

14 September 2021

TECHNICAL MEMORANDUM

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Subject: **Groundwater Dependent Ecosystems and Surface Water – Groundwater Interaction Program Update**
Zone 7 Water Agency Alternative Groundwater Sustainability Plan
(EKI C00065.00)

EKI Environment & Water, Inc. (EKI) is pleased to present to Zone 7 Water Agency (Zone 7) a memorandum documenting the update the groundwater dependent ecosystems (GDEs) and surface water – groundwater interaction program within the Livermore Valley Groundwater Basin (Basin) as part of Zone 7's 2022 Alternative Groundwater Sustainability Plan (Alt GSP or Plan) Update.

Pursuant to our approved scope of work, EKI's work efforts included: (1) identification of GDEs and other areas of potential interconnected surface water (ICSW), (2) evaluation of the need for and identification of new monitoring locations, (3) assessment of groundwater demands from GDEs, (4) development of sustainability criteria (i.e., Measurable Objectives [MOs] and Minimum Thresholds [MTs]) for Depletion of Interconnected Surface Water.

A final version of this memorandum is anticipated to be included as an attachment to the 2022 Alt GSP and/or to inform selected chapters of the Plan.

1. UPDATE TO GROUNDWATER DEPENDENT ECOSYSTEMS AND INTERCONNECTED SURFACE WATER PROGRAM

The following section describes the process used to update the GDE and ICSW program.

1.1. Identification of Groundwater Dependent Ecosystems

EKI (supported by Stillwater Sciences [Stillwater]) performed a preliminary identification of likely GDEs within the Basin based on the available data and tools, field and aerial photo surveys, and analysis

conducted in general accordance with the process laid out in The Nature Conservancy (TNC) guidance¹. A summary of the work effort is presented below and in **Attachments A and B**.

1.1.1. Preliminary Screening

Based on the available data, EKI conducted a preliminary screening to identify potential GDE areas in the Basin as described below.

Data Sources

Primary data sources that were incorporated into the screening analyses or otherwise supported the GDE field investigation and identification include the following:

- GDE information from the California Department of Water Resources' (DWR) Natural Communities Commonly Associated with Groundwater (NCCAG) dataset and TNC guidance documents^{2,3,4};
- GDE health indices from the TNC GDE Pulse tool⁵, including the Normalized Derived Moisture Index (NDMI) and the Normalized Derived Vegetation Index (NDVI), which indicate the vegetation moisture and vegetation greenness, respectively;
- Additional resources regarding the presence of GDEs in the Basin provided by Zone 7, including GDE geospatial data and Sycamore alluvial woodland data;
- United States Geological Survey (USGS) ground surface elevation data;
- Well information, including locations and well construction details as provided by Zone 7; and
- Groundwater elevation and depth to water data provided by Zone 7.

Depth to Groundwater Analysis

The NCCAG dataset identifies land areas by vegetation or wetland categories that potentially indicate the presence of GDEs, as shown on **Figure 1**. The NCCAG dataset also assigns the potential GDEs a polygon number. An additional GDE area (i.e., the Springtown Alkali Sink⁶) was not identified in the NCCAG dataset, but was included in this analysis and on **Figure 1** for completeness.

¹ Rohde et al., 2018. *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans*. The Nature Conservancy. Dated January 2018.

² Ibid.

³ Klausmeyer et al., *GDE Pulse: Taking the Pulse of Groundwater Dependent Ecosystems with Satellite Data*. The Nature Conservancy. Dated January 2019.

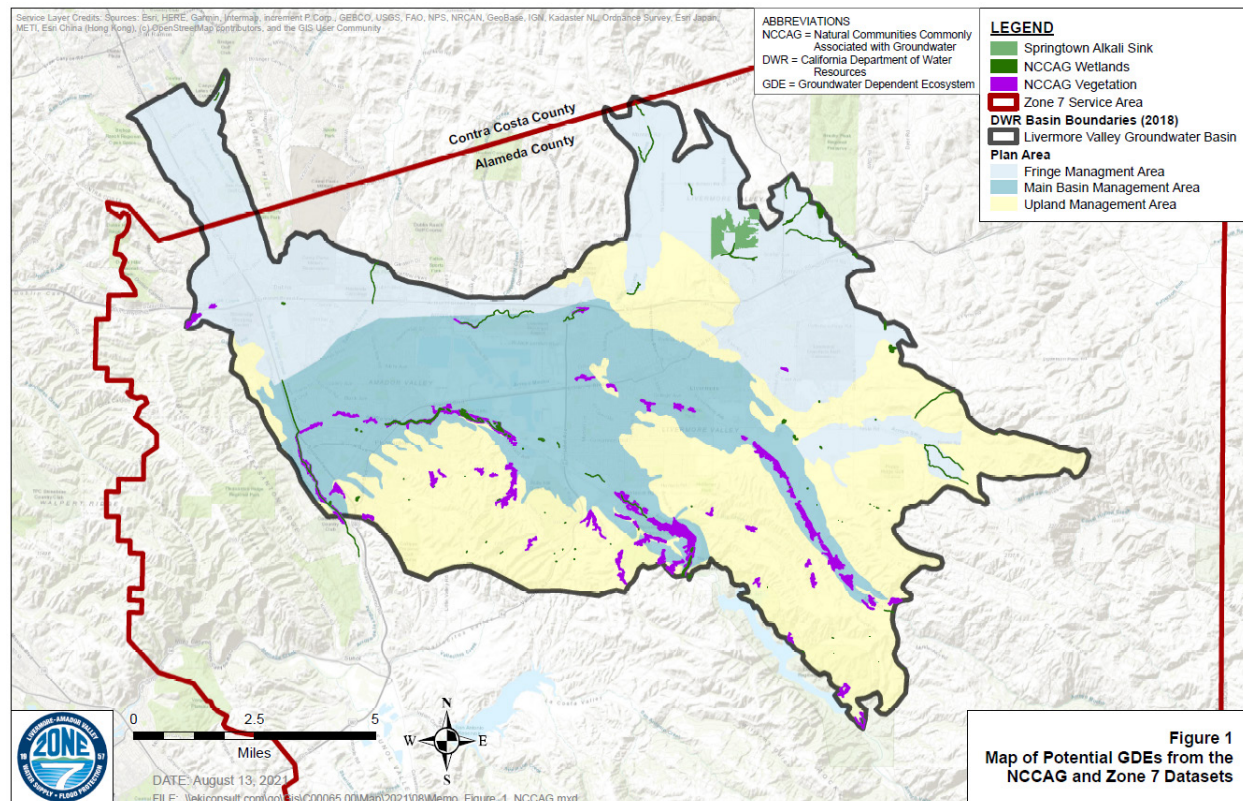
⁴ TNC, 2019. *Identifying GDEs Under SGMA: Best Practices for using the NC Dataset*. The Nature Conservancy. Dated July 2019.

⁵ <https://gde.codefornature.org/#/methodology>; The GDE Pulse interactive map developed by The Nature Conservancy provides users easy access to satellite data to view long term temporal trends of vegetation metrics. These vegetation metrics serve as an indicator of vegetation health for GDEs. In addition, the GDE Pulse web app provides long-term temporal trends of groundwater depth and regional precipitation data. This provides users with a platform to infer relationships between groundwater levels, precipitation, and GDE vegetation metrics to monitor and sustainably manage groundwater and GDEs.

⁶ The 2016 Alt GSP identified the Springtown Alkali Sink as a GDE in Section 2.1.4.

Based on review of the NCCAG dataset, the maximum rooting depth of various plant species associated with potential GDEs within the Basin is approximately 30 feet below ground surface (ft bgs).⁷ As such, if the minimum depth to groundwater between 2015 and 2020 in the vicinity of the mapped potential GDEs was greater than 30 ft bgs,⁸ it is unlikely that the mapped vegetation or wetland areas in the NCCAG dataset were accessing the principal aquifer⁹ as their source of supply. Rather, these mapped vegetative communities are likely supplied by a surface water, perched groundwater, or other source (e.g., runoff or a man-made water feature) and are therefore not GDEs in the context of SGMA.

Figure 1. Map of Potential GDEs from the NCCAG and Zone 7 Datasets



To further clarify whether the mapped vegetative communities from the NCCAG and Zone 7 datasets are likely GDEs that are dependent on the principal aquifer, the depth to groundwater for each potential GDE polygon (and the area of the Springtown Alkali Sink) was estimated by comparing the potential max GDE rooting depth (30 ft bgs) to the measured depth to groundwater from nearby Upper Aquifer wells within the Basin. Upper Aquifer wells within a one-kilometer (km) radius of the mapped potential GDEs were

⁷ <https://groundwaterresourcehub.org/sgma-tools/gde-rooting-depths-database-for-gdes/>

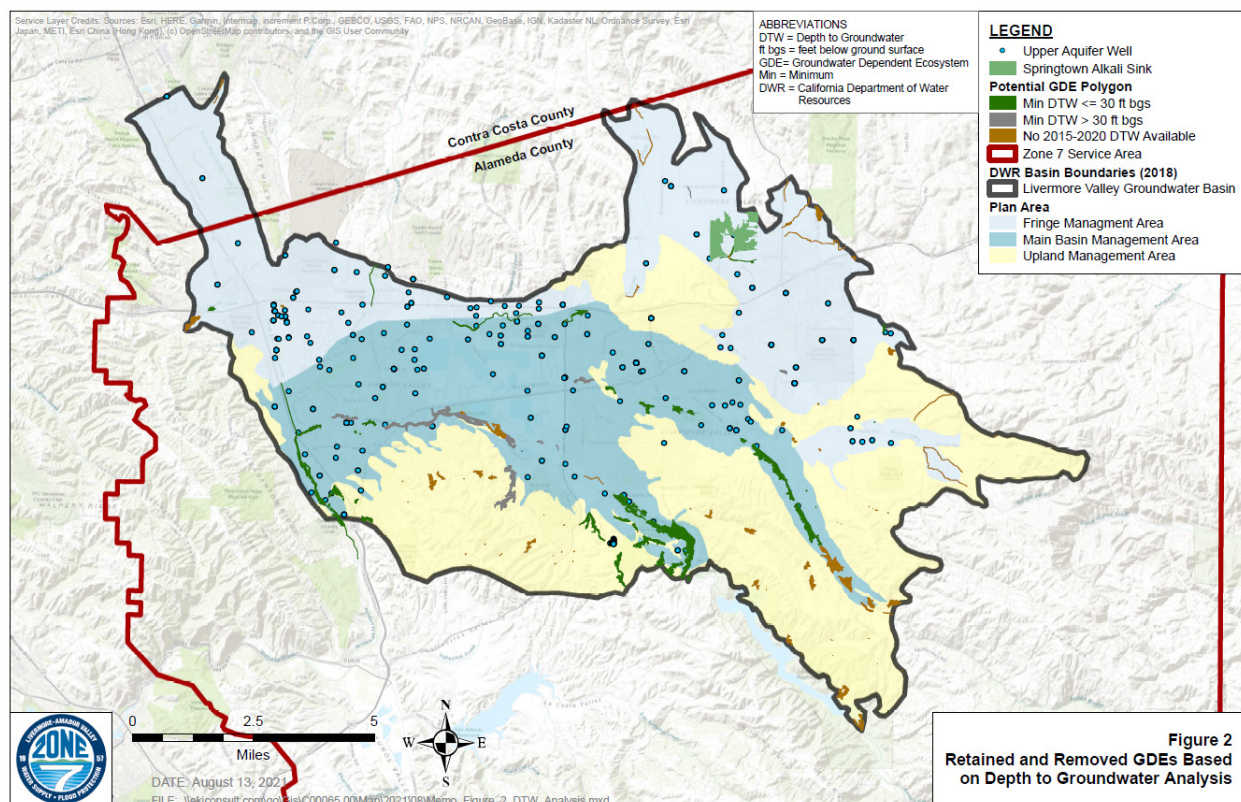
⁸ Since the Plan is not required to address undesirable results that occurred before, and have not been corrected by January 1, 2015 (Water Code Section 10727.2 (b)(4)), 2015 is selected as the start of the analysis timeframe.

⁹ Per § 351.(aa), "Principal aquifers" refer to aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. The Main Basin includes a single principal aquifer that includes two hydraulically connect zones with varying degrees of connectivity: the Upper Aquifer and Lower Aquifer.

assumed to be representative of groundwater conditions within those areas¹⁰. The locations of Upper Aquifer wells within the Basin that were used to evaluate shallow groundwater conditions are shown on **Figure 2**. If multiple wells were within one km of a GDE polygon, the minimum depth to groundwater between 2015 and 2020 from these wells was calculated.

If the minimum depth to water between 2015 and 2020 was greater than 30 ft bgs, then that respective GDE polygon was determined to likely not be a GDE that was dependent on the principal aquifer and was “removed” from further consideration. If the minimum depth to groundwater between 2015 and 2020 was less than 30 ft bgs or if no proximate groundwater data were available, the potential GDE polygon was preliminarily “retained” for further review. The retained and removed GDE polygons are shown on **Figure 2**.

Figure 2. Retained and Removed GDEs Based on Depth to Groundwater Analysis



Application of the TNC GDE Pulse Tool Methodology

The TNC GDE Pulse tool provides time series data for two remote sensing indices that are used to monitor a vegetation’s health: (1) the Normalized Derived Moisture Index (NDMI), and (2) the Normalized Derived Vegetation Index (NDVI), which indicate the vegetation moisture and vegetation greenness, respectively. Higher NDMI and NDVI values are associated with “healthier” vegetation. In the TNC GDE Pulse tool the

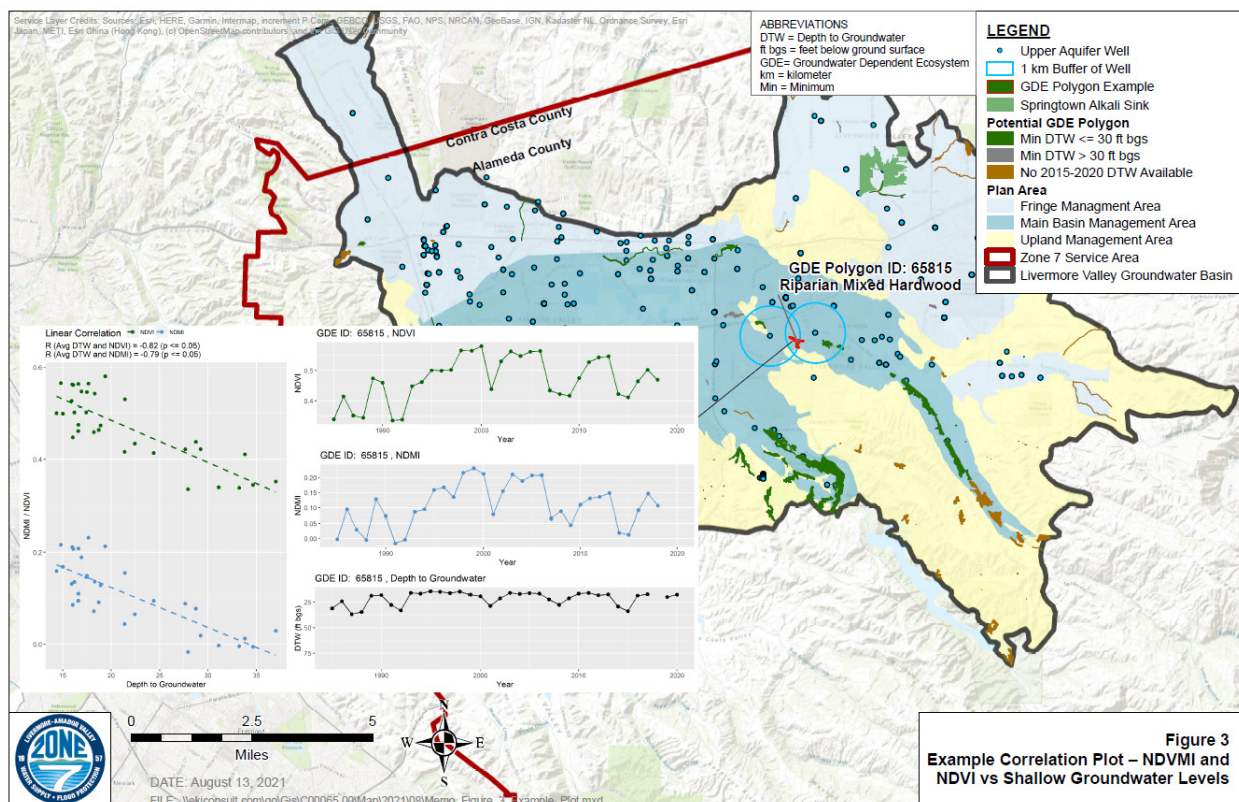
¹⁰ Klausmeyer et al., *GDE Pulse: Taking the Pulse of Groundwater Dependent Ecosystems with Satellite Data*. The Nature Conservancy. Dated January 2019.

NDMI and NDVI data are indexed to the same GDE polygon numbers included in the NCCAG dataset¹¹.

The premise of the TNC GDE Pulse tool is that, since the NDMI and NDVI indices can quantify changes in the rates and patterns of vegetation growth and moisture levels in plants over time, the relationship between these two indices and the depth to shallow groundwater can be evaluated to examine whether these measures of GDE “health” have a relationship to shallow groundwater conditions. Since limited depth to groundwater data are provided in the TNC GDE Pulse tool, depth to groundwater data provided by Zone 7 were used to supplement this analysis.

Time series data of these two indices and the nearby (i.e., within one km) depth to groundwater data were plotted for each retained GDE polygon, as shown on **Figure 3** and **Attachment A**. A linear correlation between the two indices and the local depth to groundwater data was then evaluated for each polygon. A negative correlation would mean that, when the depths to groundwater increase, the NDMI and NDVI indices decrease, indicating that the GDEs are less healthy when conditions are such that local groundwater elevations decrease, and vice versa.

Figure 3. Example Correlation Plot – NDMI and NDVI vs Shallow Groundwater Levels

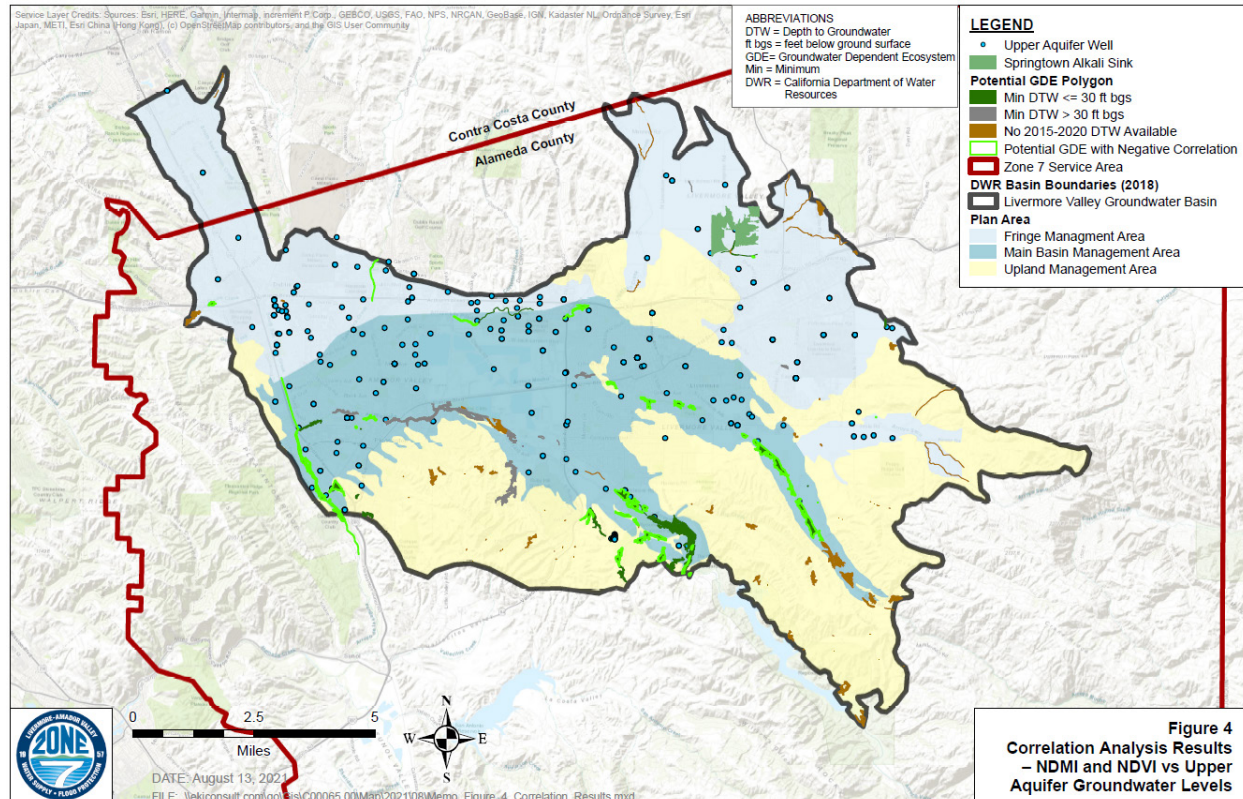


Among the preliminarily retained GDEs (i.e., those GDE polygons where the minimum depth to groundwater in the Upper Aquifer between 2015 and 2020 was less than 30 ft bgs), 84% exhibited a negative correlation between NDMI and depth to groundwater, and 71% exhibited a negative correlation

¹¹ There are no TNC GDE Pulse data for Springtown Alkali Sink, so the analysis of groundwater level trends and the NDMI and NDVI indices could not be conducted for this GDE.

between NDVI and depth to groundwater. For the purpose of this analysis, correlation with a p-value that is less or equal to 0.05 is considered to be significant. Among the potential GDEs that have negative correlations, 46% of them have a significant correlation between NDMI and depth to groundwater, and 38% of them have a significant correlation between NDVI and depth to groundwater. The potential GDE areas that exhibited negative correlations for both NDMI and NDVI are shown on **Figure 4**. These data indicate that one factor impacting vegetative health in the retained GDE area could be the depth to groundwater.

Figure 4. Correlation Analysis Results – NDMI and NDVI vs Upper Aquifer Groundwater Levels



It should be noted, however, that correlation is not the same as causation and a negative correlation does not necessarily confirm the presence of a GDE that would be impacted by changes in Upper Aquifer groundwater levels. Rather, what this analysis confirms is that GDEs are objectively less healthy when conditions are such that local groundwater elevations decrease, and vice versa. However, significant uncertainties remain. For example, the Overburden layer extent in the Fringe Management Area is uncertain, and therefore while vegetation along the Tassajara Creek and near Dublin (northeastern portion of the Basin) are retained as potential GDEs, they may be disconnected from the underlying Upper Aquifer and any apparent correlation would be meaningless.

