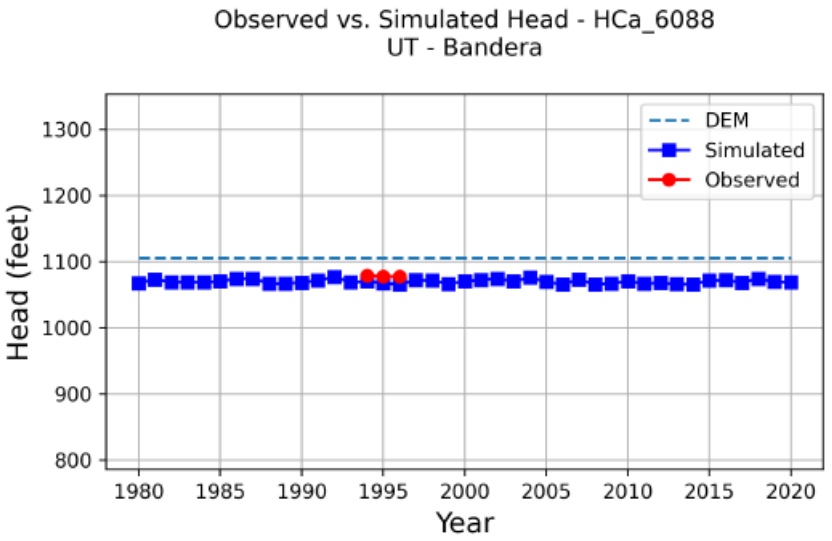


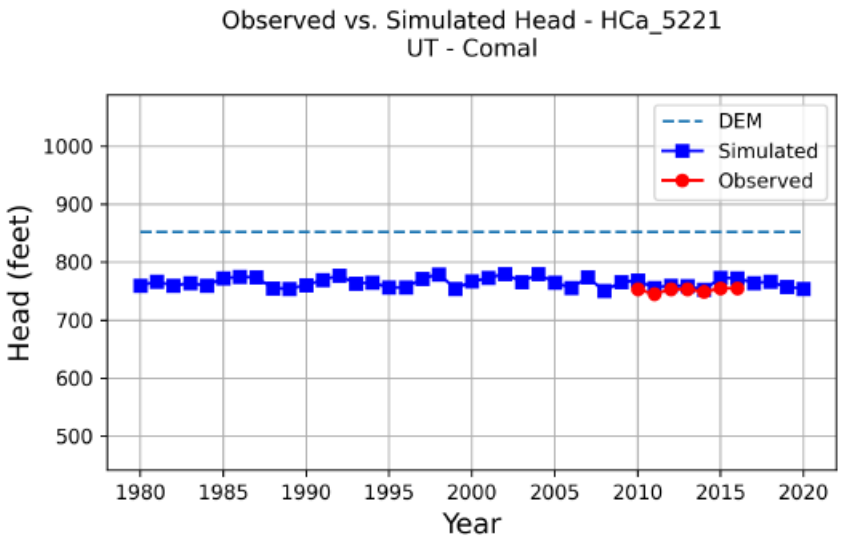


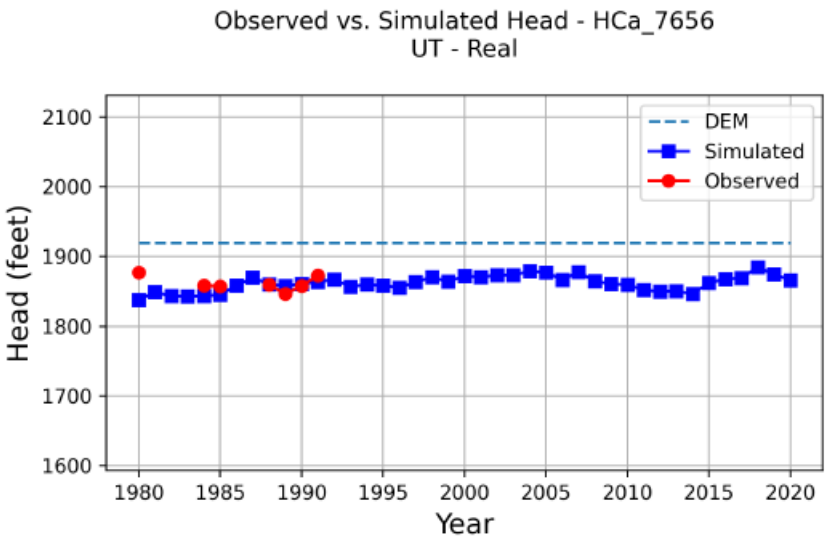


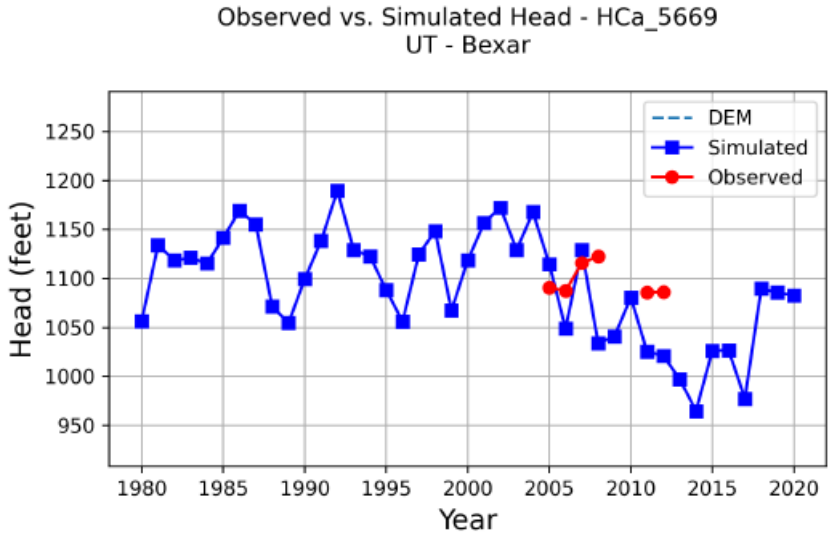


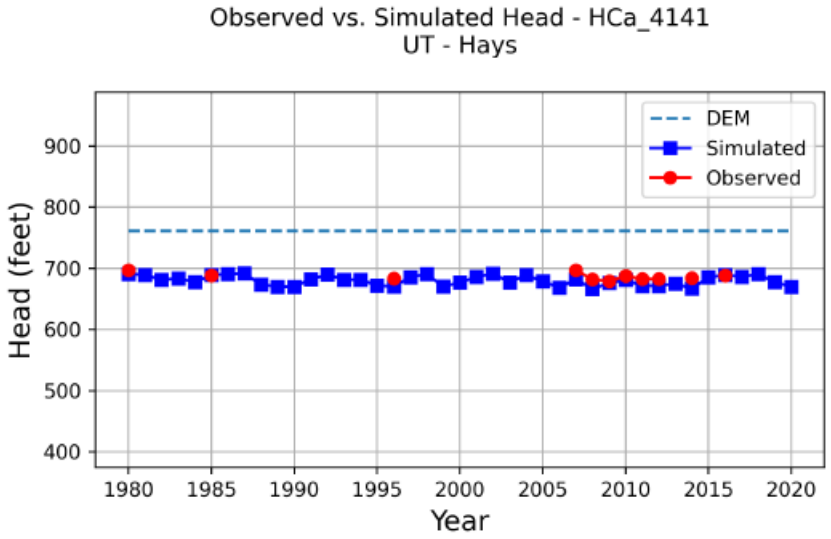
History Matching – Upper Trinity



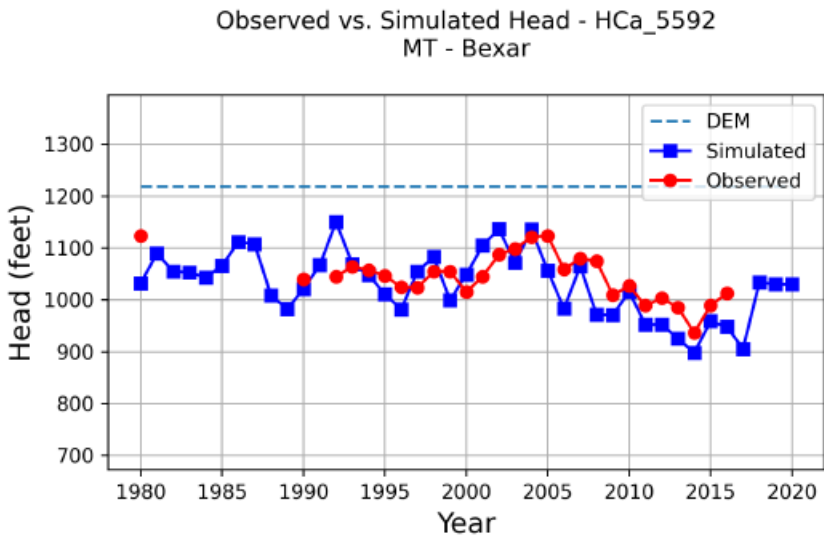


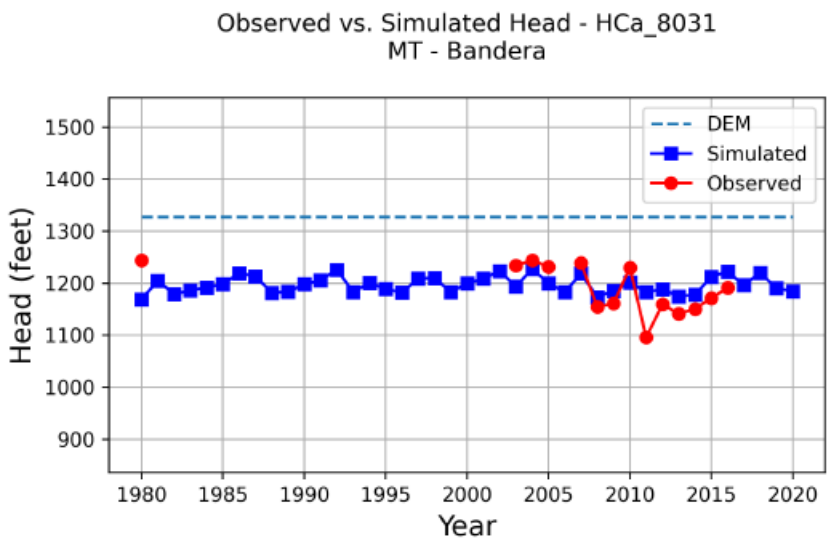


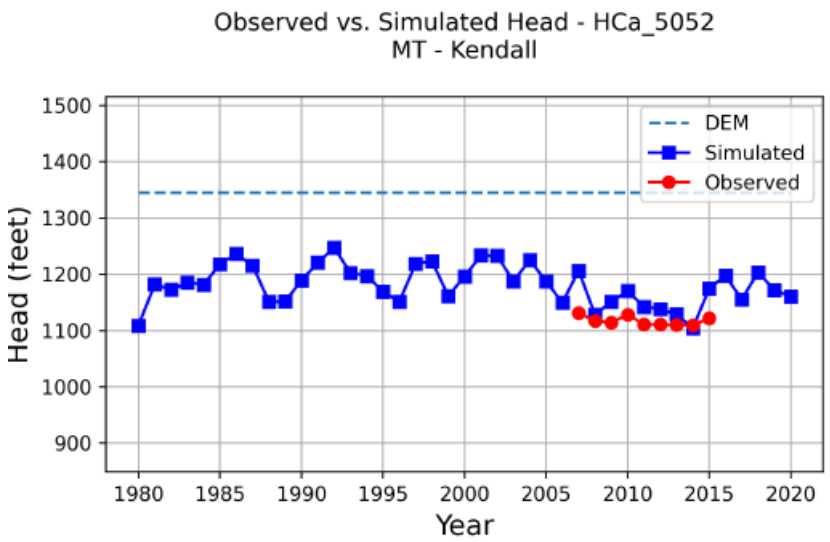


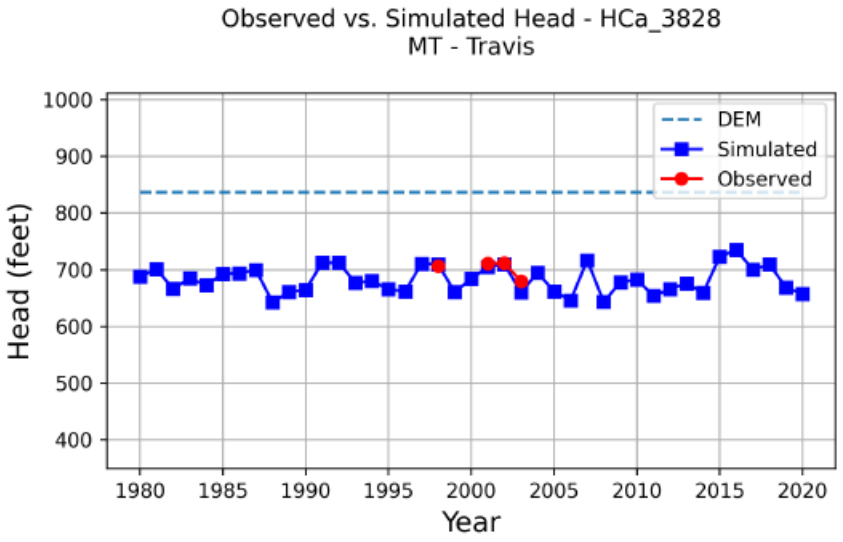


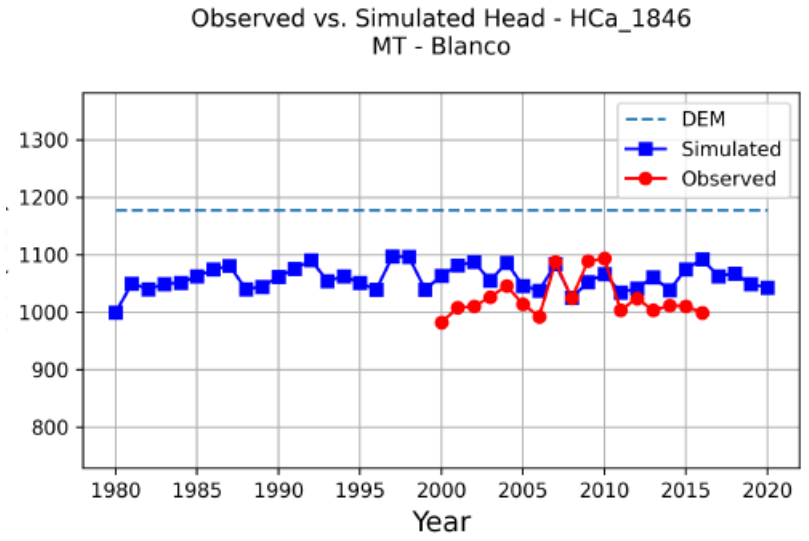
History Matching – Middle Trinity

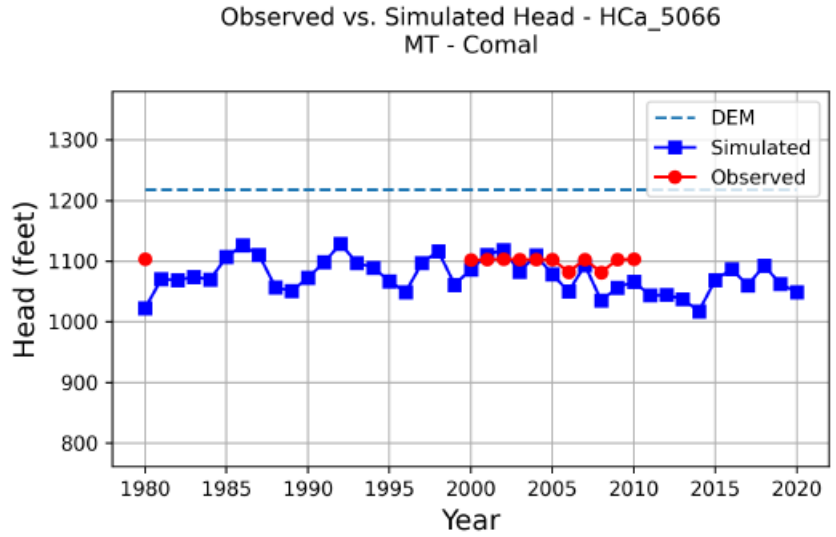




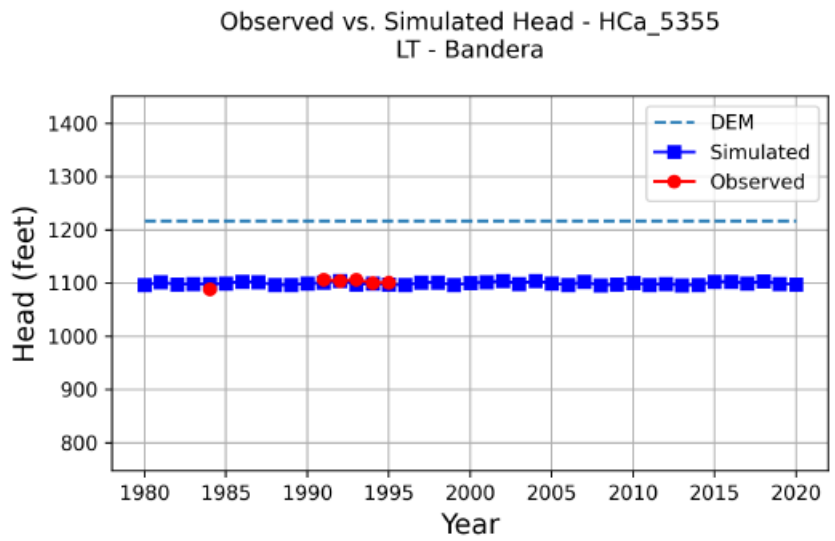


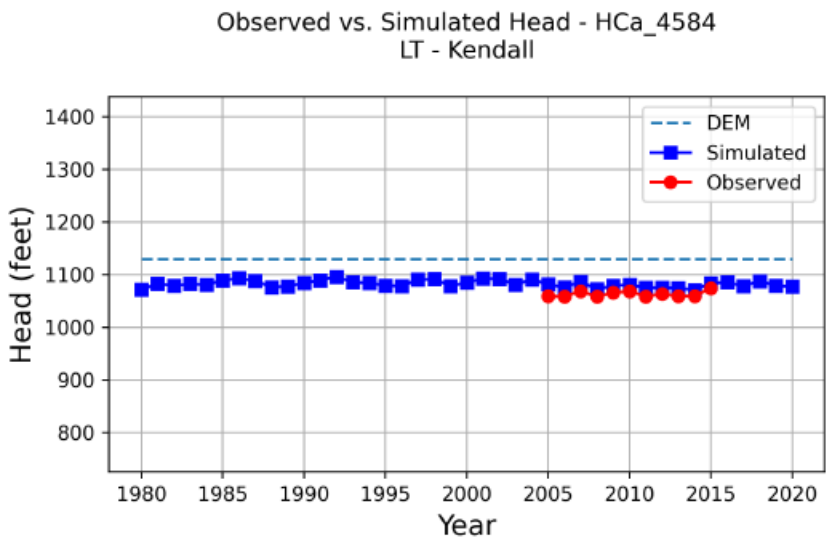


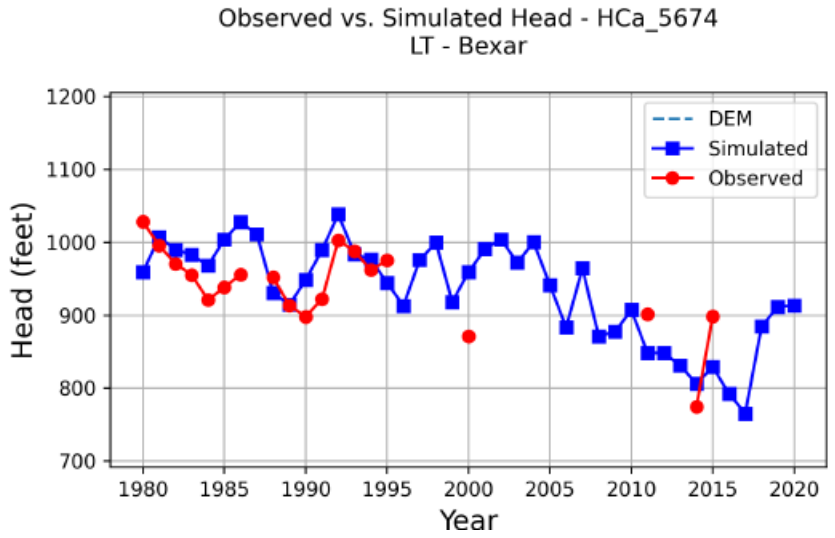


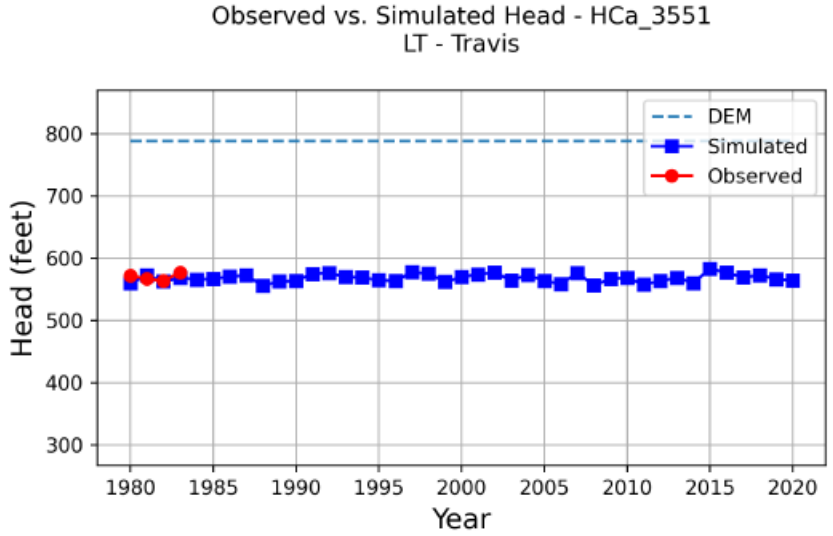


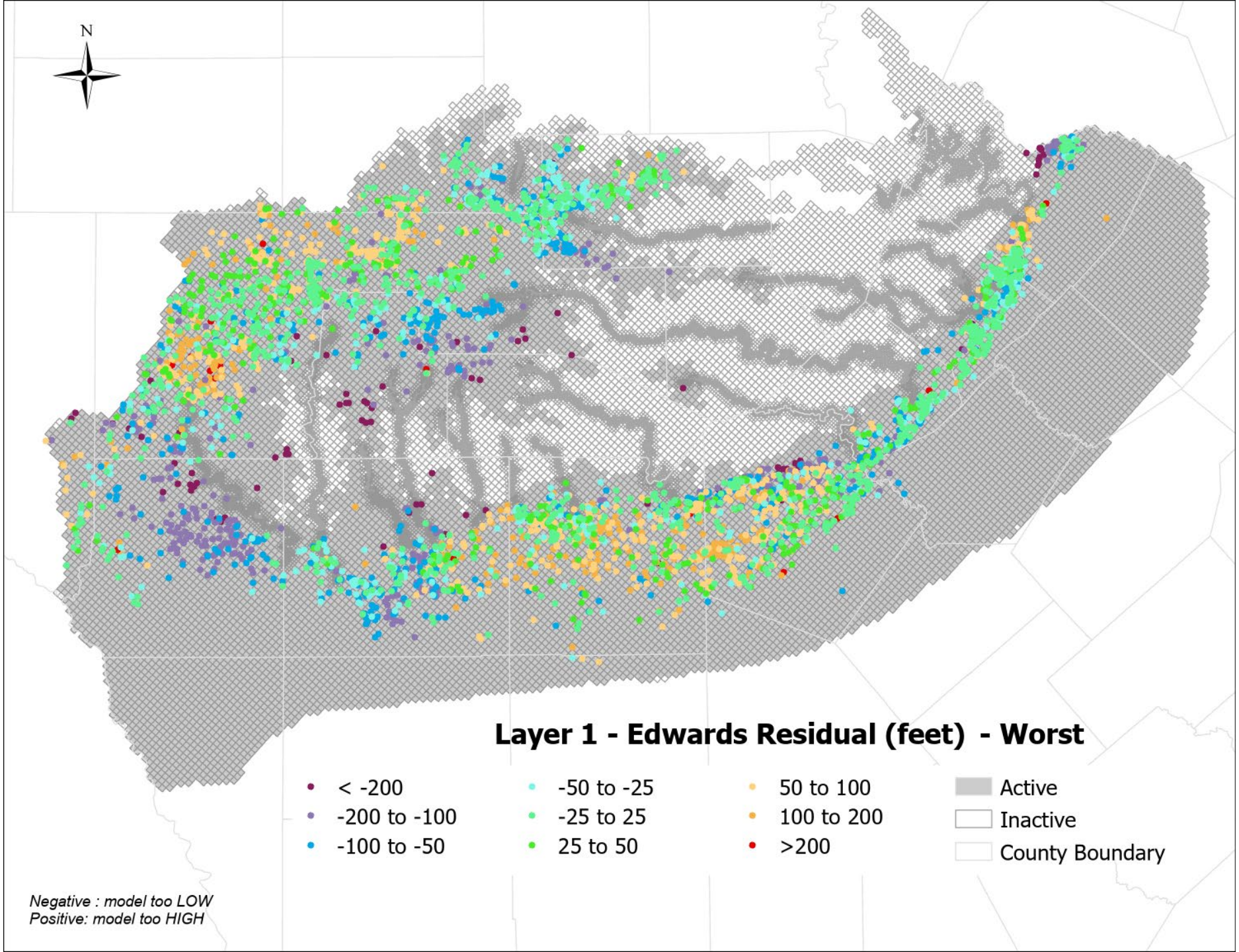
History Matching – Lower Trinity



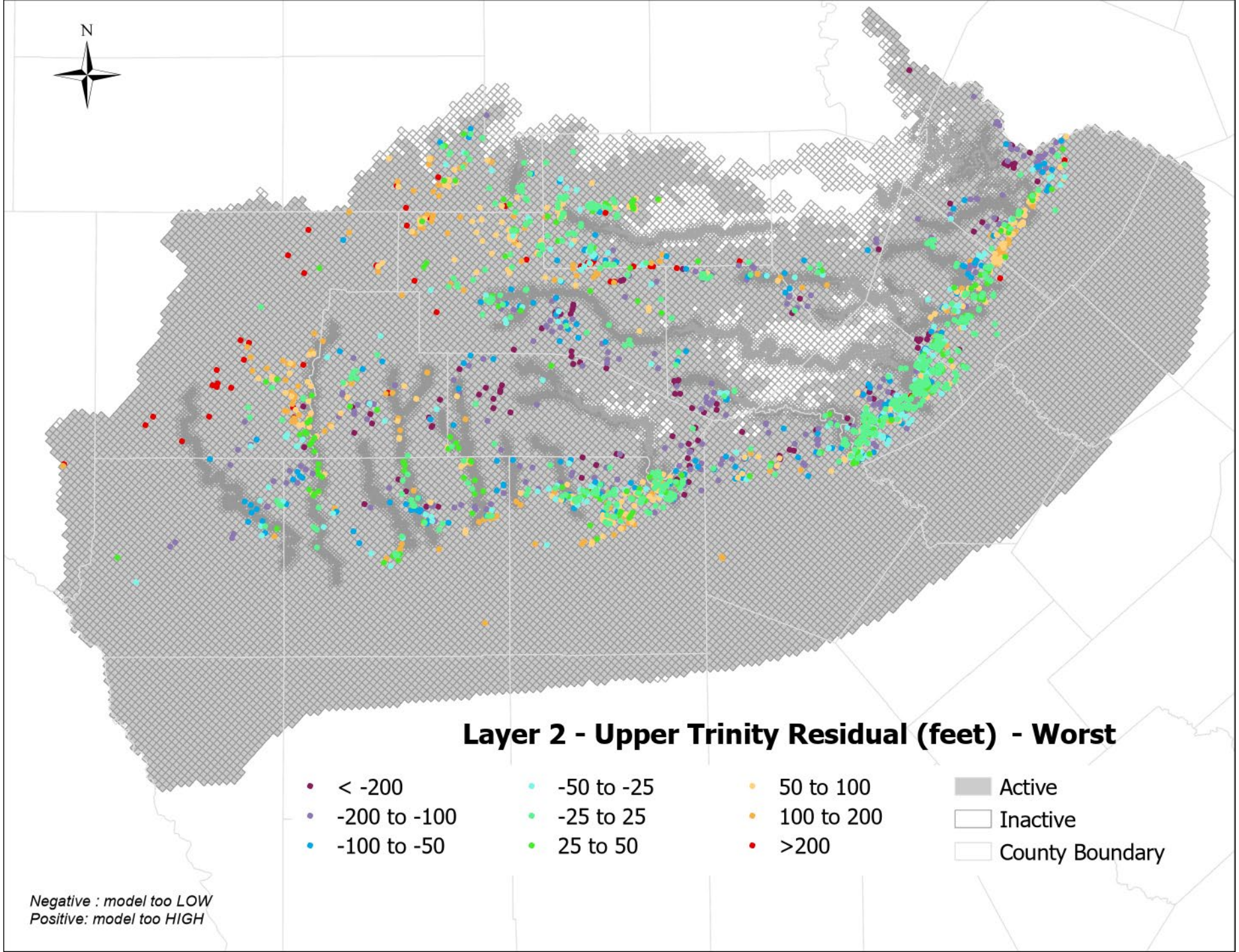


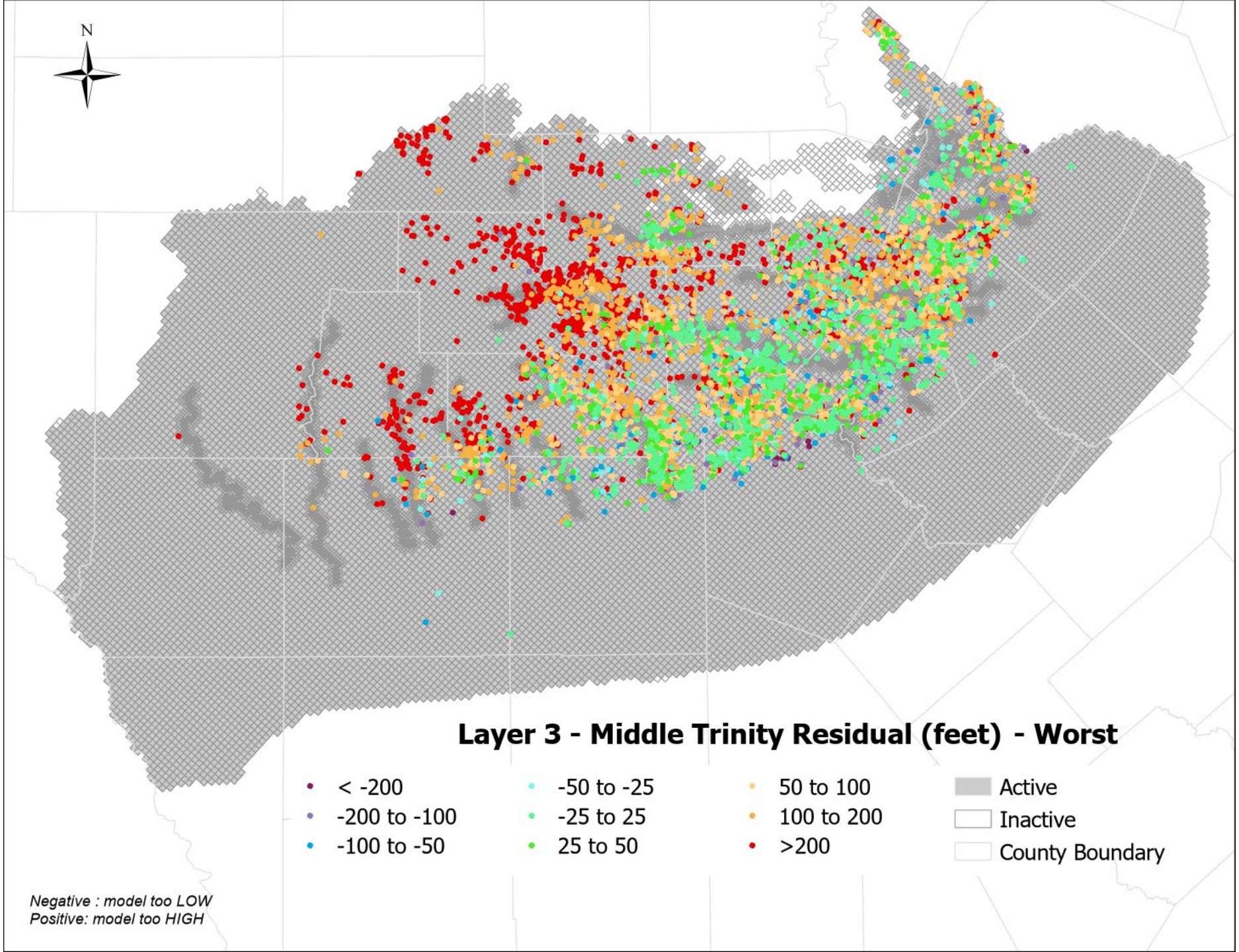


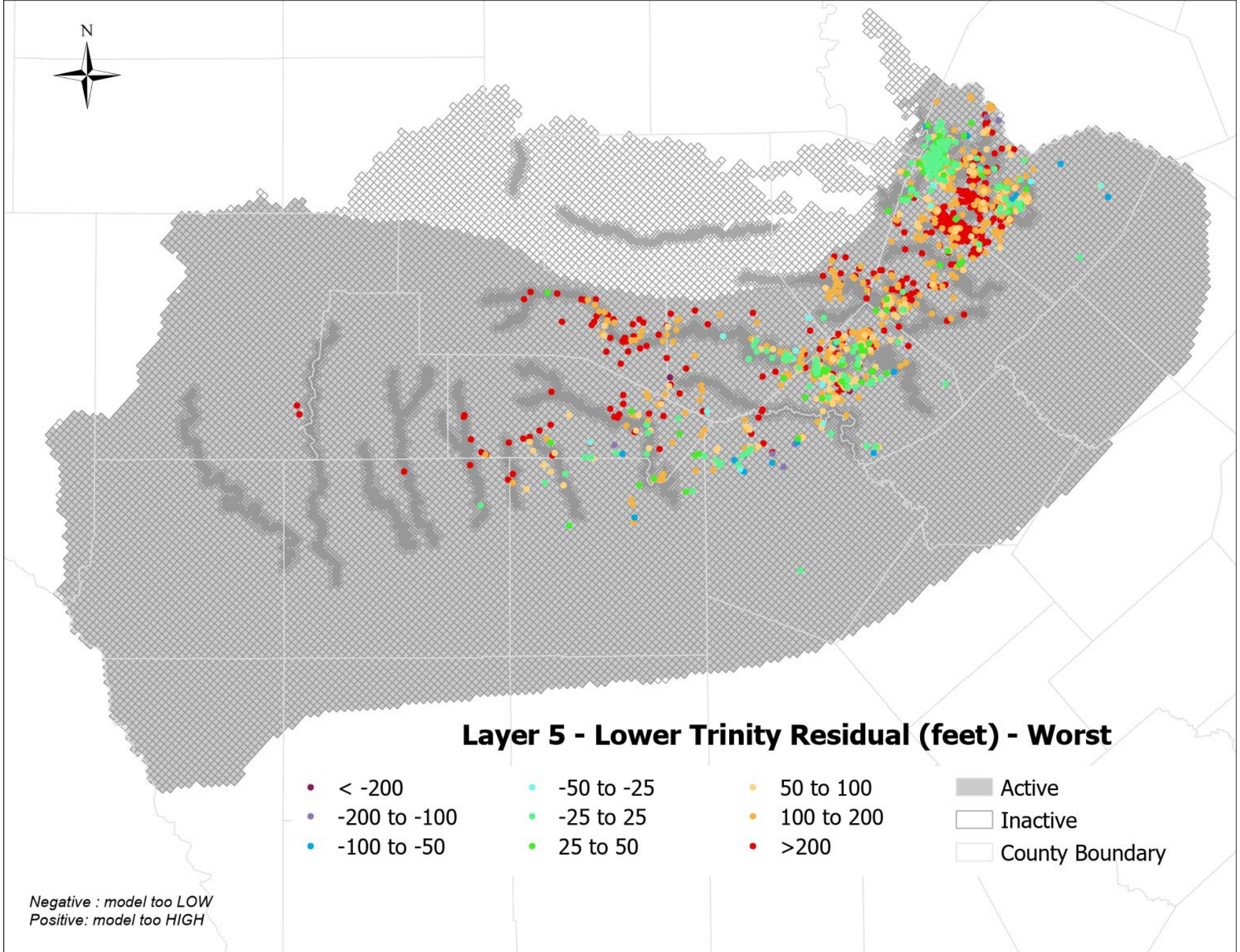




TEXAS WATER DEVELOPMENT BOARD

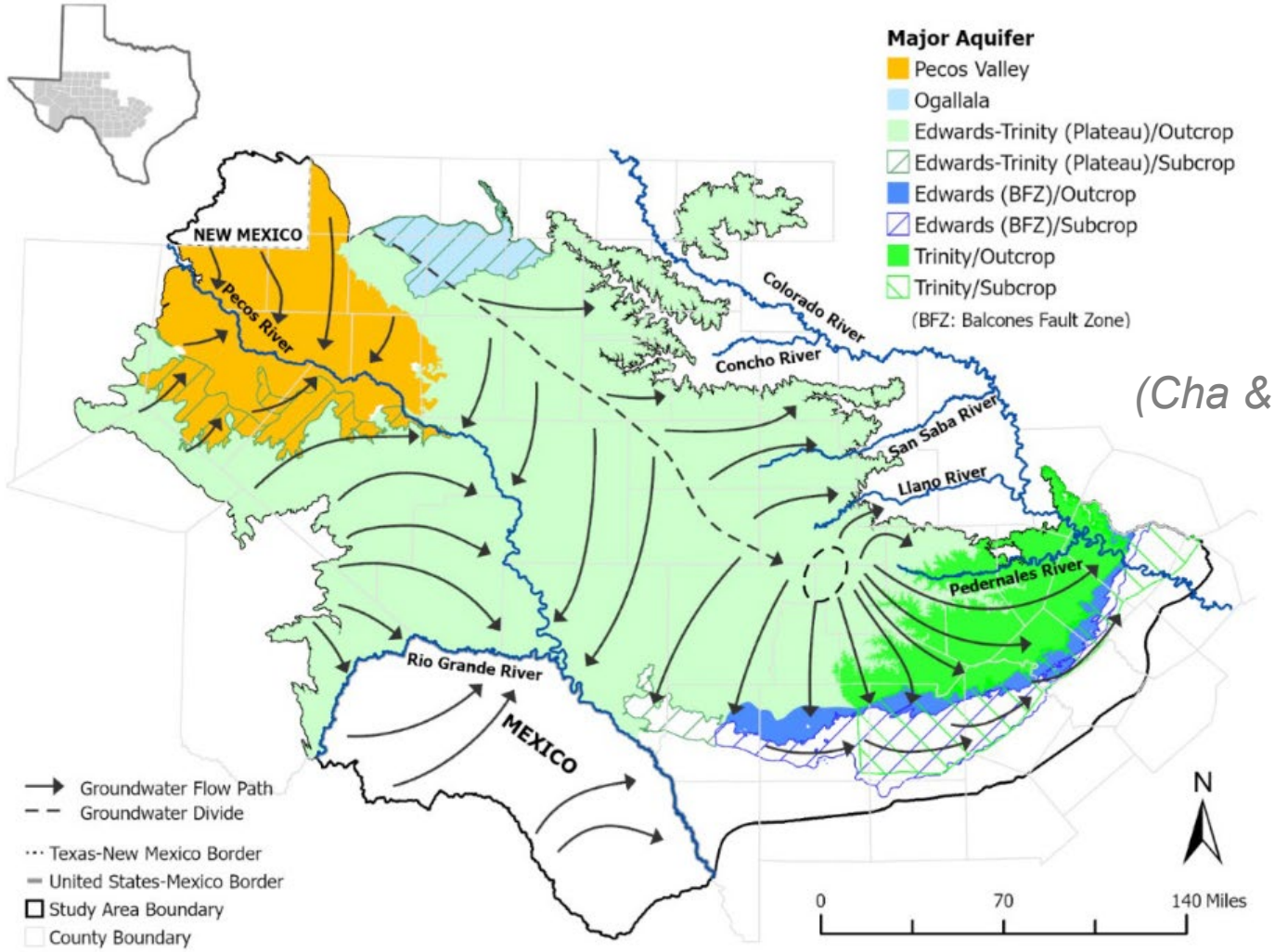

N