1.1.2. Field Investigation & Verification

As described in **Attachment B**, Stillwater Sciences integrated the aforementioned screening analysis and other available local data to conduct a refined mapping of the potential GDEs within the Basin, including: the Classification and Assessment with Landsat of Visible Ecology Groupings (CalVeg) dataset; Urban Creeks Council (UCC) 2014 CalVeg update for third-order and higher channels; Aerial Information Systems

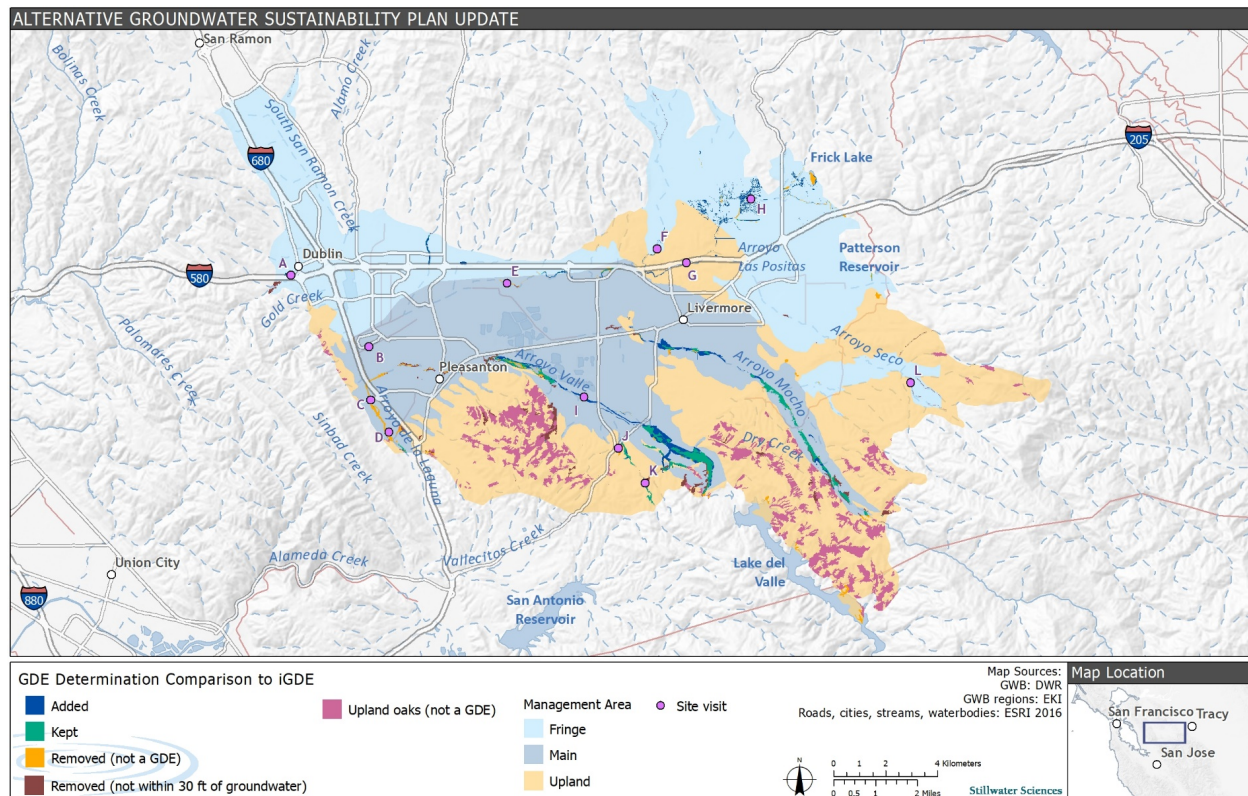
(AIS) Springtown Alkali Sink Preserve Wetlands Mapping; and Sycamore Alluvial Woodland Tree Survey in Arroyo Mocho and Arroyo Valley. Man-made open water areas (e.g., the Chain of Lakes and golf course ponds) were removed from the refined vegetation map. As part of the ecological inventory, special-status species and sensitive natural communities that are potentially associated with GDEs in the Basin were also identified using regional and local databases.¹²

On 31 March 2021, Stillwater conducted field studies and surveyed aerial photography to verify the presence of GDEs at 12 unique sites throughout the Basin (Sites A through L as shown on **Figure 5**). These sites included areas where there were: (1) apparent “gaps” in the potential GDE map shown on **Figure 1** (i.e., where vegetation similar to GDEs occurred immediately upstream and downstream of the mapped site but was not identified as a GDE); (2) where the riparian vegetation was mapped along stream channels (i.e., where the mapped GDEs are potentially supported by surface water, not groundwater); and (3) where the mapped GDEs are underlain by thick clay layers (i.e., where perched groundwater, not the principal aquifer, could be the source). Additionally, Stillwater scientists assessed potential GDEs at sites where groundwater data are sparse (e.g., near Sycamore Park and Springtown). Likely groundwater dependence of these sites was determined by assessing various local water sources and the width of the riparian zone. Where riparian zones were narrow and relatively sparse, other water sources likely support the vegetation. Where existing vegetation and wetland areas extend beyond a narrow strip along the channel, groundwater dependence was considered likely.¹³

¹² Databases used by Stillwater to identify special-status species include: (1) California Natural Diversity Database, (2) California Native Plant Society (CNPS) Manual of California Vegetation, (3) eBird, and (4) TNC freshwater species lists generated from the California Freshwater Species Database (CAFSD).

¹³ Stillwater 2021, Technical Memorandum: Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin, dated 17 May 2021.

Figure 5. Comparison of the Likely GDE Map (Figure 6) with the NCCAG Dataset (Figure 1)



Based on the totality of the above analysis, a final determination was made on the presence of likely GDEs within the Basin. The primary differences in GDE mapping relative to the initial NCCAG map of potential GDEs are summarized below and shown on **Figure 5**:

- Additional GDEs were identified in the northeast portion of the Basin where the AIS mapping occurred (Site H, **Figure 5**).
- Potential GDEs mapped in the NCCAG dataset that occur adjacent to man-made open water features along Chain of Lakes (in the Arroyo Valle corridor) and near the City of Dublin were removed.
- Some further changes in GDE mapping reflect differences between the UCC update to the CalVeg map along Arroyo Mocho and Arroyo Valle. In particular, the width of the riparian vegetation along both streams increased in places, as seen in **Figure 5**.
- The reclassification of vegetation near Lake Boris on Arroyo Valle (downstream of Site I, **Figure 5**) reduced the extent of GDEs downstream of the lake.
- The vegetation was removed along Arroyo de la Laguna and west of Pleasanton (Sites B, C, and D, **Figure 5**) after conducting field investigations. These sites occur above a thick clay layer (known colloquially as the Overburden layer) that precludes connection to the principal aquifer. Observations during the field visit suggested that the riparian vegetation at Sites B, C, and D was likely dependent on surface water rather than groundwater due to the relatively narrow riparian zone.

- The potential GDE community near Site L was also removed since the very sparse riparian vegetation suggested the area was not connected to groundwater.
- Wetlands mapped within man-made lakes and ponds (e.g., Frick Lake in the eastern part of the basin) were also removed.¹⁴

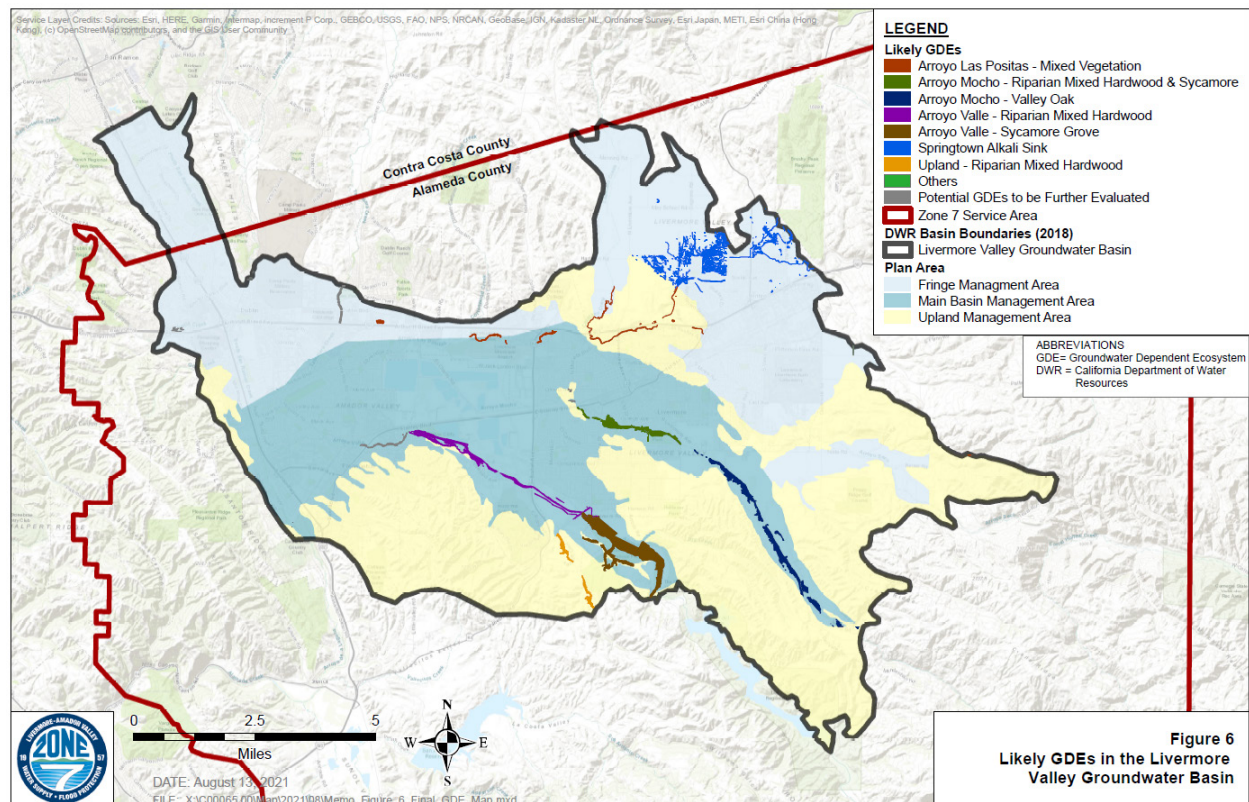
The final likely GDE map is presented on **Figure 6**. Likely GDEs are grouped and named based on their location and major vegetation types, as shown on **Figure 6** and in **Table 1**. However, significant uncertainties remain. For example, the Overburden layer extent in the Fringe Management Area is uncertain, and therefore while vegetation along the Tassajara Creek and near Dublin (northeastern portion of the Basin) are retained as potential GDEs, they may be disconnected from the Upper Aquifer. Other areas retained as potential GDEs include areas of non-native vegetation (such as Eucalyptus trees) or that are adjacent to shallow bedrock outcrops in the center of the Basin (e.g., the “Oak Knoll” area). These GDE areas have been preliminarily retained, but will be further evaluated through monitoring and periodic visual inspections as discussed in **Section 2** below.

Table 1. GDE Region and Major Vegetative Composition

Management Area	Likely GDE Name	Acreages
Main Basin Management Area	Arroyo Valle – Riparian Mixed Hardwood	137
	Arroyo Valle – Sycamore Grove	343
	Arroyo Mocho – Riparian Mixed Hardwood & Sycamore	94
	Arroyo Mocho – Valley Oak	178
Fringe Management Area	Springtown Alkali Sink	173
	Arroyo Las Positas – Mixed Vegetation	56
Upland Management Area	Upland – Riparian Mixed Hardwood	35
Basin-Wide	Potential GDEs to be Further Evaluated	37
Total Acreages		1,052

¹⁴ Ibid.

Figure 6. Likely GDEs in the Livermore Valley Groundwater Basin



In total, the Basin includes approximately 1,052 acres of likely GDEs, approximately 2% of the total Basin area. The Main Basin Management Area contains approximately 69% of the total likely GDE area, the Fringe Management Area contains approximately 20%, and the Upland Management Area contains the remaining 11% of the likely GDEs. The most prevalent vegetation communities across all likely GDE units are the riparian mixed hardwood alliance and California sycamore alliance, which respectively comprise 40% and 30% of the likely GDE areas in the Basin and are located almost entirely in the Main Basin Management Area. The Alkaline mixed grasses and forbs alliance comprises 10% of total likely GDE area and is located almost entirely in the Fringe Management Area.¹⁵

The Basin includes United States Fish and Wildlife Service (USFWS) designated critical habitat for four federally listed species: the Alameda whipsnake, California red-legged frog, California tiger salamander, and vernal pool fairy shrimp. As described in **Attachment B**, of the designated critical habitat, most of the habitat for the vernal pool fairy shrimp is co-located with mapped GDEs, but this species relies on vernal pools, which are dependent on rainfall, rather than groundwater and is therefore unlikely to be groundwater dependent. Most of the critical habitat for California red-legged frogs and Alameda whipsnake occurs outside of the defined GDEs, with approximately two acres of their critical habitat overlapping with a riparian GDE at the upstream end of Arroyo Mocho.¹⁶ Zone 7 adheres to the East

¹⁵ Ibid.

¹⁶ Ibid.

Alameda County Conservation Strategy (EACCS) that was developed to preserve endangered species by developing a shared vision for long term habitat protection.¹⁷

As described in **Attachment B**, 22 special-status plants occur within the Basin, including Alkali milk-vetch, Heartscale, Brittscale, Livermore tarplant, and Jepson's coyote-thistle. Of these, 12 plant types were likely dependent upon groundwater, four were possibly dependent on groundwater, one was unlikely to be groundwater dependent, and five were not groundwater dependent. All 12 special-status plants likely dependent on groundwater occurred in the Fringe Management Area, and three of the 12 occurred in the Upland Management Area. The likely groundwater dependent special-status plants in the Fringe Management Area mostly were observed in or around the Springtown Alkali Sink.¹⁸

Thirty-one special-status terrestrial and aquatic wildlife species were identified as having the potential to occur within the Basin, including the Crotch bumble bee, Southwestern pond turtle, and American peregrine falcon. Of these, 14 were potentially groundwater dependent species: two amphibian species, two reptile species, seven bird species, and three mammal species. Additional information on these groundwater dependent species, including regulatory status and habitat associations, is provided in **Attachment B**. Ten of the groundwater dependent special status species are likely to occur in the Main Basin Management Area, eight of the groundwater-dependent special status species are likely to occur in the Fringe Management Area, and 13 of the groundwater-dependent special status species are likely to occur in the Upland Management Area.¹⁹

1.2. Identification of Interconnected Surface Water Locations

EKI performed various statistical and geospatial analyses to identify locations in the Basin where surface water bodies (e.g., streams) are likely interconnected to shallow groundwater. A summary of this work effort is presented below and in **Attachments C and D**.

1.2.1. Preliminary Screening

Information regarding the locations of streams within the Basin was provided by Zone 7 and are shown on **Figure 7**. EKI conducted a preliminary screening of potential ICSW locations as further described below.

Data Sources

The primary data sources that were incorporated into the analyses include the following:

- Stream mapping provided by Zone 7;
- Stream daily flow data and gauge height between 2015 and 2020 provided by Zone 7;
- Stream recharge rates shapefile provided by Zone 7 based on synoptic surveys;
- Groundwater elevation and depth to water data provided by Zone 7;
- Stream cross sections provided by Zone 7; and

¹⁷ EACCS website, <http://eastalco-conservation.org/about.html>.

¹⁸ Stillwater 2021, Technical Memorandum: Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin, dated 17 May 2021.

¹⁹ Ibid.

- Guidance document from Environmental Defense Fund (EDF),²⁰ USGS,²¹ and UC Berkeley.²²

Physical and Operational Exemptions

Artificial stream sections (i.e., those that have been channelized and lined with concrete) were excluded from the depth to groundwater analysis discussed below that was used to identify potential ICSW. Similarly, stream sections that overlie the Overburden layer were excluded. The Overburden layer consists of a thick, continuous surficial lens of clay reaching up to 70 feet thickness that precludes connection to the Upper Aquifer, and mainly exists in the Main Basin Management Area and extends from the north central portion of the Basin to the western edge of the Basin.

Although in its comment letter the DWR identified the Chain of Lakes (COL) as a potential ICSW feature, as stated in the 2016 Alt GSP, “Ongoing mining and reclamation are changing to some degree the connection between upper and lower aquifers and surface water, as some areas are capped or filled (thus reducing connection), and as excavation of wet pits effectively creates surface water ponds. However, no GDEs exist in the mining area and the surface water pits are not identified for specific beneficial uses in the Basin Plan. Releases of water for recharge along the arroyos have resulted in dry season flows in the arroyos; however, these flows are relatively warm and not equivalent to cool pre-mining flows that could support some native species.” Therefore, COL is also excluded from ICSW consideration.

Depth to Groundwater Analysis

The relationship between groundwater and surface water largely depends upon the depth to groundwater relative to the streambed depth. For groundwater to be interconnected with a stream channel, the depth to groundwater in the vicinity of the stream must be less than the streambed depth. Conversely, for surface water to seep to groundwater, which indicates disconnectivity between surface water and groundwater, the depth to groundwater in the vicinity of the stream must be deeper than the streambed depth.

Based on review of the stream cross section profiles provided by Zone 7, the maximum streambed depth of the streams within the Basin is approximately 30 feet. As such, if the minimum depth to groundwater between 2015 and 2020 in the vicinity of the stream sections is more than 30 ft bgs, it is unlikely that the mapped stream sections are interconnected with groundwater. Conversely, if the depth to groundwater is less than 30 ft bgs along the stream sections, the groundwater and stream sections are likely to be interconnected. Upper Aquifer groundwater elevation rasters between 2015 and 2020 were provided by Zone 7, and the depth to groundwater rasters were generated by subtracting the groundwater elevation rasters from the ground surface elevation raster. Depth to groundwater estimates in the vicinity of the mapped streams were made at 500 foot intervals along the length of the mapped streams.

²⁰ EDF, 2018. *Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act*, dated August 2018.

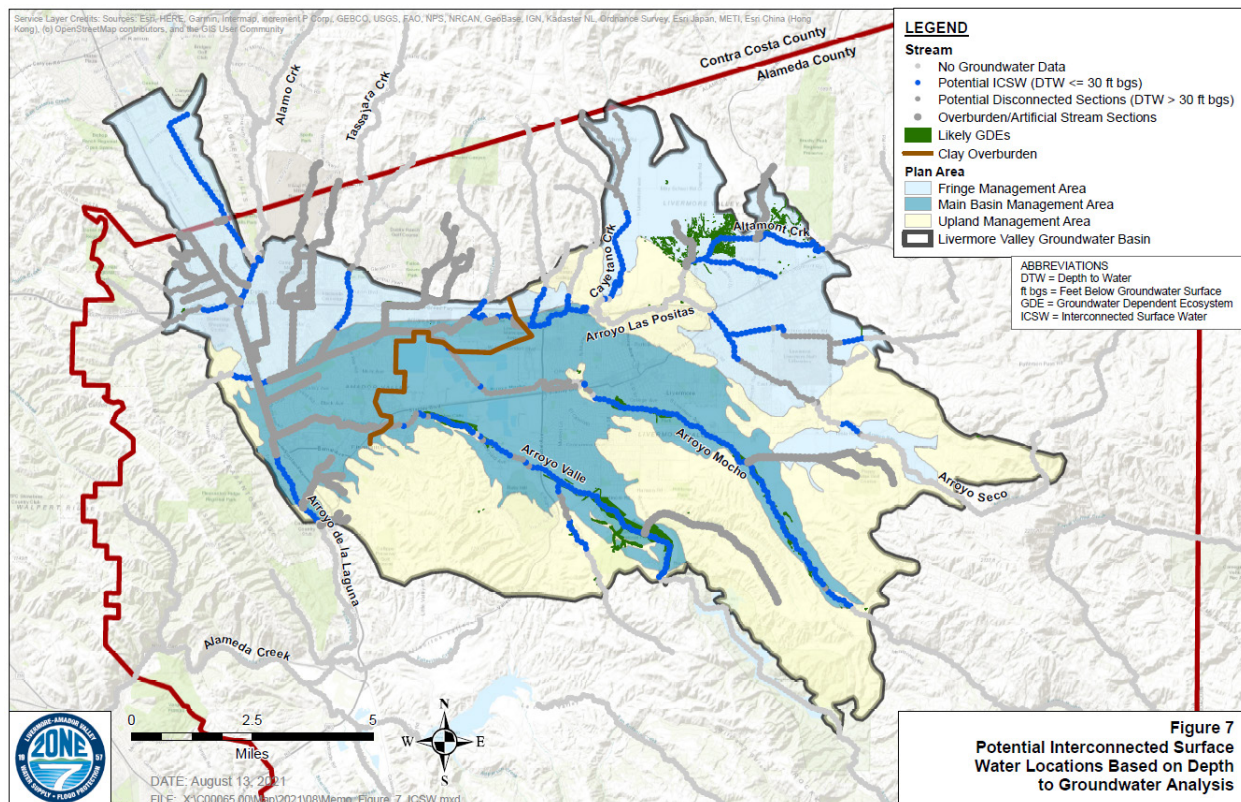
²¹ Winter et al., 1998. *Ground Water and Surface Water: A Single Resource*. USGS. Dated 1998.

²² Cantor et al., 2018. *Navigating Groundwater-Surface Water Interactions under the Sustainable Groundwater Management Act*. Center for Law, Energy & the Environment, UC Berkeley School of Law. Dated March 2018.

Additionally, Zone 7 has conducted synoptic surveys to identify the reaches of major streams in the Basin and whether they are gaining or losing, and what the respective rates are, as shown on Figure 2-4 of the 2016 Alt GSP (**Attachment C**).

Based on the above data and analysis, locations of potential ICSW locations are shown on **Figure 7**.

Figure 7. Potential Interconnected Surface Water Locations Based on Depth to Groundwater Analysis



Correlation Analysis

SGMA requires that the sustainability criteria of the ICSW Sustainability Indicator be developed based on the "...rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water..."²³ Alternatively, groundwater levels can be used as a proxy.²⁴

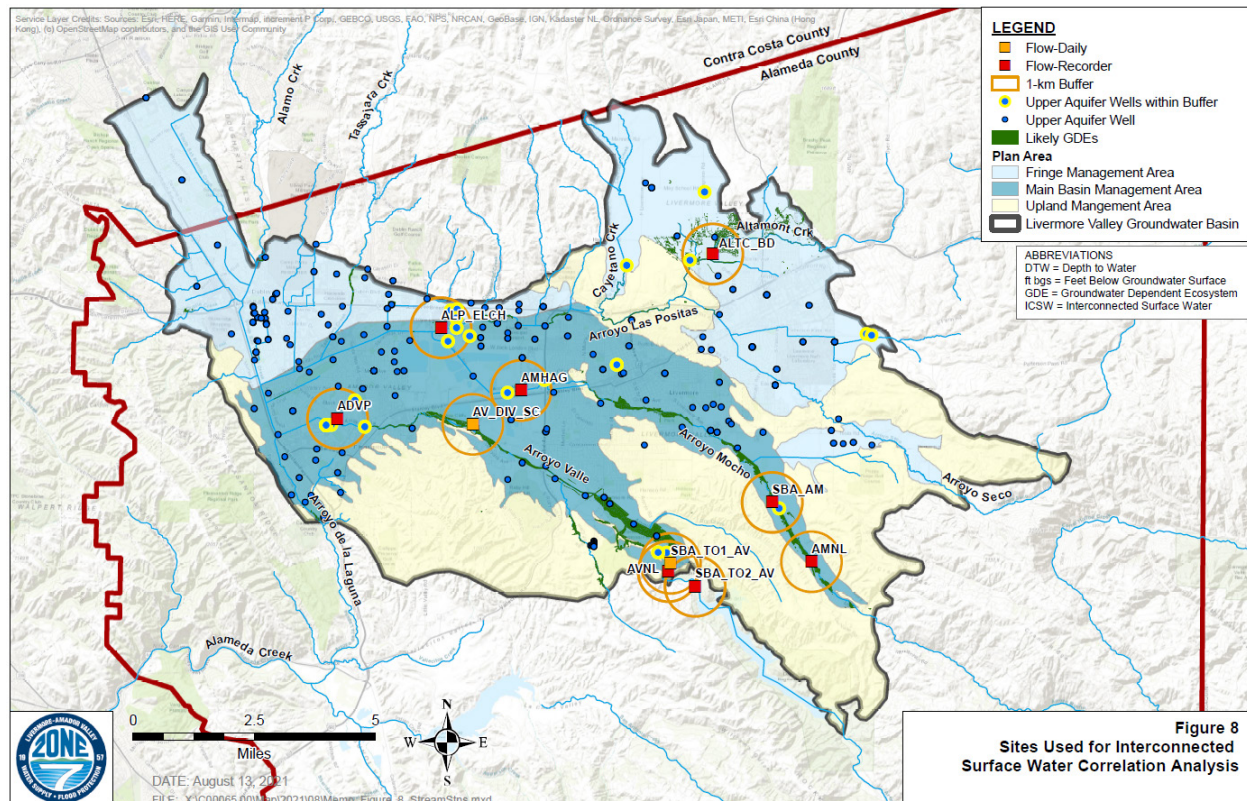
Based on the above, the potential correlation between Upper Aquifer groundwater elevation and streamflow data, including gauge height and flow rate, were evaluated to examine whether the portions of the streams that were identified as likely ICSW have a quantifiable relationship to the principal aquifer. Stream gauging stations along potential ICSW sections and near likely GDEs (from **Figure 7** and

²³ § 354.28(b)(6)

²⁴ § 354.28(d) An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence

Attachment C) were selected for the correlation analysis, as shown on **Figure 8**. Zone 7 provided daily flow data and gauge height between 2015 and 2020 for the selected stations.