Layer 2 - Upper Trinity Residual (feet) - Worst
< -200
-200 to -100
-100 to -50
-50 to -25
-25 to 25
25 to 50
50 to 100
100 to 200
>200
Active
Inactive
County Boundary
Negative : model too LOW
Positive: model too HIGH


N
Layer 3 - Middle Trinity Residual (feet) - Worst
< -200
-200 to -100
-100 to -50
-50 to -25
-25 to 25
25 to 50
50 to 100
100 to 200
>200
Active
Inactive
County Boundary
Negative : model too LOW
Positive: model too HIGH



Negative : model too LOW
Positive: model too HIGH

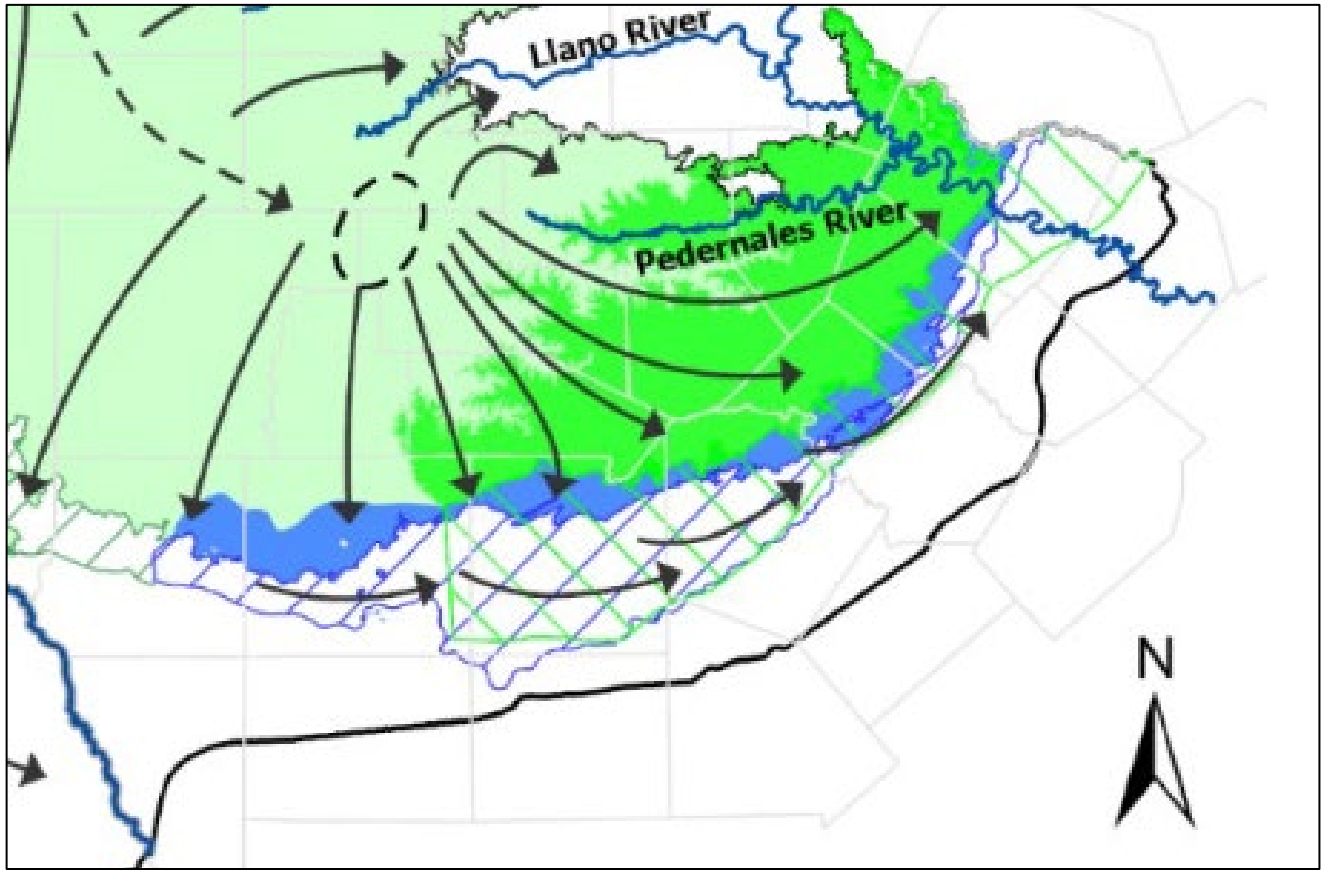
Model Results



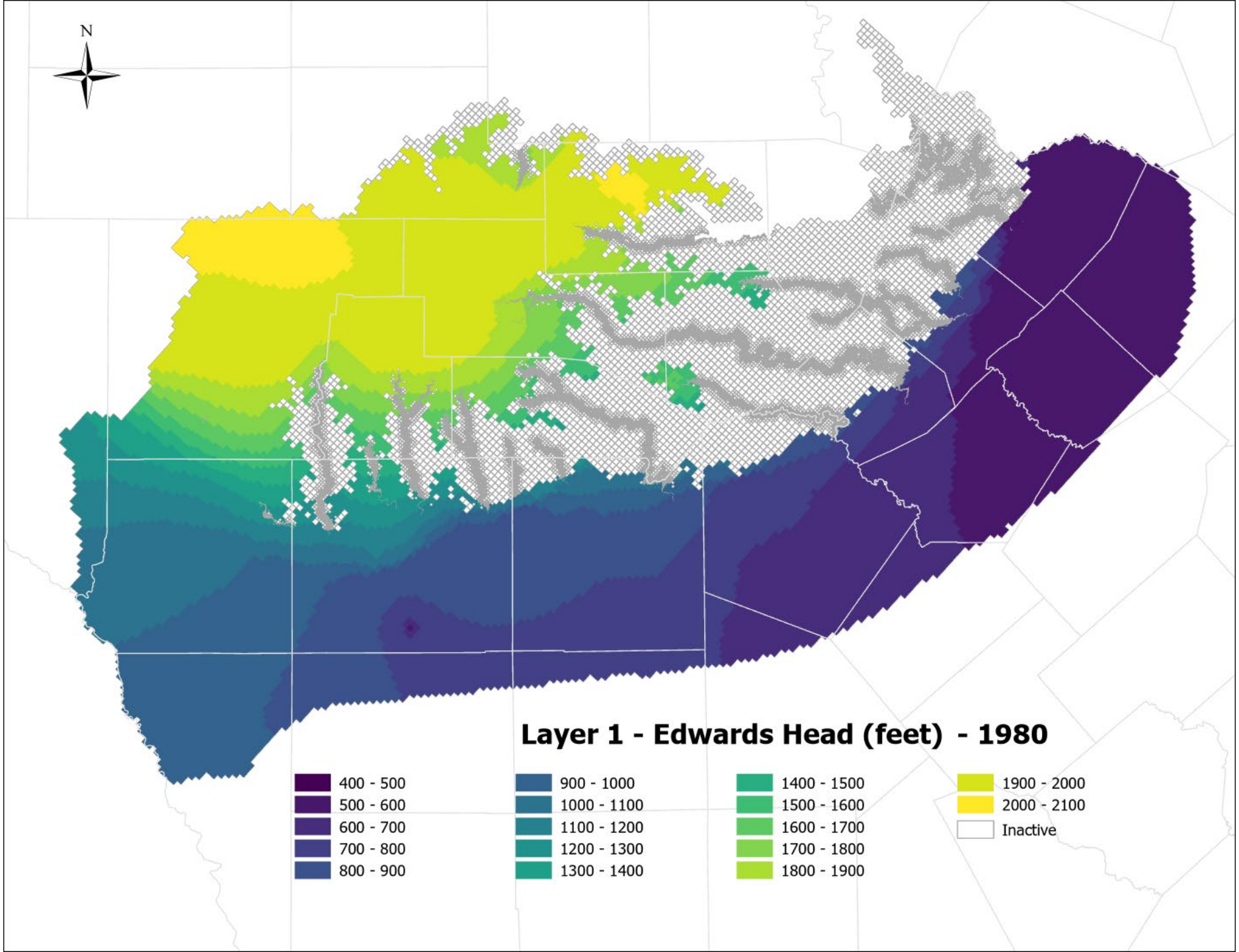
(Cha & others, 2022)

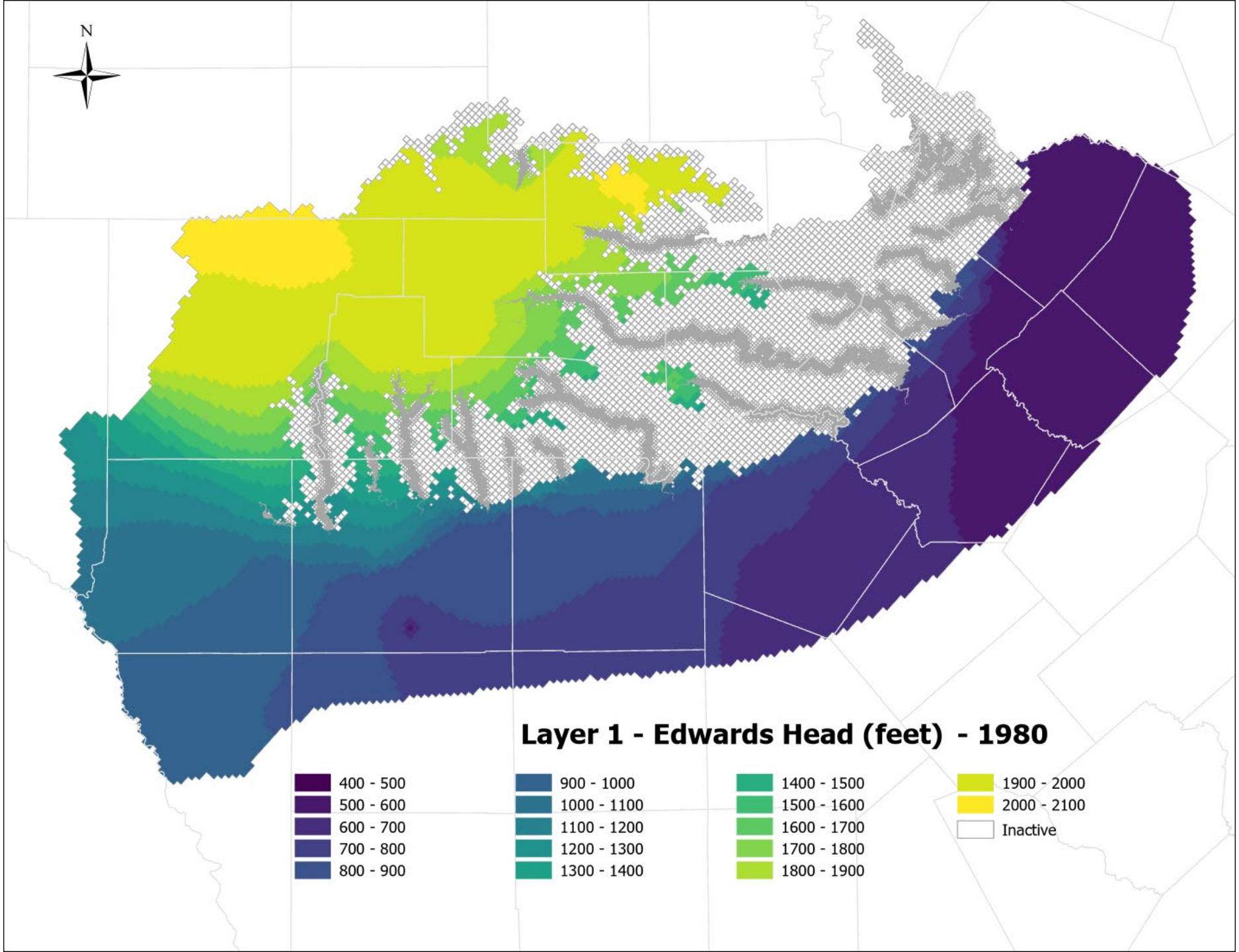
Figure 4.3-17. Generalized regional groundwater flow path for the Pecos Valley and Edwards-Trinity (Plateau) Region (modified from Anaya and Jones, 2009; Edwards Aquifer Authority, 2021).

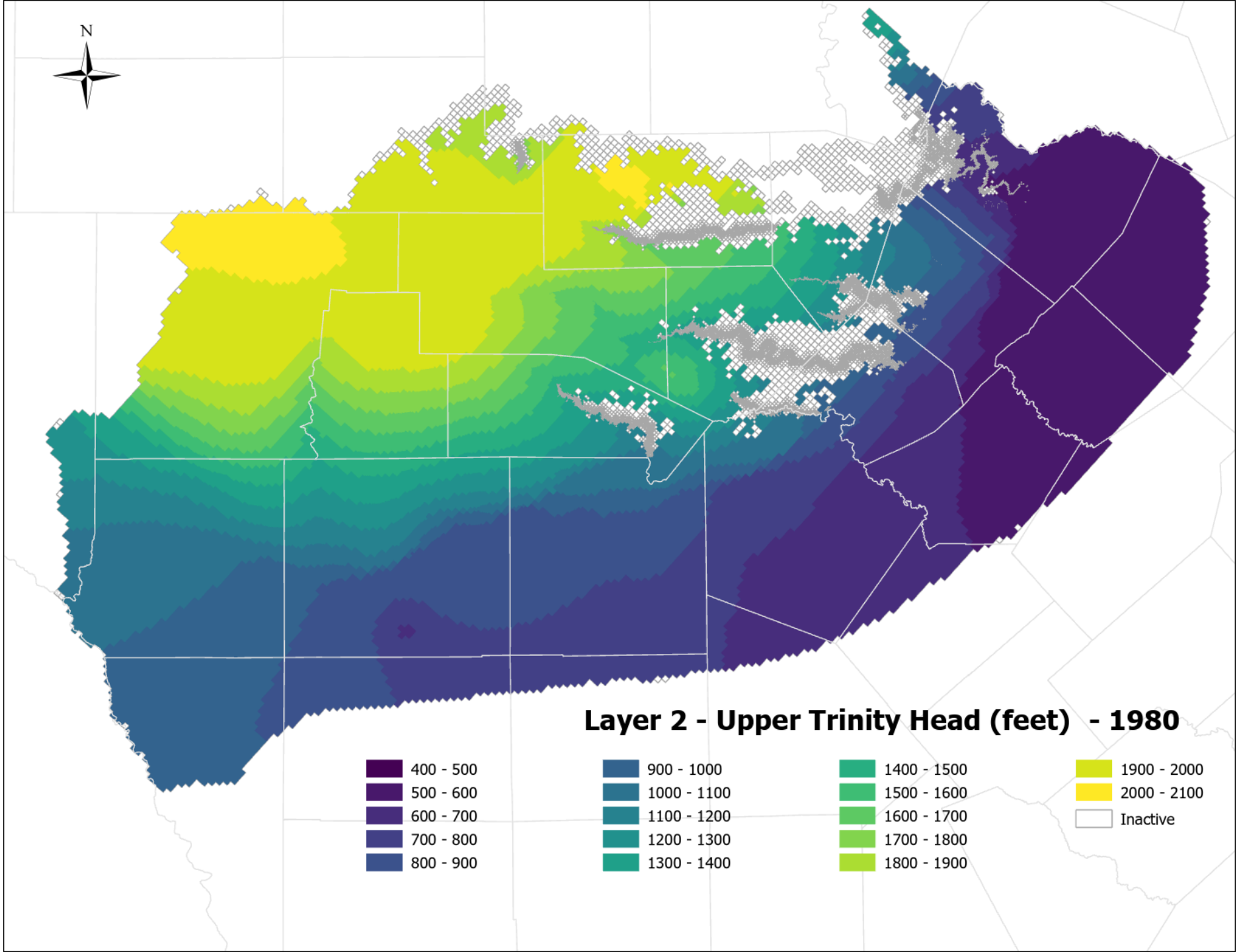
Model Results

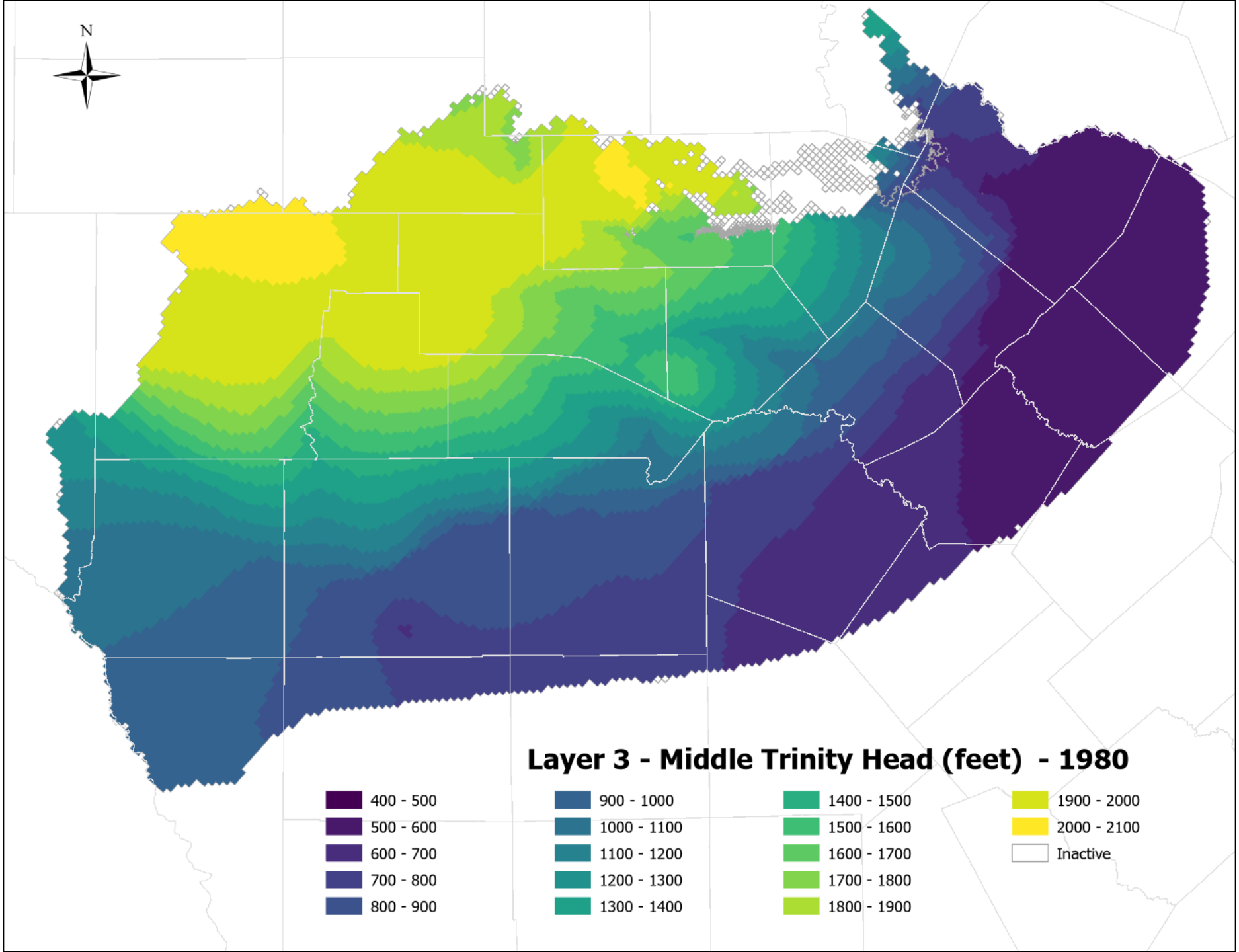


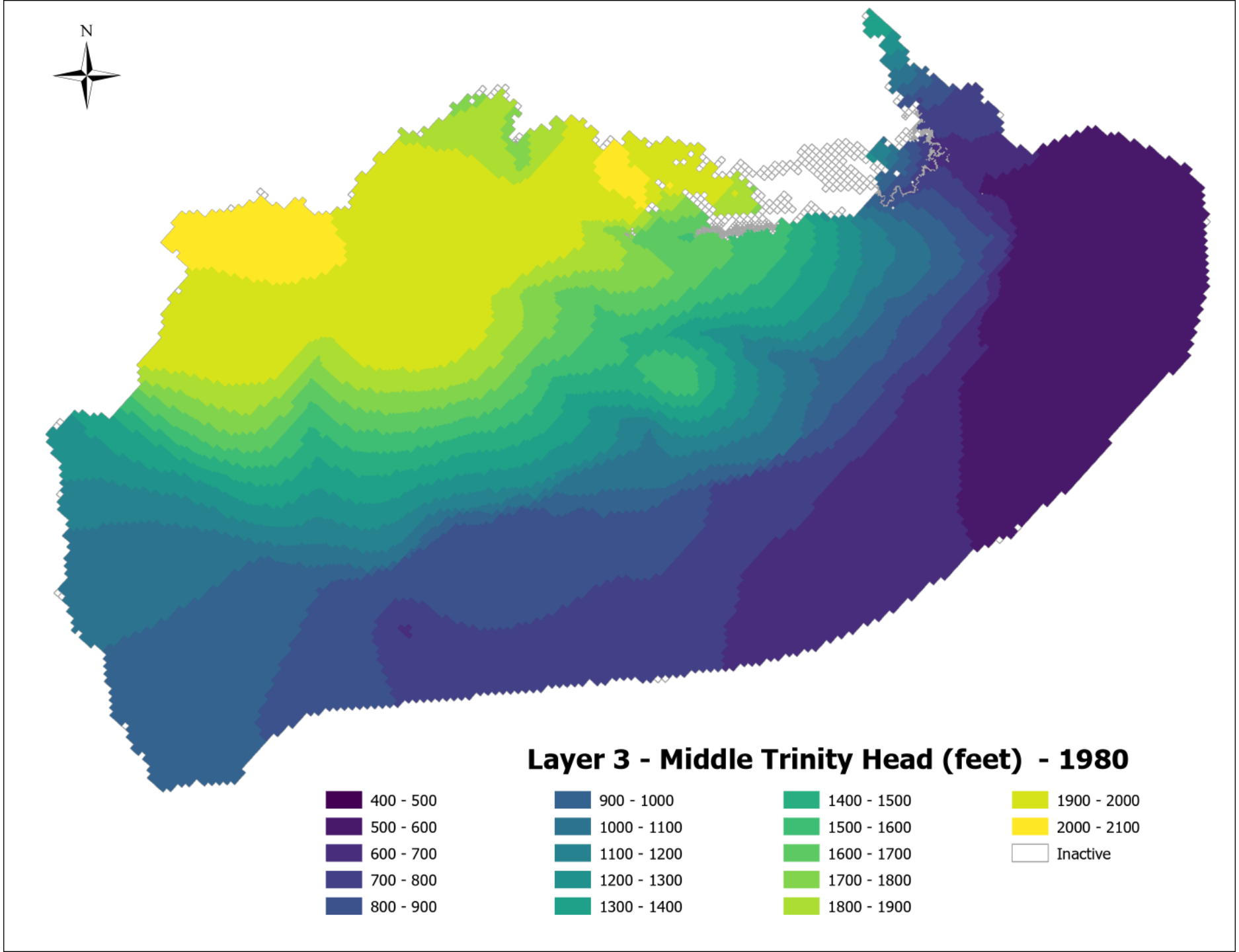
(Cha & others, 2022)