Figure 8. Sites Used for Interconnected Surface Water Correlation Analysis



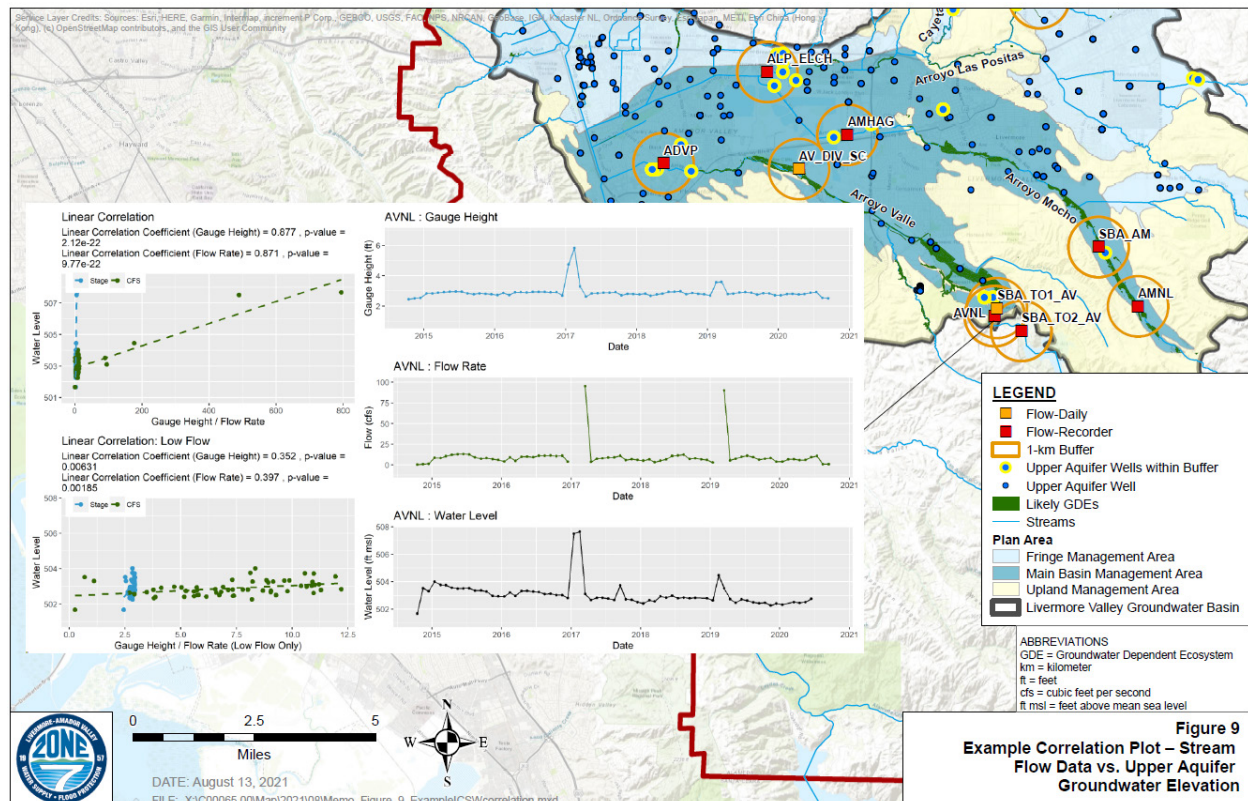
Upper Aquifer wells within a one km radius of the selected stream gauging stations were assumed to be representative of groundwater conditions in vicinity of the stations. If multiple wells were associated with (i.e., within one km of) a stream gauging station, average groundwater elevations from these wells were calculated. The Upper Aquifer wells within the one km buffer of each selected stream gauging station are shown on **Figure 8**. Since most of the groundwater elevations were measured monthly, monthly average flow data and gauge height were calculated.

Time series data of the gauge height and flow rate were plotted for each stream gauging station, as shown on **Figure 9** and in **Attachment D**. A linear correlation between the stream flow data (gauge height and flow rate) and the local groundwater elevation was then evaluated for each station. A positive correlation would mean that, when the gauge height or flow rate increases, the groundwater elevation also increases, indicating that there is potential interconnectivity between the stream and groundwater, and vice versa.

As part of its active management of the Basin, Zone 7 imports surface water from the State Water Project (SWP) through the South Bay Aqueduct (SBA) for treatment, storage, and groundwater recharge. Since the streams within the Basin are also used for artificial recharge, correlation between low flow, which better represents the natural streamflow conditions, and Upper Aquifer groundwater elevation was also performed. Low flow data for each stream gauging station were obtained by removing the gauge height

and flow rate data that fell outside of the 90th percentile²⁵. The low flow correlation result for each stream gauging station is also shown on **Figure 9** and in **Attachment D**.

Figure 9. Example Correlation Plot – Stream Flow Data vs. Upper Aquifer Groundwater Elevation



Among the selected stream gauging stations (i.e., stations located along potential ICSW and near likely GDEs), only the AVNL station exhibited statistically significant positive correlations between streamflow data (gauge height and flow rate) and groundwater elevation data.²⁶ The ADV station also showed a low but statistically significant positive correlation for low flow conditions only. Groundwater elevation measurements from the wells located close to the other stream gauging stations are generally collected biannually, and thus there is insufficient groundwater elevation data to support statistically significant correlation between groundwater levels and monthly average stream flow data. This data gap is addressed further under **Section 2**.

For the AVNL station, the correlation using all stream flow data has a larger correlation coefficient and smaller p-value than those for the correlation using low flow data only (i.e., for all stream flow data, correlation coefficients and p-values are 0.88 and 2.1e-22 for gauge height, 0.87 and 9.8e-22 for flow rate; for low flow data, the correlation coefficients and p-values are 0.35 and 0.006 for gauge height, 0.40 and 0.002 for flow rate). The AVNL station is located along Arroyo Valle and near the location where imported

²⁵ Ratio of high flow events to low flow events is approximately 1:9 in most of the stream stations, and therefore 90th percentile is used as a threshold to retain low flow data.

²⁶ For the purpose of this analysis, correlation with a p-value that is less or equal to 0.05 is considered to be significant.

SWP water is released into the stream. Nearby likely GDEs (Sycamore Grove located in the southeastern portion of the Basin) have been documented to rely on the released imported water for artificial recharge,²⁷ which is also reflected in the higher correlation for all flow data (i.e., during active Zone 7 recharge operations).

Additionally, cross-correlation was performed for the AVNL station data to examine whether a time lag exists between the stream flow data and shallow groundwater elevations.²⁸ The cross-correlation result shows that maximum correlation is reached when time lag equals zero months and the correlation is significant, which indicates that limited time lag exists between the stream flow data and groundwater elevations for the AVNL station.

1.3. GDE and ICSW Program Update

Based on the above analyses and field investigation, the Basin includes approximately 1,052 acres of likely GDEs, which encompass approximately 2% of the total Basin area. The most prevalent vegetation communities across all likely GDE units are the riparian mixed hardwood alliance, California sycamore alliance, and the Alkaline mixed grasses and forbs alliance. Most of the likely GDEs are located along the Arroyo Valle and Arroyo Mocho creeks in the Main Basin Management Area and around Altamont Creek in the Fringe Management Area.

Likely ICSW sections have also been identified along several reaches of the major surface water features within the Basin, including Arroyo Valle, Arroyo Mocho, Arroyo Las Positas, and Altamont Creek. Unsurprisingly, most of the areas where potential ICSW sections occur also support likely GDEs, as these stream corridors consistently encounter some of the shallowest groundwater elevations observed within the Basin, see **Figure 7**.

Where sufficient data and ICSW conditions exist, groundwater levels in the Upper Aquifer can be correlated to ICSW conditions and GDE locations. As such, Upper Aquifer wells and the selected stream gauging stations can serve as the representative monitoring sites for purposes of SGMA implementation, and sustainability criteria that are protective of both GDEs and ICSW can be developed using groundwater levels as a proxy.

2. GDE AND ICSW MONITORING NETWORK

This section describes the existing and proposed Monitoring Network for areas of the Basin that have likely GDEs and/or ICSW reaches. As mentioned above, the locations of likely GDE communities within the Basin are largely coincident with the presence of ICSW reaches, given that both GDEs and ICSW are supported by shallow local groundwater conditions. As such, the proposed ICSW Monitoring Network presented in this section is designed to provide a “dual benefit” of: (1) assessing ongoing surface water - shallow groundwater connectivity within ICSW reaches, as well as (2) supporting monitoring of groundwater conditions that are one of the factors that can contribute to the health of nearby GDE communities.

²⁷ Zone 7, 2009. Phase 2 Technical Report: Sycamore Grove Recovery Program, Sycamore Grove Park, Livermore, California, dated December 2009.

²⁸ Cross-correlation is a measurement that tracks the movements of two or more sets of time series data relative to one another.

2.1. Existing Monitoring Locations

Zone 7 has about 240 program wells for the groundwater elevation monitoring program in order to track groundwater levels and flow, identify short- and long-term trends, estimate subsurface flow between Management Areas, and support water budget and storage analyses.²⁹ Among the 240 program wells, about 110 wells are Upper Aquifer wells, as shown on **Figure 10**. The program wells are measured at least biannually. Water level measurements are also taken monthly in several wells to track performance of recharge and pumping operations and groundwater conditions. Figure 2-17 and Appendix C-1 of the 2016 Alt GSP show the location and well construction information of the program wells. Two wells (2S2E34E001 and 2S2E27P002) are currently used for monitoring of Springtown Alkali Sink, which is one of the likely GDE areas (see **Table 1** and **Figure 6**).

Zone 7 monitors also streamflow within the Basin and has a stream monitoring program that includes 15 stream gauging stations that record flow data at 15-minute intervals. Figure 4-2 and Table 4-3 of the 2016 Alt GSP show the location and detail of the stations.

In addition to the existing network, as part of the development of the 2022 Plan, Zone 7 has identified and secured access to additional well sites. Several of these new wells have been identified as candidates for the ICSW Monitoring Network; selected others will become program wells.

2.2. Proposed ICSW Monitoring Network

The objective of a SGMA Representative Monitoring Network is to collect sufficient data for the correct assessment of the Sustainability Indicators relevant to the Basin, and the impacts to the beneficial uses and users of groundwater.³⁰ The proposed SGMA Representative Monitoring Network for Depletions of Interconnected Surface Water (RMN-ICSW) is therefore comprised of selected Upper Aquifer program wells, new wells, and stream gauging stations along the ICSW reaches and near the likely GDEs identified in **Section 1.1.2**.

In developing the RMW-ICSW, the EDF guidance, which recommends a monitoring location every four to six miles along an ICSW stream for a “reasonable balance between rigor and practicality” was considered.³¹ Upper Aquifer wells with a long period of record and located in close proximity to a stream gauging station were preferentially selected and a higher density of monitoring wells was selected in some likely ICSW reaches to sufficiently cover nearby likely GDEs within the Basin.

Figure 10 shows the RMN-ICSW, including both representative monitoring wells and representative stream gauging stations. **Table 2** shows the monitoring network details, including the nearby likely GDEs, nearby stream gauging stations, monitoring methods, monitoring frequency, and well construction information. In total 14 wells and 10 stream gauging stations have been selected as part of the RMN-ICSW, where data will be collected manually every month, semi-annually, or using data loggers every 15 minutes, depending on the site.³² These data will be evaluated annually to assess the correlation between

²⁹ Zone 7, 2016. Alternative Groundwater Sustainability Plan for the Livermore Valley Groundwater Basin, dated December 2016.

³⁰ Pursuant to § 354.32

³¹ Hall et al., 2018. *Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act*. Environmental Defense Fund. Dated 2018.

³² Two of the wells (3S1E16P005 and 3S2E30D002) currently have data loggers installed.

shallow groundwater levels and GDE health and ICSW flow rates to confirm that groundwater levels can serve as an appropriate proxy for purposes of developing and applying sustainability criteria. Monitoring frequency will be re-evaluated if groundwater levels decline below their Minimum Thresholds (MT) in the RMN-ICSW monitoring wells.

In addition to monitoring the proposed RMN-ICSW, Zone 7 plans to perform periodic visual inspections to monitor the health of likely GDEs and ICSW conditions. Visual inspections will be either examination of areal images or field investigation, or a combination thereof. Bi-annual or monthly monitoring of the remaining Upper Aquifer program wells will also continue, which will provide additional data and perspective on shallow aquifer conditions within the Basin.

Figure 10. Proposed Representative Monitoring Network for Depletions of Interconnected Surface Water

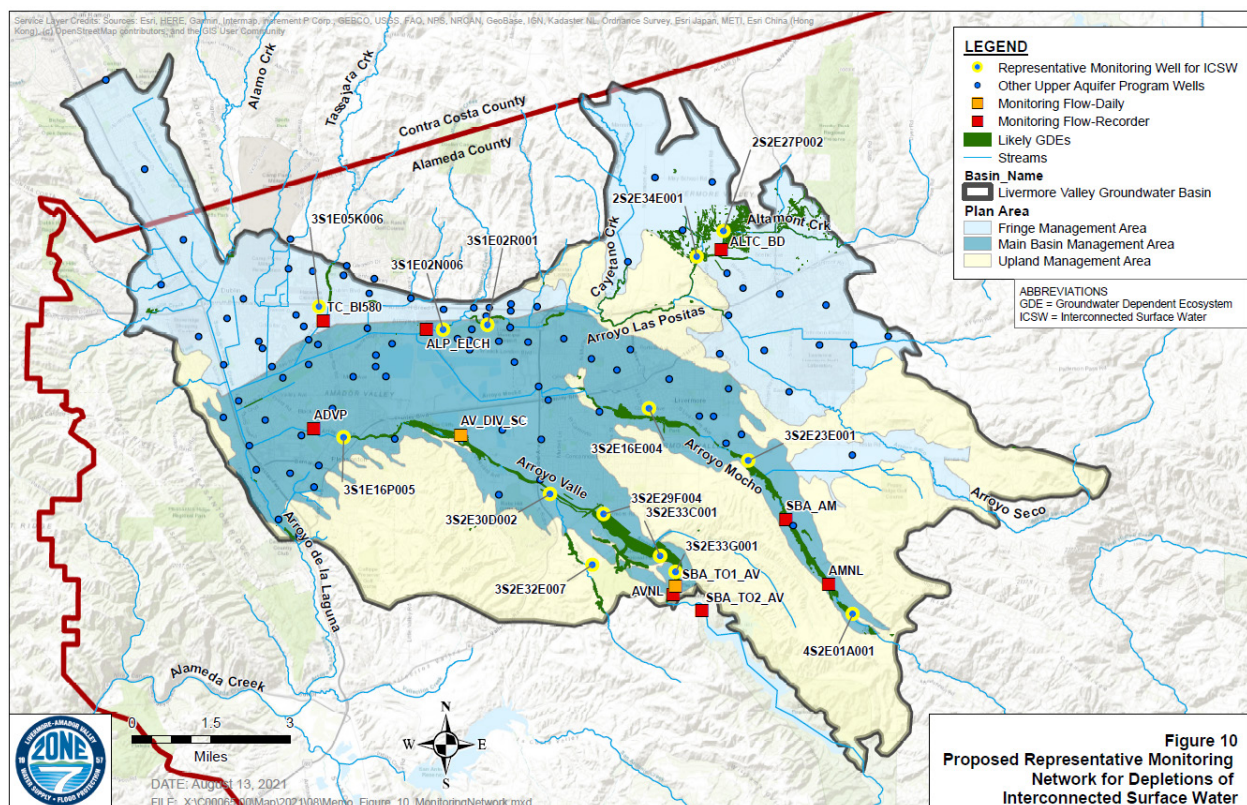


Table 2. Proposed Representative Monitoring Network for Depletions of Interconnected Surface Water Details

Well Name	Well Type	Nearby GDE	Nearby ICSW	Nearby Stream Station (<=1km)	Monitoring Method	Monitoring Frequency	RP Elev (ft msl)	Top Perf (ft bgs)	Bot Perf (ft bgs)	Well Depth (ft bgs)
2S2E27P002	Program Well	Springtown Alkali Sink	Altamont Creek	ALTC_BD	Collect Manually	SemiAnnual	505.43	35	63	68
2S2E34E001	Program Well	Springtown Alkali Sink	Altamont Creek	ALTC_BD	Collect Manually	SemiAnnual	499.73	40	45	49
3S1E05K006	Program Well	TC-Riparian Mixed Hardwood	Tassajara Creek	TC_BI580	Collect Manually	SemiAnnual	346.05	40	70	75
3S2E30D002	Program Well	AV-Riparian Mixed Hardwood	Arroyo Valle	--	Logger (existing)	15 Minutes	431.6	24	39	44
3S1E16P005	Program Well	AV-Riparian Mixed Hardwood	Arroyo Valle	ADVP	Logger (existing)	15 Minutes	354.51	64	69	75
3S2E33G001	Program Well	AV-Sycamore Grove	Arroyo Valle	AVNL, SBA_TO1_AV, SBA_TO2_AV	Collect Manually	Monthly	511.52	9	14	17
3S2E29F004	Program Well	AV-Sycamore Grove	Arroyo Valle	--	Collect Manually	Monthly	457.50	26	31	36
3S2E33C001	New Program Well (Monitoring)	AV-Sycamore Grove	Arroyo Valle	--	Collect Manually	SemiAnnual	493.23	5	20	20
3S1E02R001	Program Well	ALP-Mixed Vegetation	Arroyo Las Positas	--	Collect Manually	SemiAnnual	376.29	21	26	33
3S1E02N006	Program Well	ALP-Mixed Vegetation	Arroyo Las Positas	ALP_ELCH	Collect Manually	SemiAnnual	366.14	40	55	55
3S2E16E004	Program Well	AM-Riparian Mixed Hardwood & Sycamore	Arroyo Mocho	--	Collect Manually	SemiAnnual	506.26	35	40	45
3S2E23E001	Program Well	AM-Valley Oak	Arroyo Mocho	--	Logger (to be added)	15 Minutes	613.36	20	35	40
4S2E01A001	New Program Well (Ag)	AM-Valley Oak	Arroyo Mocho	AMNL	Collect Manually	SemiAnnual	819.76	45	130	150
3S2E32E007	Program Well	Upland-Riparian Mixed Hardwood	Vineyard Creek	--	Collect Manually	SemiAnnual	610.94	19	34	37

Table 2. Proposed Representative Monitoring Network for Depletions of Interconnected Surface Water (Cont.)

Station ID	Measures	Nearby GDE	Nearby ICSW	Flow Frequency	Gauge Height	Flow Rate
ALTC_BD	Streamflow	Springtown Alkali Sink	Altamont Creek	15 Min	x	x
ALP_ELCH	Streamflow	ALP-Mixed Vegetation	Arroyo Las Positas	15 Min	x	x
ADVP	Streamflow	AV-Riparian Mixed Hardwood	Arroyo Valle	15 Min	x	x
AV_DIV_SC	Diversion From AV	AV-Riparian Mixed Hardwood	Arroyo Valle	Daily	-	x
AVNL	Streamflow	AV-Sycamore Grove	Arroyo Valle	15 Min	x	x
SBA_TO1_AV	Release into AV	AV-Sycamore Grove	Arroyo Valle	15 Min	-	x
SBA_TO2_AV	Release into AV	AV-Sycamore Grove	Arroyo Valle	15 Min	-	x
SBA_AM	Release into AM	AM-Valley Oak	Arroyo Mocho	15 Min	-	x
AMNL	Streamflow	AM-Valley Oak	Arroyo Mocho	15 Min	x	x
TC_BI580	Streamflow	Tassajara Creek - Riparian Mixed Hardwood	Tassajara Creek	15 Min	x	x

2.3. Data Gap Filling Activities

Zone 7 uses Arroyo Valle and Arroyo Mocho for artificial recharge of the Basin using imported SWP water. Currently two representative monitoring wells, 3S2E30D002 and 3S1E16P005 along Arroyo Valle, have automatic dataloggers installed that collect data at 15-minute intervals. In addition, to better evaluate the relationship between the Upper Aquifer groundwater elevations and the stream flow data collected along the Arroyo Mocho, Zone 7 plans to install dataloggers in well 3S2E23E001.

Additional analyses that may help further characterize the degree of connectivity between stream reaches and the underlying principal aquifer system include installation of additional data loggers, pumping tests, geophysical investigations, and tracer studies within potential ICSW reaches and nearby GDE communities. Zone 7 will evaluate these data gap filling activities prior to the 2027 Alt GSP update.

3. GROUNDWATER DEPENDENT ECOSYSTEM DEMANDS

Quantifying groundwater consumptive use from GDEs can be estimated using a soil moisture balance model. Evapotranspiration (ET) uptake from groundwater occurs when the saturated groundwater table is accessible by the root zone of a GDE or is within a small enough depth below the root zone such that groundwater can be accessed via capillary rise. As part of this work effort, EKI has utilized DWR's Integrated Water Flow Model Demand Calculator (IDC) soil moisture balance model to provide initial estimates of ET uptake from groundwater for the GDE communities identified in the above analyses. The IDC employs the "Root Water Uptake" package to simulate shallow groundwater uptake by GDE communities to meet ET demands³³. In its current form, the Zone 7 IDC model explicitly simulates shallow groundwater uptake from the five largest and most contiguous GDE communities identified in the Basin, including:

- Arroyo Valle - Riparian Mixed Hardwood
- Arroyo Valle - Sycamore Grove
- Arroyo Mocho - Riparian Mixed Hardwood & Sycamore
- Arroyo Mocho - Valley Oak
- Springtown Alkali Sink

These GDE communities collectively comprise approximately 925 acres, or roughly 90% of the total mapped GDE areas within the Basin.

Based on IDC model outputs for DWR Water Years 2011 – 2020, approximately 2,900 acre-feet per year (AFY) of shallow groundwater are consumed by GDE communities to help meet ET demands, equating to approximately 3.0 AF/acre. This represents roughly 70% of the total potential ET demand estimated for GDEs within the Basin (~4.3 AFY/acre)³⁴. Given the considerable uncertainties in soil properties, shallow groundwater availability, and plant-specific groundwater uptake rates embedded in this calculation, a

³³ Dogrul, E.C., Kadir, T.N. (DWR). 2020. *IWFM Demand Calculator, IDC-2015. Theoretical Documentation and User's Manual*.