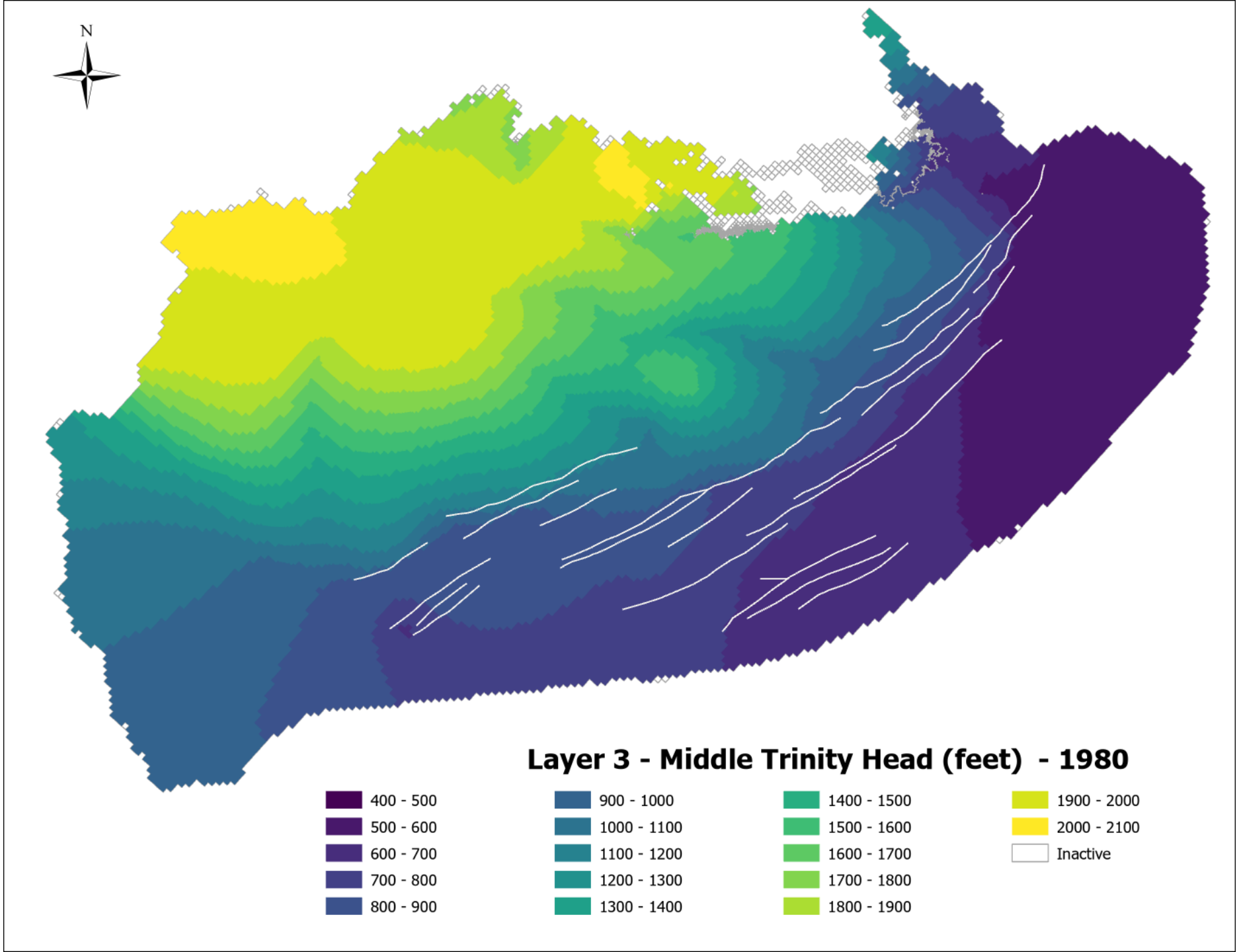

N
Layer 1 - Edwards Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

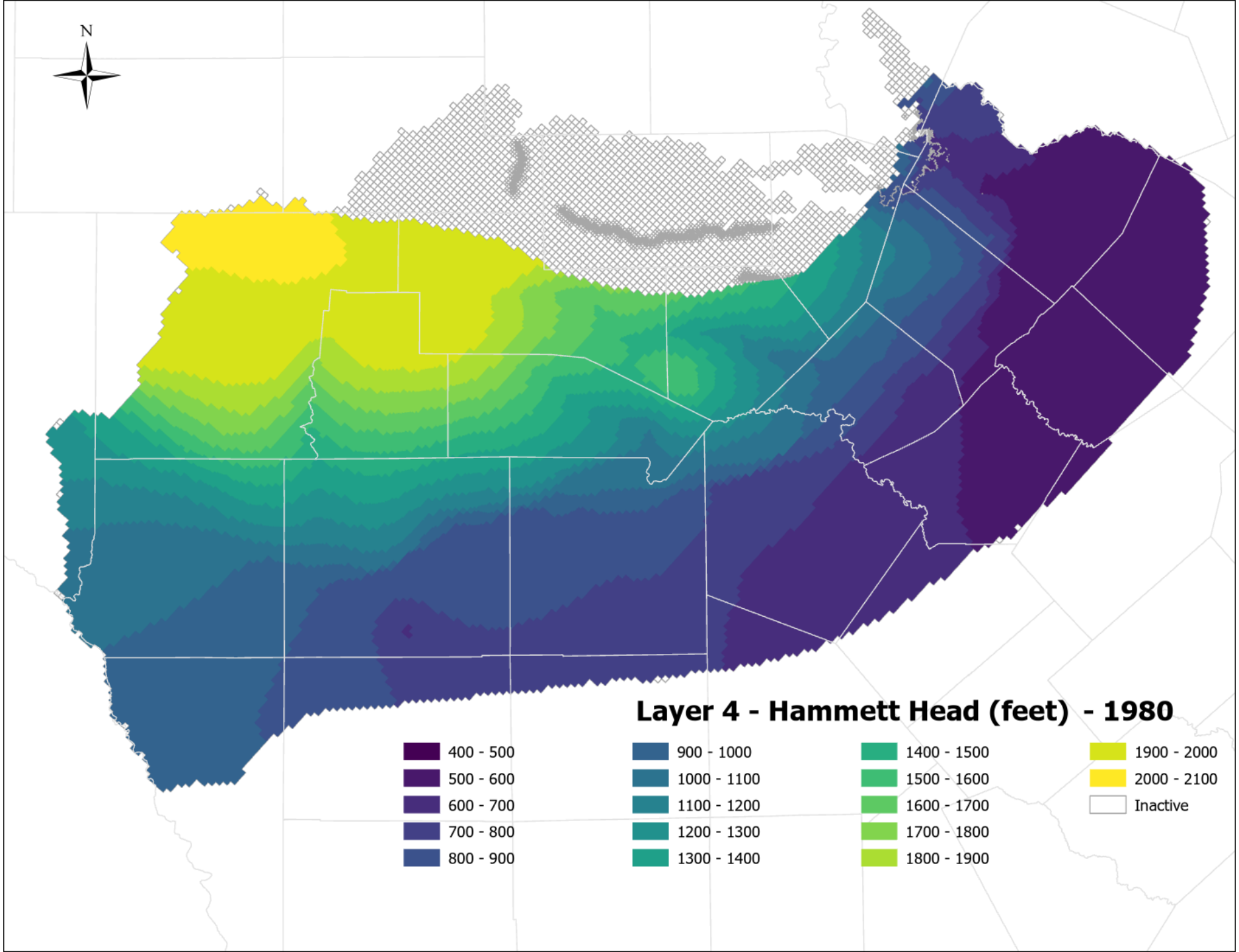

N
Layer 1 - Edwards Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

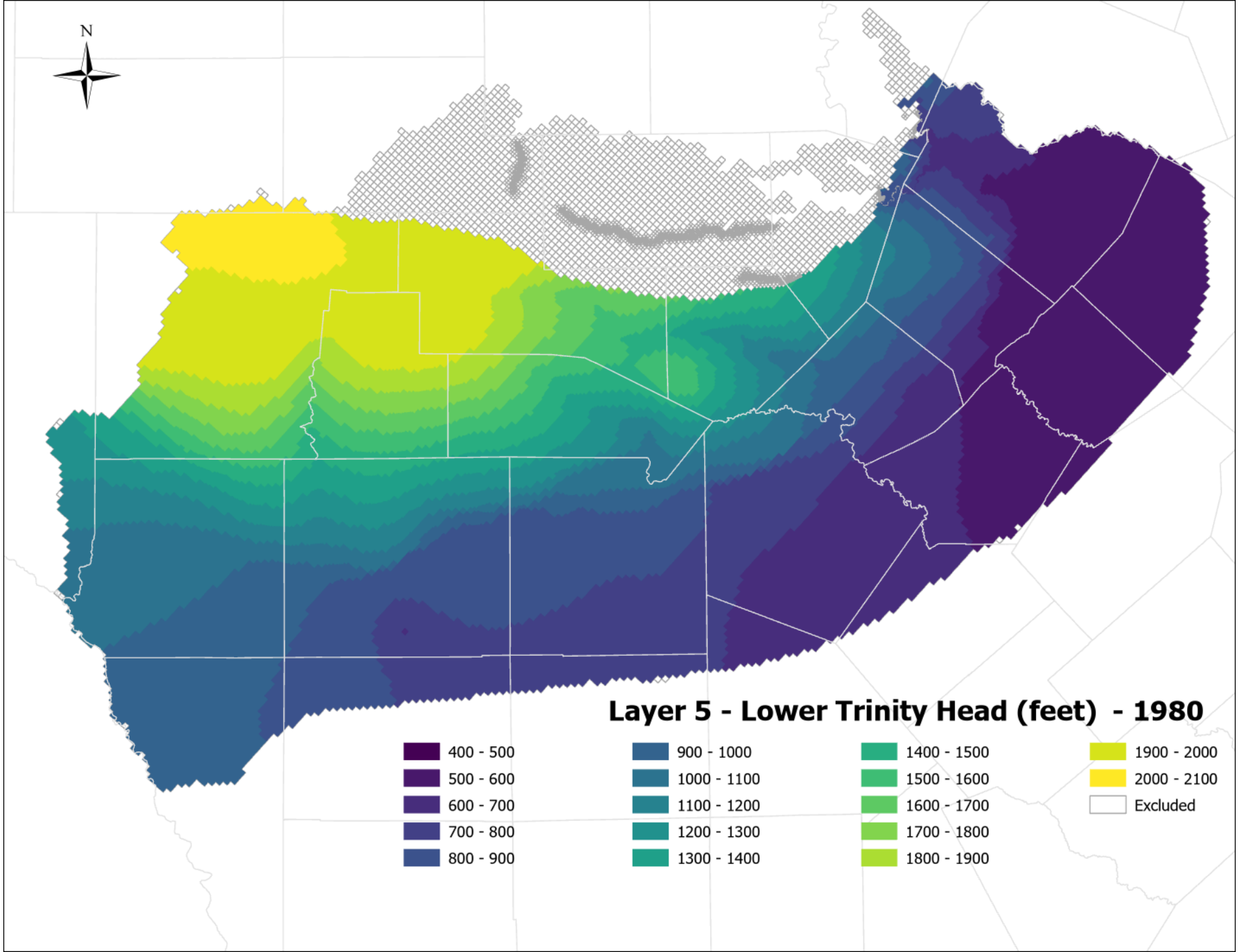

N
Layer 2 - Upper Trinity Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

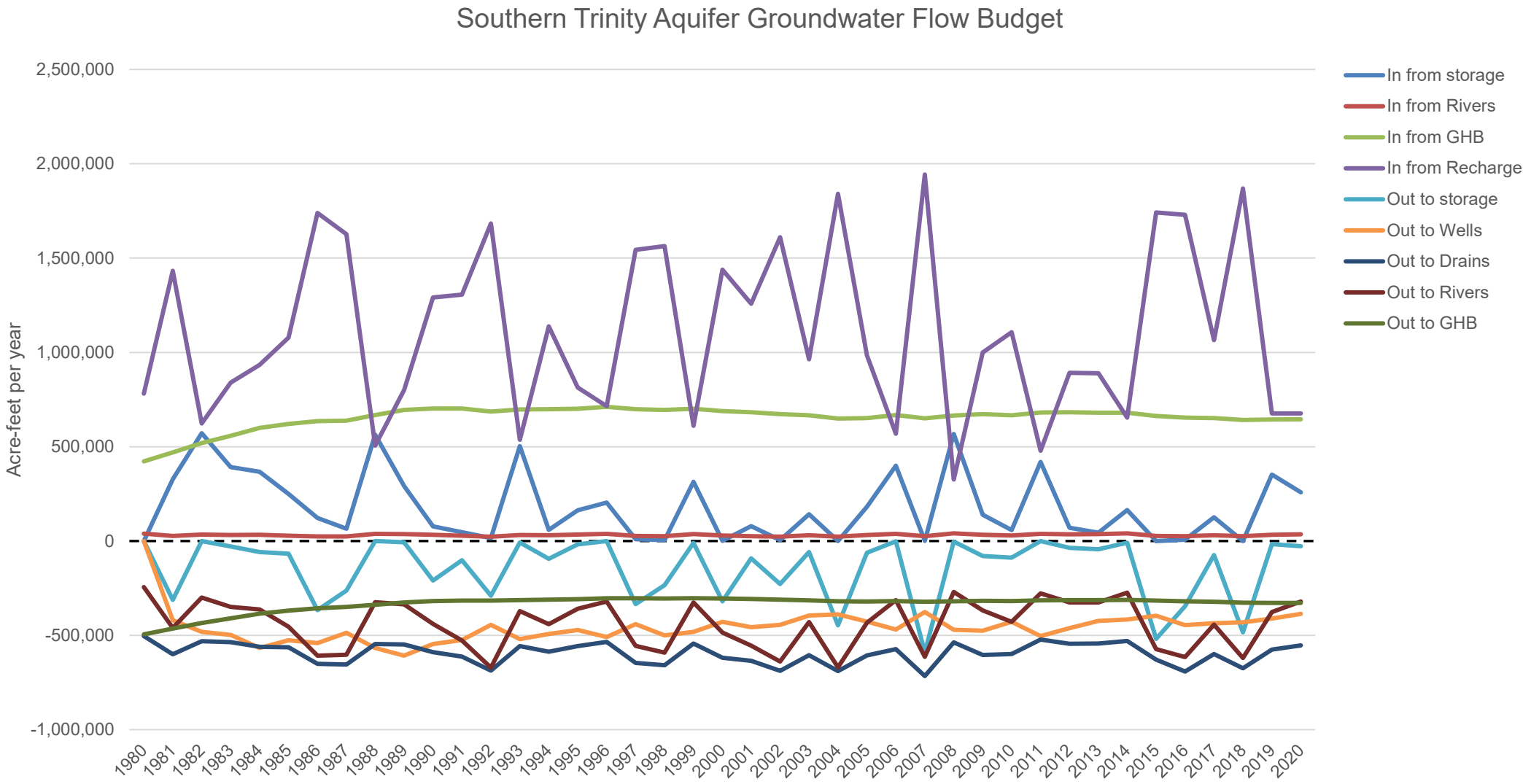

N
Layer 3 - Middle Trinity Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

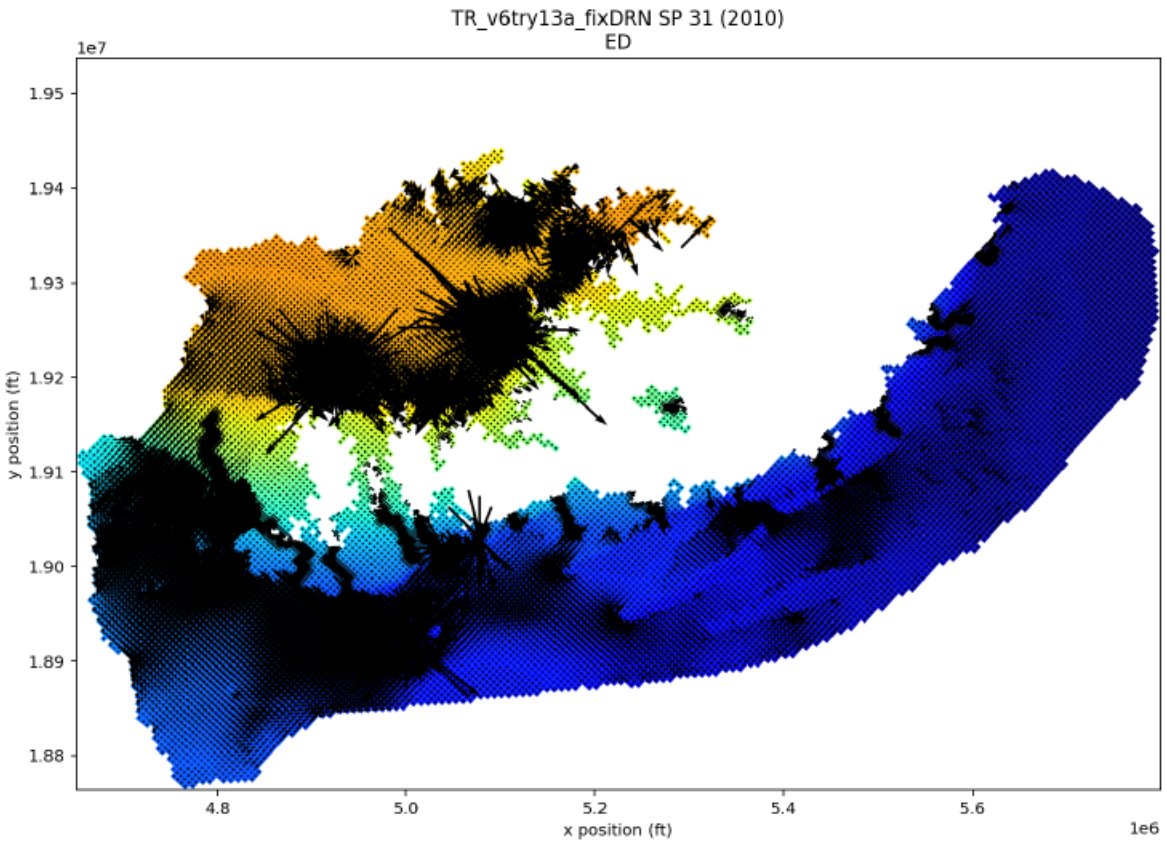

N
Layer 3 - Middle Trinity Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

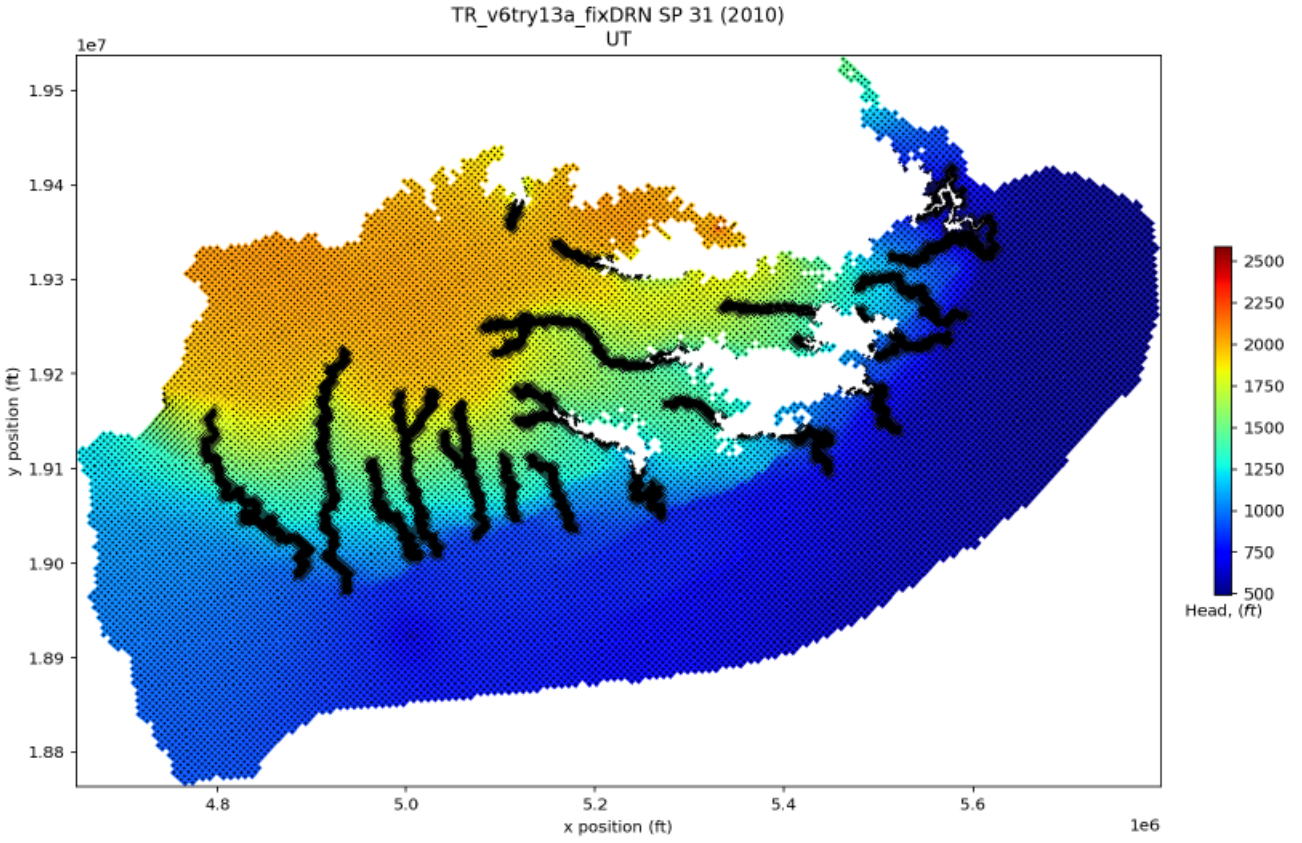

N
Layer 3 - Middle Trinity Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

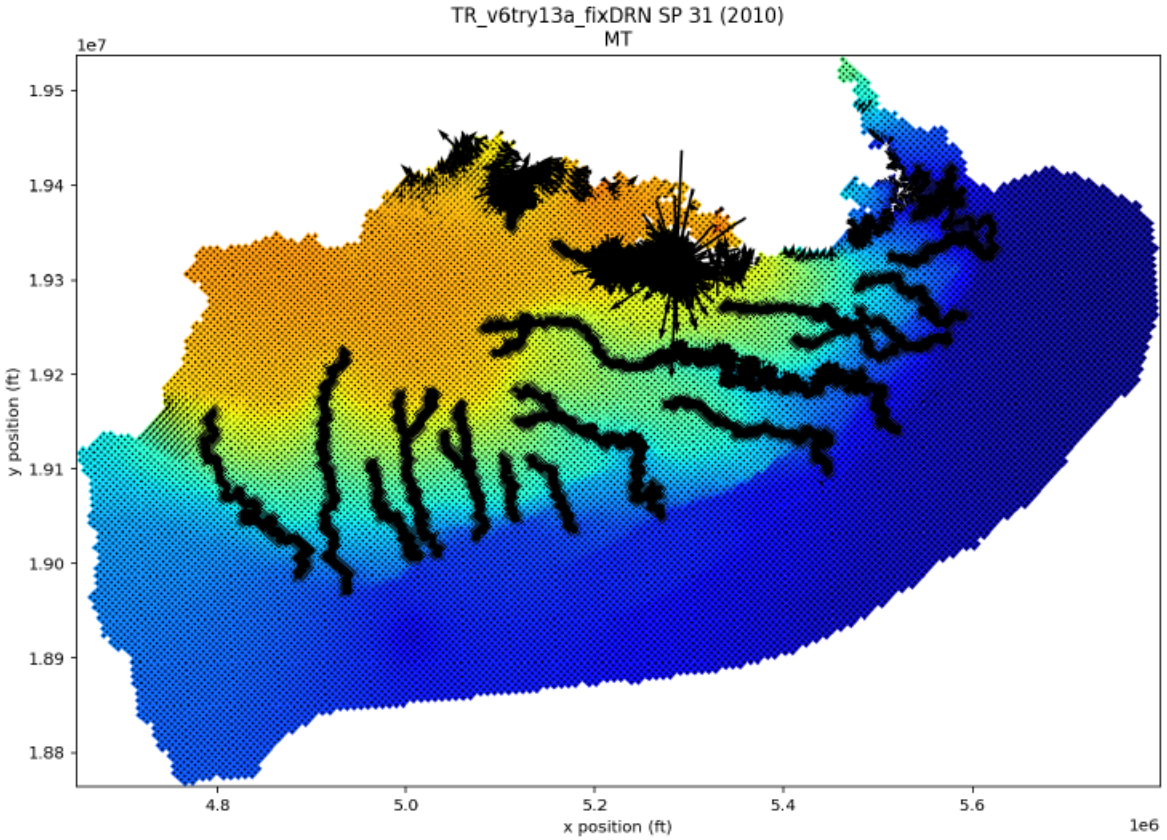

N
Layer 4 - Hammett Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Inactive

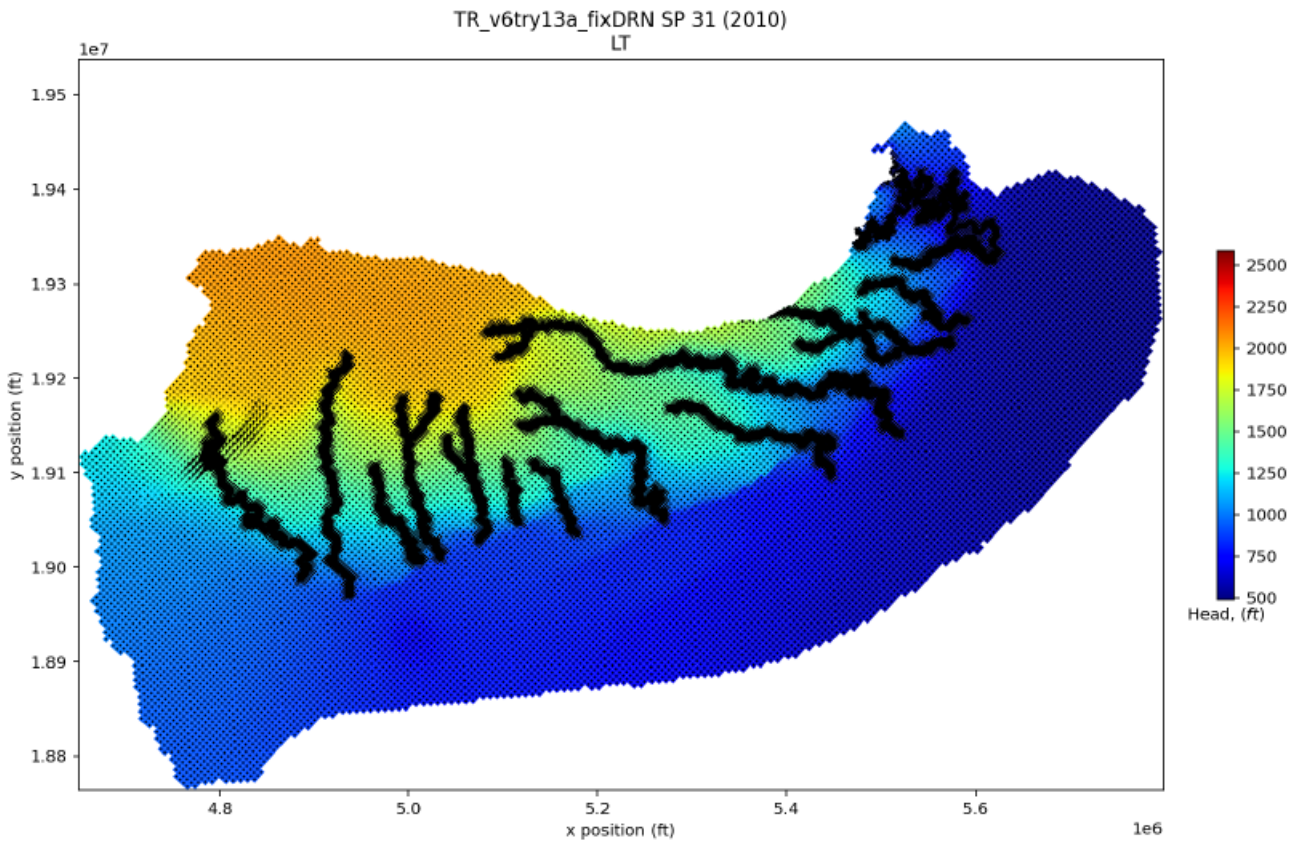

N
Layer 5 - Lower Trinity Head (feet) - 1980
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1700
1700 - 1800
1800 - 1900
1900 - 2000
2000 - 2100
Excluded


Southern Trinity Aquifer Groundwater Flow Budget
Acre-feet per year
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
-500,000
-1,000,000
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
In from storage
In from Rivers
In from GHB
In from Recharge
Out to storage
Out to Wells
Out to Drains
Out to Rivers
Out to GHB


TR_v6try13a_fixDRN SP 31 (2010)
ED
1e7
1.95
1.94
1.93
1.92
1.91
1.90
1.89
1.88
y position (ft)
4.8
5.0
5.2
5.4
5.6
1e6
x position (ft)


TR_v6try13a_fixDRN SP 31 (2010)
UT
1e7
1.95
1.94
1.93
1.92
1.91
1.90
1.89
1.88
y position (ft)
4.8
5.0
5.2
5.4
5.6
1e6
x position (ft)
2500
2250
2000
1750
1500
1250
1000
750
500
Head, (ft)


TR_v6try13a_fixDRN SP 31 (2010)
MT
1e7
1.95
1.94
1.93
1.92
1.91
1.90
1.89
1.88
y position (ft)
4.8
5.0
5.2
5.4
5.6
1e6
x position (ft)


TR_v6try13a_fixDRN SP 31 (2010)
LT
1e7
1.95
1.94
1.93
1.92
1.91
1.90
1.89
1.88
y position (ft)
4.8
5.0
5.2
5.4
5.6
1e6
x position (ft)
2500
2250
2000
1750
1500
1250
1000
750
500
Head, (ft)

Model Design: Packages

Model Design

- Model Packages
  - IMS *(solver)*
  - TDIS *(time discretization)*
  - IC *(initial conditions)*
  - DISU *(grid)*
  - NPF *(hydrologic properties)*
  - STO *(storage properties)*
  - RIV *(rivers)*
  - DRN *(springs)*
  - GHB *(general head boundary)*
  - RCH *(recharge)*
  - WEL *(pumping)*

```
BEGIN options
  SAVE_FLOWS
  NEWTON  UNDER_RELAXATION
END options

BEGIN packages
  RIV6  trnt_s.riv  riv_0
  DRN6  trnt_s.drn  drn_0
  GHB6  trnt_s.ghb  ghb_0
  STO6  trnt_s.sto  sto
  ic6  trnt_s.ic  ic
  disu6  trnt_s.disu  disu
  npf6  trnt_s.npf  npf
  obs6  trnt_s.obs  headobs
  RCH6  trnt_s.rch  rch
  OC6  trnt_s.oc  oc
  WEL6  trnt_s.wel  irrigation
  WEL6  trnt_s_0.wel  municipal
  WEL6  trnt_s_1.wel  livestock
  WEL6  trnt_s_2.wel  ruraldomestic
  WEL6  trnt_s_3.wel  manufacturing
  WEL6  trnt_s_4.wel  mining
END packages
```

```
BEGIN options
  CONTINUE
END options

BEGIN timing
  TDIS6  modflowsim.tdis
END timing

BEGIN models
  gwf6  trnt_s.nam  trnt_s
END models

BEGIN exchanges
END exchanges

BEGIN solutiongroup  1
  ims6  trnt_s.ims  trnt_s
END solutiongroup  1
```