³⁴ Based on local CIMIS station reference evapotranspiration (ET_o) data and monthly riparian/native vegetation ET coefficients provided by DWR's Cal-SIMETAW model for the Livermore study area.

more reasonable range of average GDE groundwater demands within the Basin is likely somewhere between 2,000 AFY (~2 AFY/acre) and 4,000 AFY (~4 AFY/acre).

4. SUSTAINABLE MANAGEMENT CRITERIA

The SGMA legislation defines a “Sustainability Goal” as “the existence and implementation of one or more groundwater sustainability plans [GSPs] that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield”.³⁵ The SGMA requires Groundwater Sustainability Agencies (GSAs) to develop and implement GSPs to meet the Sustainability Goal³⁶ and defines terms related to achievement of the Sustainability Goal, including:

- Measurable Objective (MO) – “specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin”;³⁷
- Minimum Threshold (MT) – “a numeric value for each sustainability indicator used to define undesirable results”;³⁸ and
- Interim Milestone (IM) – “a target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan”.³⁹

Collectively, the Sustainability Goal, IMs, MOs, and MTs are referred to herein as Sustainable Management Criteria (SMCs).

This section describes the proposed SMCs for Depletions of Interconnected Surface Water, including the Undesirable Results (URs), MOs and MTs for areas of the Basin that have confirmed GDEs and/or ICSW. These SMCs were developed in consideration of the California Water Code (CWC) §10727.2(b)(4) which states that the Plan may, but is not required to, address undesirable results that occurred before, and have not been corrected by, January 1, 2015. It is further noted that the GSP Emergency Regulations (23-CCR § 354.28(c)) state that the SMCs for a given Sustainability Indicator can be set by using groundwater levels as a proxy, which is the approach utilized herein.

4.1. Undesirable Results

Undesirable Results are defined in the SGMA as “when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin”. For Depletions of Interconnected Surface water, SGMA defines an UR as “depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water”.⁴⁰

³⁵ CWC § 10721(u)

³⁶ CWC § 10727(a)

³⁷ 23 CCR § 351(s)

³⁸ 23 CCR § 351(t)

³⁹ 23 CCR § 351(q)

⁴⁰ CWC § 10721(x) (6)

As shown in **Attachment E**, based on information provided by TNC,⁴¹ the area-weighted average change in the size of the GDE areas between 2014 and 2018 within the Basin was approximately 40% (i.e., the mapped GDE area in 2014 was 40% smaller than the GDE areas mapped in 2018).⁴² Based on the change in GDE area analysis, a 40% reduction in GDE area is within the historical range of GDE area fluctuation under recently-observed, post-SGMA hydrologic conditions.

As such, the Undesirable Results for Depletions of Interconnected Surface Water would be experienced in the Basin when surface water depletions, as result of SGMA-related groundwater management actions, negatively affect the beneficial users and uses of the surface water, including the likely GDEs and protected species. Specifically, a significant and unreasonable negative effect would be experienced if the health of up to 40% of the GDE areas in the Basin are adversely impacted by mechanisms that can be directly attributed to pumping-related lowering of groundwater levels rather than effects of natural or climactic processes and/or unfavorable hydrologic conditions or land use changes.

This Undesirable Results definition is preliminary pending the collection of additional data. At this time, as described above, the relationship between ICSW, GDE health and groundwater conditions has not been definitively determined and the ability of Zone 7 to manage the ICSW and GDE areas is limited given the significant other factors that impact their occurrence and health (e.g., climate, hydrology, invasive species, land development, etc.). Furthermore, if groundwater levels in the vicinity of ICSW (and the co-located GDEs) remain too high, Zone 7's ability to actively manage the Basin through recharge operations will be negatively impacted. Consideration of all the above was included as part of the development of the SMCs. Zone 7 will continue to monitor the ICSW and GDE areas and may refine the definition of Undesirable Results once the information regarding the relationship between the occurrence of ICSW and GDEs and the management of the Basin is better understood.

4.1.1. Potential Causes of Undesirable Results

Depletions of Interconnected Surface Water are generally correlated to Chronic Lowering of Groundwater Levels in a system of ICSW and groundwater. Therefore, the potential causes of URs for the Depletions of Interconnected Surface Water are generally the same as the potential causes for URs due to Chronic Lowering of Groundwater Levels, including increased groundwater pumping and reduced recharge. Additional causes directly related to surface water bodies can also influence depletions including, but not limited to, hydrology, increased diversions, reduced return flows, and water consumption by riparian vegetation. Additional causes related to GDEs can include hydrology, land use changes and the occurrence of invasive species, among other things. Currently there are little to no quantitative data regarding the impacts from these potentially contributing causes to ICSW and GDEs within the Basin.

⁴¹ Statewide raster data that show NDVI trends are provided by TNC on 30 August 2021. Since NDVI is used to estimate vegetation greenness and provides a proxy for vegetation growth, change in GDE area can be estimated using TNC GDE Pulse raster data that shows the NDVI trends between 2014 and 2018. Moderate to large increases in NDVI trends represent an increase in the GDE area and moderate to large decreases in NDVI trends represent a decrease in the GDE area. Therefore, the change in GDE area can be estimated by subtracting GDE area with decreasing NDVI trends from GDE area with increasing NDVI trends.

⁴² Since the Plan is not required to address undesirable results that occurred before, and have not been corrected by January 1, 2015 (Water Code Section 10727.2 (b)(4)), 2014 is selected as the start of the analysis timeframe. 2018 is selected as the end of the analysis timeframe since it is a recent wet year when GDE conditions might be above average.

4.1.2. Criteria Used to Define Undesirable Results

Per Section 354.26(b)(2) of the GSP Emergency Regulations, the description of Undesirable Results must include a quantitative description of the combination of MT exceedances that constitute an UR. The MTs for Depletions of Interconnected Surface Water are described below in **Section 4.2.1**. Based on application of the MTs at the RMN-ICSW and the significant and unreasonable negative effect discussed above, Undesirable Results will be experienced if and when Depletions of Interconnected Surface Water occur as a result of unsustainable groundwater extraction such that groundwater levels decline below their MTs in 40% of the wells (6 out of 14 wells) in the RMN-ICSW for more than two consecutive non-drought years.

This Undesirable Results criteria is preliminary pending the collection of additional data. At this time, as described above, the relationship between ICSW, GDE health and groundwater conditions has not been definitively determined and the ability of Zone 7 to manage the ICSW and GDE areas is limited given the significant other factors that impact their occurrence and health (e.g., climate, hydrology, invasive species, land development, etc.). Furthermore, if groundwater levels in the vicinity of ICSW (and the co-located GDEs) remain too high, Zone 7's ability to actively manage the Basin through recharge operations will be negatively impacted. Consideration of all the above was included as part of the development of the SMCs. Zone 7 will continue to monitor the ICSW and GDE areas and may refine the criteria used to determine Undesirable Results once the information regarding the relationship between the occurrence of ICSW and GDEs and the management of the Basin is better understood.

4.1.3. Potential Effects of Undesirable Results

Potential effects of Undesirable Results of Depletion of Interconnected Surface Water may include impacts to environmental users, such as likely GDEs, critical habitat for federally listed species, special-status plants, and special-status terrestrial and aquatic wildlife species, as discussed in **Section 1.1.2**. Furthermore, there may be reduced surface water flows to support downstream or in-stream uses. Conversely, if groundwater levels in the vicinity of ICSW (and the co-located GDEs) remain too high, Zone 7's ability to actively manage the Basin through recharge operations will be negatively impacted. Consideration of all the above was included as part of the development of the SMCs.

4.2. Minimum Threshold, Measurable Objective, and Interim Milestones Development

The sections below discussed the development of MOs, IMs, and MTs for Depletions of Interconnected Surface Water.

The GSP Emergency Regulations (23 CCR 354.28(c)) state that the MT for Depletions of Interconnected Surface Water "shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial users of the surface water and may lead to undesirable results". Based on the analysis presented in **Sections 1.1** and **1.2**, where sufficient data are available and ICSW conditions exist, a reasonable correlation exists between groundwater levels in the monitoring wells included in the RMW-ICSW. As such, for the purposes of developing SMCs, water levels in those monitoring wells are used as a proxy for developing the MTs.

4.2.1. Minimum Threshold

MTs are the numeric criteria for each Sustainability Indicator that, if exceeded, may cause URs for that indicator or for other indicators by proxy. This section describes the MTs that have been developed to avoid URs related to the of Depletions of Interconnected Surface Water in the Basin.

Water levels are considered reasonably effective (and the best available) criteria because they can be utilized to help maintain conditions and instream flows that support environmental water users and, in the case of Zone 7, Basin recharge operations. A composite map of historic lows observed in the Upper Aquifer, as shown on Figure 3-1 of the Alt GSP, has been prepared by Zone 7. For several decades, Zone 7 has operated the Basin to maintain water levels above historic low levels throughout the Main Basin Management Area [without causing URs].⁴³ Water levels outside of the Main Basin Management Area have not fluctuated significantly over time, and no areas of significant downward trends [or areas with URs] have been identified.⁴⁴

Generally consistent with the definition used for the MT for the Chronic Lowering of Groundwater Levels, the MT for the Depletions of Interconnected Surface Water is defined as the historic low water level at the wells included in the RMN-ICSW. The resultant MTs for the RMN-ICSW within the Basin are shown in **Table 3**. Where historical water level measurements are not available, estimated values at the RMWs are sourced from the groundwater elevation rasters developed by Zone 7 as discussed in **Section 1.2.1. Attachment F** shows the hydrograph and SMC for the Depletions of Interconnected Surface Water for each RMW-ICSW.

Currently there are no significant quantitative data representing negative impacts from the contributing causes identified in **Section 4.1.1** to ICSW and GDEs within the Basin. Therefore, historical groundwater conditions are concluded to be sufficient to sustain ICSW and GDEs within the Basin.

As discussed above, the 10 stream stations located along the potential ICSW within the Basin (as shown in **Table 1**) that are included in the RMN-ICSW will record either flow rates and/or gauge heights. These data, combined with water level measurements from the monitoring wells in the RMN-ICSW, will better quantify relationships between measured changes in groundwater levels and surface water flows that can help ensure that these MTs are protective and will allow for refinement of the SMC approach over time.

⁴³ Zone 7, 2016. Alternative Groundwater Sustainability Plan for the Livermore Valley Groundwater Basin, dated December 2016.

⁴⁴ Ibid.

Table 3. Sustainable Management Criteria for Depletions of Interconnected Surface Water

Well Name	Minimum Thresholds (ft msl)	Interim Milestones (ft msl)			Measurable Objectives (ft msl)
		<i>IM-5</i>	<i>IM-10</i>	<i>IM-15</i>	
2S2E27P002	501.0	501.0	501.0	501.0	501.0
2S2E34E001	491.2	492.1	492.4	492.7	493.0
3S1E05K006	326.0	328.2	328.2	328.2	328.2
3S2E30D002	401.0	403.8	404.7	405.6	406.5
3S1E16P005	285.2	285.2	285.2	285.2	285.2
3S2E33G001	501.0	501.1	501.2	501.2	501.3
3S2E29F004	437.8	441.2	442.3	443.5	444.6
3S2E33C001	482.1	484.2	484.8	485.5	486.2
3S1E02R001	345.3	349.4	350.8	352.2	353.6
3S1E02N006	331.5	333.9	333.9	333.9	333.9
3S2E16E004	466.9	466.9	466.9	466.9	467.0
3S2E23E001	595.4	595.4	595.4	595.4	595.4
4S2E01A001	781.2 (a)	781.2 (a)	781.2 (a)	781.2 (a)	781.2 (a)
3S2E32E007	591.4	591.4	591.4	591.4	591.4

Notes:

- (a) RMW 4S2E01A001 is a new well and there are insufficient water level data to establish an MT, MO, and IM based on historical water levels. As such, initial MT, MO, and IM for these RMW are based on the minimum water level values sourced from 2014 to 2020 groundwater elevation rasters developed by Zone 7 for the Basin.

4.2.2. Measurable Objective and Interim Milestones

MO Determination

As described in the Sustainable Management Criteria BMP document, “Measurable Objectives should be set such that there is a reasonable margin of operation flexibility (or ‘margin of safety’), between the minimum threshold and measurable objective that will accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities”.⁴⁵

The MOs for Depletion of Interconnected Surface Water were similarly developed based on measured groundwater levels in the monitoring wells included in the RMN-ICSW. Specifically, the MOs are equal to the minimum water levels measured between 2014 and 2020 at each RMN-ICSW, which represents the recent groundwater conditions that are protective of ICSW and GDEs following the adoption of SGMA. Where water level measurements between 2014 and 2020 are not available, estimated values at the RMWs are sourced from the groundwater elevation rasters developed by Zone 7 as discussed in **Section**

⁴⁵ DWR, 2017. Best Management Practices for the Sustainable Management of Groundwater, dated November 2017.

1.2.1. The hydrographs and SMCs for the Depletions of Interconnected Surface Water at each RMW-ICSW are shown in **Attachment F**.

Based on the defined MOs and MTs (**Table 3**), Zone 7 considers there to be a sufficient Margin of Operational Flexibility at each RMN-ICSW. Data collected regularly from the RMN-ICSW will better quantify relationships between measured changes in groundwater levels, surface water flows and GDE areas that can help ensure that these MOs are protective and will allow for refinement of the SMC approach over time.

IM Determination

Interim Milestones for Depletion of Interconnected Surface Water are defined herein based on a trajectory for groundwater levels informed by the groundwater level trends since 2015, MOs, and MTs. If the RMN-ICSWs have decreasing groundwater level trends since 2015, the IM for the first 5-year period is set as the average between MOs and MTs, and the IMs for the following three 5-year periods are set as groundwater elevations that are linearly interpolated between IM for the first 5-year period and the MO. This trajectory allows for and assumes a continuation of current groundwater level trends for the first 5-year period, and recovery towards the MOs over the following three 5-year periods. Conversely, if the RMN-ICSWs have increasing groundwater level trends since 2015, the subsequent IMs are all equal to the MOs. The IMs are presented in **Table 3** and the methodology used to develop them is shown in **Table 4**.

Table 4. Interim Milestone Trajectory for Depletion of Interconnected Surface Water

Calendar Year	Interim Milestone for Depletion of Interconnected Surface Water	Basis for Interim Milestone
2022	Not applicable	Not applicable
2027	IM-5	$\frac{1}{2} * (MO_{GWL} + MT_{GWL})$
2032	IM-10	$IM-5_{GWL} + \frac{1}{3} * (MO_{GWL} - IM-5_{GWL})$
2037	IM-15	$IM-5_{GWL} + \frac{2}{3} * (MO_{GWL} - IM-5_{GWL})$
2045	MO	MO_{GWL}

Where:

IM-5, IM-10, and IM-15 are the IM for Depletion of Interconnected Surface Water after 5 years, 10 years and 15 years respectively; and
MO and MT are the MO and MT for Depletion of Interconnected Surface Water defined previously.

ATTACHMENTS

Attachment A: Time Series Data and Correlation Plots by GDE Polygon

Attachment B: Technical Memorandum from Stillwater: Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin

Attachment C: Surface Water Bodies and Monitoring Sites

Attachment D: Time Series Data and Correlation Plots by Stream Station

Attachment E: Change in GDE Area Analysis

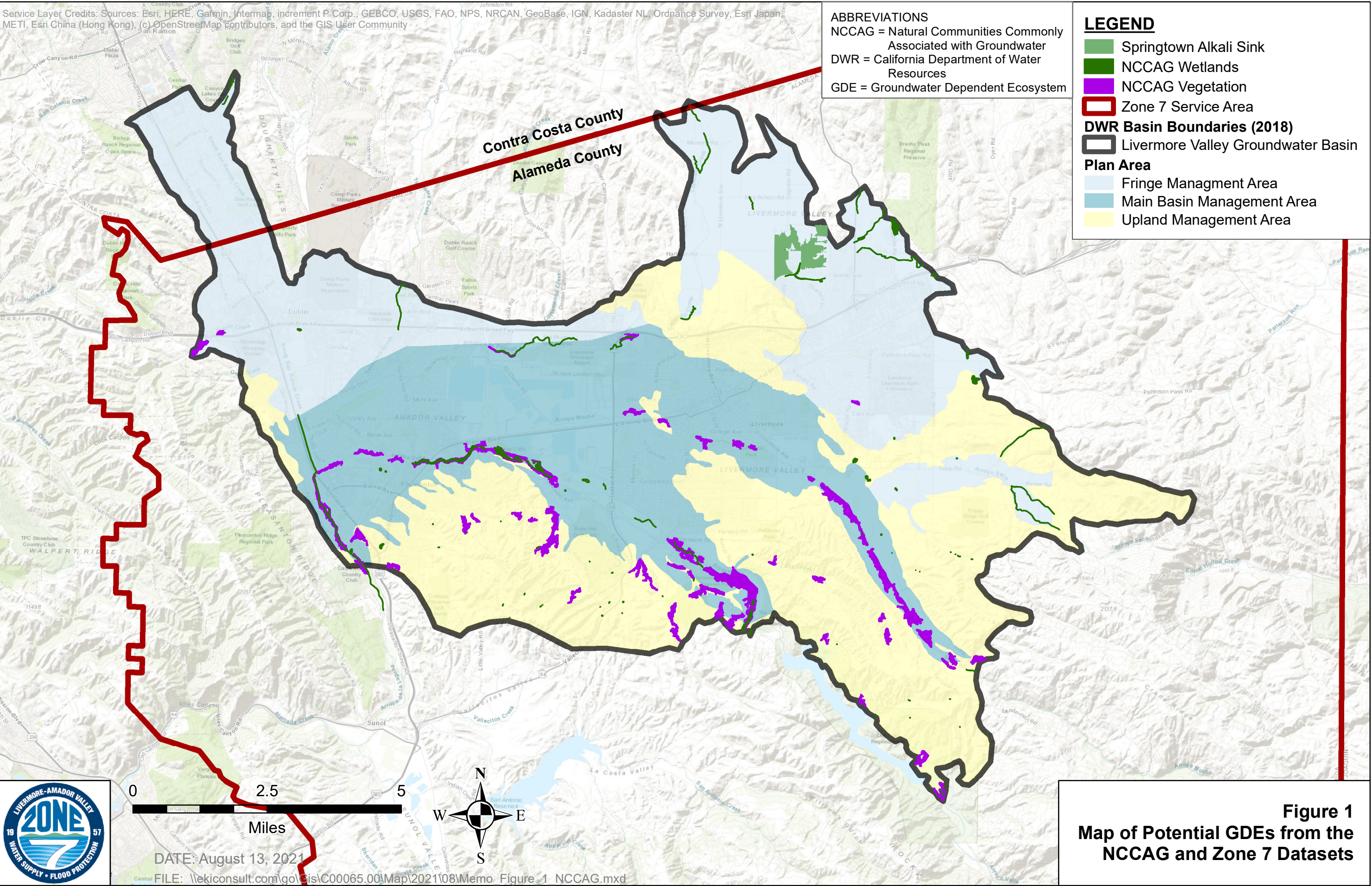
Attachment F: Water Levels and SMC Plots by RMW-ICSW

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

ABBREVIATIONS
NCCAG = Natural Communities Commonly
Associated with Groundwater
DWR = California Department of Water
Resources
GDE = Groundwater Dependent Ecosystem

LEGEND

- Springtown Alkali Sink
- NCCAG Wetlands
- NCCAG Vegetation
- Zone 7 Service Area
- DWR Basin Boundaries (2018)**
- Livermore Valley Groundwater Basin
- Plan Area**
- Fringe Management Area
- Main Basin Management Area
- Upland Management Area



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

ABBREVIATIONS
DTW = Depth to Groundwater
ft bgs = feet below ground surface
GDE= Groundwater Dependent Ecosystem
Min = Minimum
DWR = California Department of Water Resources

LEGEND

- Upper Aquifer Well
- Springtown Alkali Sink
- Potential GDE Polygon**
- Min DTW <= 30 ft bgs
- Min DTW > 30 ft bgs
- No 2015-2020 DTW Available
- Zone 7 Service Area
- DWR Basin Boundaries (2018)**
- Livermore Valley Groundwater Basin
- Plan Area**
- Fringe Management Area
- Main Basin Management Area
- Upland Management Area

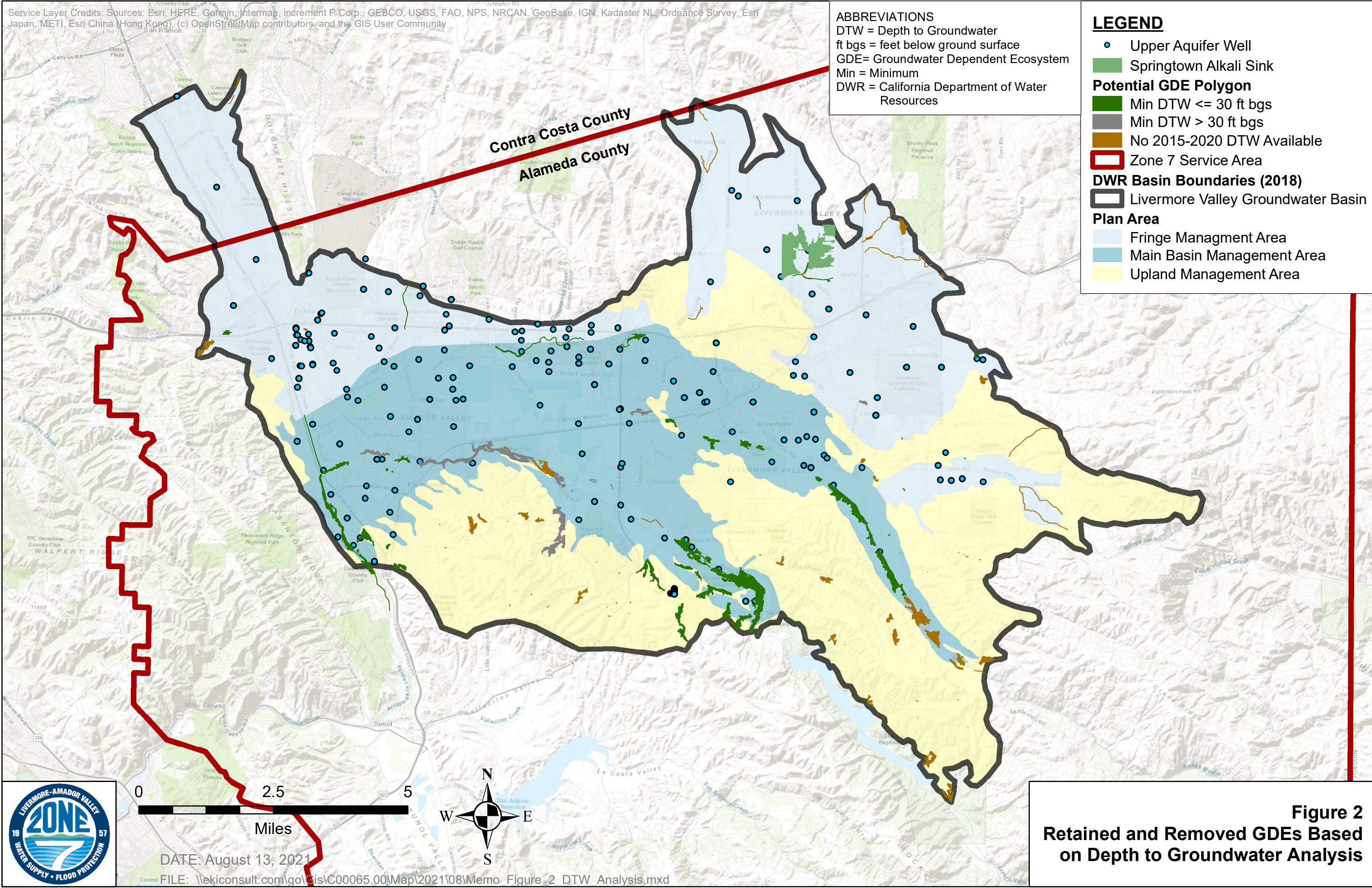


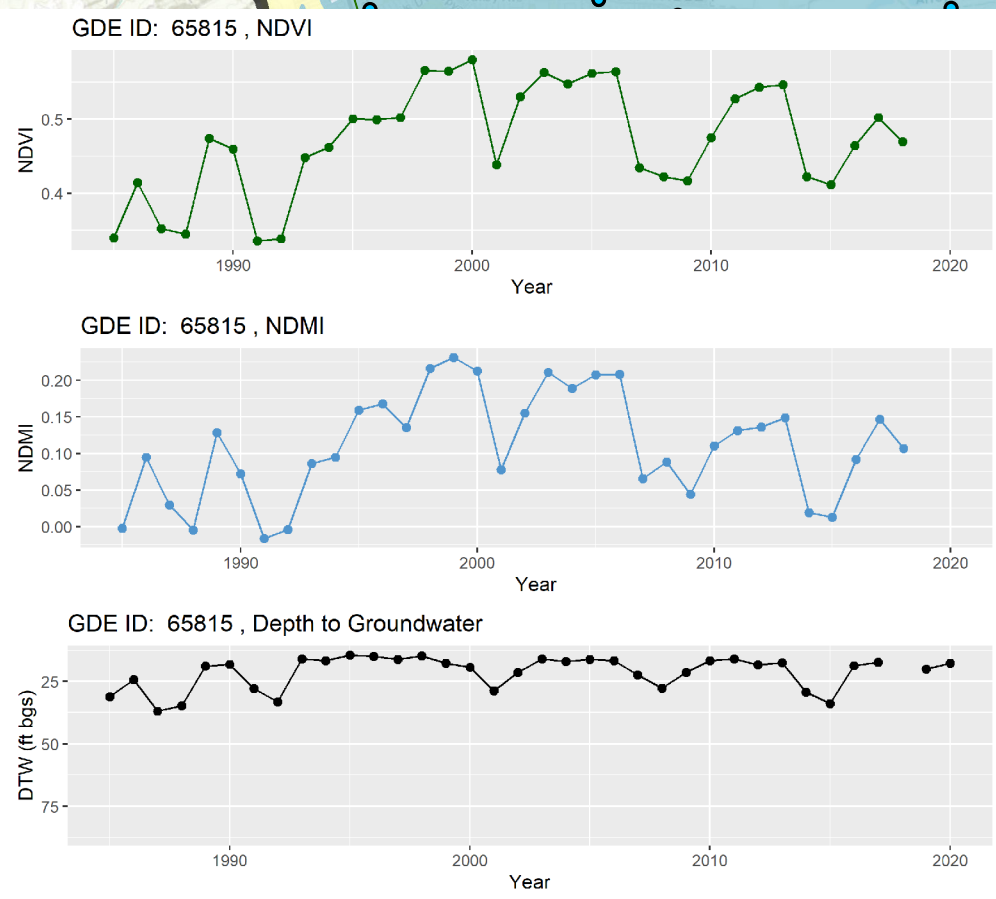
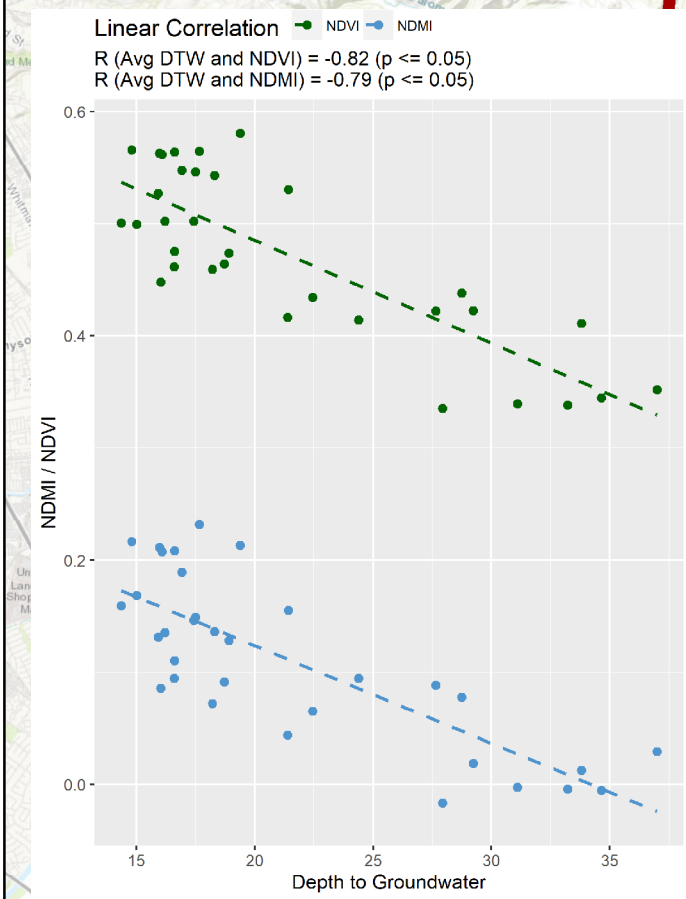
Figure 2
Retained and Removed GDEs Based
on Depth to Groundwater Analysis

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

ABBREVIATIONS
DTW = Depth to Groundwater
ft bgs = feet below ground surface
GDE= Groundwater Dependent Ecosystem
km = kilometer
Min = Minimum

LEGEND

- Upper Aquifer Well
- 1 km Buffer of Well
- GDE Polygon Example
- Springtown Alkali Sink
- Potential GDE Polygon**
 - Min DTW <= 30 ft bgs
 - Min DTW > 30 ft bgs
 - No 2015-2020 DTW Available
- Plan Area**
 - Fringe Management Area
 - Main Basin Management Area
 - Upland Management Area
 - Zone 7 Service Area
 - Livermore Valley Groundwater Basin



GDE Polygon ID: 65815
Riparian Mixed Hardwood

LIVERMORE-AMADOR VALLEY ZONE 7 WATER SUPPLY - FLOOD PROTECTION

0 2.5 5 Miles

DATE: August 13, 2021

FILE: \\ekiconsult.com\go\Gis\C00065.00\Map\2021\08\Memo Figure 3 Example Plot.mxd

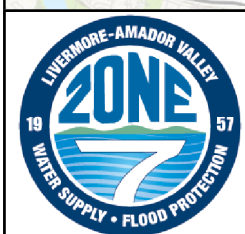
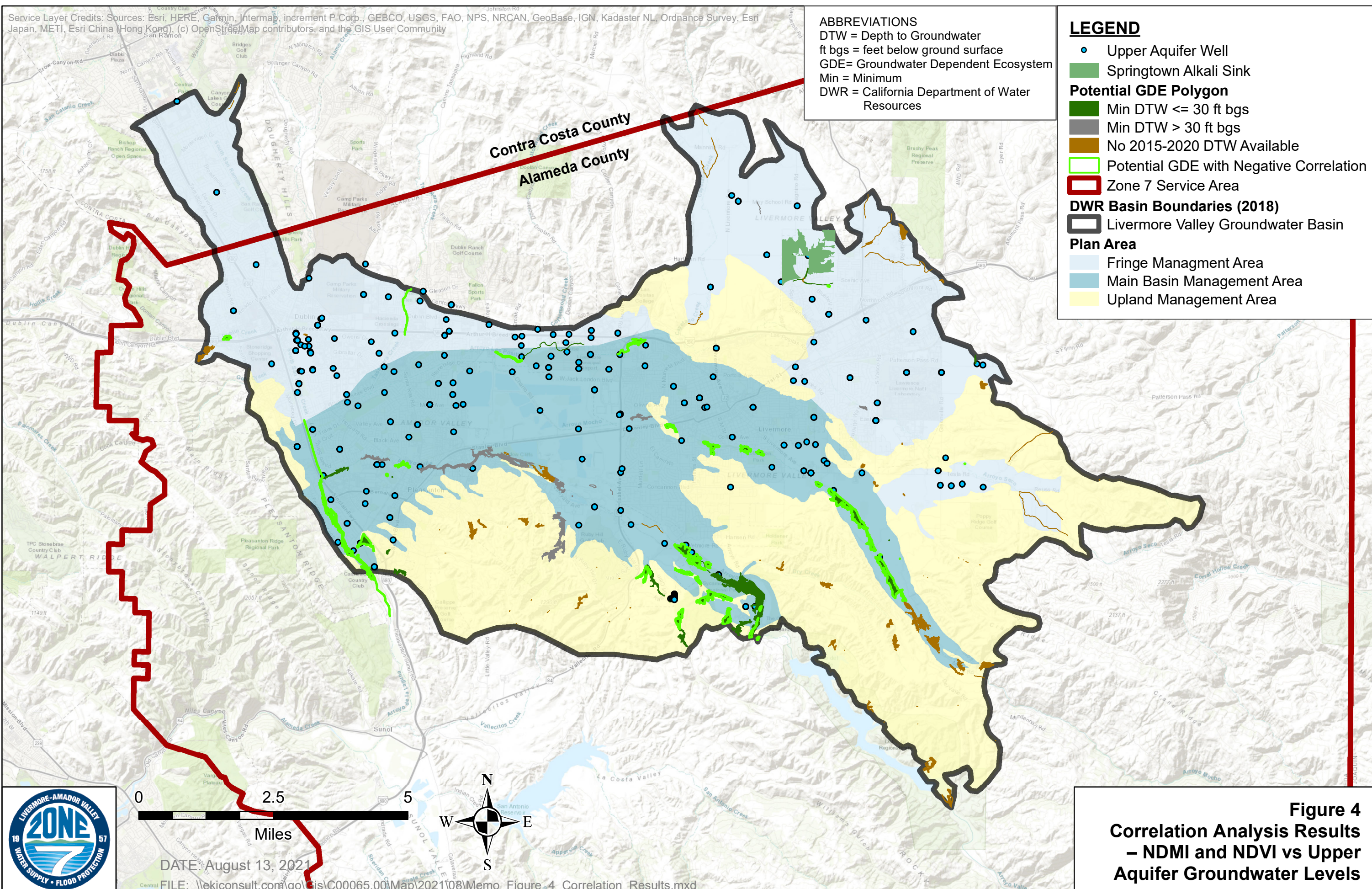
Figure 3
Example Correlation Plot – NDVI and
NDVI vs Shallow Groundwater Levels

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

ABBREVIATIONS
DTW = Depth to Groundwater
ft bgs = feet below ground surface
GDE= Groundwater Dependent Ecosystem
Min = Minimum
DWR = California Department of Water Resources

LEGEND

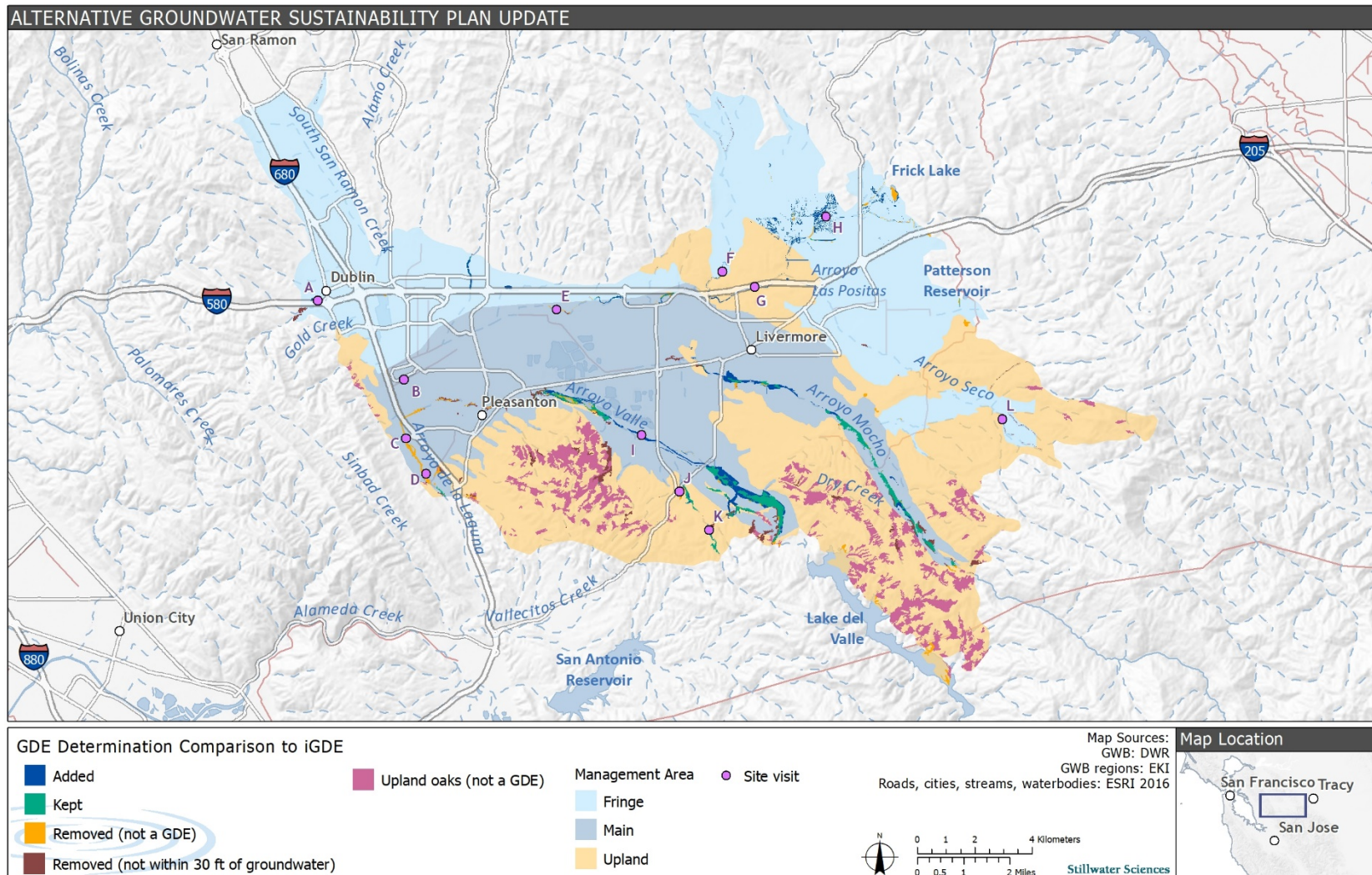
- Upper Aquifer Well
- Springtown Alkali Sink
- Potential GDE Polygon**
 - Min DTW <= 30 ft bgs
 - Min DTW > 30 ft bgs
 - No 2015-2020 DTW Available
 - Potential GDE with Negative Correlation
- Zone 7 Service Area
- DWR Basin Boundaries (2018)**
 - Livermore Valley Groundwater Basin
- Plan Area**
 - Fringe Management Area
 - Main Basin Management Area
 - Upland Management Area

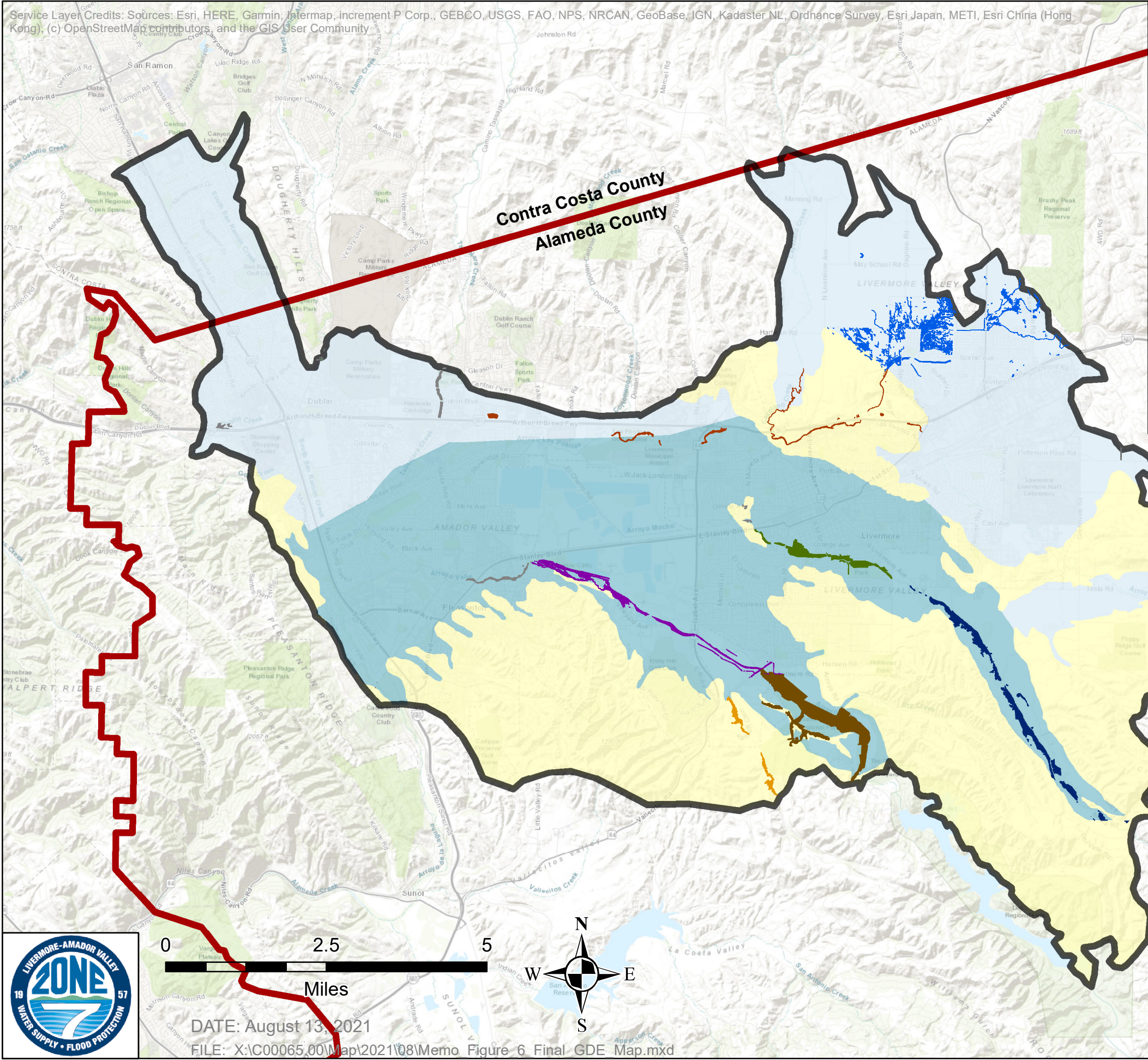


DATE: August 13, 2021
FILE: \\ekiconsult.com\gis\C00065.00\Map\2021\08\Memo Figure 4 Correlation Results.mxd

Figure 4
Correlation Analysis Results
– NDMI and NDVI vs Upper
Aquifer Groundwater Levels

Figure 5. Comparison of the Likely GDE Map (Figure 6) with the NCCAG Dataset (Figure 1)





LEGEND

Likely GDEs

- Arroyo Las Positas - Mixed Vegetation
- Arroyo Mocho - Riparian Mixed Hardwood & Sycamore
- Arroyo Mocho - Valley Oak
- Arroyo Valle - Riparian Mixed Hardwood
- Arroyo Valle - Sycamore Grove
- Springtown Alkali Sink
- Upland - Riparian Mixed Hardwood
- Others
- Potential GDEs to be Further Evaluated

Zone 7 Service Area

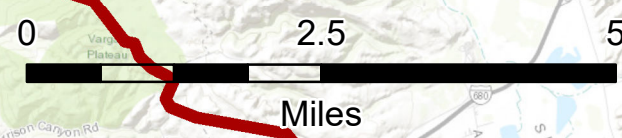
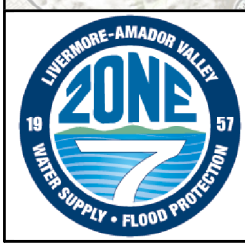
DWR Basin Boundaries (2018)

- Livermore Valley Groundwater Basin

Plan Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area

ABBREVIATIONS
GDE= Groundwater Dependent Ecosystem
DWR = California Department of Water Resources



DATE: August 13, 2021
FILE: X:\C00065_00\Map\2021\08\Memo Figure 6 Final GDE Map.mxd