TEXAS WATER DEVELOPMENT BOARD

Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  } Model Setup

  - DISU
  - NPF
  - STO

  } Physical Properties

  - RIV
  - DRN
  - GHB
  - RCH
  - WEL

  } Boundary Conditions

```
BEGIN options
  SAVE_FLOWS
  NEWTON  UNDER_RELAXATION
END options

BEGIN packages
  RIV6  trnt_s.riv  riv_0
  DRN6  trnt_s.drn  drn_0
  GHB6  trnt_s.ghb  ghb_0
  STO6  trnt_s.sto  sto
  ic6  trnt_s.ic  ic
  disu6  trnt_s.disu  disu
  npf6  trnt_s.npf  npf
  obs6  trnt_s.obs  headobs
  RCH6  trnt_s.rch  rch
  OC6  trnt_s.oc  oc
  WEL6  trnt_s.wel  irrigation
  WEL6  trnt_s_0.wel  municipal
  WEL6  trnt_s_1.wel  livestock
  WEL6  trnt_s_2.wel  ruraldomestic
  WEL6  trnt_s_3.wel  manufacturing
  WEL6  trnt_s_4.wel  mining
END packages
```

```
BEGIN options
  CONTINUE
END options

BEGIN timing
  TDIS6  modflowsim.tdis
END timing

BEGIN models
  gwf6  trnt_s.nam  trnt_s
END models

BEGIN exchanges
END exchanges

BEGIN solutiongroup  1
  ims6  trnt_s.ims  trnt_s
END solutiongroup  1
```

TEXAS WATER DEVELOPMENT BOARD

Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  Model Setup
  - **DISU**
  - NPF
  - STO

  Physical Properties
  - RIV
  - DRN
  - GHB
  - RCH
  - WEL

  Boundary Conditions

```
BEGIN options
  SAVE_FLOWS
  NEWTON  UNDER_RELAXATION
END options

BEGIN packages
  RIV6  trnt_s.riv  riv_0
  DRN6  trnt_s.drn  drn_0
  GHB6  trnt_s.ghb  ghb_0
  STO6  trnt_s.sto  sto
  ic6  trnt_s.ic  ic
  disu6  trnt_s.disu  disu
  npf6  trnt_s.npf  npf
  obs6  trnt_s.obs  headobs
  RCH6  trnt_s.rch  rch
  OC6  trnt_s.oc  oc
  WEL6  trnt_s.wel  irrigation
  WEL6  trnt_s_0.wel  municipal
  WEL6  trnt_s_1.wel  livestock
  WEL6  trnt_s_2.wel  ruraldomestic
  WEL6  trnt_s_3.wel  manufacturing
  WEL6  trnt_s_4.wel  mining
END packages
```

```
BEGIN options
  CONTINUE
END options

BEGIN timing
  TDIS6  modflowsim.tdis
END timing

BEGIN models
  gwf6  trnt_s.nam  trnt_s
END models

BEGIN exchanges
END exchanges

BEGIN solutiongroup  1
  ims6  trnt_s.ims  trnt_s
END solutiongroup  1
```

TEXAS WATER DEVELOPMENT BOARD

Model Packages: Grid (DISU)

Model Packages: DISU

MODFLOW 6 Discretization Options:

Completely remove inactive cells	Add refinement around areas of interest	Specify cell connections regardless of layer
DIS		
DISV	DISV	
DISU	DISU	DISU

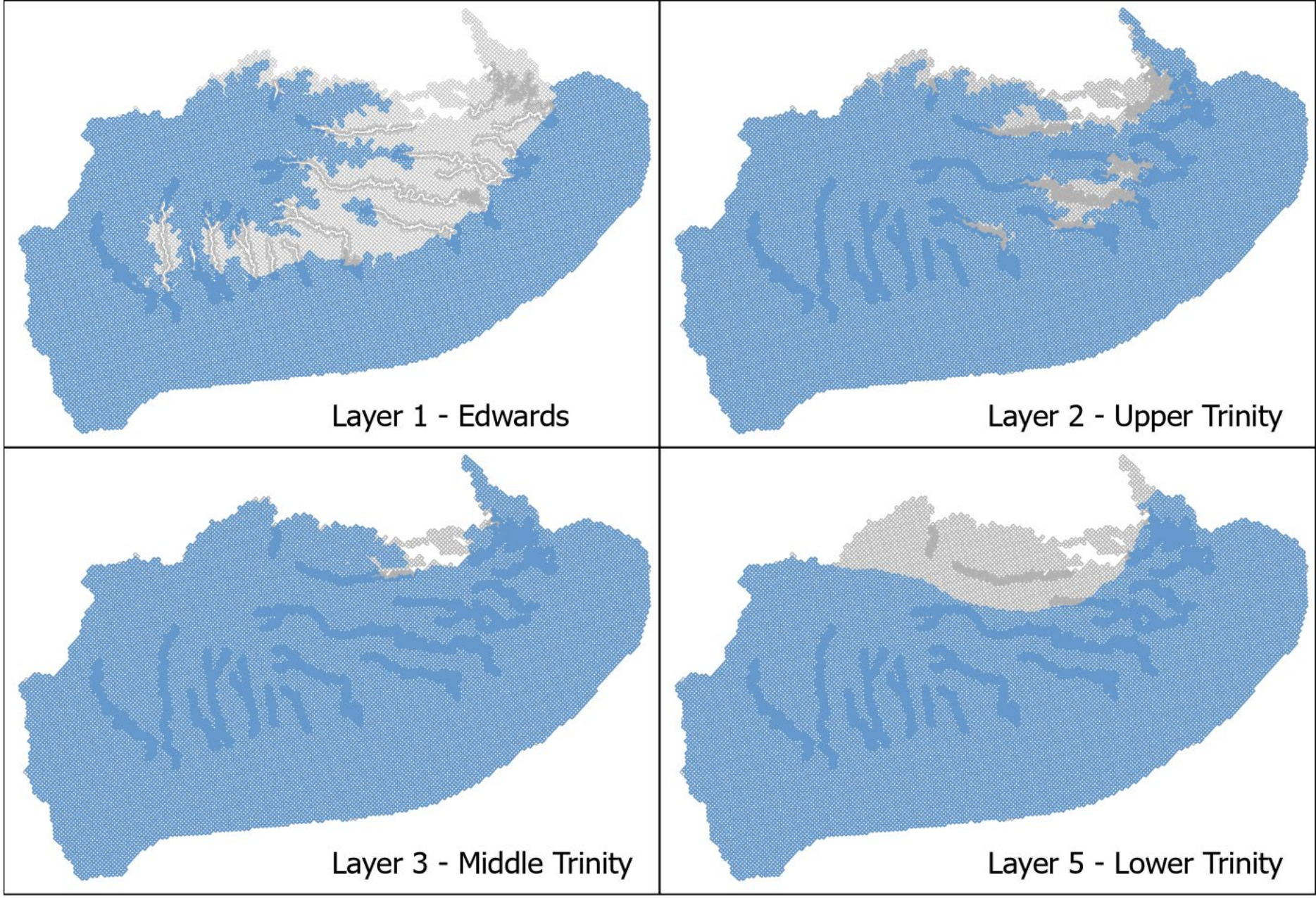
Model Packages: DISU

MODFLOW 6 Discretization Options:

Completely remove inactive cells	Add refinement around areas of interest	Specify cell connections regardless of layer
DIS		
DISV	DISV	
DISU	DISU	DISU

Model Grid

- 443,425 total cells
  (341,249 active)
- All layers same # of cells
- Eroded areas are inactive
- Bottom 2 layers pinchout



TEXAS WATER DEVELOPMENT BOARD

** Layer 4 Hammett Shale extent approximately same as Layer 5*

Model Packages: DISU

MODFLOW 6 Discretization Options:

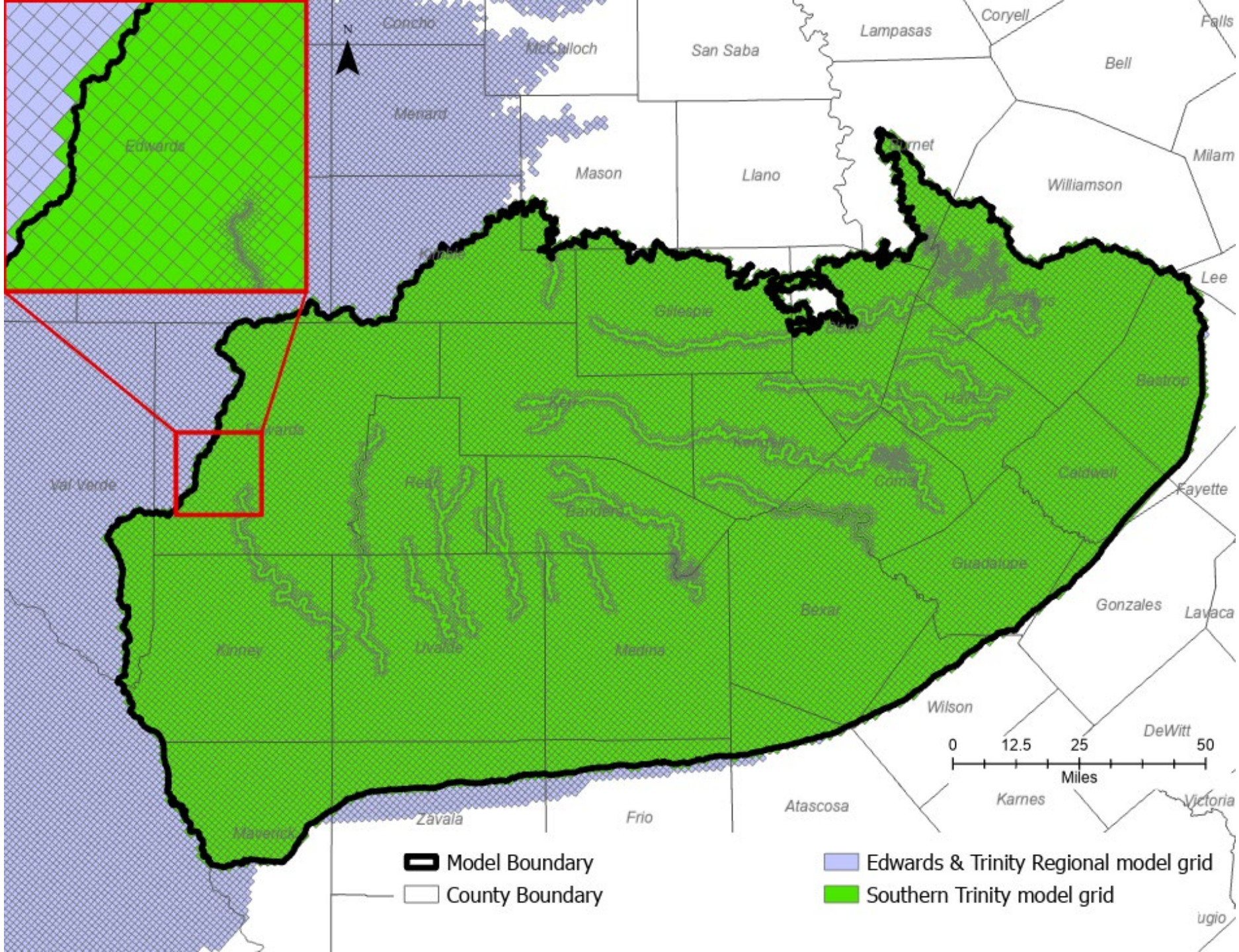
Completely remove inactive cells	Add refinement around areas of interest	Specify cell connections regardless of layer
DIS		
DISV	DISV	
DISU	DISU	DISU

Model Grid

- Quadtree Refinement
- Max cell = 1 mile
- Min Cell:

  Streams ($^1/_{16}$ mile)

  Lakes ($^1/_4$ mile)



Model Packages: DISU

MODFLOW 6 Discretization Options:

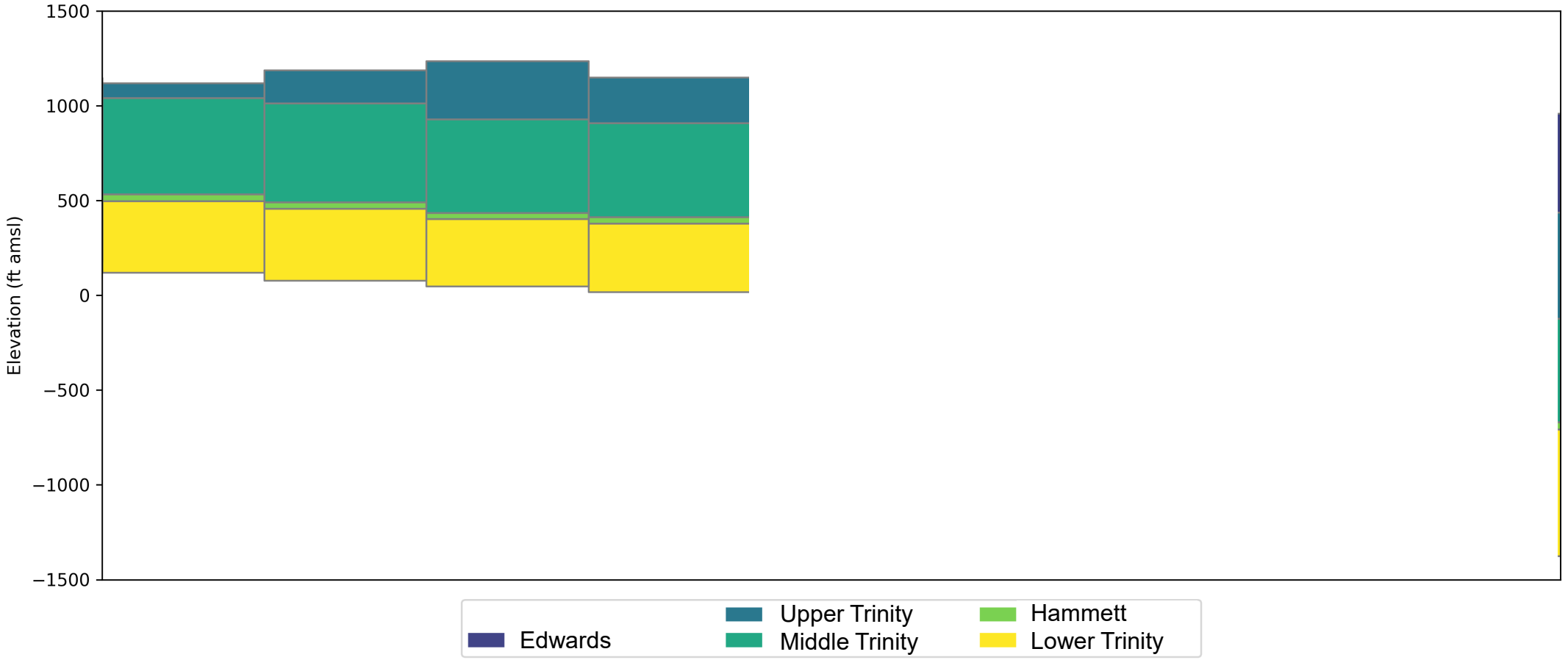
Completely remove inactive cells	Add refinement around areas of interest	Specify cell connections regardless of layer
DIS		
DISV	DISV	
DISU	DISU	DISU

Model Packages: DISU

Model	MODFLOW Version	Grid Type	Remove Excess cells	Quadtree Refinement	Different grids in different layers	Connections across layers
Llano Uplift *(TWDB)*	USG	DISV*	-	-	-	-
S. Gulf Coast *(TWDB)*	USG	DISV*	-	X	-	-
N. Gulf Coast *(USGS)*	6	DIS	-	-	-	-
S. Carrizo-Wilcox *(Panday et al)*	6	DISU	X	X	-	-
N. Carrizo-Wilcox *(Panday et al)*	6	DISU	X	-	X	-
Cross Timbers *(INTERA)*	6	DIS	-	-	-	-
CURRENT	**6**	**DISU**	**X**	**X**	**-**	**X**

TEXAS WATER DEVELOPMENT BOARD

**MODFLOW-USG "DISU" package is equivalent to MODFLOW-6 "DISV" package*


1500
1000
500
0
−500
−1000
−1500
Elevation (ft amsl)
Edwards
Upper Trinity
Middle Trinity
Hammett
Lower Trinity

- Typical model assumes that horizontal flow mostly follows model layers
- Decent simplifying assumption for most geology in Texas
- Easy for structured grid models to replicate

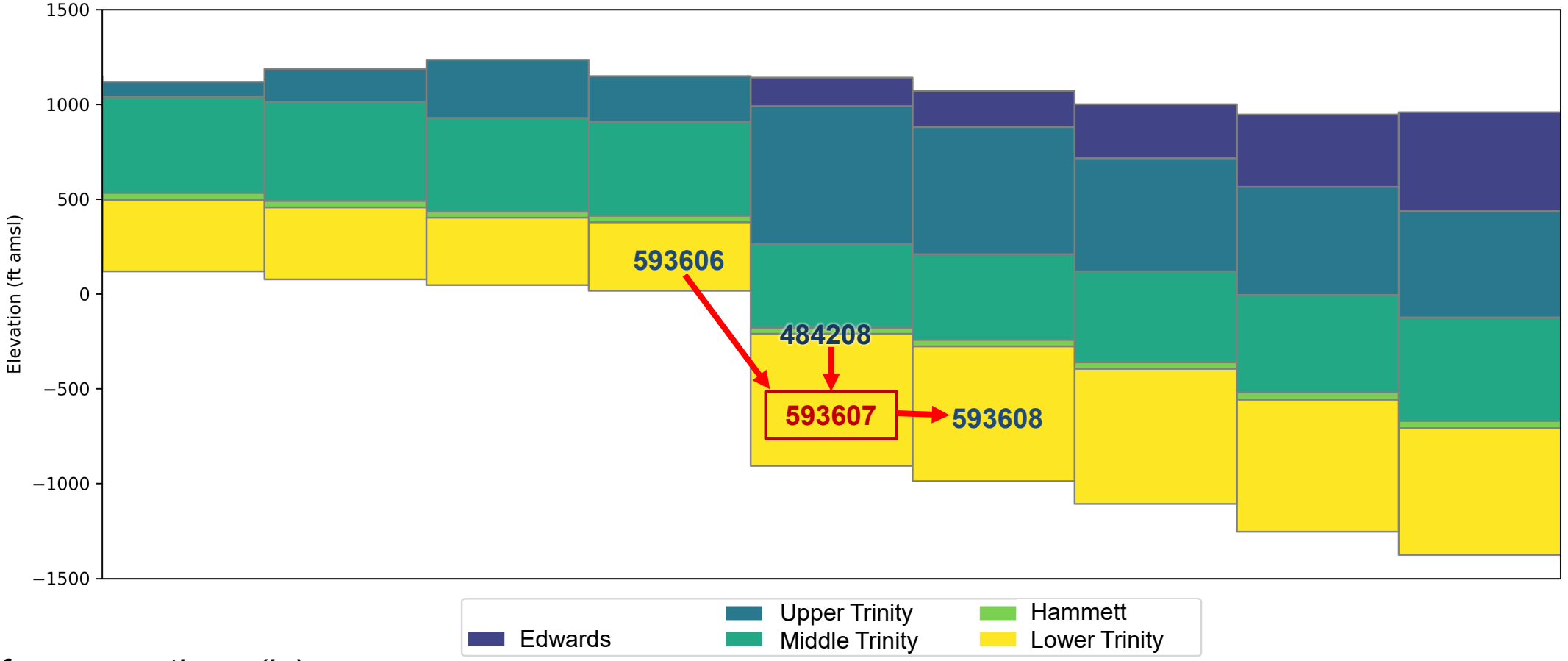
- Fault blocks & disconnected geology are more complicated

- MODFLOW will automatically connect model layers even if elevations don’t overlap

- Typical solution : Don’t include complicated geology!
- This is why original “Hill Country” Trinity GAM does NOT include Edwards Balcones Fault Zone

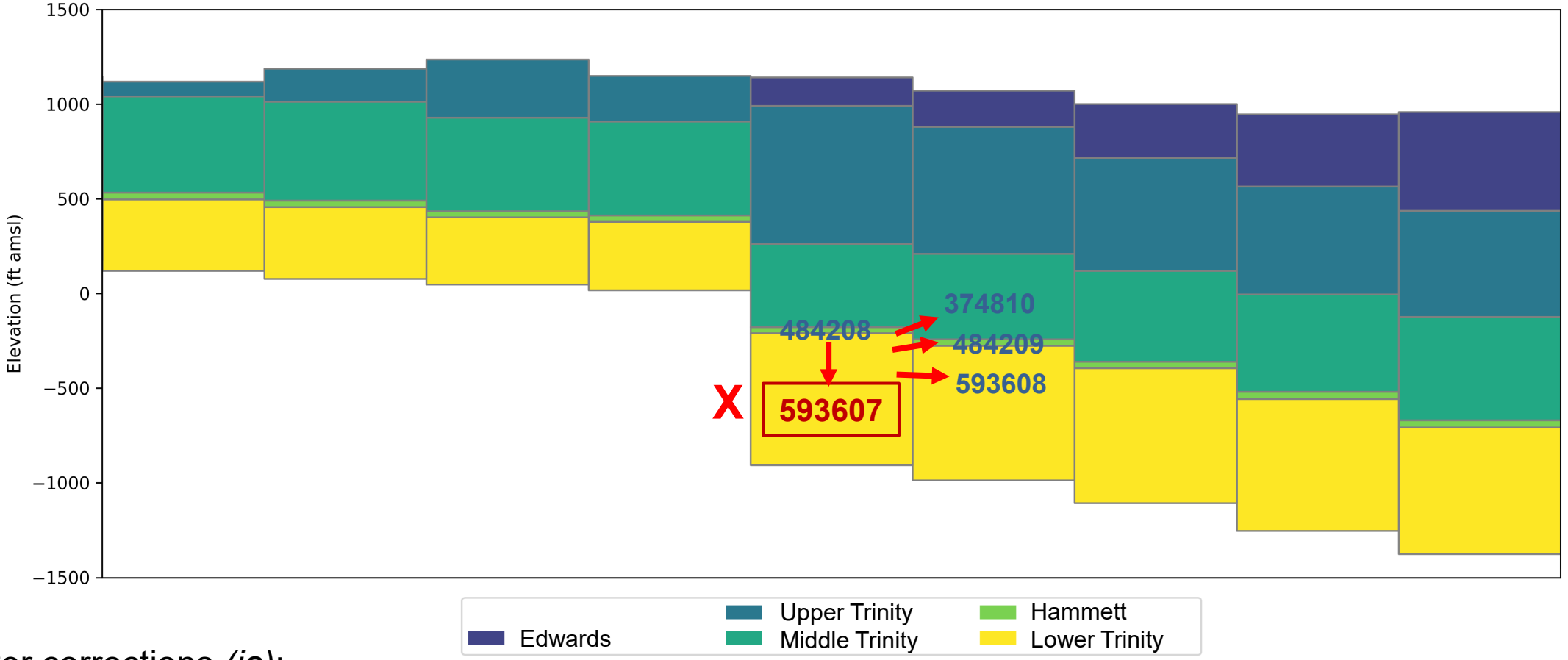
- Workaround: Define Model layers separately from Geology (ex. HUF package)
- Requires simplifications & assumptions
- Makes post-processing by geologic layer difficult

- Fully unstructured grid – less reliant on model “layers”
- Can specify flow connections for individual model cells



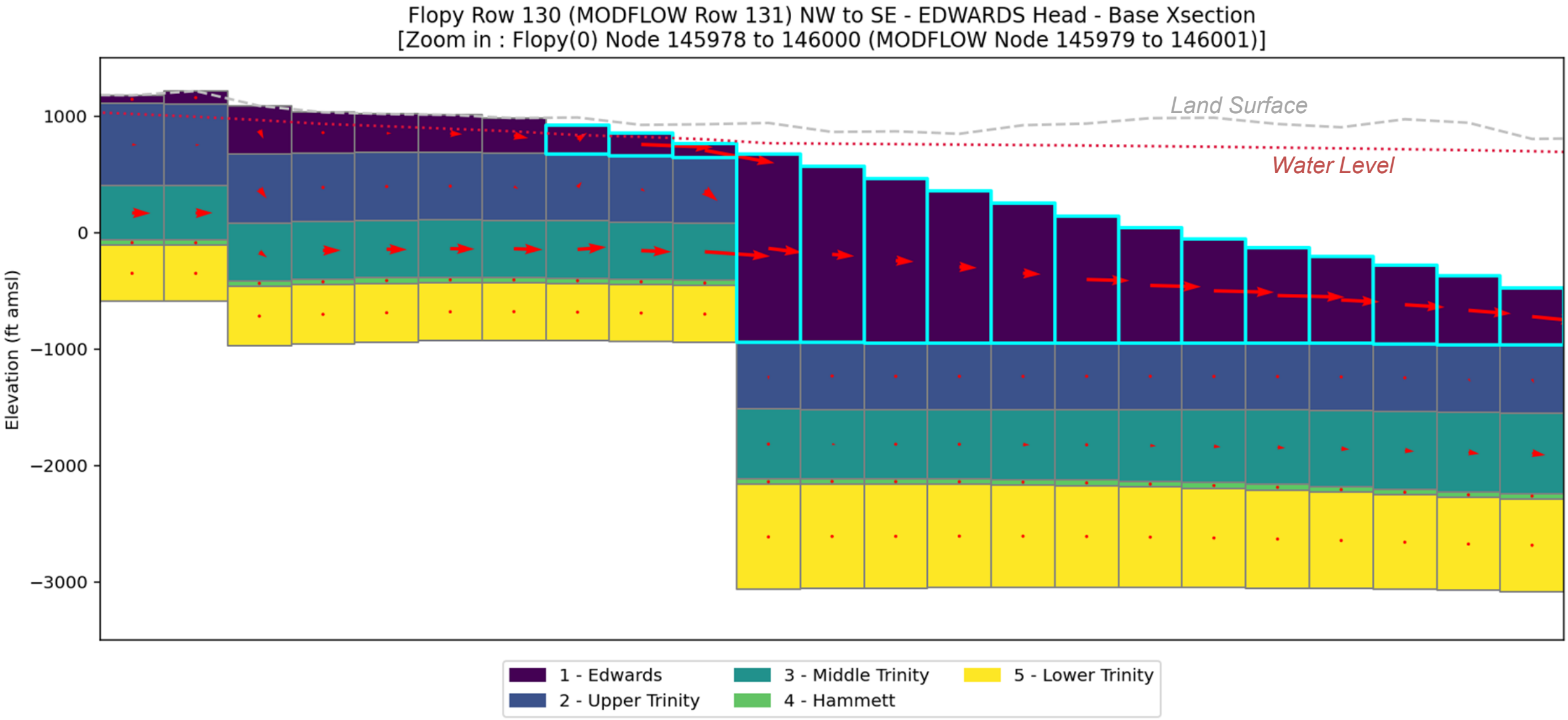
Before corrections *(ja)*:

593607 → **484208** 593223 **593606** **593608** 594050



After corrections *(ja)*:

593607 → **374810** **484208** **484209** **593608** 594050


Flopy Row 130 (MODFLOW Row 131) NW to SE - EDWARDS Head - Base Xsection
[Zoom in : Flopy(0) Node 145978 to 146000 (MODFLOW Node 145979 to 146001)]
Land Surface
Water Level
Elevation (ft amsl)
1000
0
−1000
−2000
−3000
1 - Edwards
2 - Upper Trinity
3 - Middle Trinity
4 - Hammett
5 - Lower Trinity

Model Packages: DISU

- **Unstructured Grid - Getting more usefulness from Real-life geology info**
  - Calculate fault flow based on elevation first
    - ➢ *Minimizes reliance on uncertain fault property assumptions*
  - Identify cells that are not physically attached to rest of model
    - ➢ *Minimizes errors from forcing connections that aren't REAL*
  - Identify true erosional edges
    - ➢ *Minimizes guessing about boundaries*

Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  } Model Setup

  - DISU
  - NPF
  - STO

  } Physical Properties

  - RIV
  - DRN
  - GHB
  - RCH
  - **WEL**

  } Boundary Conditions

Model Packages: Pumping (WEL)

Pumping Distribution

Individual WEL package by Water Use Type*

- Municipal (MUN)
- Irrigation (IRR)
- Industrial (IND)
- Mining (MIN)
- Stock (STK)
- Rural-Domestic (RD)

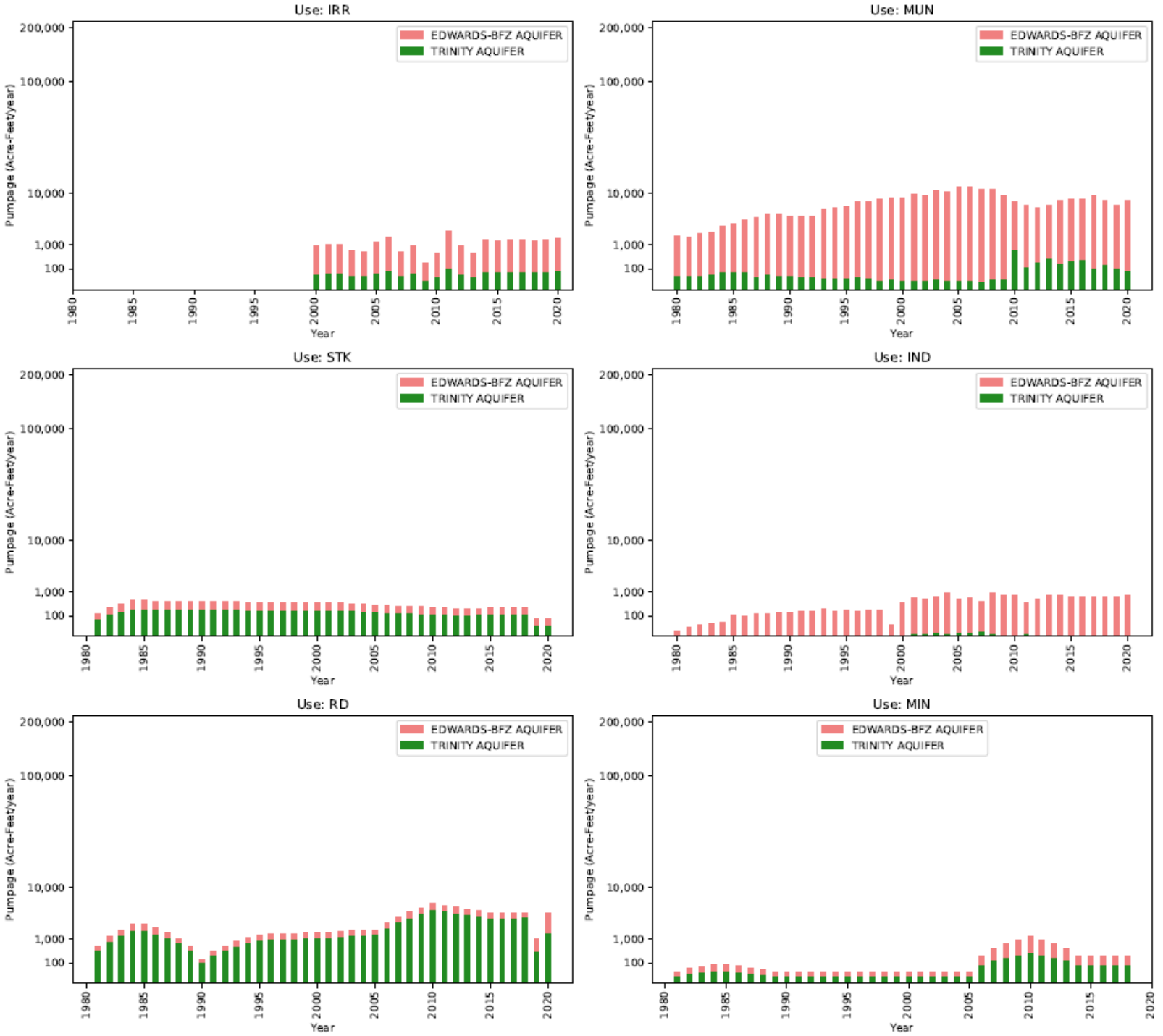
```
4.84430000E+04 -13507 HCa_7043;Bexar_IRR
4.84450000E+04 -13507 HCa_7049;Bexar_IRR
4.84480000E+04 -13507 HCa_7524;Bexar_IRR
4.92130000E+04 -13507 HCa_6175;Bexar_IRR
4.92300000E+04 -13507 HCa_7508;Bexar_IRR
4.92310000E+04 -864 HCa_7522;Bexar_IRR
4.92320000E+04 -13507 HCa_7507;Bexar_IRR
4.99440000E+04 -61806 HCa_6171;Medina_IRR
4.99550000E+04 -27014 HCa_6919;HCa_6926;Bexar_IRR
5.07270000E+04 -13507 HCa_6918;Bexar_IRR
5.07350000E+04 -27014 HCa_7541;HCa_7546;Bexar_IRR
5.16380000E+04 -61806 HCa_6799;Medina_IRR
5.16390000E+04 -61806 HCa_6800;Medina_IRR
5.16560000E+04 -13507 HCa_7544;Bexar_IRR
5.28760000E+04 -61806 HCa_6166;Medina_IRR
```