Figure 6
Likely GDEs in the Livermore Valley Groundwater Basin

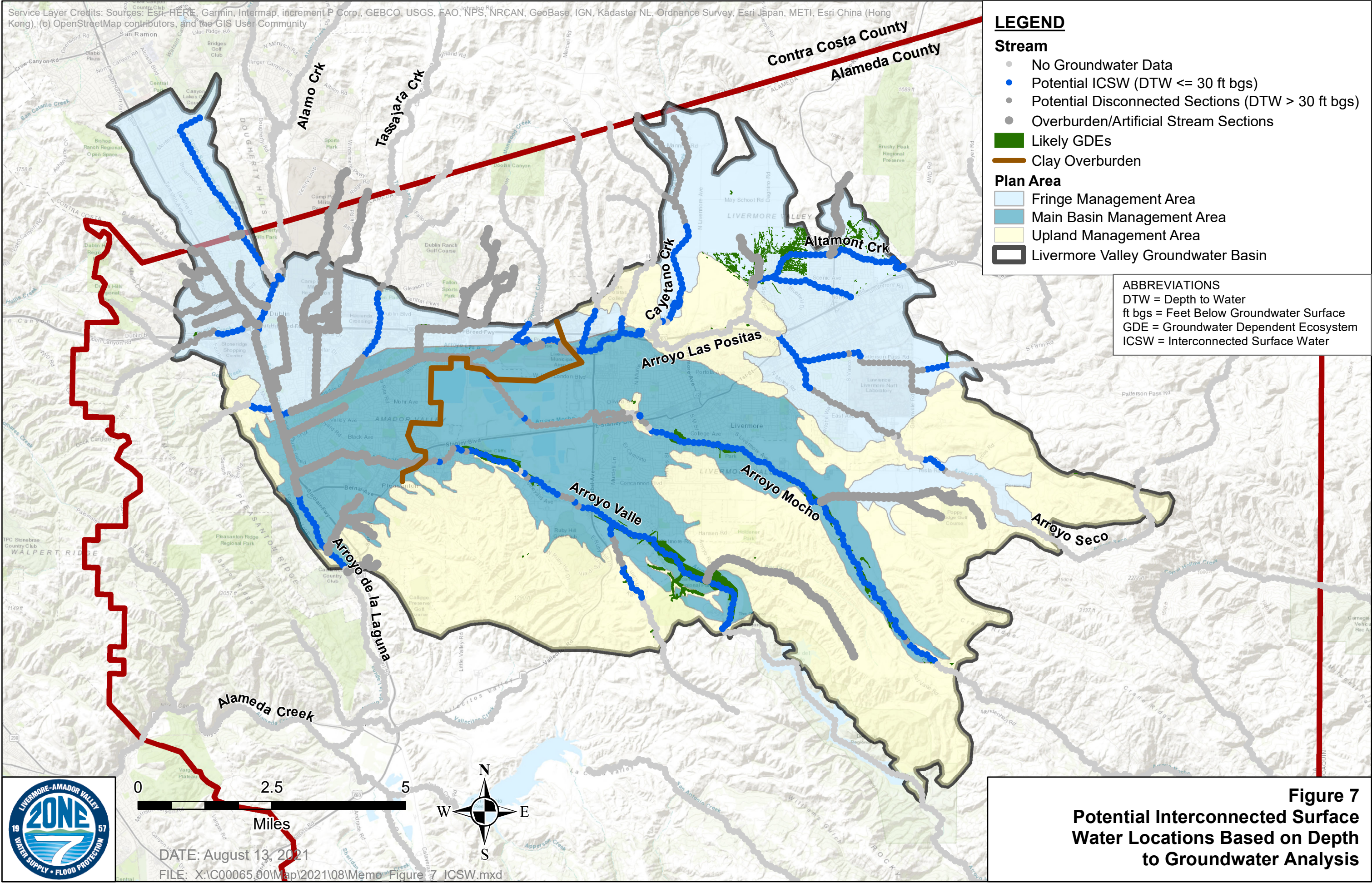
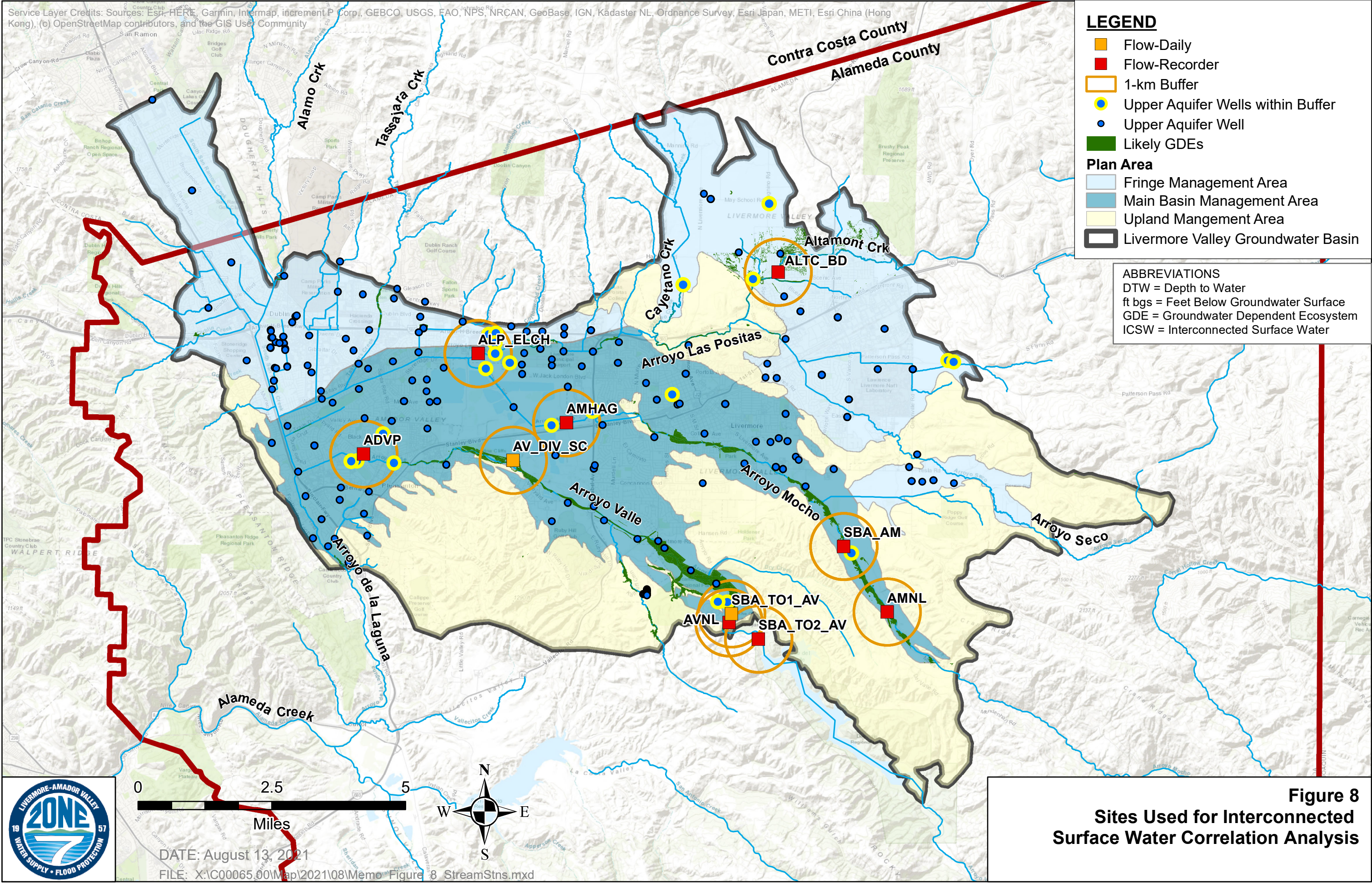
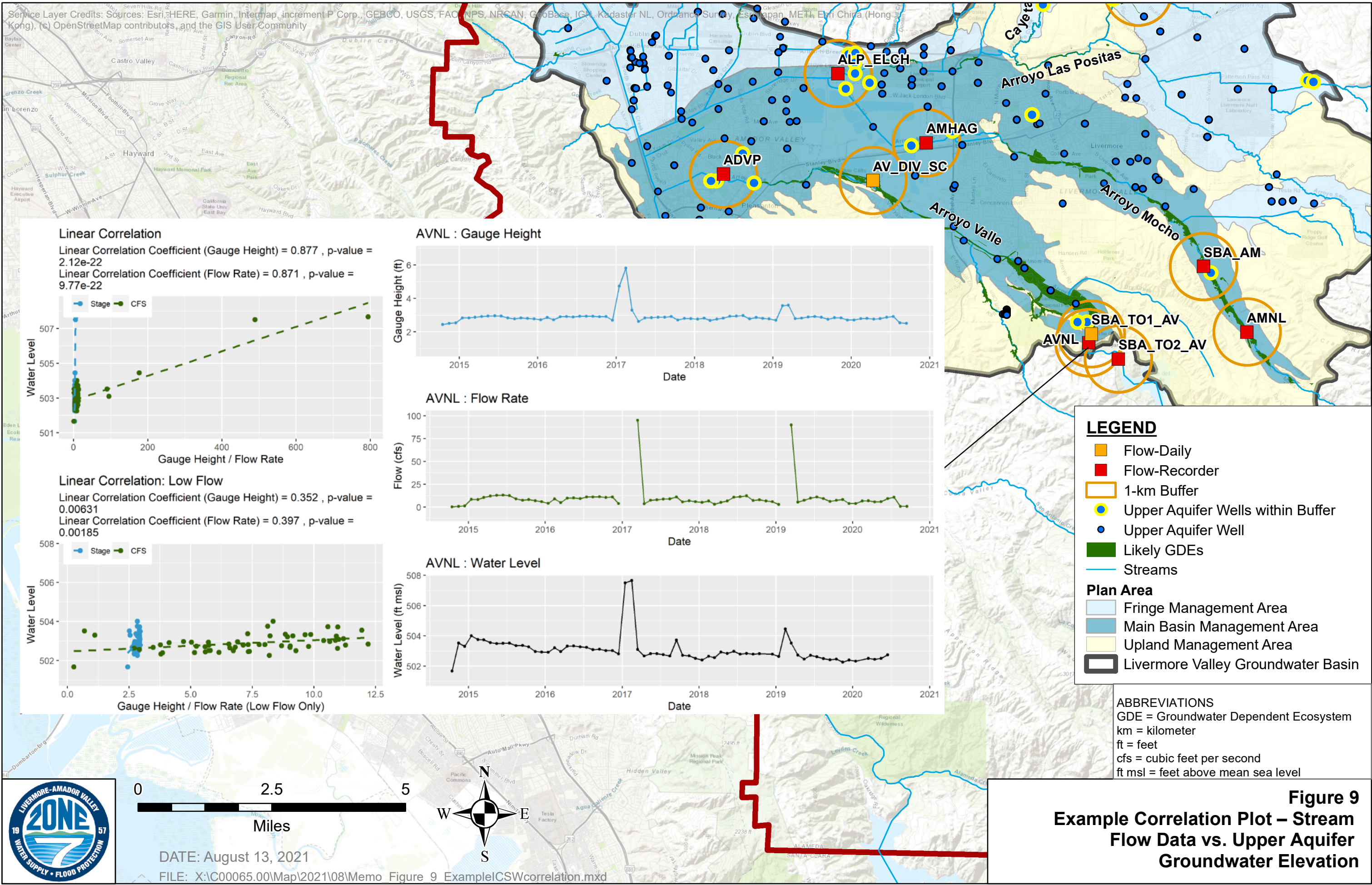


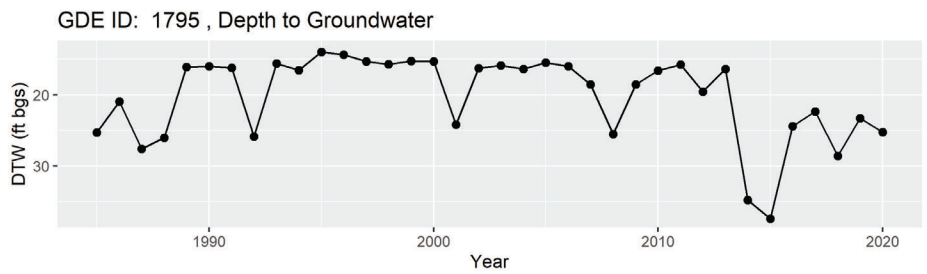
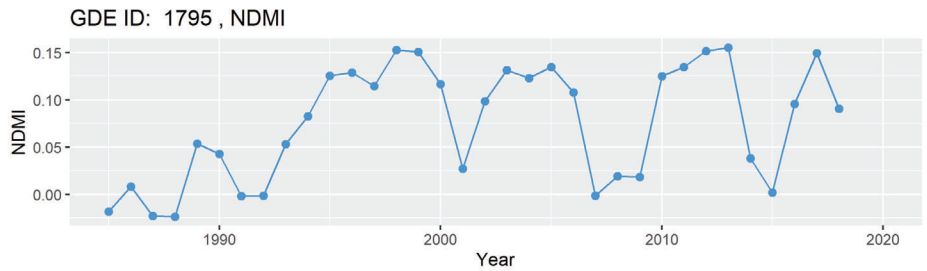
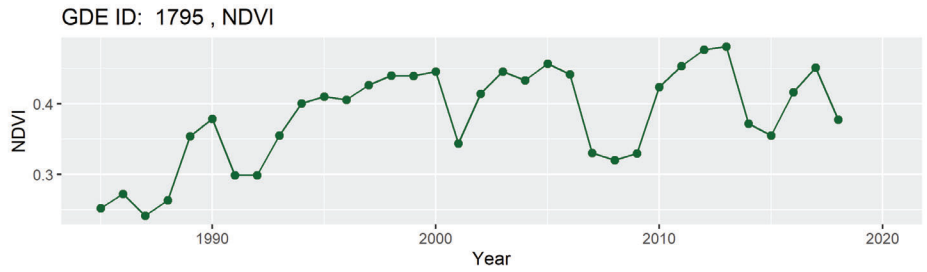
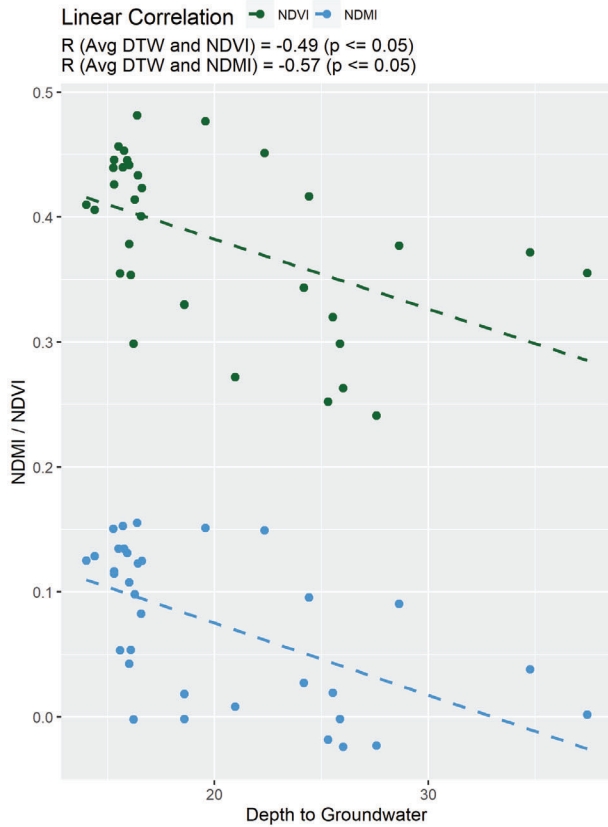
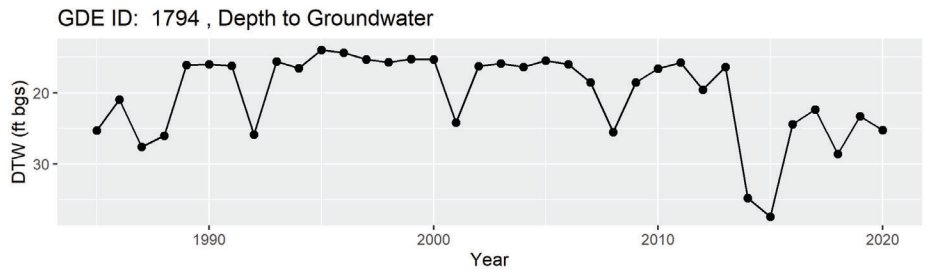
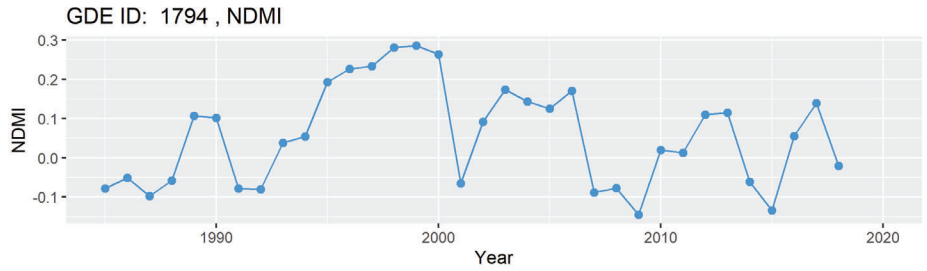
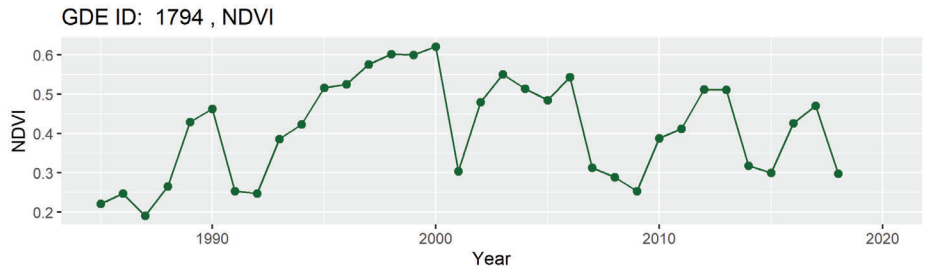
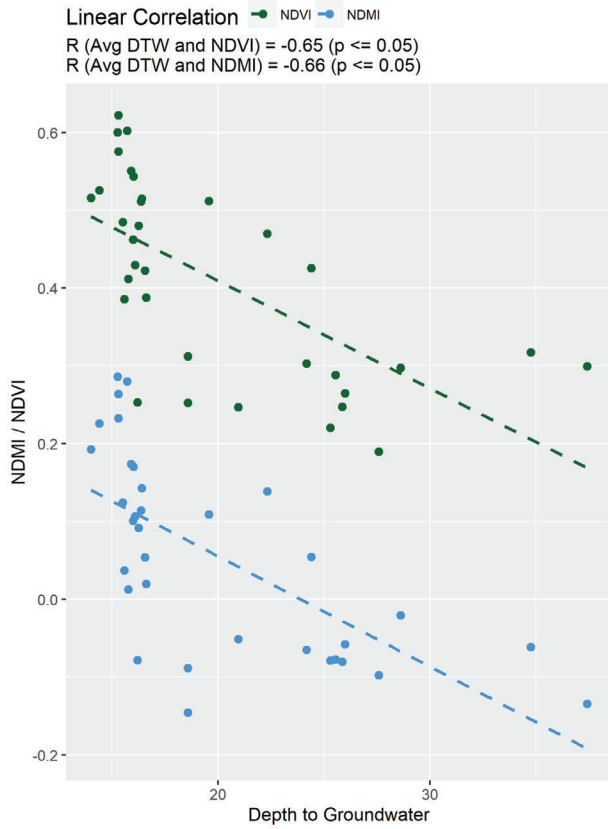
Figure 7
Potential Interconnected Surface
Water Locations Based on Depth
to Groundwater Analysis

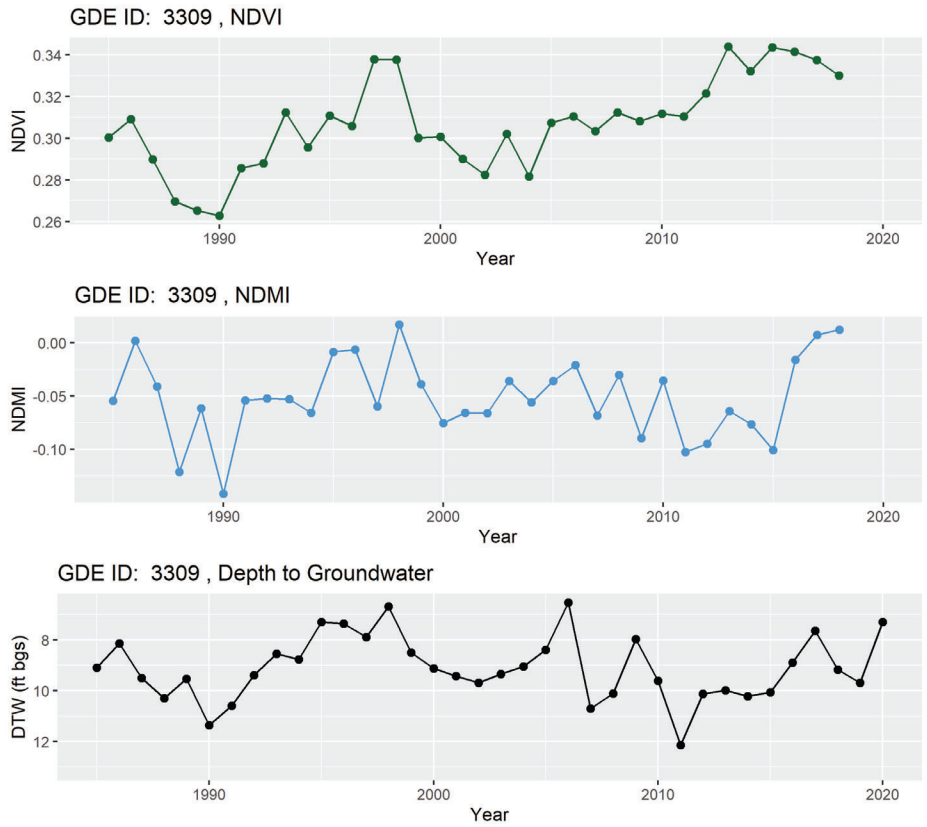
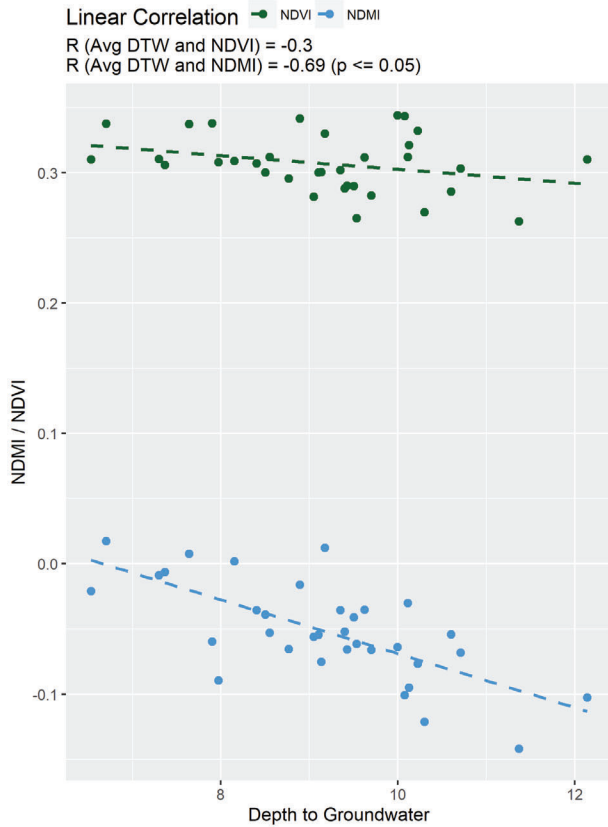
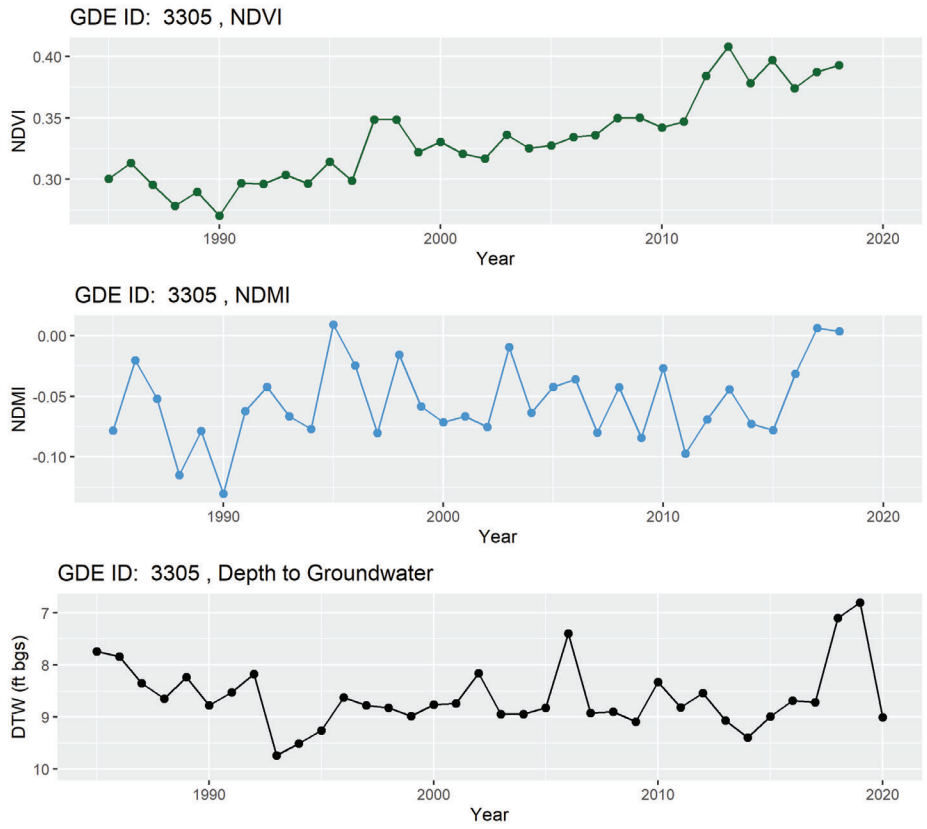
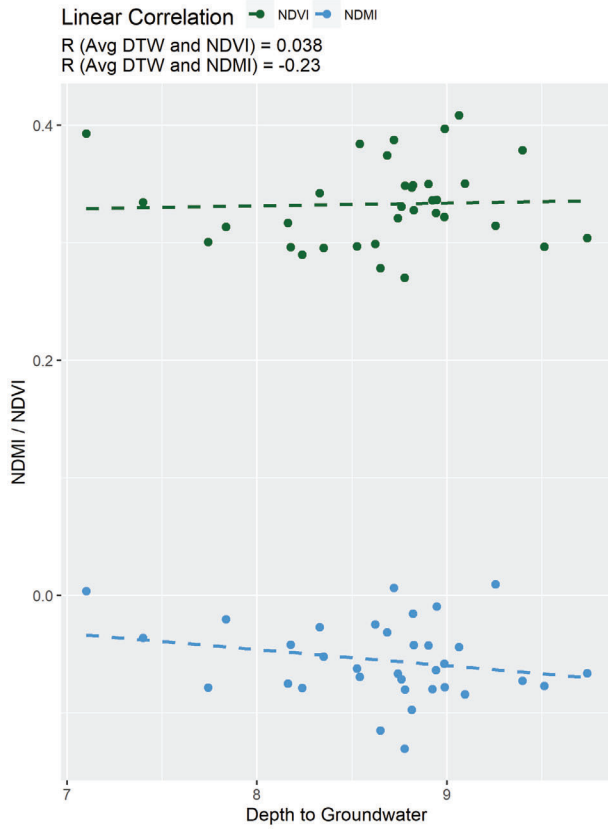


Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



**Attachment A: Time Series Data and Correlation Plots
by GDE Polygon**

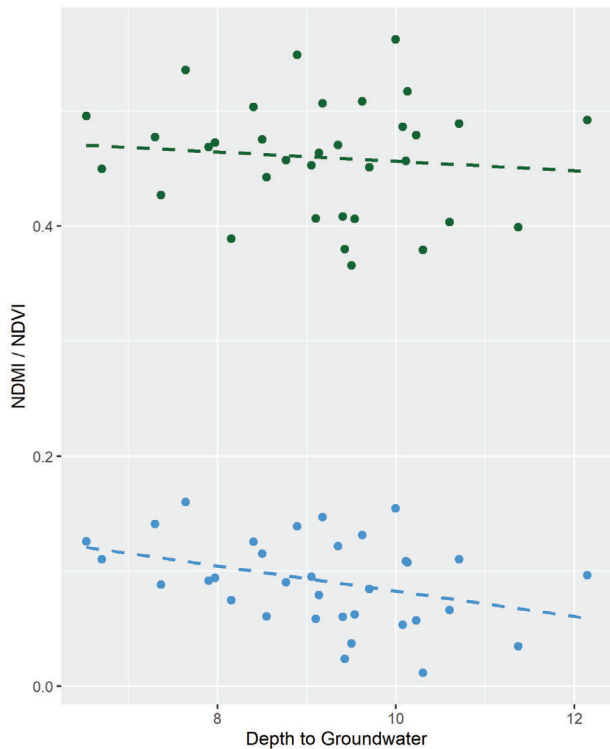




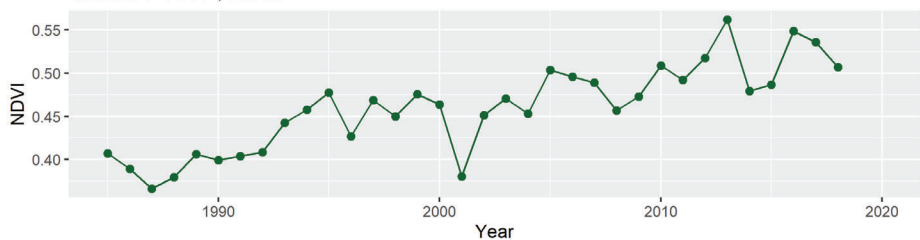
Linear Correlation

● NDVI
 ● NDMI

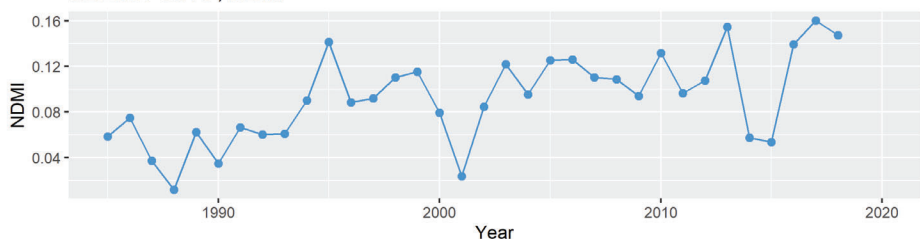
$R(\text{Avg DTW and NDVI}) = -0.1$
 $R(\text{Avg DTW and NDMI}) = -0.36 \text{ (} p \leq 0.05 \text{)}$



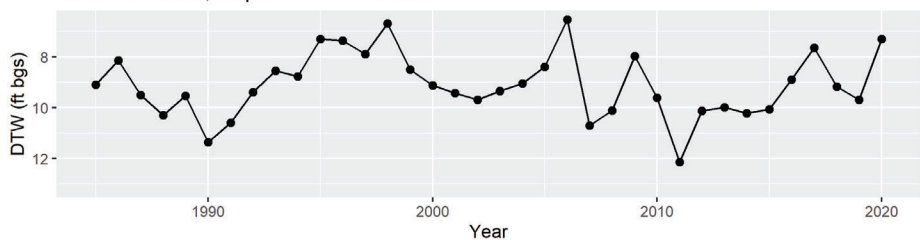
GDE ID: 3310 , NDVI



GDE ID: 3310 , NDMI



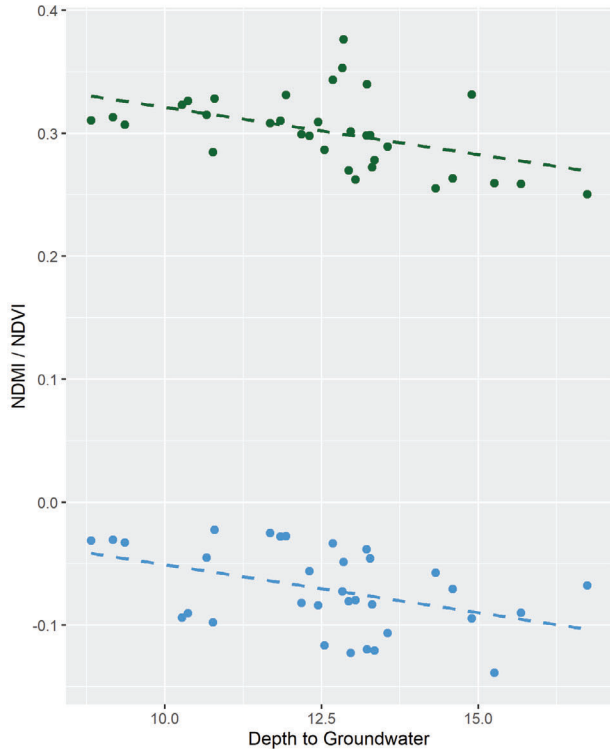
GDE ID: 3310 , Depth to Groundwater



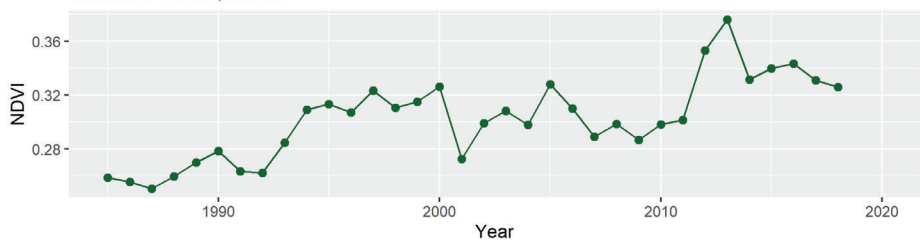
Linear Correlation

● NDVI
 ● NDMI

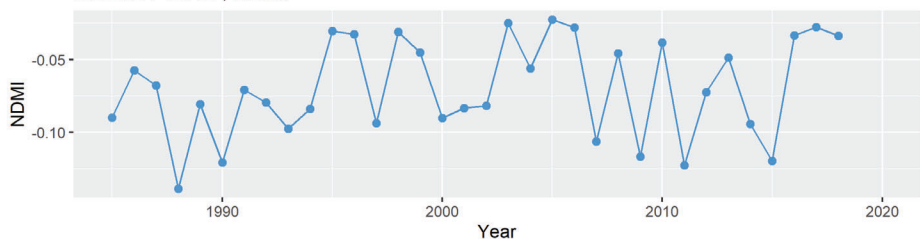
$R(\text{Avg DTW and NDVI}) = -0.46 \text{ (} p \leq 0.05 \text{)}$
 $R(\text{Avg DTW and NDMI}) = -0.43 \text{ (} p \leq 0.05 \text{)}$



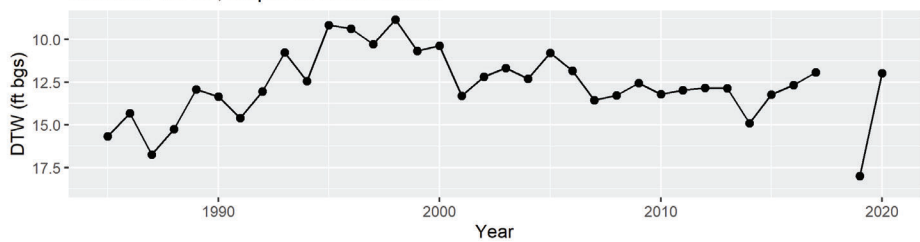
GDE ID: 3312 , NDVI

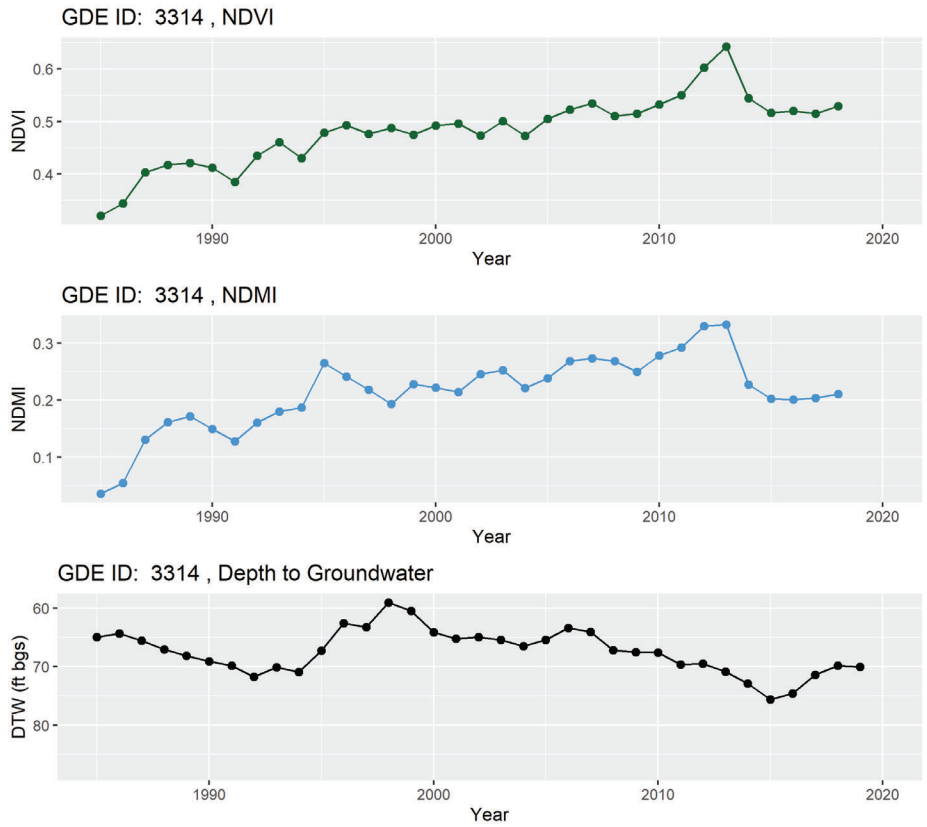
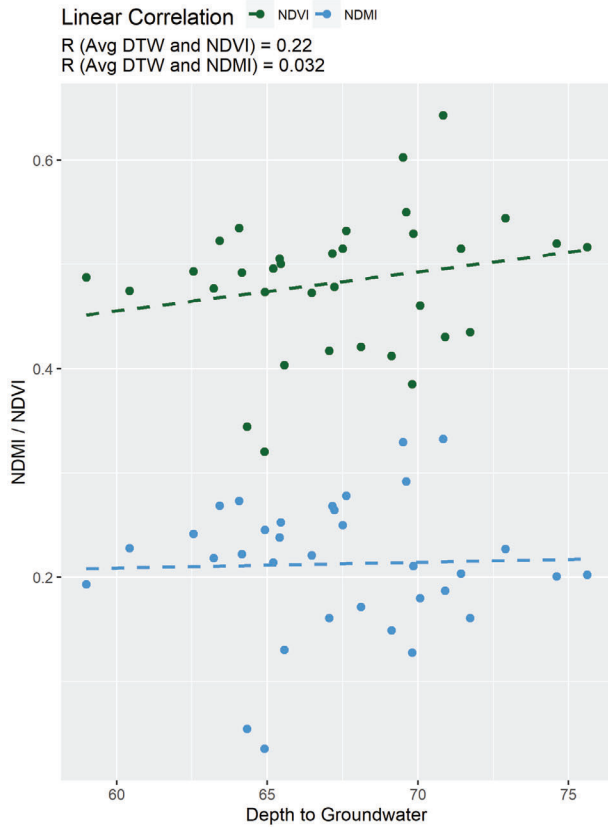
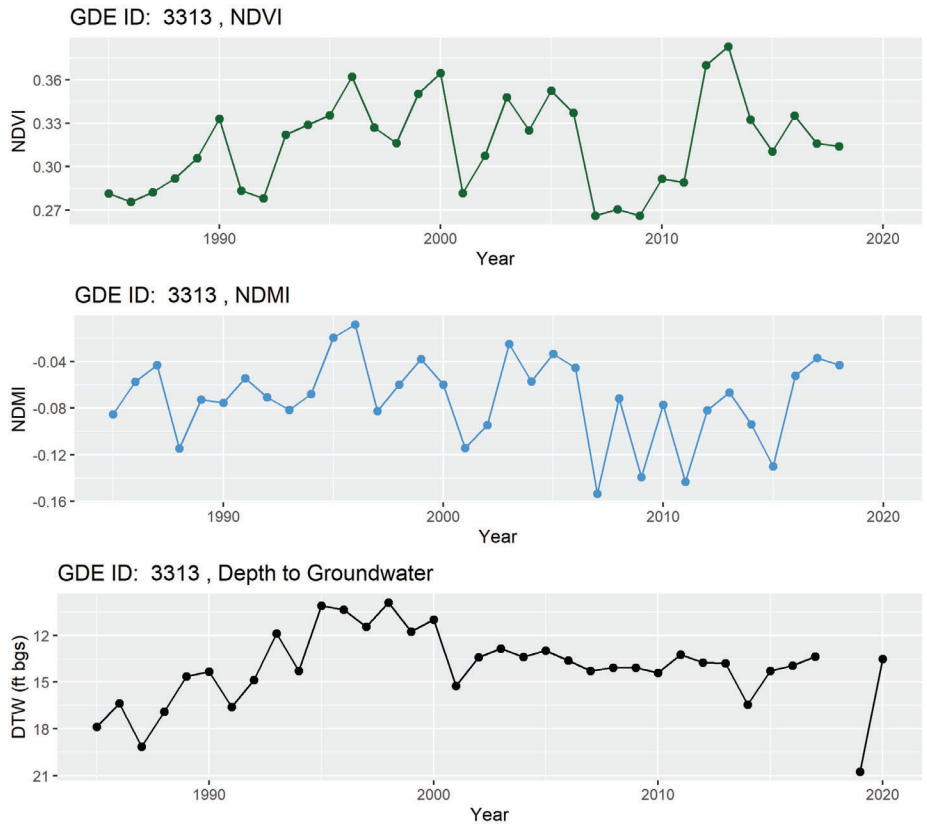
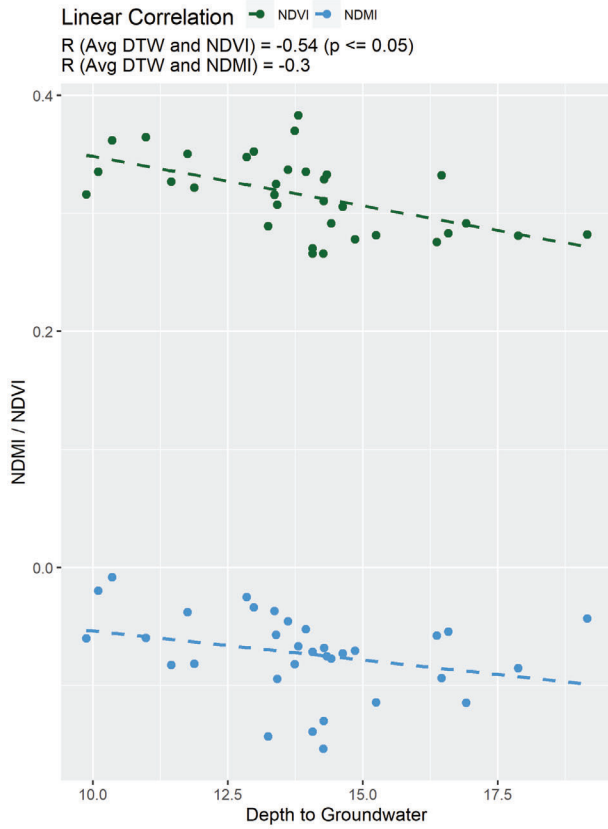