Variables:

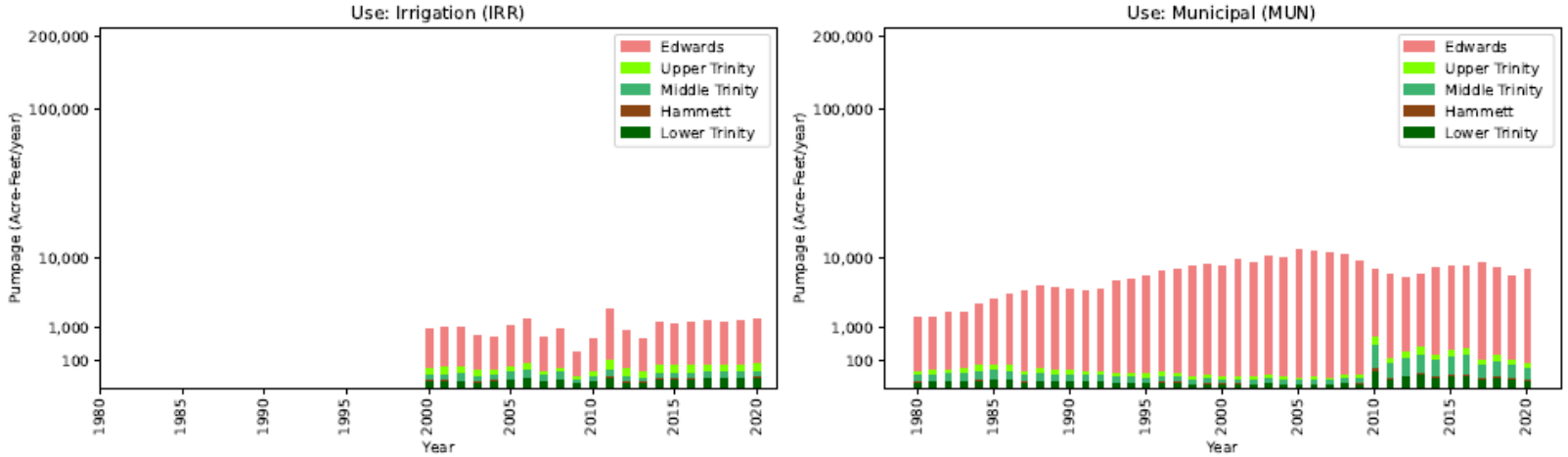
- Pumping rate
  - Values from LRE-contracted study & TWDB Water Use Survey
  - By Water Use Type*
  - By TWDB Major Aquifer (Edwards-BFZ, Edwards-Trinity Plateau, & Trinity)

**categories from TWDB Water Use Survey*

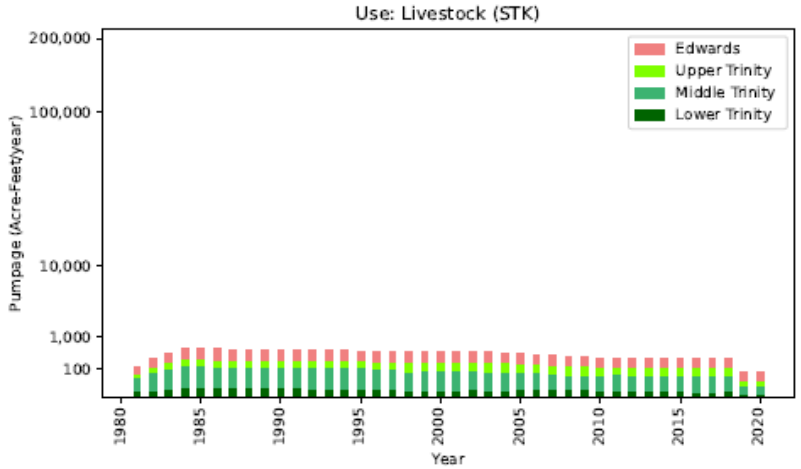
TRAVIS

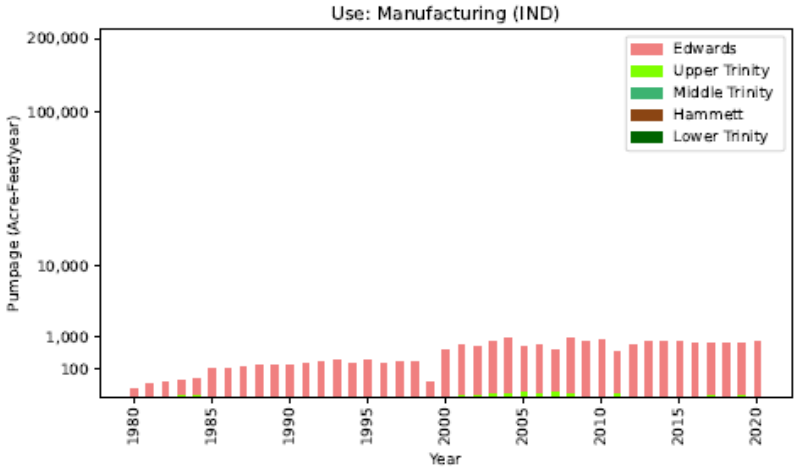

Use: IRR
Use: MUN
Use: STK
Use: IND
Use: RD
Use: MIN
EDWARDS-BFZ AQUIFER
TRINITY AQUIFER
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

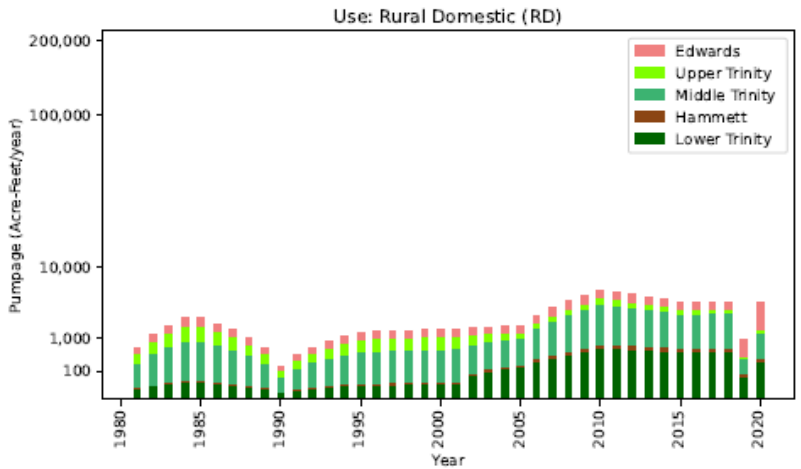
TRAVIS

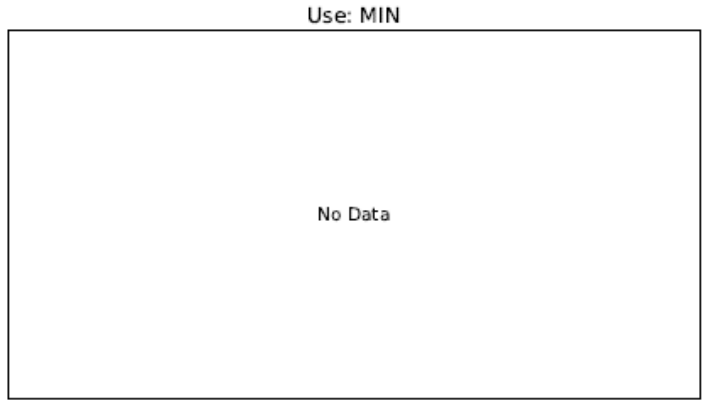

Use: Irrigation (IRR)
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Edwards
Upper Trinity
Middle Trinity
Hammett
Lower Trinity

Use: Municipal (MUN)
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Edwards
Upper Trinity
Middle Trinity
Hammett
Lower Trinity

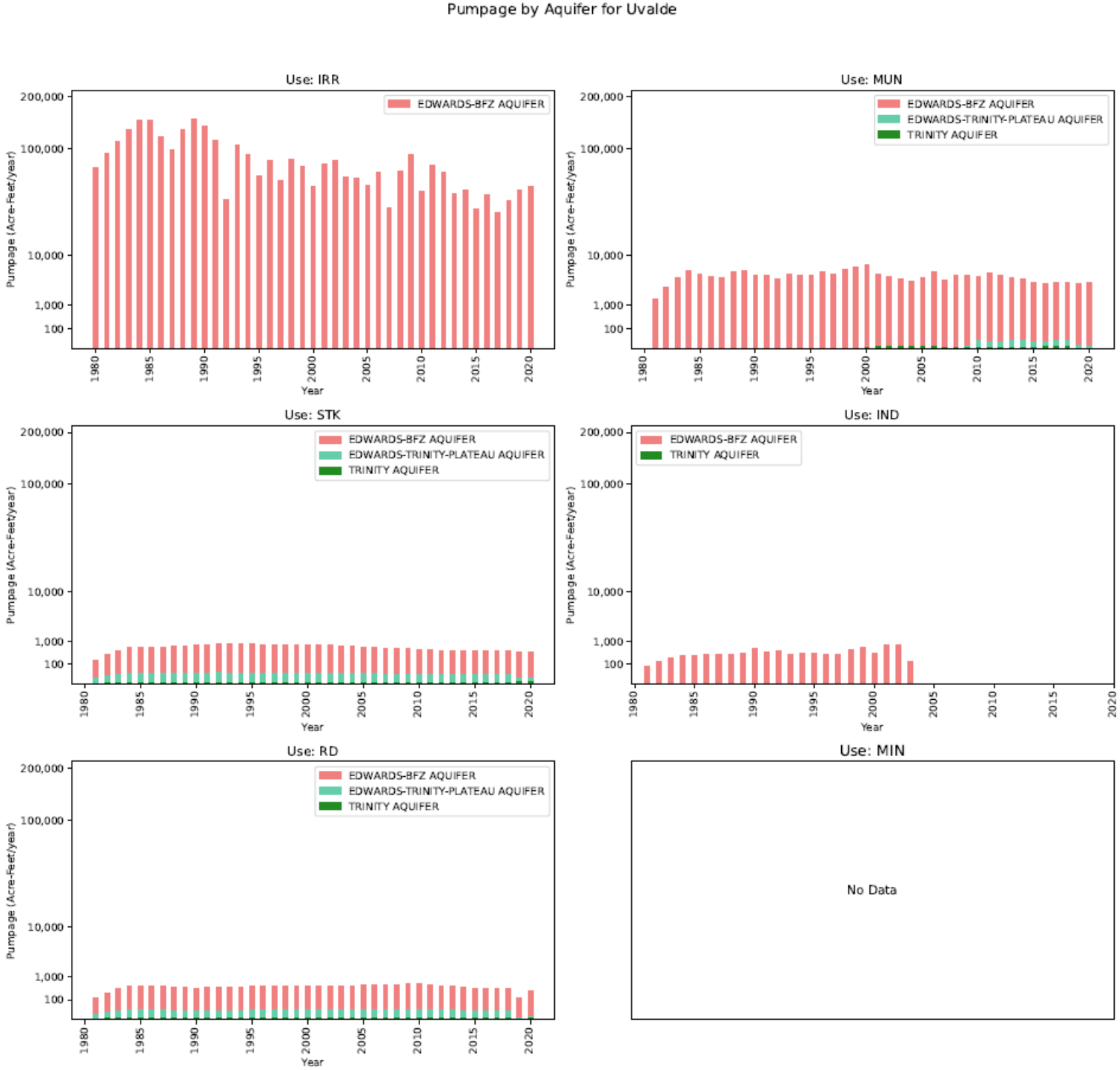

Use: Livestock (STK)
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Edwards
Upper Trinity
Middle Trinity
Lower Trinity


Use: Manufacturing (IND)
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Edwards
Upper Trinity
Middle Trinity
Hammett
Lower Trinity

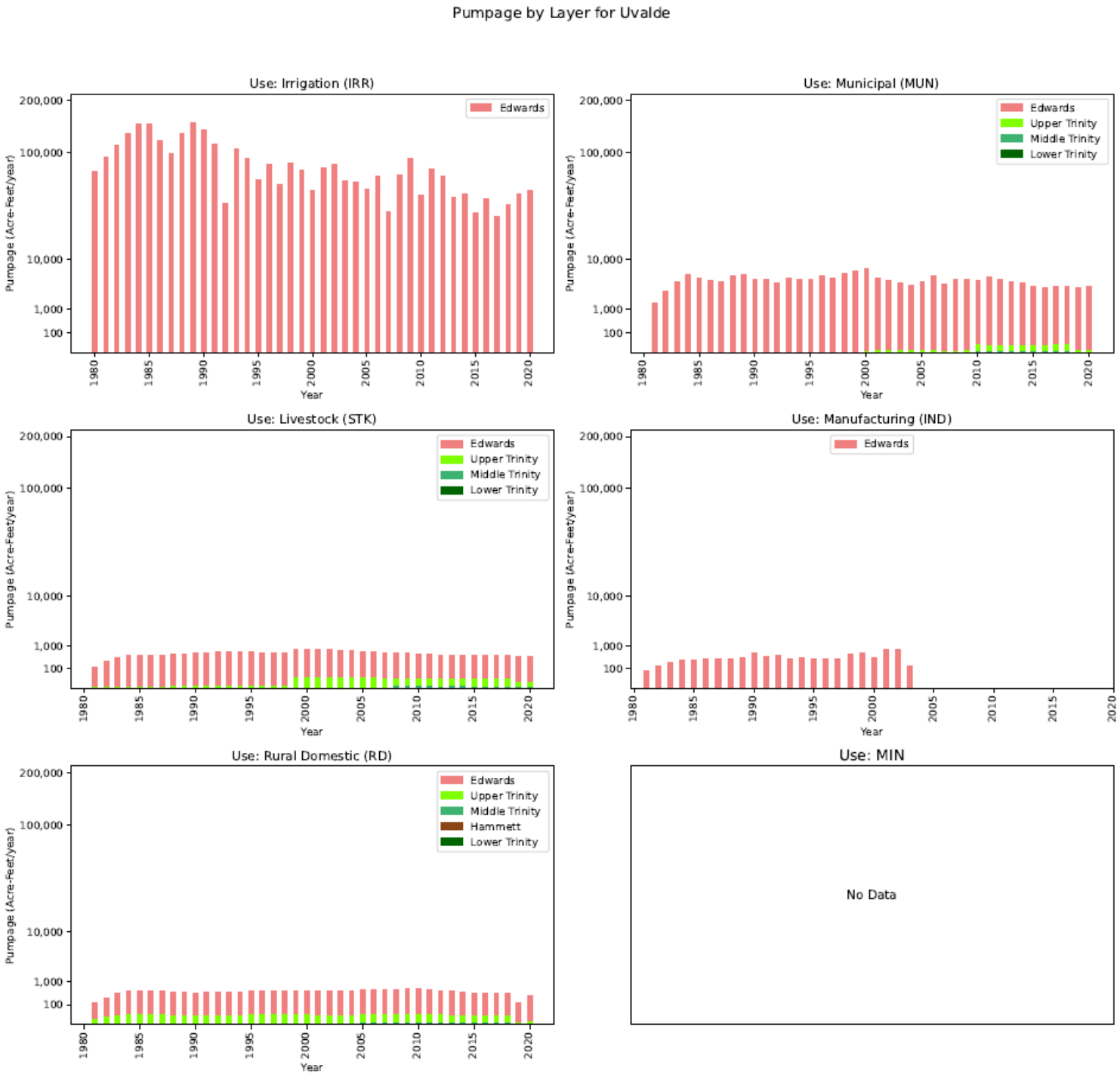

Use: Rural Domestic (RD)
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Edwards
Upper Trinity
Middle Trinity
Hammett
Lower Trinity

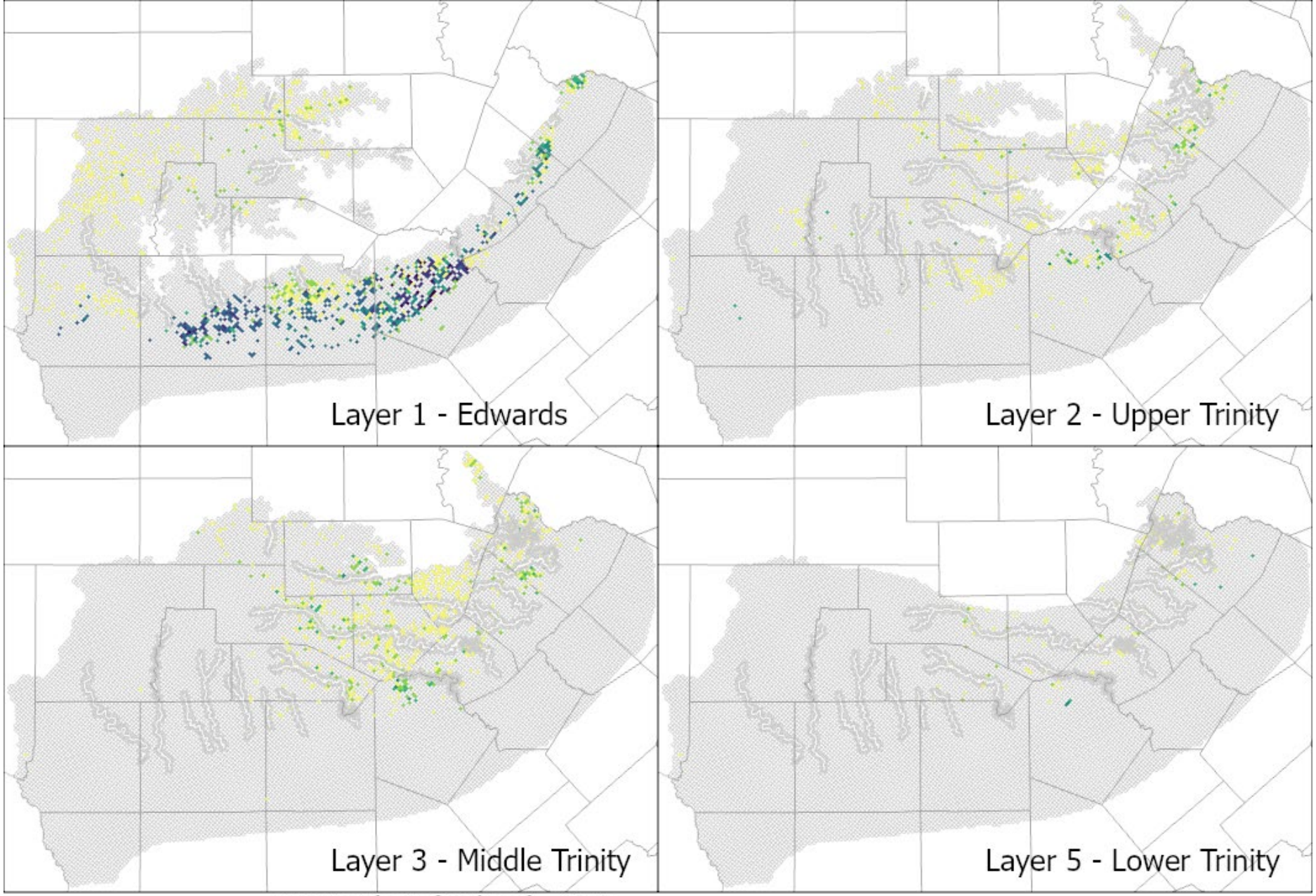

Use: MIN
No Data

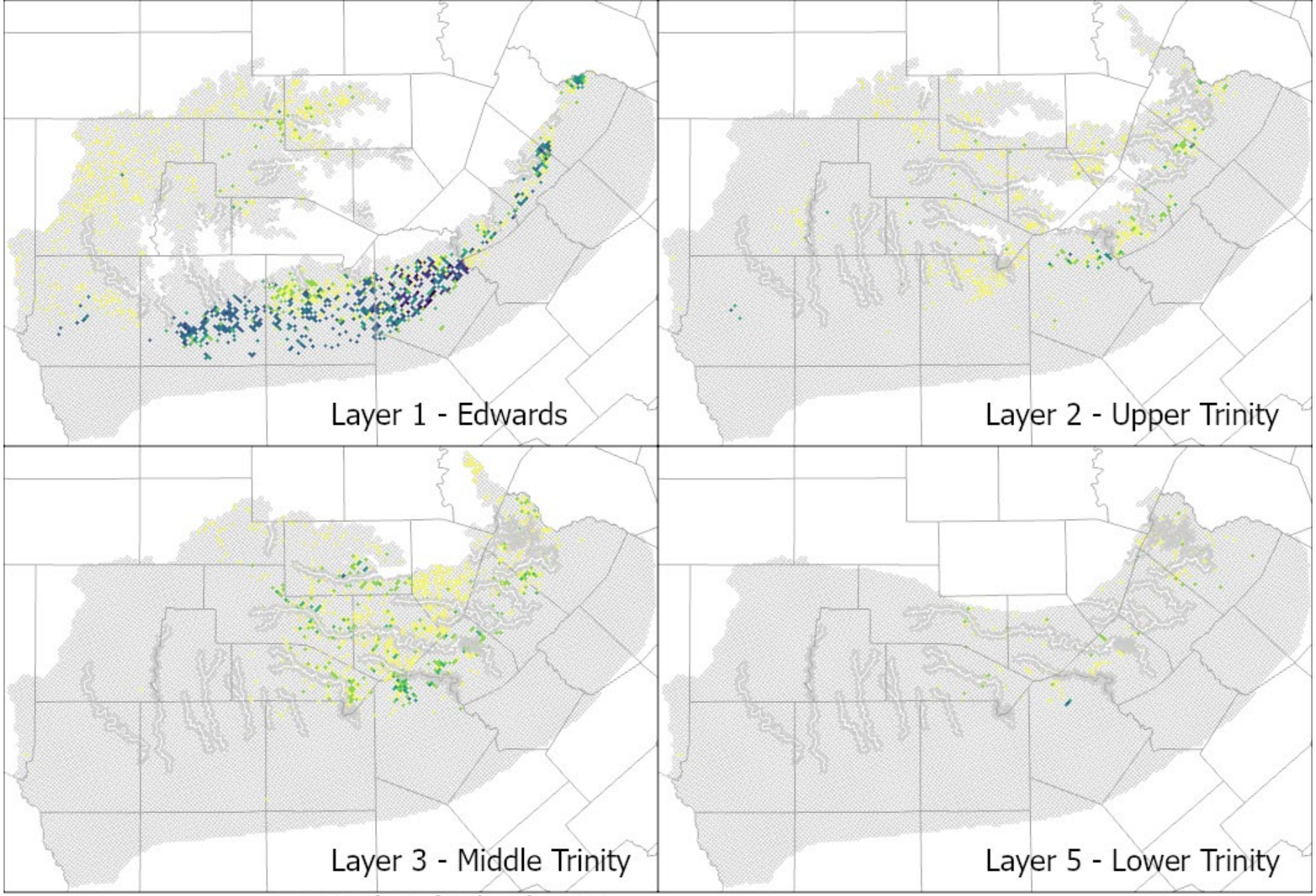
UVALDE

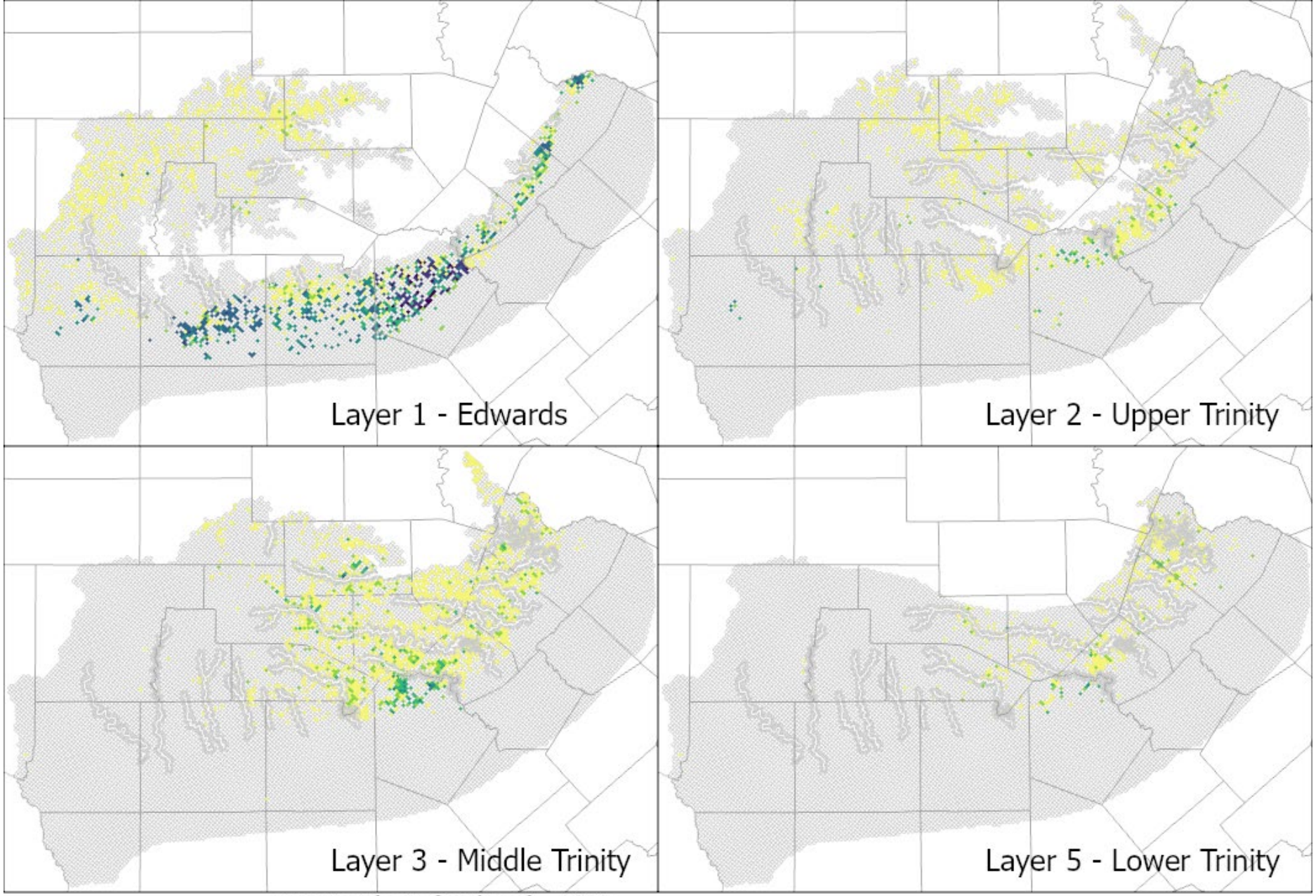

Pumpage by Aquifer for Uvalde
Use: IRR
EDWARDS-BFZ AQUIFER
Use: MUN
EDWARDS-BFZ AQUIFER
EDWARDS-TRINITY-PLATEAU AQUIFER
TRINITY AQUIFER
Use: STK
EDWARDS-BFZ AQUIFER
EDWARDS-TRINITY-PLATEAU AQUIFER
TRINITY AQUIFER
Use: IND
EDWARDS-BFZ AQUIFER
TRINITY AQUIFER
Use: RD
EDWARDS-BFZ AQUIFER
EDWARDS-TRINITY-PLATEAU AQUIFER
TRINITY AQUIFER
Use: MIN
No Data
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

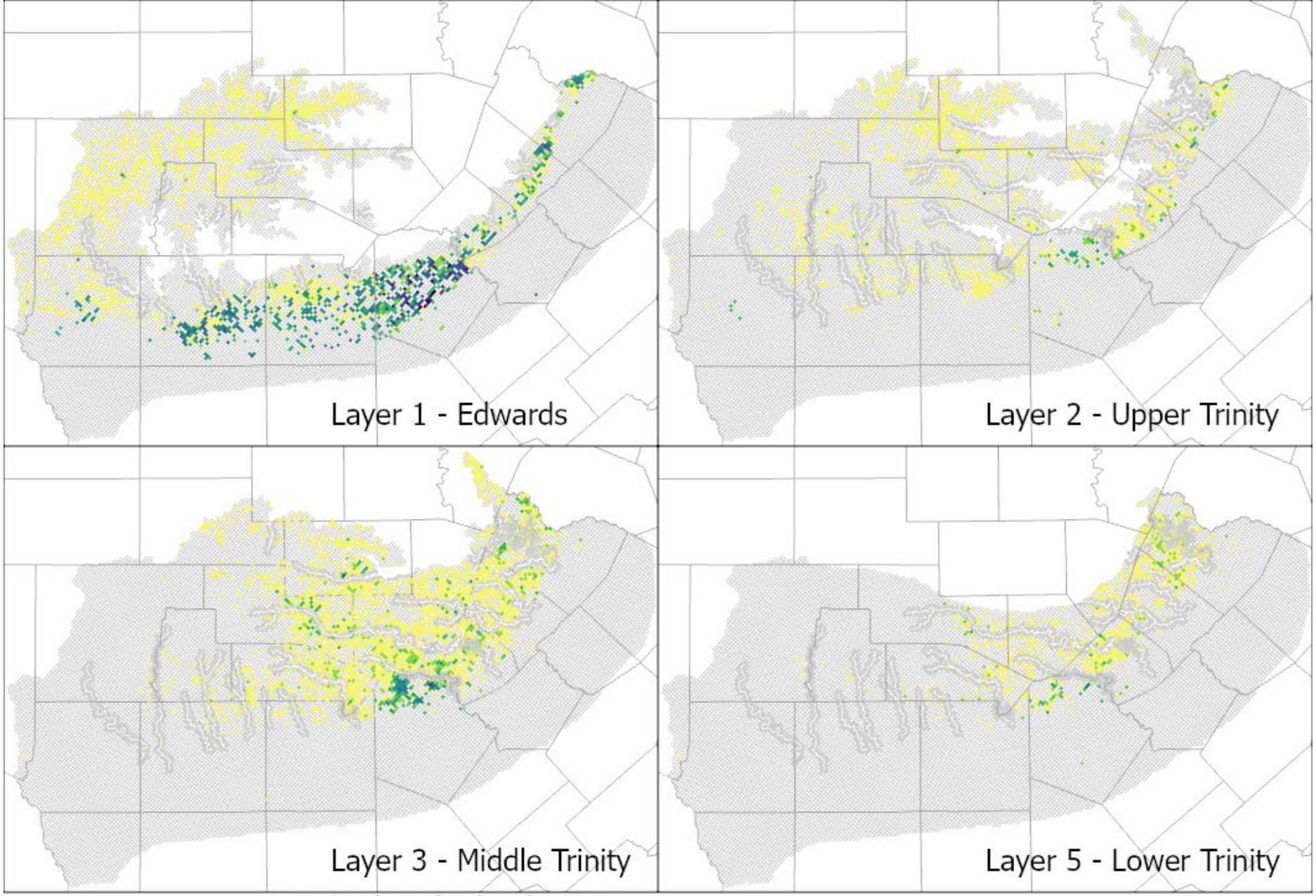
UVALDE


Pumpage by Layer for Uvalde
Use: Irrigation (IRR)
Edwards
Use: Municipal (MUN)
Edwards
Upper Trinity
Middle Trinity
Lower Trinity
Use: Livestock (STK)
Edwards
Upper Trinity
Middle Trinity
Lower Trinity
Use: Manufacturing (IND)
Edwards
Use: Rural Domestic (RD)
Edwards
Upper Trinity
Middle Trinity
Hammett
Lower Trinity
Use: MIN
No Data
Pumpage (Acre-Feet/year)
200,000
100,000
10,000
1,000
100
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Layer 1 - Edwards
Layer 2 - Upper Trinity
Layer 3 - Middle Trinity
Layer 5 - Lower Trinity
Pumping (acre-feet/year) - 1985
> 3,000
1,000 - 3,000
300 - 1,000
100 - 300
30 - 100
10 - 30
<10
Active grid
TWDB_Counties
0
25
50
100
Miles
N


Layer 1 - Edwards
Layer 2 - Upper Trinity
Layer 3 - Middle Trinity
Layer 5 - Lower Trinity
Pumping (acre-feet/year) - 1995
> 3,000
1,000 - 3,000
300 - 1,000
100 - 300
30 - 100
10 - 30
<10
Active grid
TWDB_Counties
0
25
50
100
Miles
N


Layer 1 - Edwards
Layer 2 - Upper Trinity
Layer 3 - Middle Trinity
Layer 5 - Lower Trinity
Pumping (acre-feet/year) - 2005
> 3,000
1,000 - 3,000
300 - 1,000
100 - 300
30 - 100
10 - 30
<10
Active grid
TWDB_Counties
0
25
50
100
Miles
N


Layer 1 - Edwards
Layer 2 - Upper Trinity
Layer 3 - Middle Trinity
Layer 5 - Lower Trinity
Pumping (acre-feet/year) - 2015
> 3,000
1,000 - 3,000
300 - 1,000
100 - 300
30 - 100
10 - 30
<10
Active grid
TWDB_Counties
0
25
50
100
Miles
N

Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  } Model Setup

  - DISU
  - NPF
  - STO

  } Physical Properties

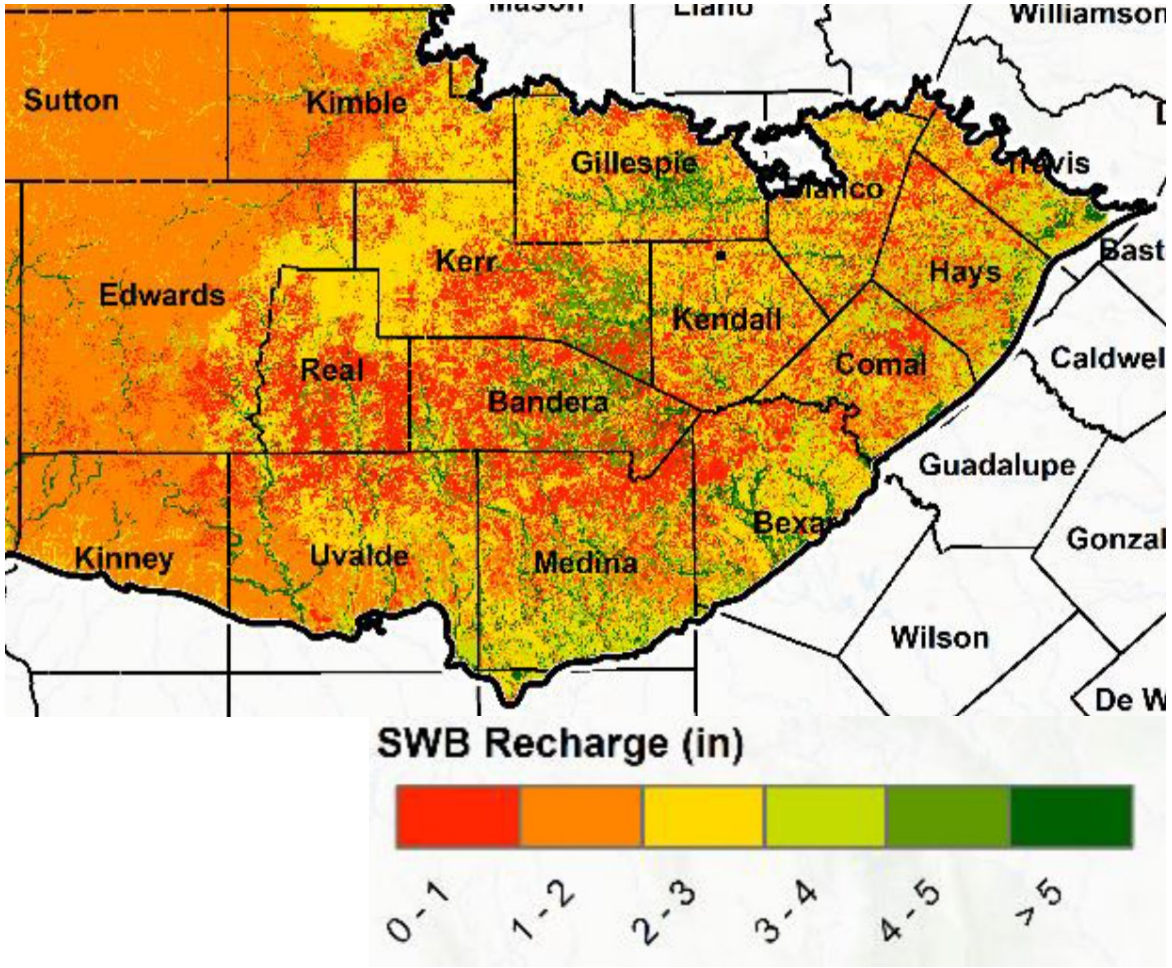
  - RIV
  - DRN
  - GHB
  - **RCH**
  - WEL

  } Boundary Conditions

Model Packages: Recharge (RCH)

Recharge Distribution

- Initial values from contracted WSP Recharge study
- Chose most “realistic” spatial distribution:
  - Soil-water-balance (SWB) method
- Avoid double-counting:
  - Did not apply Recharge to RIV cells
  - Only in topmost active layer
- Variables:
  - Recharge flux rate (LT^{-1})
    - Multipliers by Surface Geology Zones

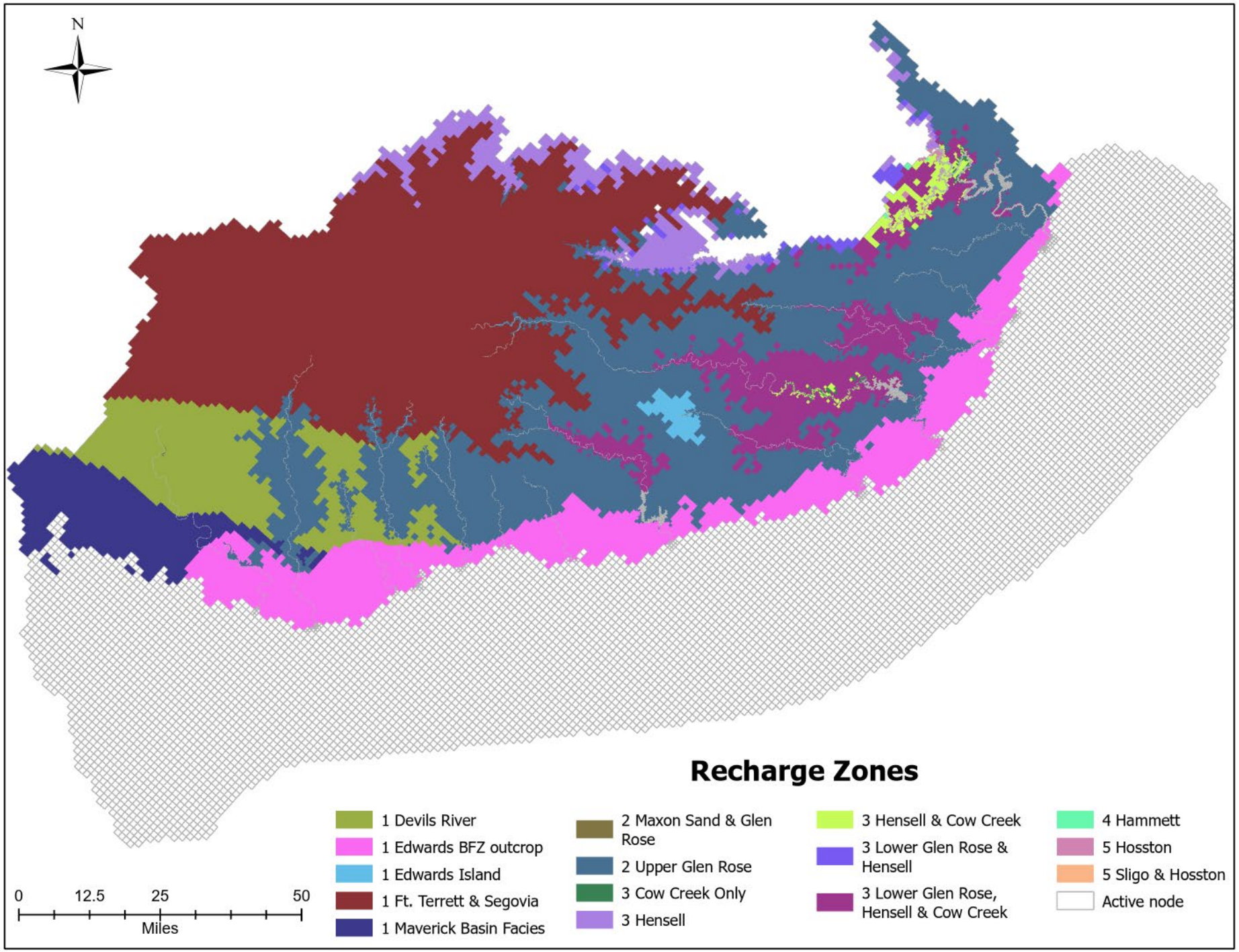


Recharge Distribution

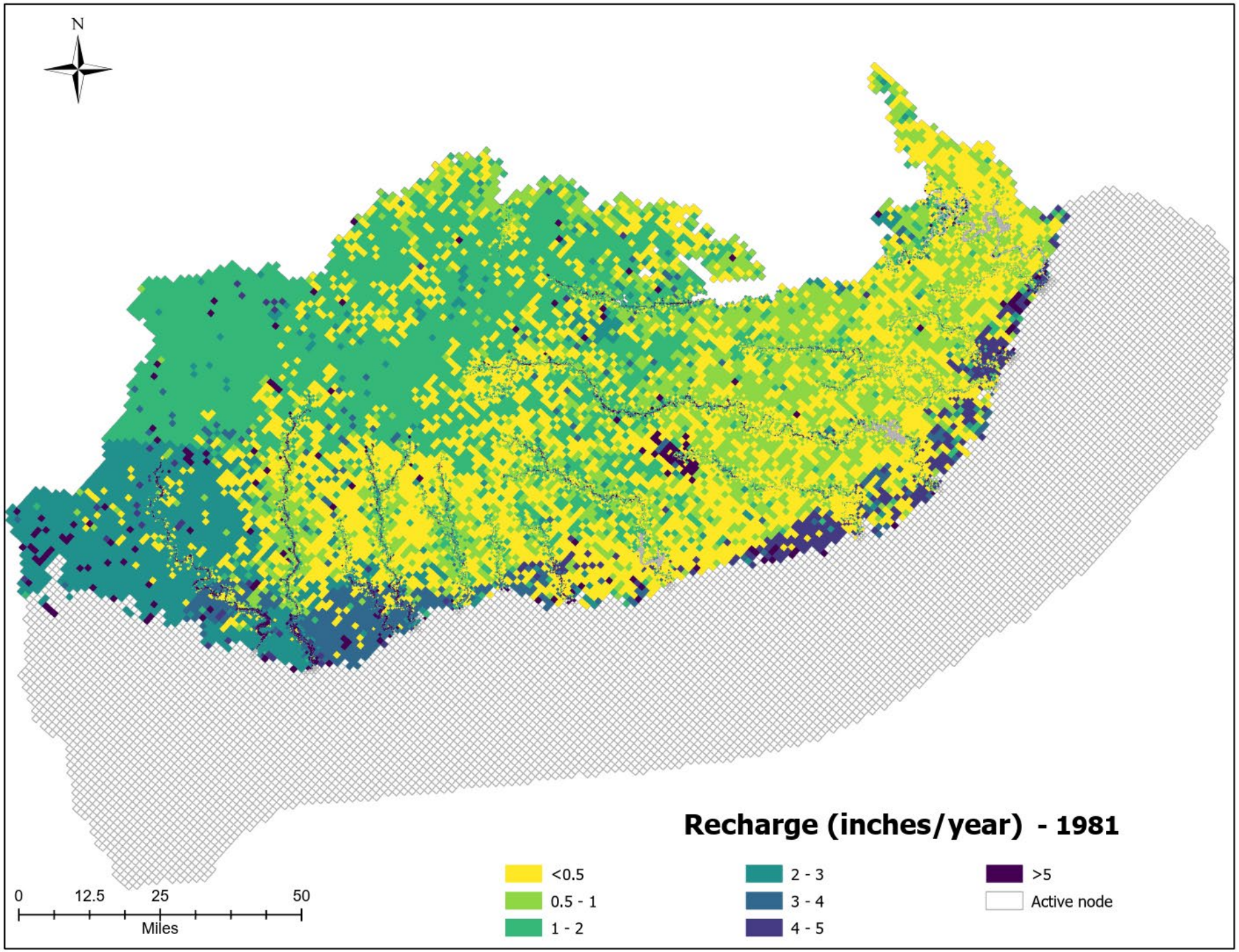
- Variables:
  - Recharge flux rate (LT^{-1})
    - Multipliers by Surface Geology Zones

```
60976 1.66872007E-04 ED_Devils_River
60993 1.25804241E-03 ED_Devils_River
61017 1.00000000E-07 ED_Devils_River
61018 1.00000000E-07 ED_Devils_River
61020 1.00000000E-07 ED_Devils_River
61023 1.00000000E-07 ED_Devils_River
61024 1.00000000E-07 ED_Devils_River
61326 1.00000000E-07 ED_Edwards_BFZ_outcrop
61327 6.84462721E-04 ED_Edwards_BFZ_outcrop
61328 7.87132085E-05 ED_Edwards_BFZ_outcrop
61329 2.52110418E-04 ED_Edwards_BFZ_outcrop
61330 6.39516278E-04 ED_Edwards_BFZ_outcrop
61331 1.00000000E-07 ED_Edwards_BFZ_outcrop
61332 5.66050643E-04 ED_Edwards_BFZ_outcrop
61333 5.57608961E-04 ED_Edwards_BFZ_outcrop
61334 5.58293425E-04 ED_Edwards_BFZ_outcrop
61376 4.87109297E-04 ED_Fort_Terrett_and_Segovia
61377 4.84371412E-04 ED_Fort_Terrett_and_Segovia
61378 6.21263986E-04 ED_Fort_Terrett_and_Segovia
61379 4.67944366E-04 ED_Fort_Terrett_and_Segovia
```

Recharge Zones



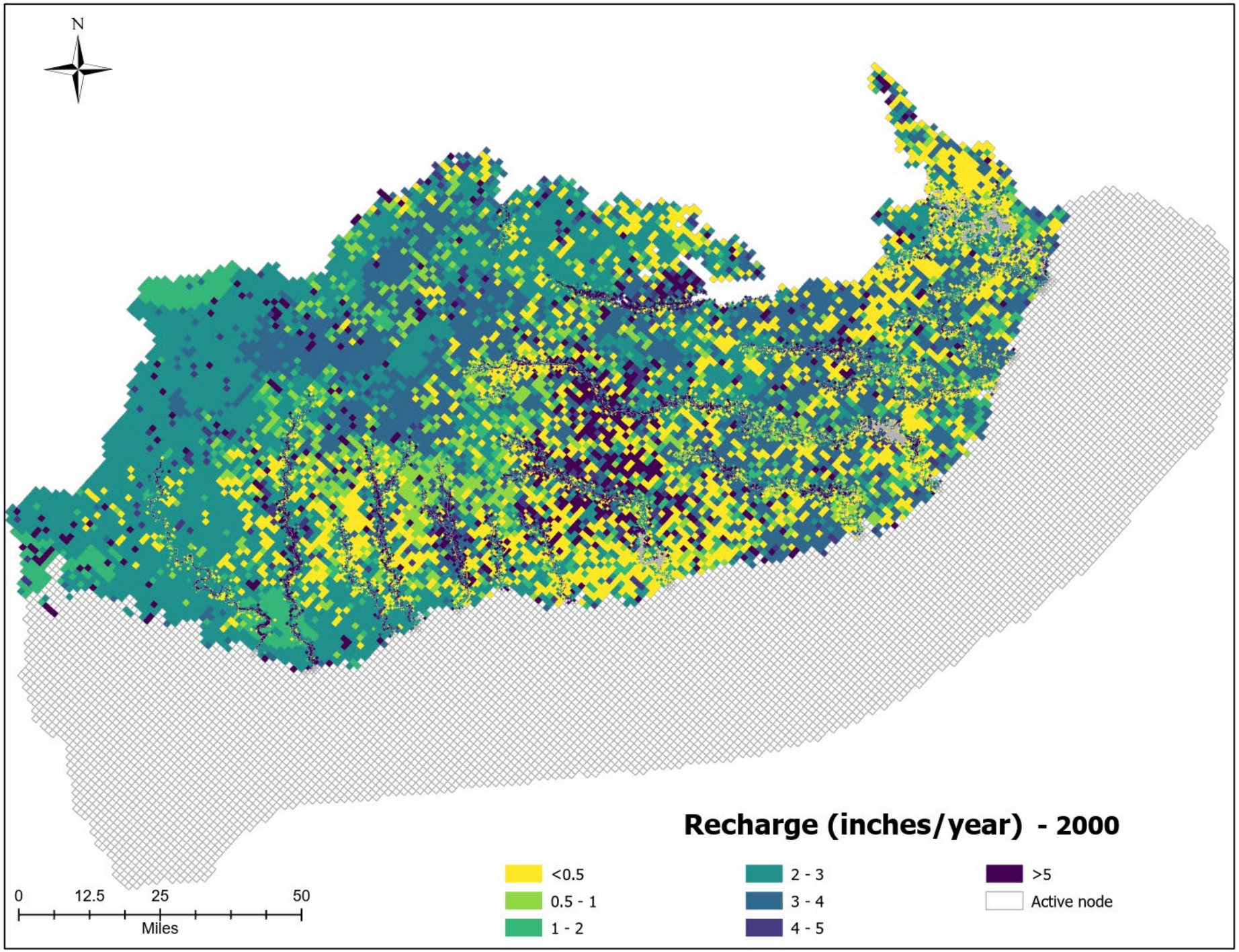
Model Packages: RCH



1981 Recharge

TEXAS WATER DEVELOPMENT BOARD

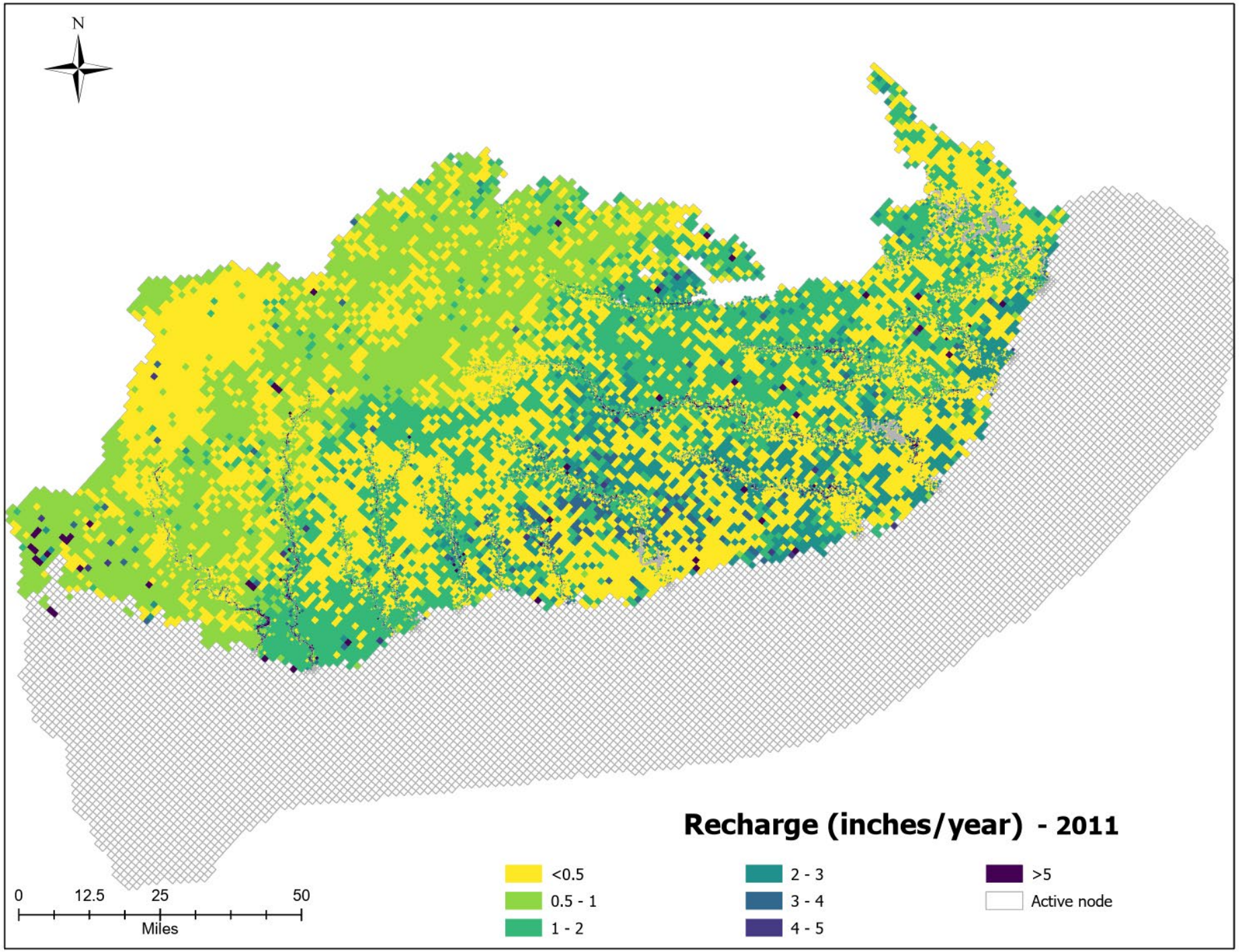
Model Packages: RCH



2000 Recharge

TEXAS WATER DEVELOPMENT BOARD

Model Packages: RCH



2011 Recharge

Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  } Model Setup

  - DISU
  - **NPF**
  - STO

  } Physical Properties

  - RIV
  - DRN
  - GHB
  - RCH
  - WEL

  } Boundary Conditions

Model Packages: Properties (NPF)

Model Packages: NPF

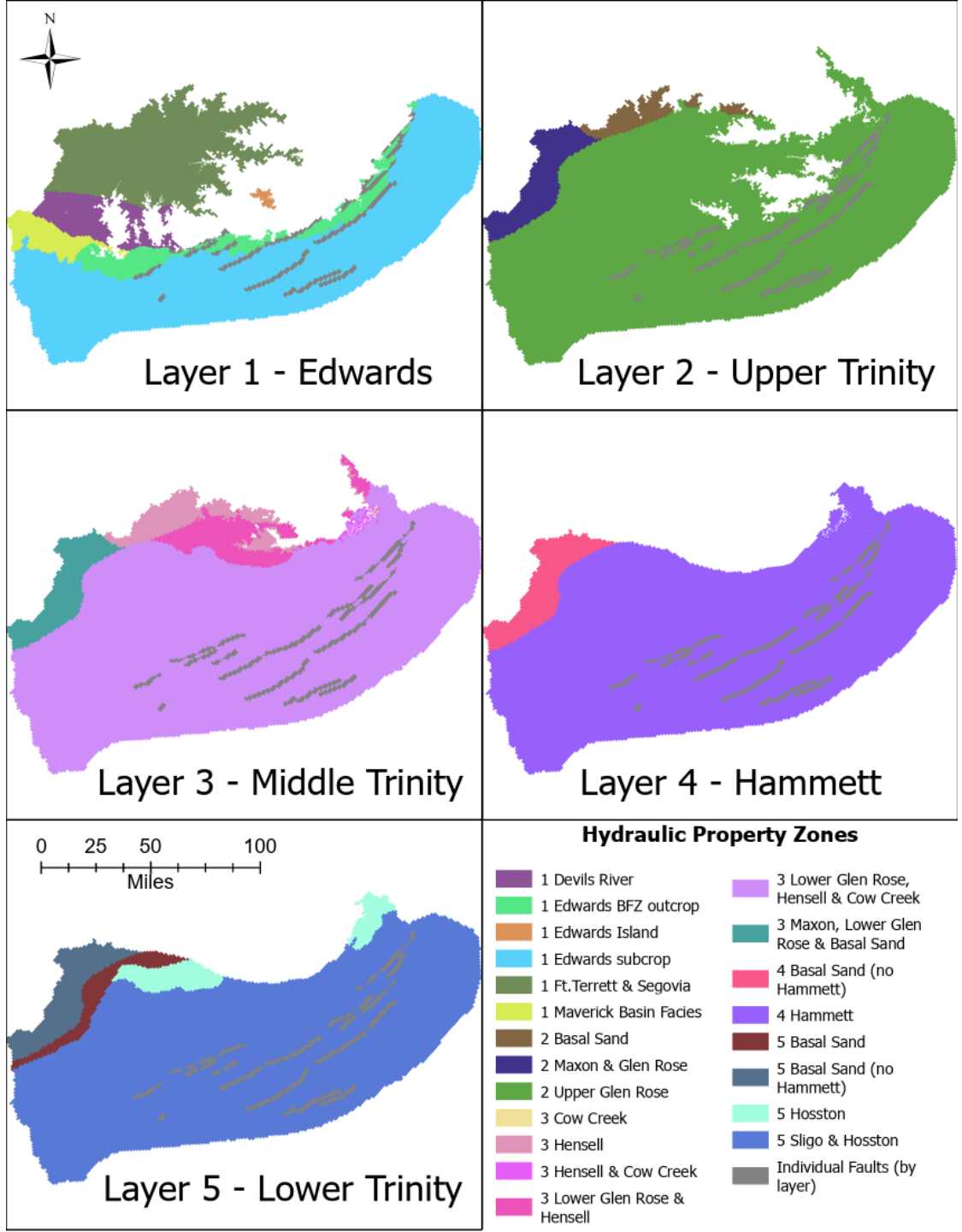
Variables:

- Cell type
  - All cells convertible *(confined/unconfined based on head)*
- Hydraulic conductivity:
  - Horizontal : Calibrated values *(zone multipliers – see map)*
  - Vertical : tied to Horizontal
    - Kv = 0.1 x Kh *(majority)*
    - Kv = Kh *(faults and in Western Edwards-Trinity Plateau region)*

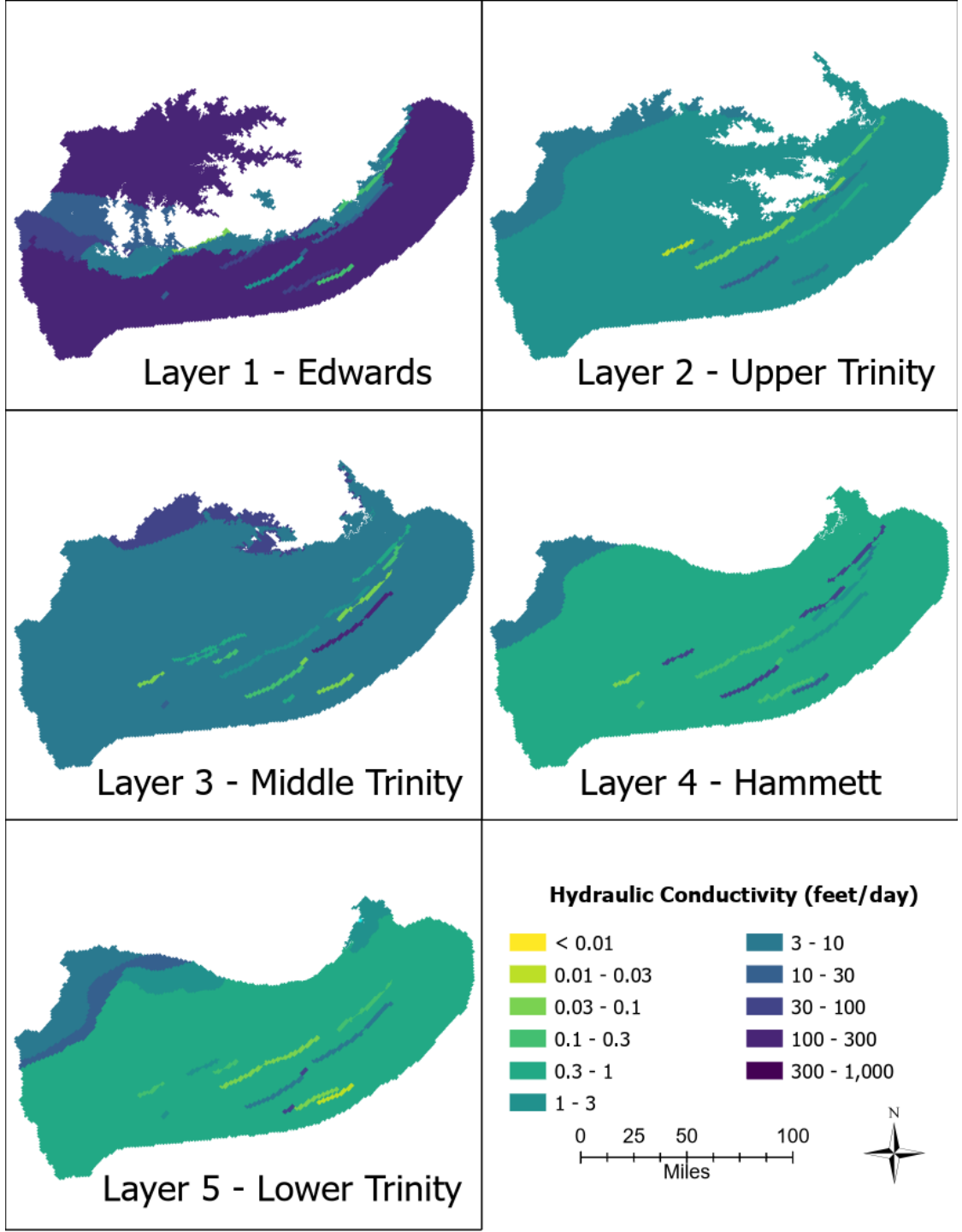
K Zones

Layer	Layer Name	K Zones	
		Geologic	Fault*
1	Edwards	6	16
2	Upper Trinity	3	16
3	Middle Trinity	6	16
4	Hammett	2	16
5	Lower Trinity	4	16

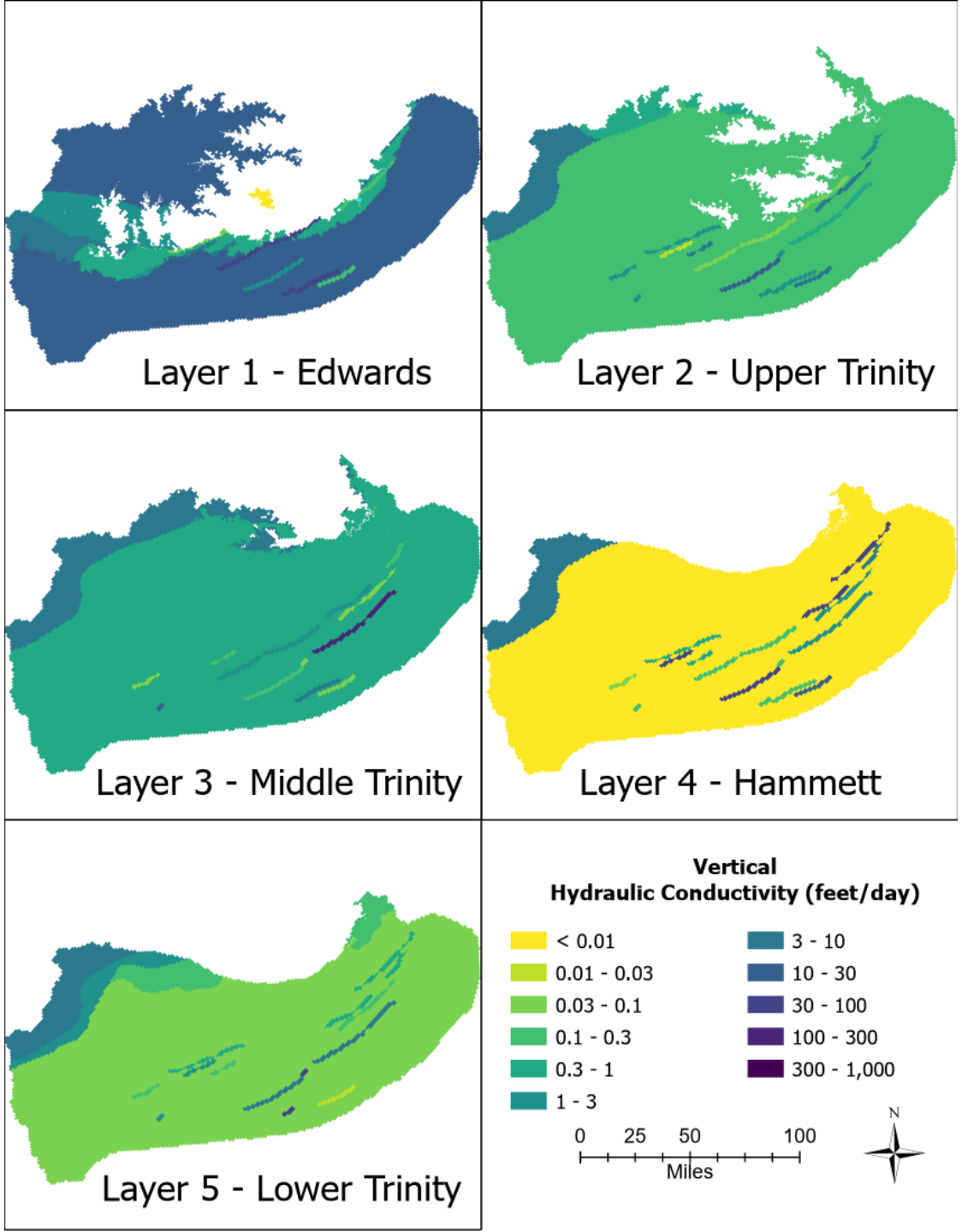
**Faults based on traces + model layer displacement*



Horizontal Hydraulic Conductivity



Vertical Hydraulic Conductivity



Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  } Model Setup

  - DISU
  - NPF
  - **STO**

  } Physical Properties

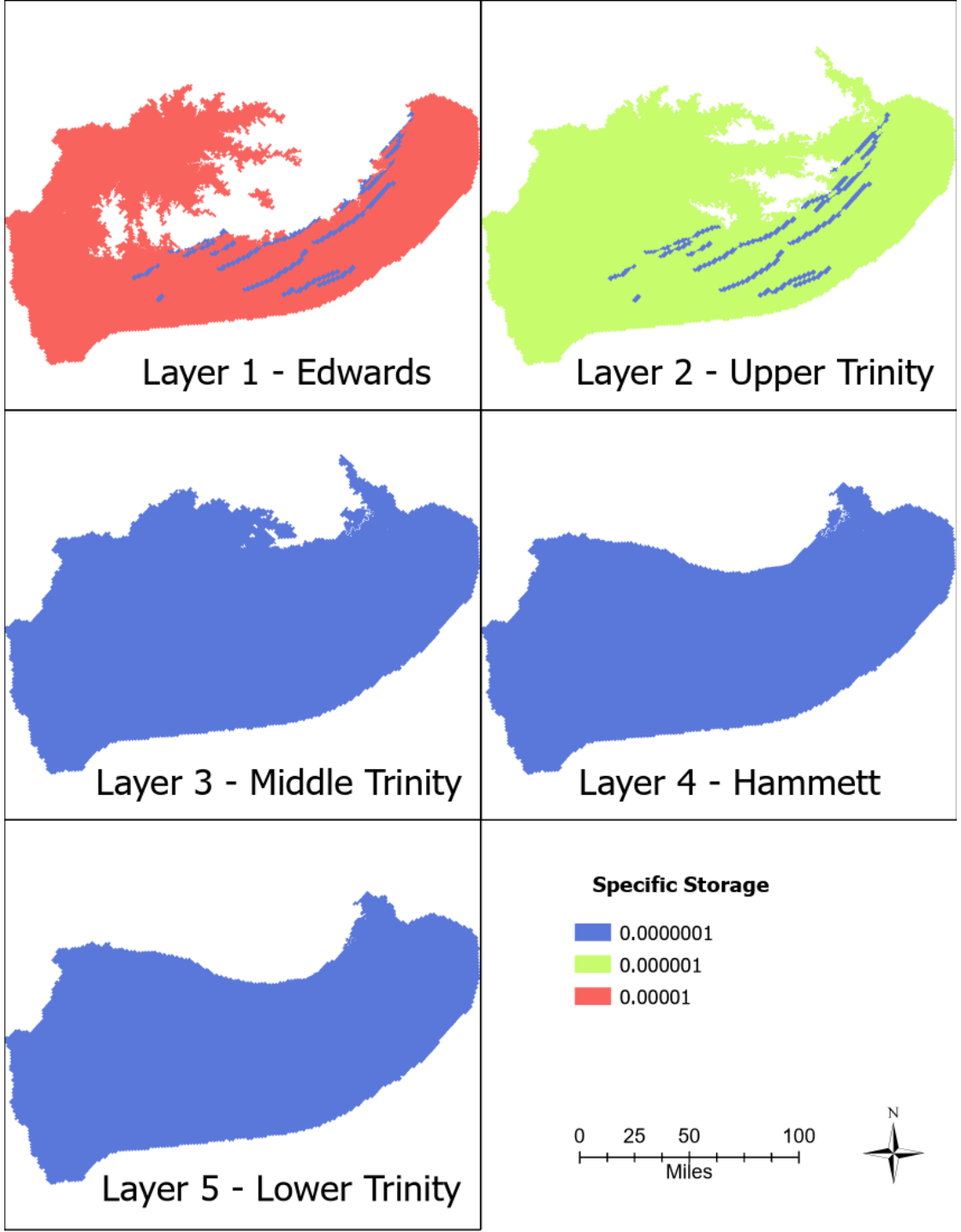
  - RIV
  - DRN
  - GHB
  - RCH
  - WEL

  } Boundary Conditions

Model Packages: Storage (STO)

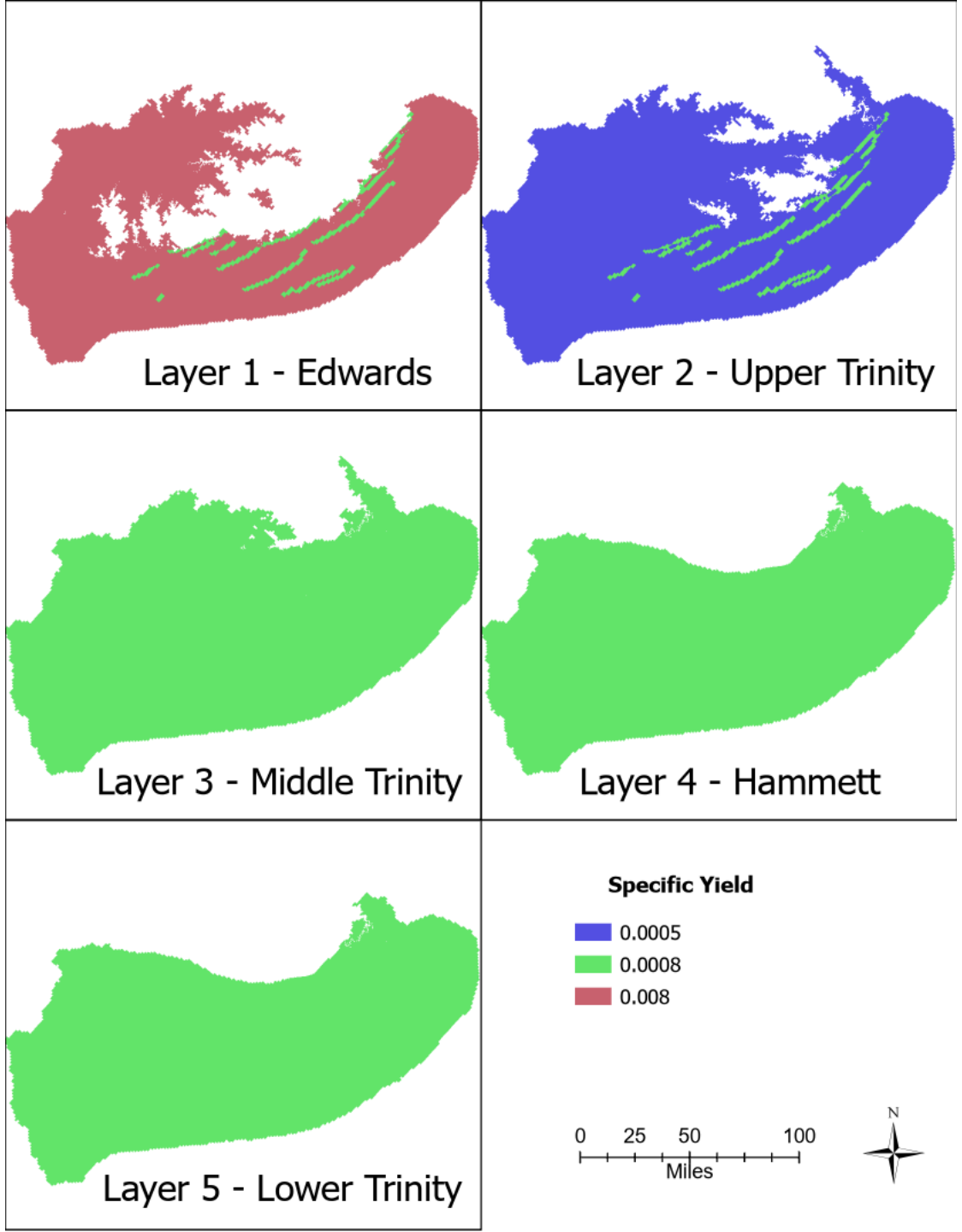
Specific storage

Values from previous GAM



Specific yield

Values from previous GAM



Model Design

- Model Packages
  - IMS
  - TDIS
  - IC

  } Model Setup

  - DISU
  - NPF
  - STO

  } Physical Properties

  - **RIV**
  - DRN
  - GHB
  - RCH
  - WEL

  } Boundary Conditions

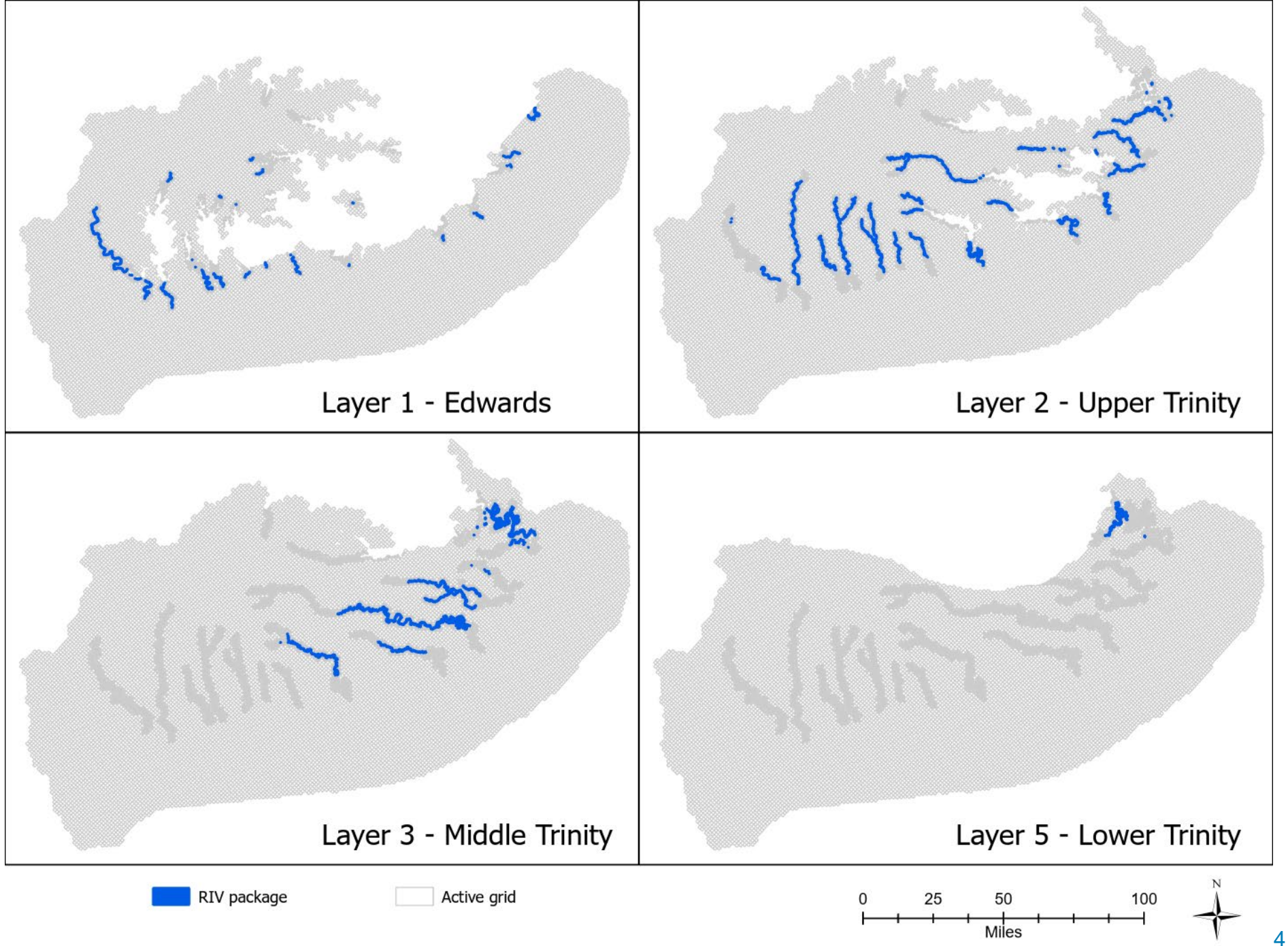
Model Packages: Rivers (RIV)

Model Packages: RIV

Represents:

- Perennial rivers
- Major Lakes

  Lake Travis
  Lake Austin
  Canyon Lake
  Medina Lake



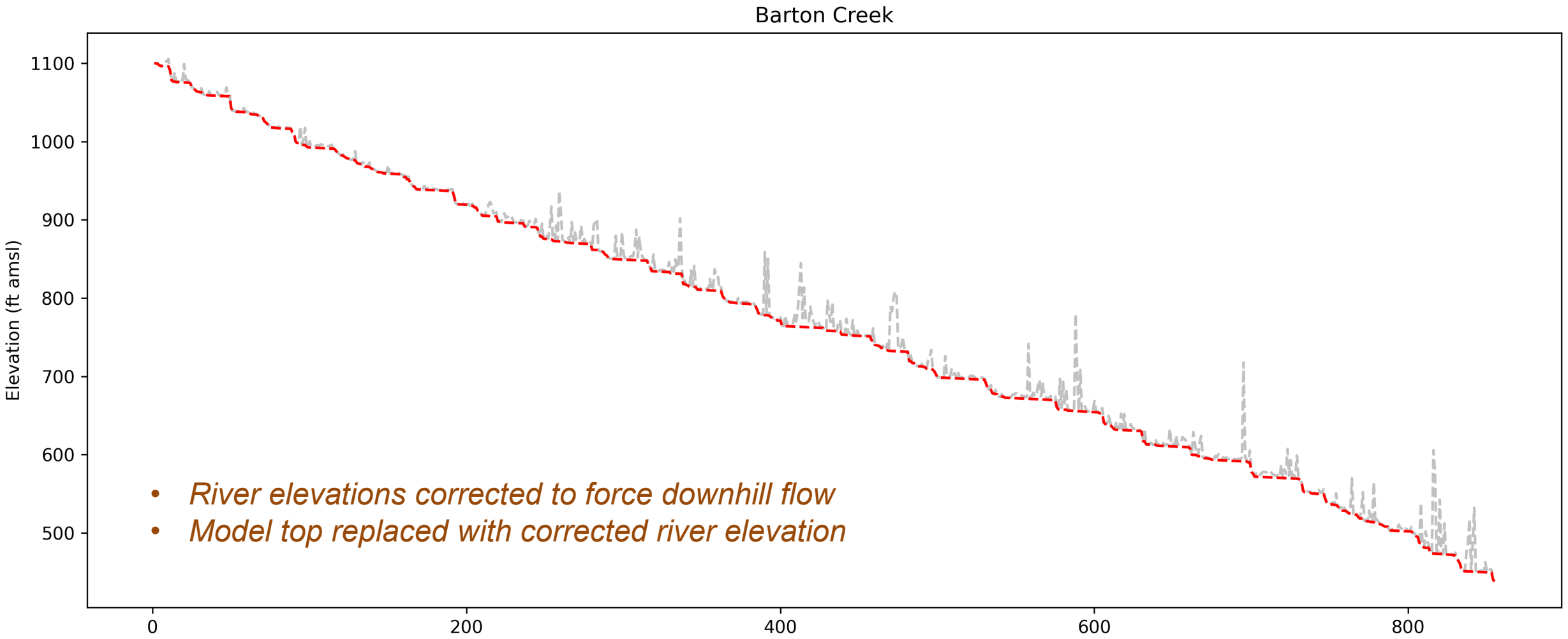
TEXAS WATER DEVELOPMENT BOARD

Model Packages: RIV

Variables:

- Stream stage (elevation):
  - land surface elevation (corrected to flow downhill)
- Stream bottom (elevation):
  - 0.5 feet below land surface elevation
- Conductance:
  - Calibrated value (multiplier by river)

Model Packages: RIV



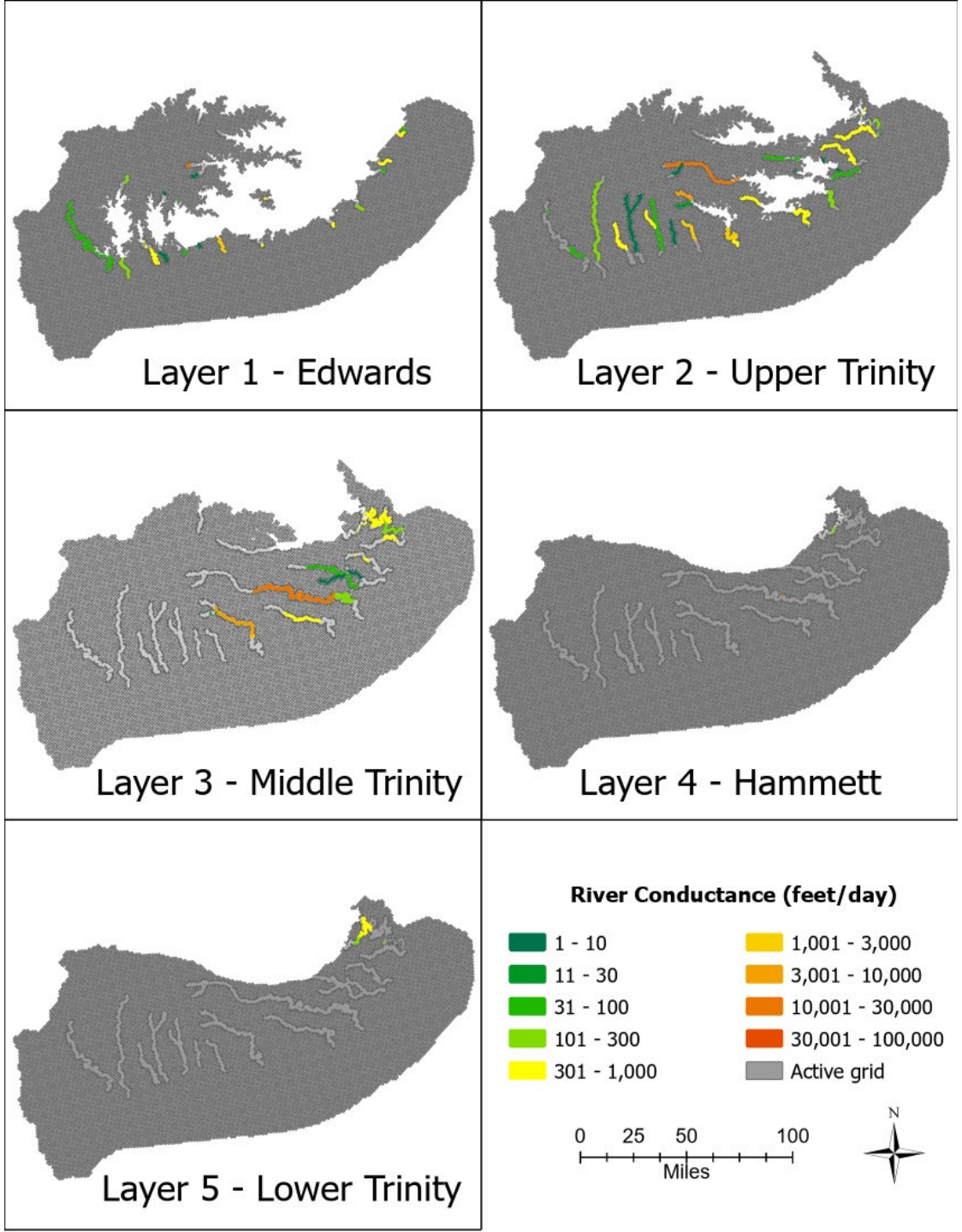
Model Packages: RIV

Variables:

- Stream stage (elevation):
  - ➢ land surface elevation
- Stream bottom (elevation):
  - ➢ 0.5 feet below land surface
- Conductance:
  - ➢ Calibrated value (multiplier by river)

```
151167 1.74123669E+03 2.82972000E+00 1.74073669E+03 frio_river
151172 1.74012122E+03 2.82972000E+00 1.73962122E+03 frio_river
151173 1.74002122E+03 2.82972000E+00 1.73952122E+03 frio_river
151176 1.73992122E+03 2.82972000E+00 1.73942122E+03 frio_river
151201 1.69295203E+03 4.92576000E+00 1.69245203E+03 east_frio_river
151219 1.69285203E+03 4.92576000E+00 1.69235203E+03 east_frio_river
151221 1.69275203E+03 4.92576000E+00 1.69225203E+03 east_frio_river
151222 1.69038379E+03 4.92576000E+00 1.68988379E+03 east_frio_river
151225 1.68231287E+03 4.92576000E+00 1.68181287E+03 east_frio_river
151228 1.68221287E+03 4.92576000E+00 1.68171287E+03 east_frio_river
151230 1.68034436E+03 4.92576000E+00 1.67984436E+03 east_frio_river
151237 1.68024436E+03 4.92576000E+00 1.67974436E+03 east_frio_river
151238 1.67771973E+03 4.92576000E+00 1.67721973E+03 east_frio_river
151240 1.67761973E+03 4.92576000E+00 1.67711973E+03 east_frio_river
151243 1.67751973E+03 4.92576000E+00 1.67701973E+03 east_frio_river
151245 1.67741973E+03 4.92576000E+00 1.67691973E+03 east_frio_river
151255 1.67721973E+03 4.92576000E+00 1.67671973E+03 east_frio_river
151256 1.67731973E+03 4.92576000E+00 1.67681973E+03 east_frio_river
151257 1.67711973E+03 4.92576000E+00 1.67661973E+03 east_frio_river
151262 1.67681973E+03 4.92576000E+00 1.67631973E+03 east_frio_river
151263 1.67701973E+03 4.92576000E+00 1.67651973E+03 east_frio_river
151265 1.67691973E+03 4.92576000E+00 1.67641973E+03 east_frio_river
151272 1.67666992E+03 4.92576000E+00 1.67616992E+03 east_frio_river
151274 1.67434045E+03 4.92576000E+00 1.67384045E+03 east_frio_river
151277 1.67128931E+03 4.92576000E+00 1.67078931E+03 east_frio_river
151279 1.66325122E+03 4.92576000E+00 1.66275122E+03 east_frio_river
151305 1.61731958E+03 4.09260000E+02 1.61681958E+03 west_sabinal_river
151306 1.61695874E+03 4.09260000E+02 1.61645874E+03 west_sabinal_river
151308 1.61531824E+03 4.09260000E+02 1.61481824E+03 west_sabinal_river
```

River Conductance

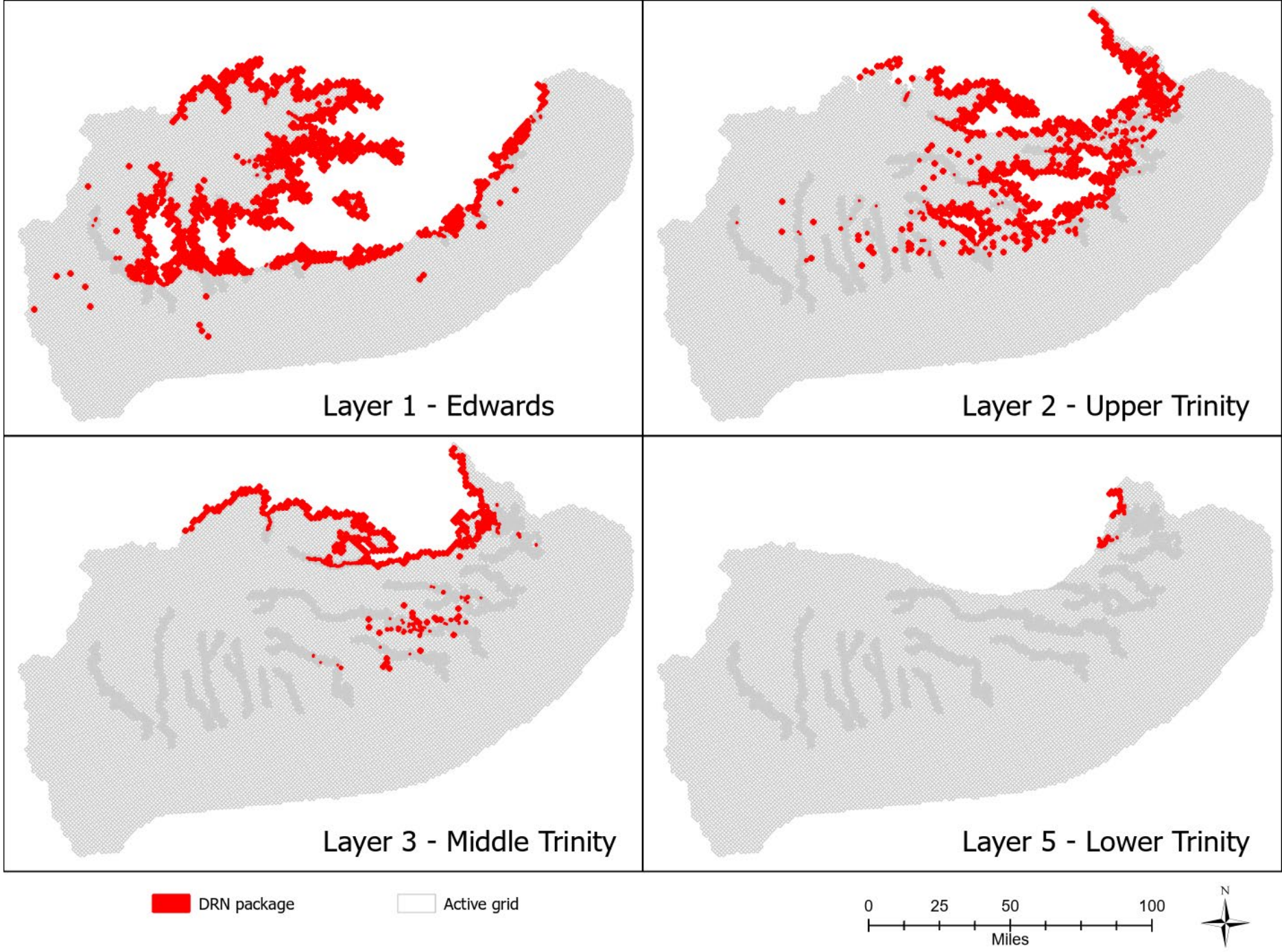


Model Packages: Drains (DRN)

Model Packages: DRN

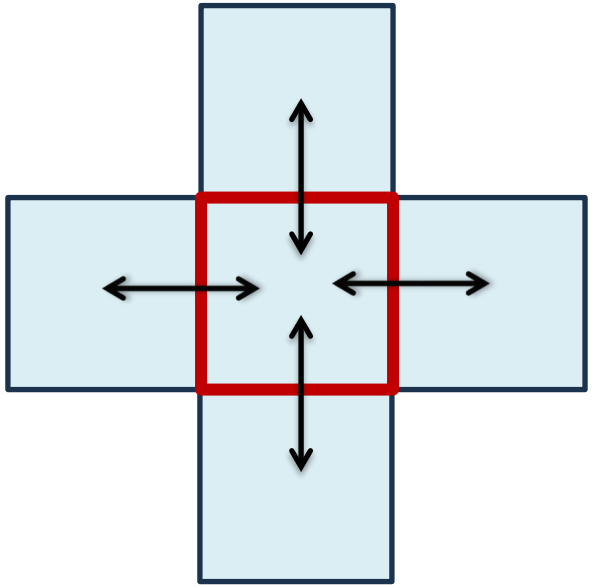
Represents:

- Springs
- Rivers
  - *Llano*
  - *Upper Pedernales*
  - *Little Devils*
- Erosional edges

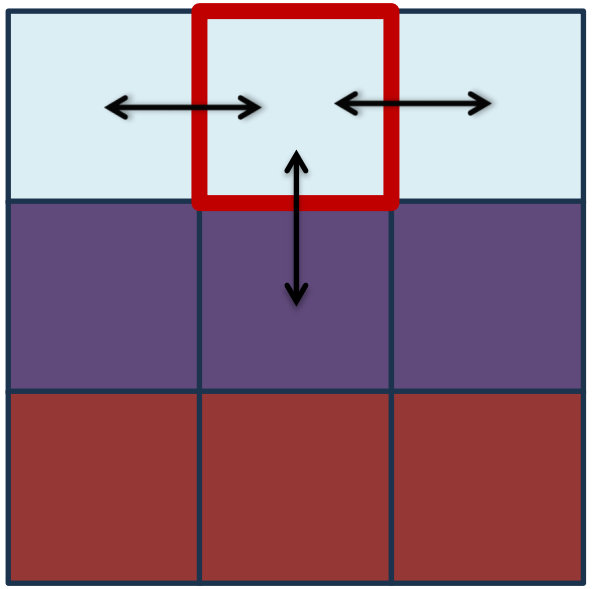


TEXAS WATER DEVELOPMENT BOARD

Uncorrected Grid *(only horizontal & vertical connections)*

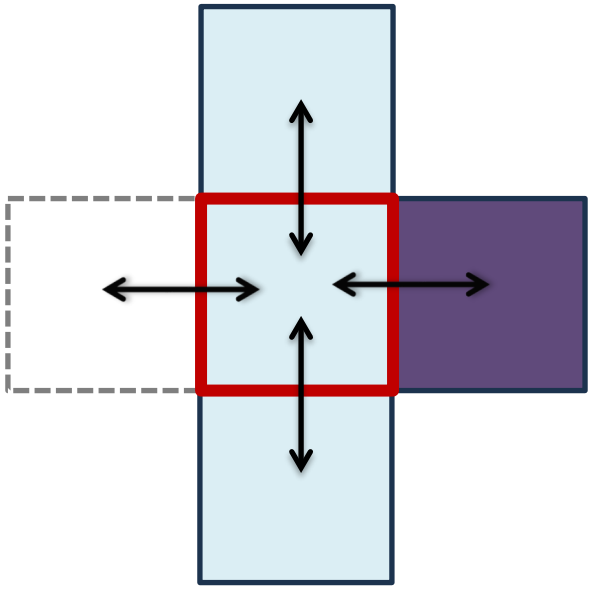


Plan view

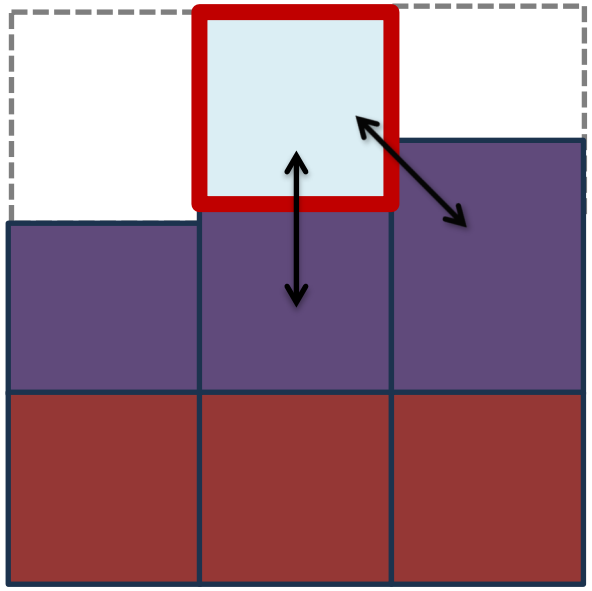


Cross-section

Corrected Grid *(diagonal connections & inactive cells)*

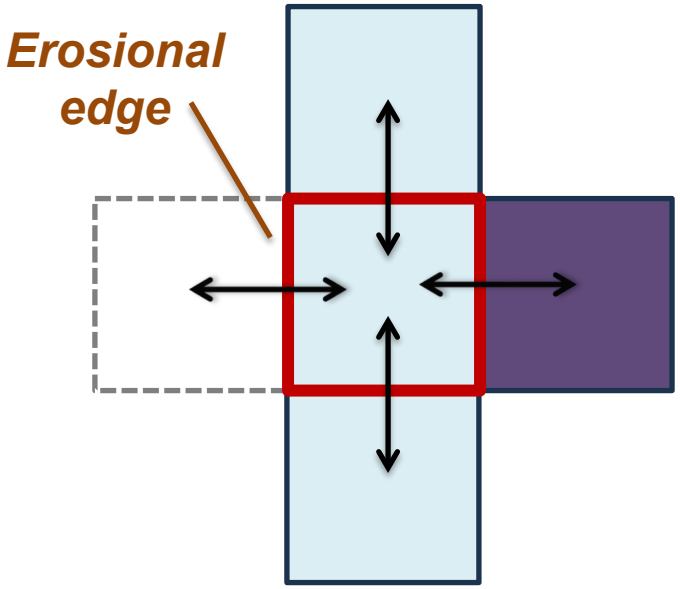


Plan view

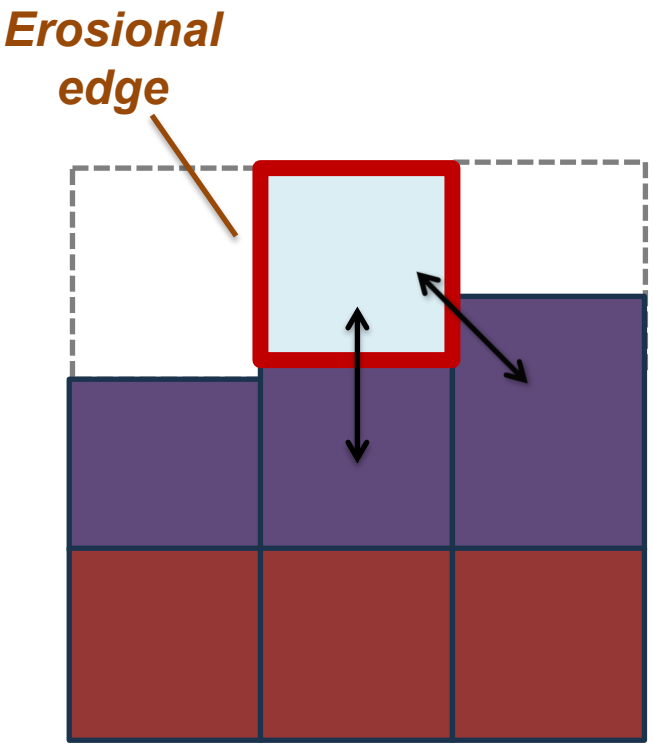


Cross-section

Erosional Edge:
1) A cell loses a horizontal connection
2) The lost horizontal connection does not get replaced with a diagonal connection

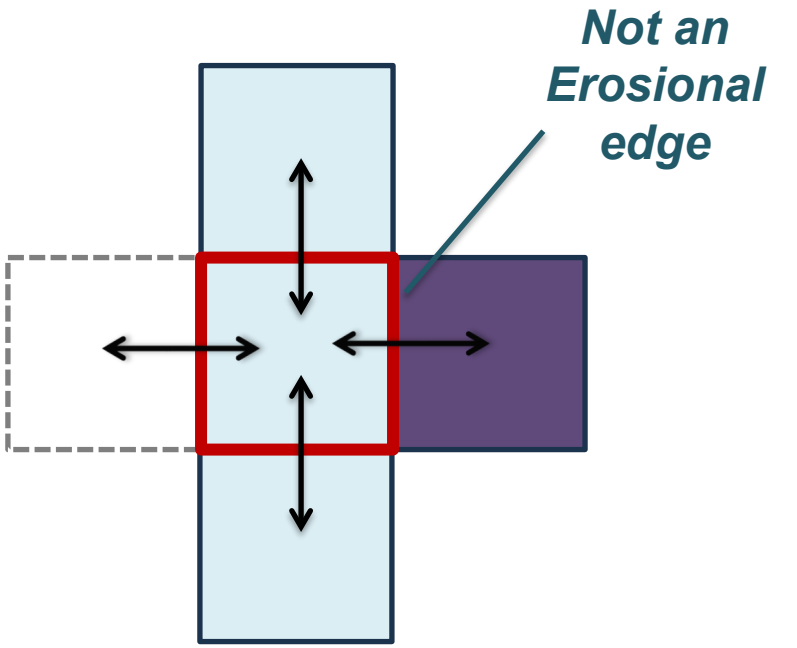


Plan view

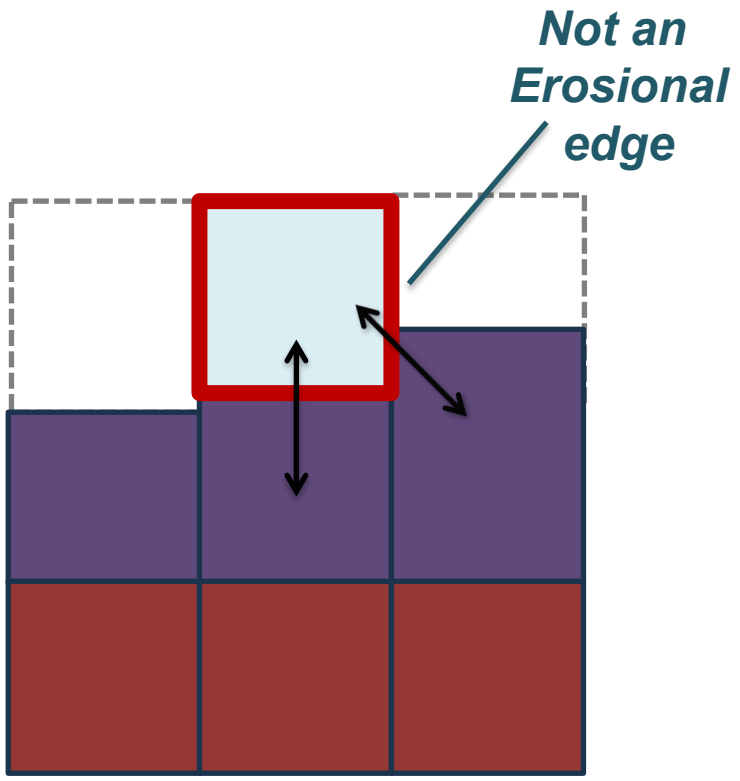


Cross-section

Non-Erosional Edge:
1) A cell loses a horizontal connection
2) The lost horizontal connection is replaced with a diagonal connection (in same vertical “family”*)



Plan view



Cross-section

Model Packages: DRN

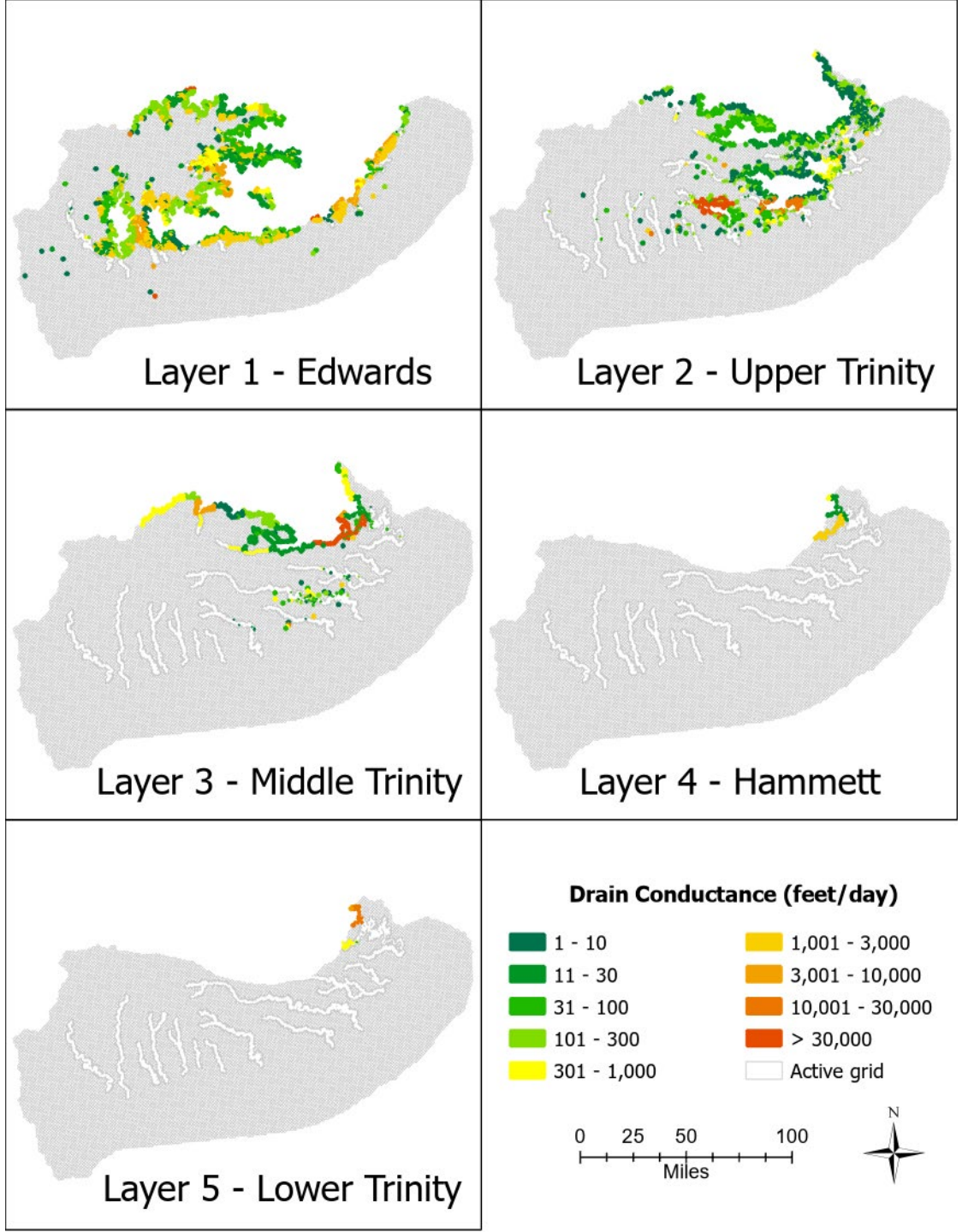
Variables:

- Head (elevation):
  - ➢ land surface elevation at spring/drain location

- Conductance
  - ➢ calibrated value (multiplier by individual spring or edge zone)

```
774 8.25818542E+02 1.50000000E-01 yd-58-43-107_+_yd-58-42-308_+_spicewood_springs
1550 5.31921509E+02 5.19510000E+01 yd-58-42-617
1816 4.12998840E+02 3.05919000E+01 power_house_spring
2150 4.38220917E+02 1.26637000E+01 barton_springs
3455 5.69544556E+02 3.12439500E+00 backdoor_spring
6436 9.06887939E+02 1.50000000E-01 unnamed_64
7658 1.03270789E+03 3.52026000E+01 e-13_hays
11860 1.06479443E+03 1.77586500E+00 d-54_hays
12807 8.56658386E+02 1.24305600E+00 g-23_hays
13118 2.59848663E+02 2.78672000E+02 san_marcos_springs
17504 1.25127698E+03 2.10856500E-01 devil's_backbone_spring_+_rancho_cima_dam_spring
17946 1.20705139E+03 5.15565000E+02 bailey_ranch_spring
```

Model Packages: DRN

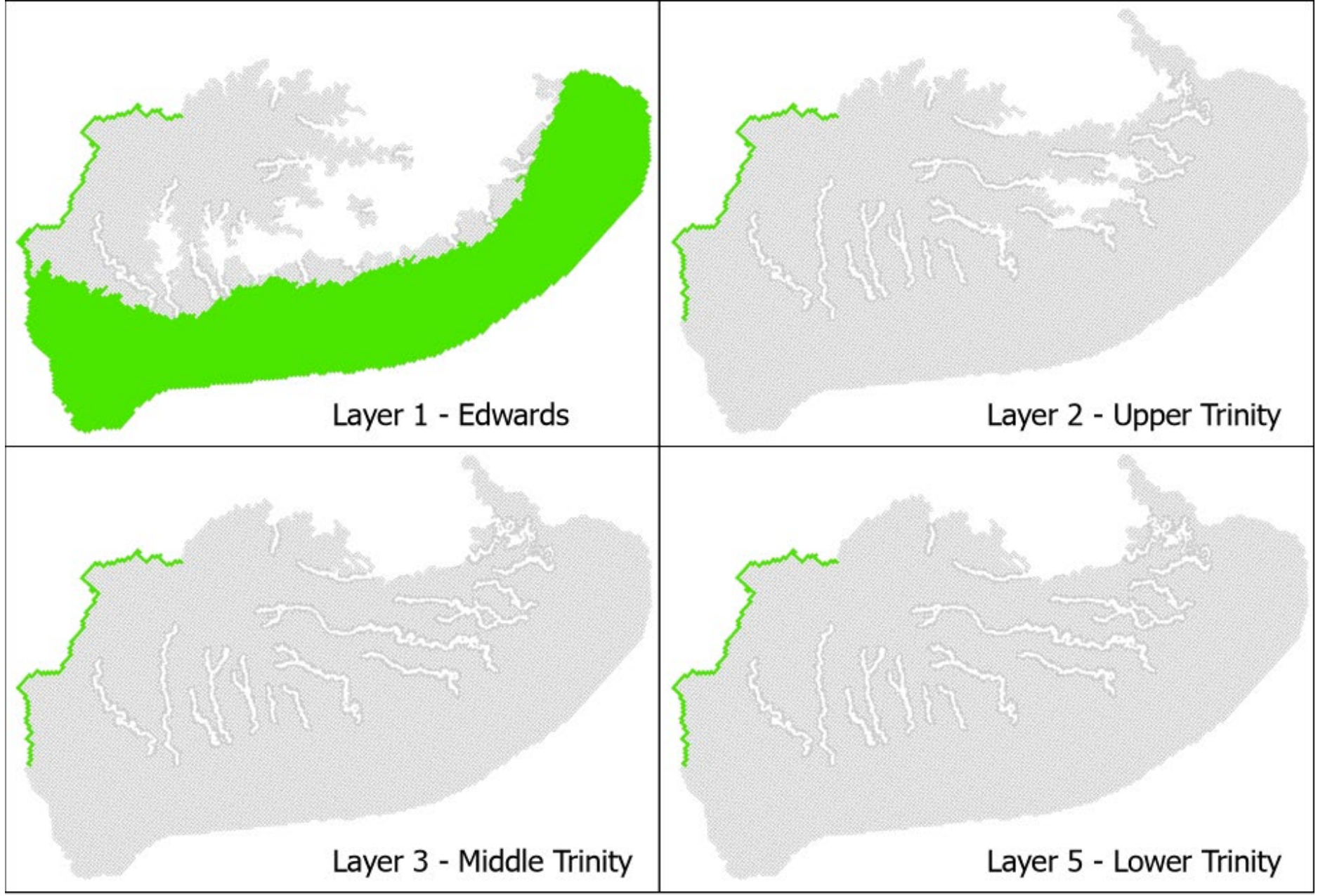


Model Packages: Boundary Flow (GHB)

Model Packages: GHB

Represents:

- Western Boundary
- Edwards Downdip



Model Packages: GHB

Variables:

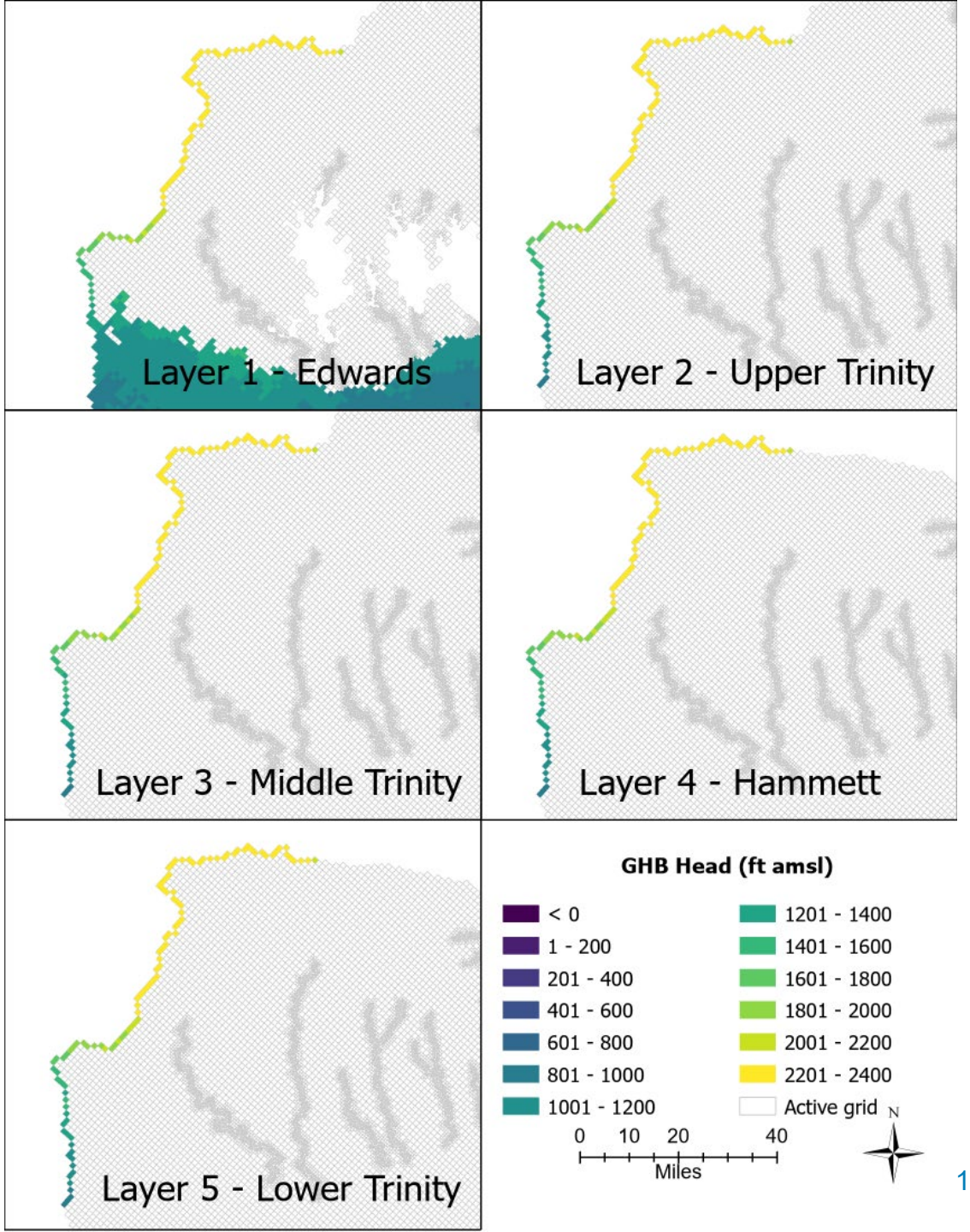
- Boundary Head
  - Western Boundary
    - Edwards (Layer 1)
      - Assumed to be unconfined
      - calibrated value above Edwards bottom *(as additive value by grid cell)*
    - Trinity (Layers 2-5)
      - Assumed to be confined
      - calibrated value above Edwards bottom *(as additive value by grid cell)*
  - Southeastern Edwards downdip
    - Edwards (Layer 1) only
    - calibrated value below land surface *(as additive value by grid cell)*

- Conductance
  - Calibrated value *(as multiplier by zone – Western or Edwards)*

Model Packages: GHB

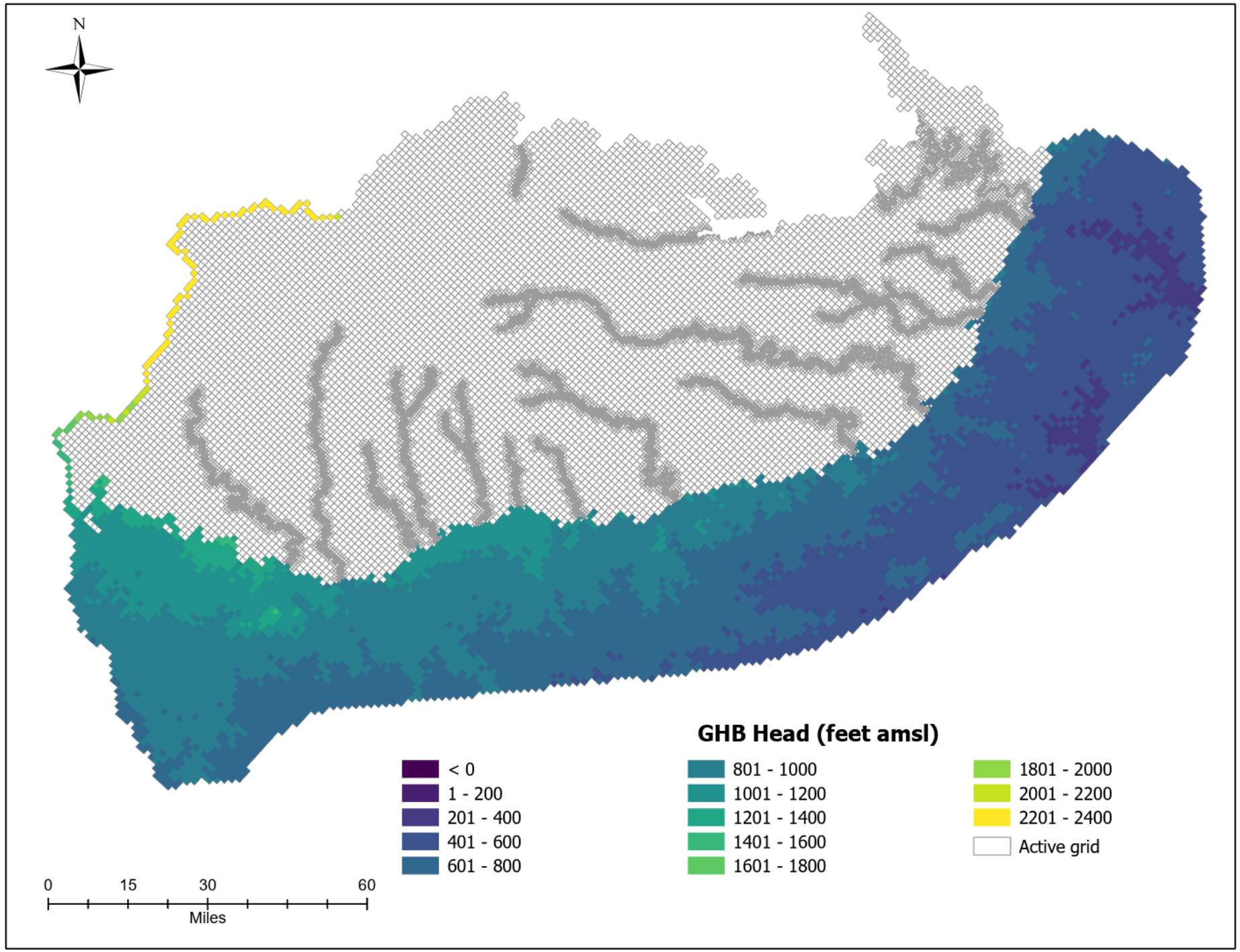
Western Boundary:

- Edwards – Layer 1
- Trinity – Layers 2 through 5 *(lumped)*



Model Packages: GHB

Edwards Downdip:
Edwards – Layer 1

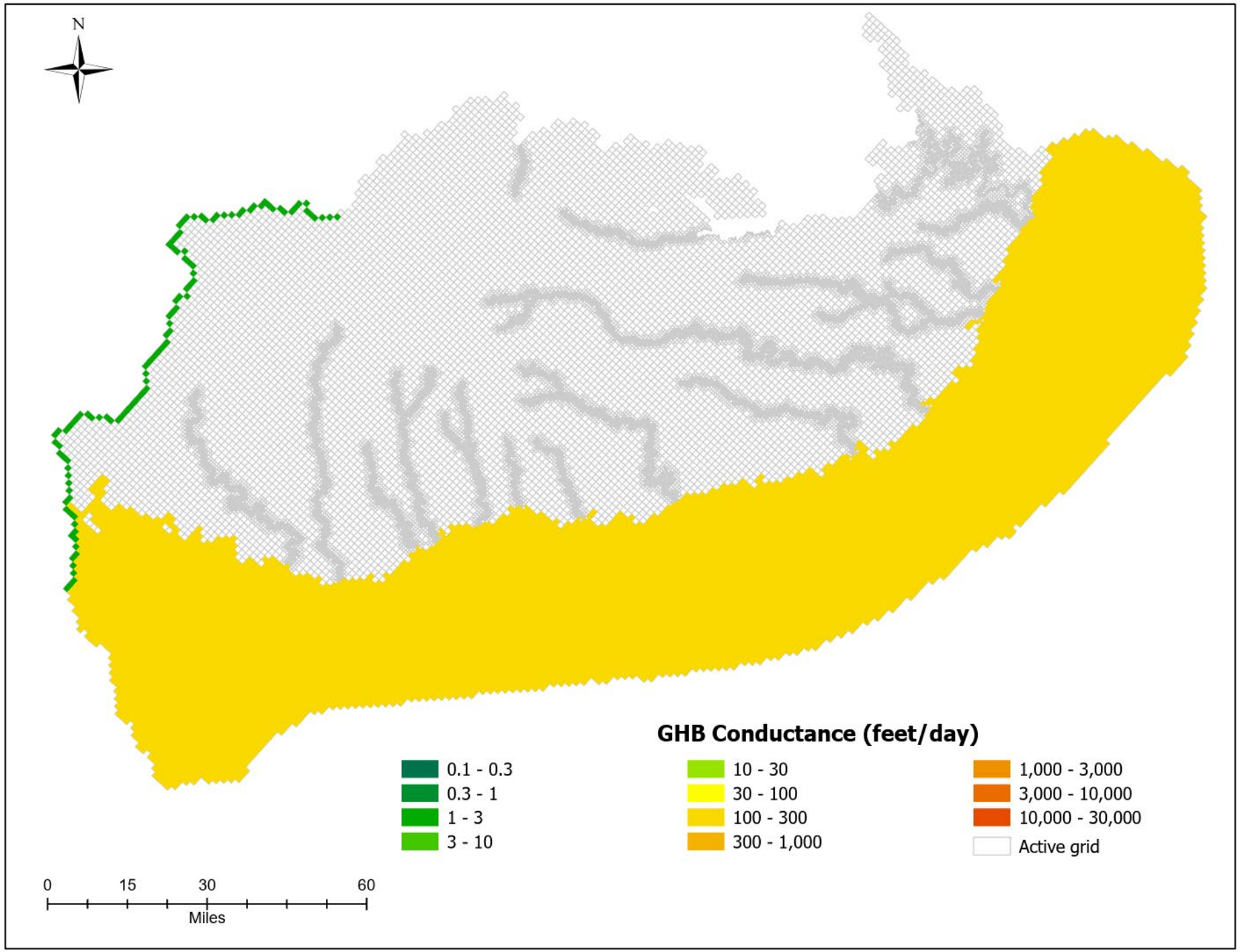


TEXAS WATER DEVELOPMENT BOARD

Model Packages: GHB

Conductance Zones:

1) Western Boundary
2) Edwards Downdip:



Discussion

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