GDE ID: 3312 , NDMI

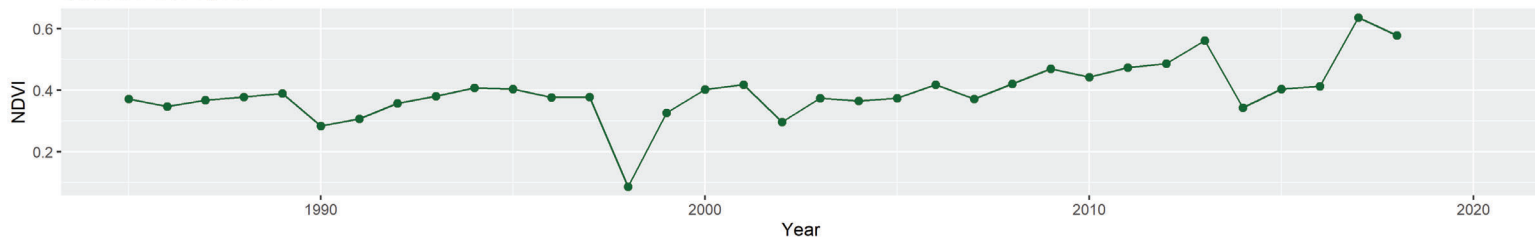


GDE ID: 3312 , Depth to Groundwater

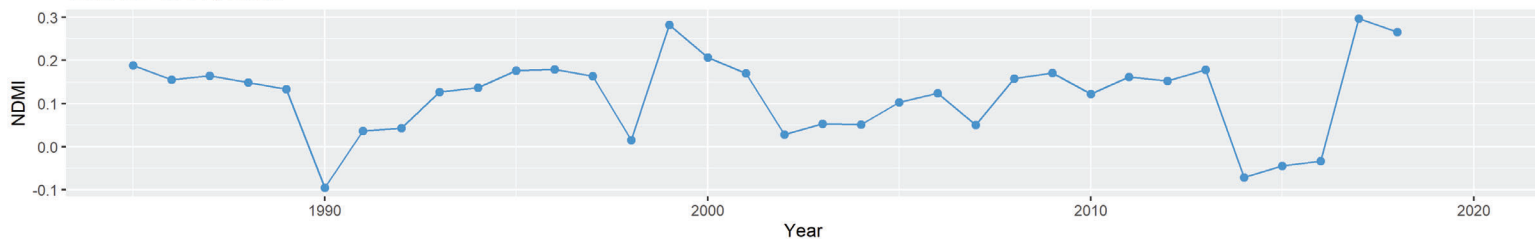




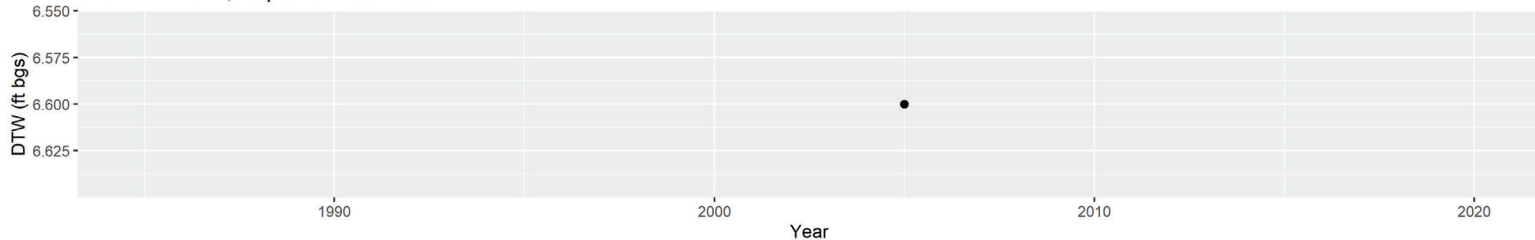
GDE ID: 8551 , NDVI



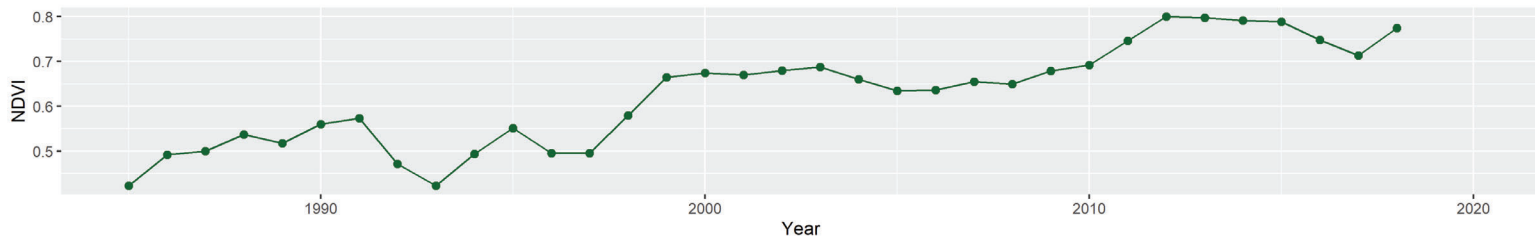
GDE ID: 8551 , NDMI



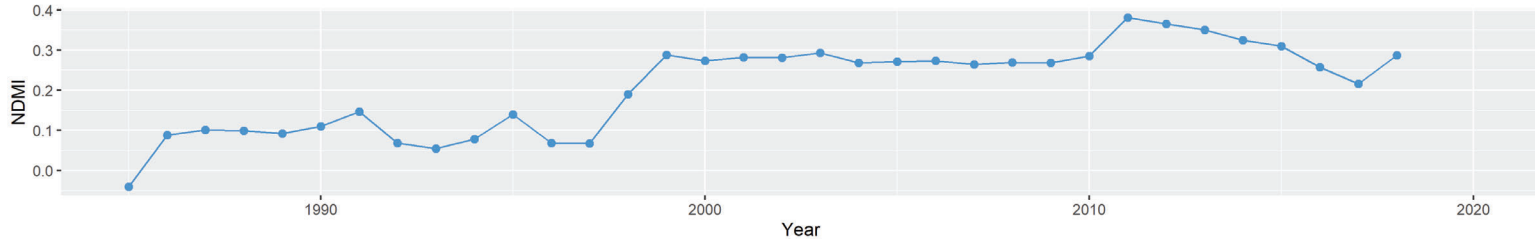
GDE ID: 8551 , Depth to Groundwater



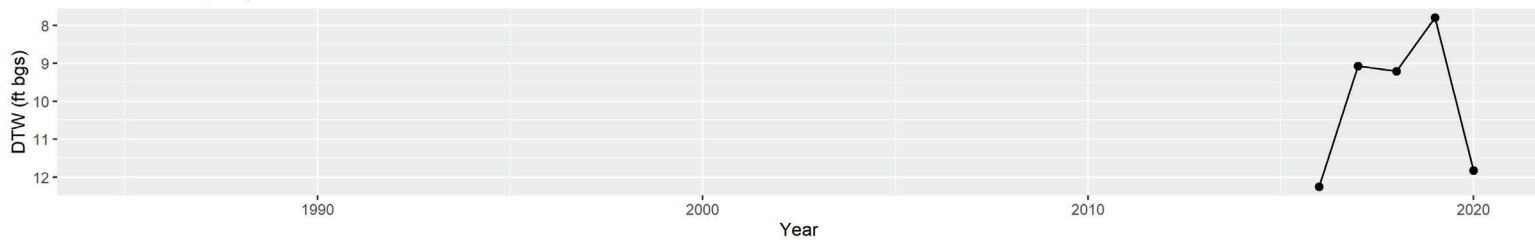
GDE ID: 8572 , NDVI

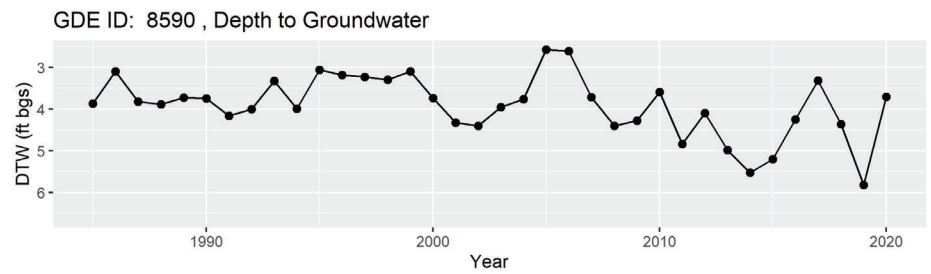
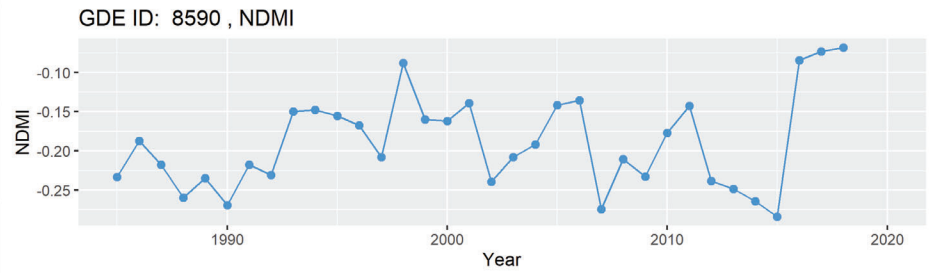
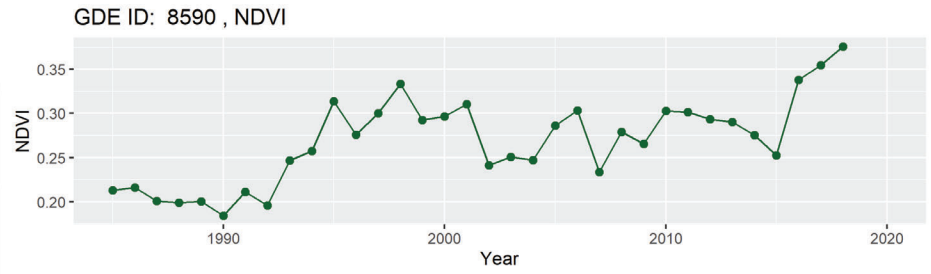
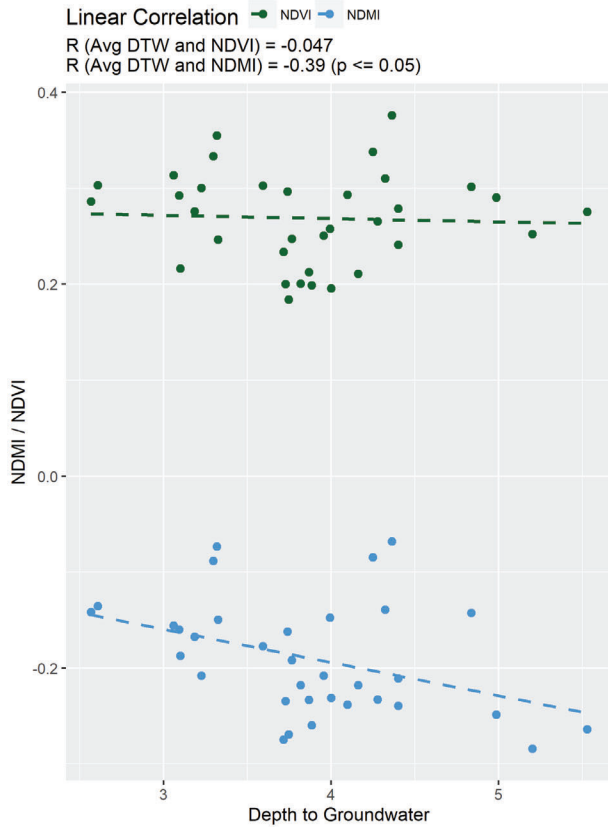
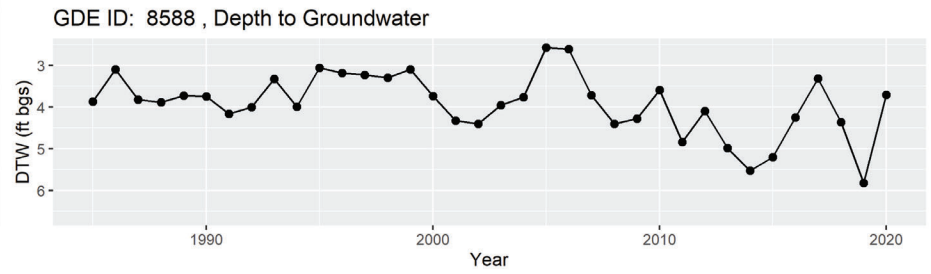
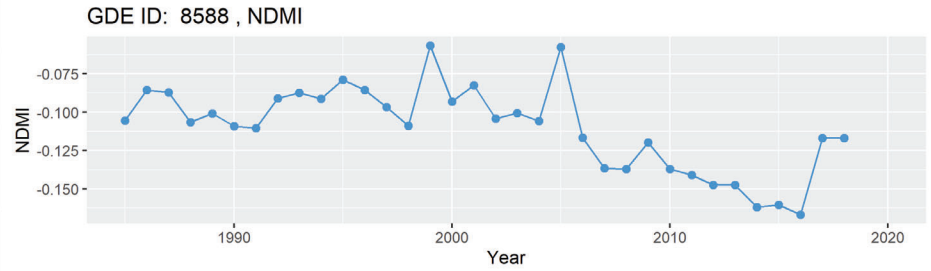
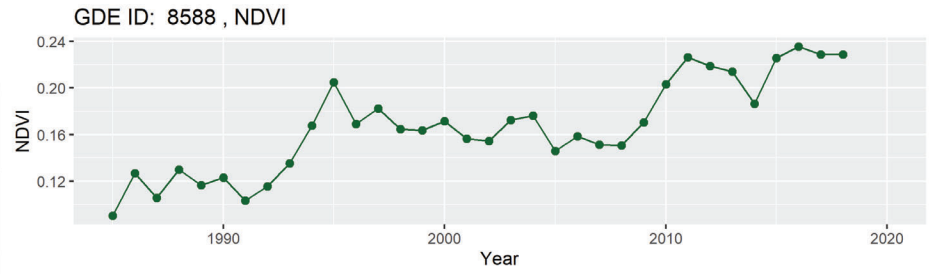
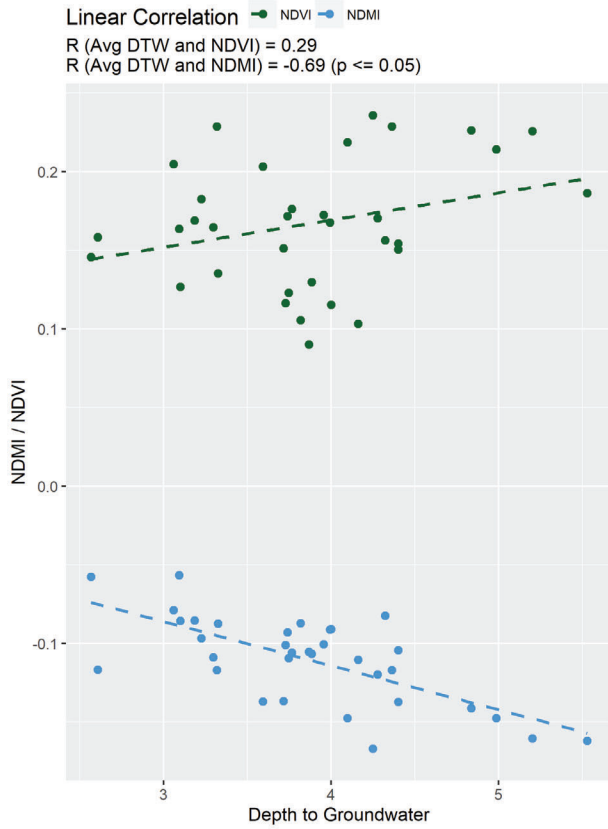


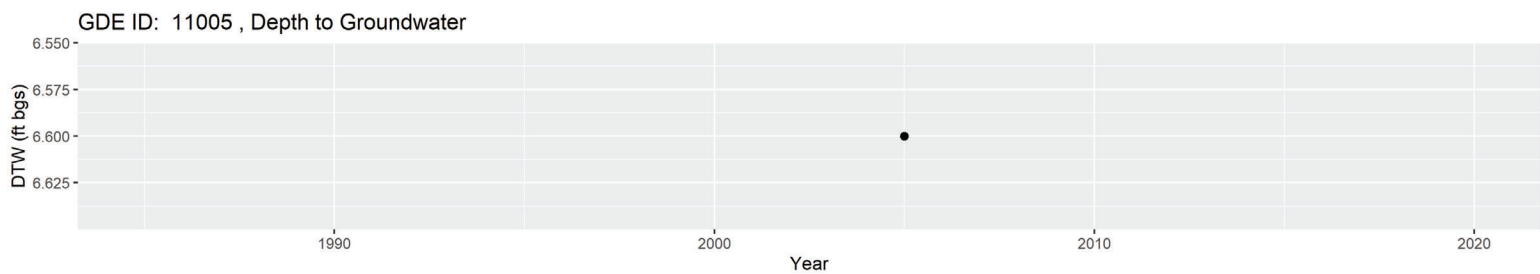
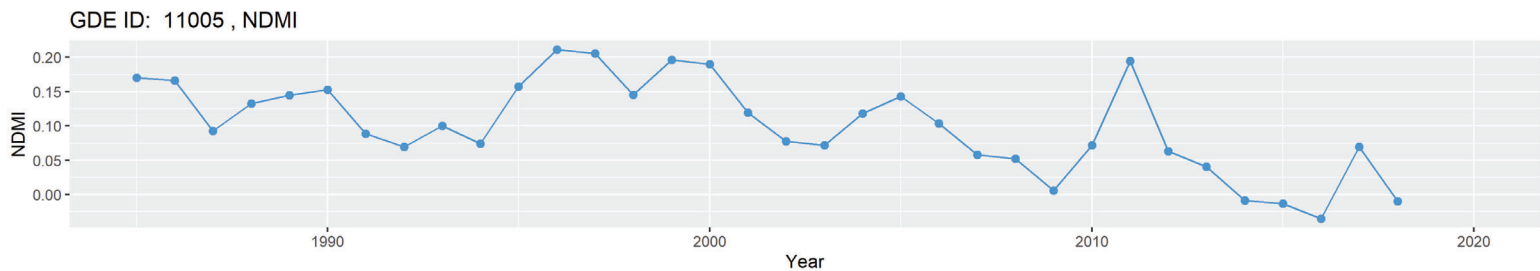
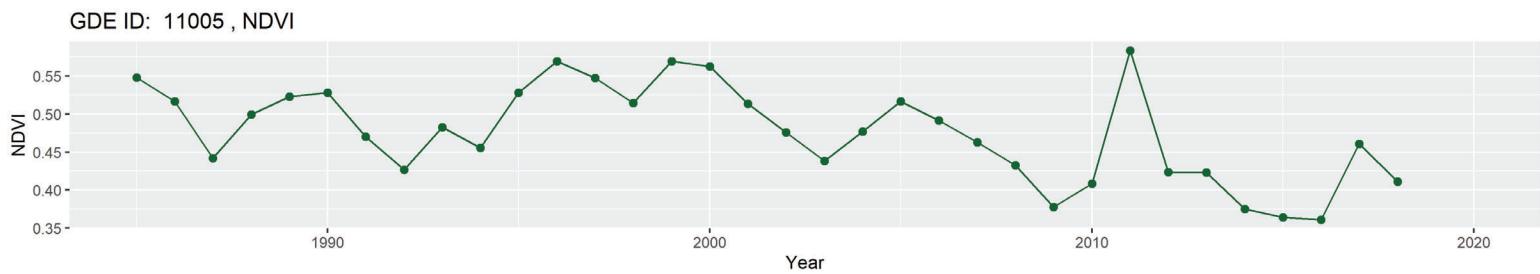
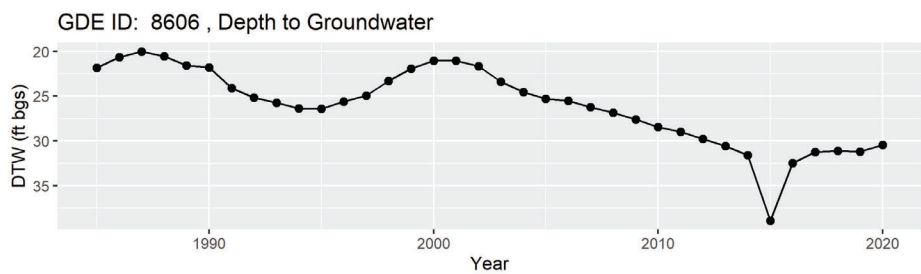
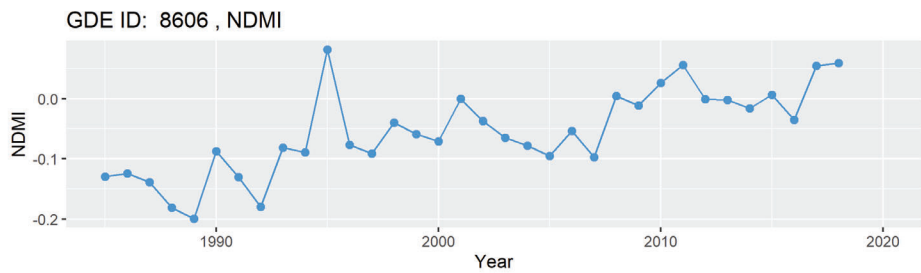
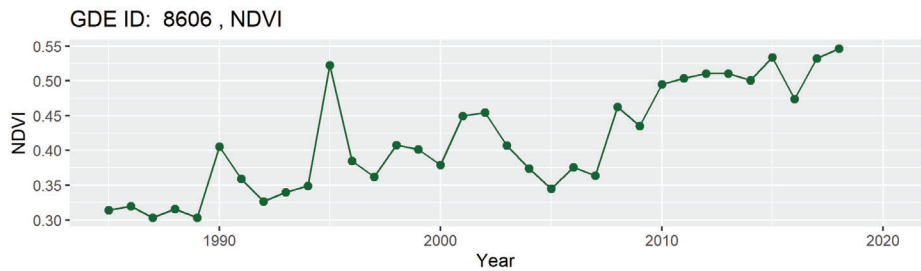
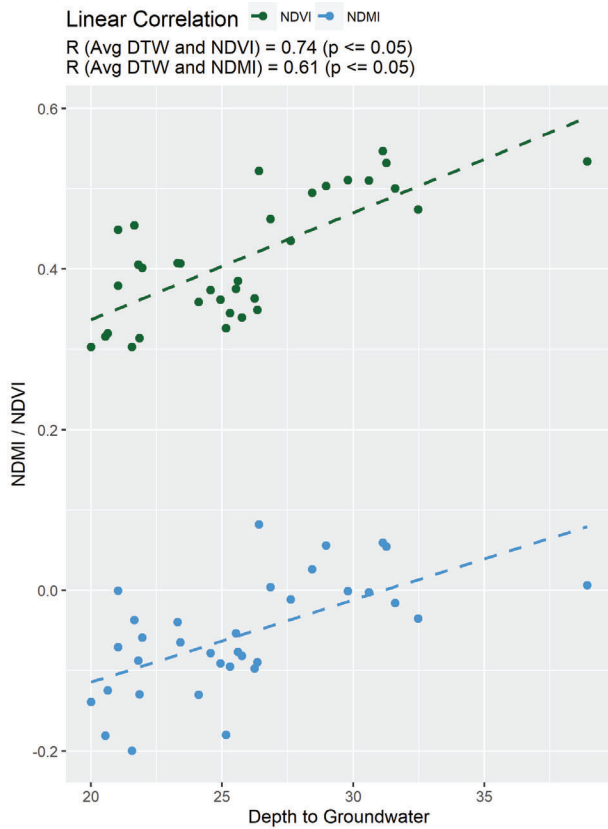
GDE ID: 8572 , NDMI



GDE ID: 8572 , Depth to Groundwater



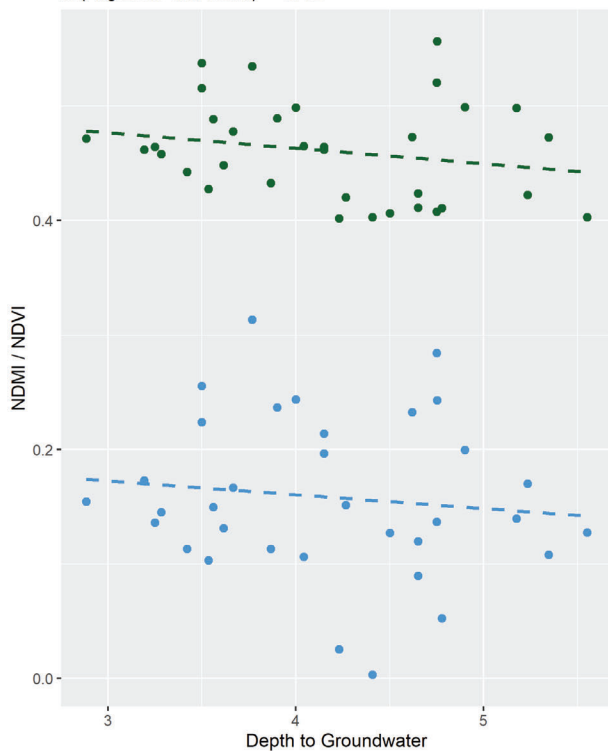




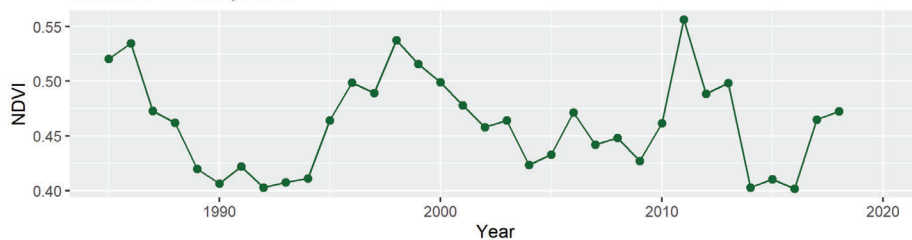
Linear Correlation

R (Avg DTW and NDVI) = -0.22

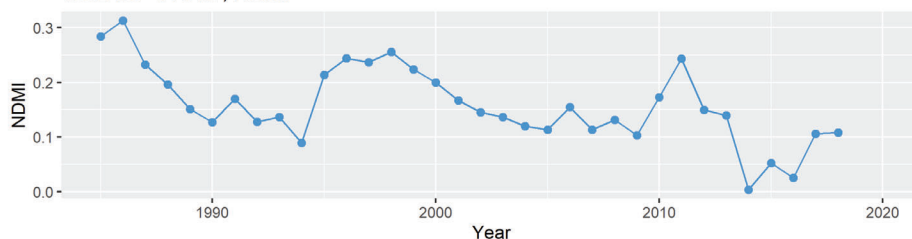
R (Avg DTW and NDMI) = -0.12



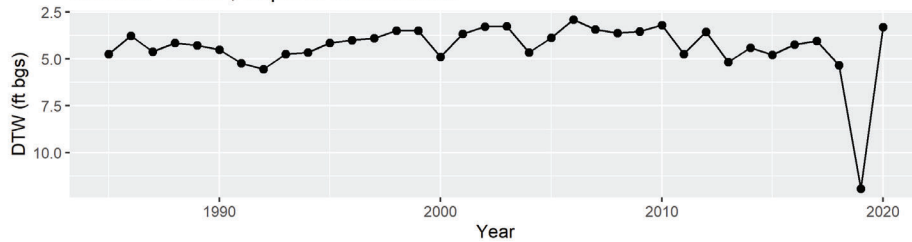
GDE ID: 11013 , NDVI



GDE ID: 11013 , NDMI



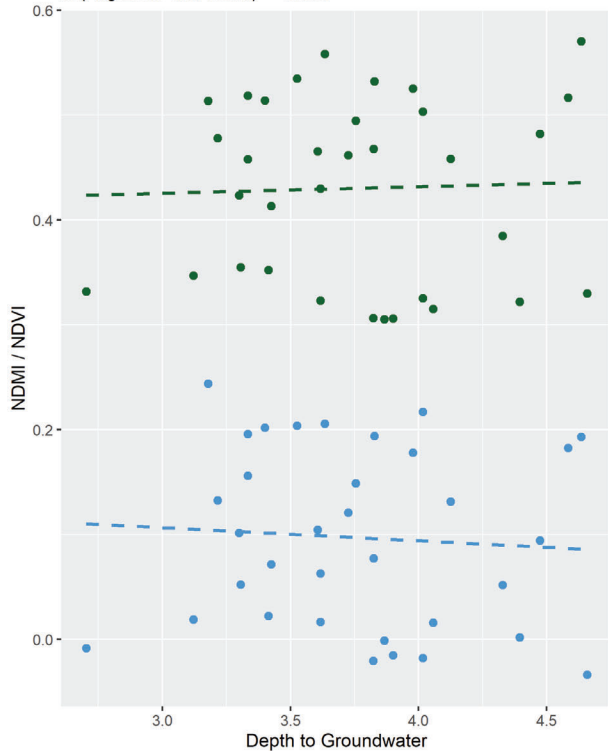
GDE ID: 11013 , Depth to Groundwater



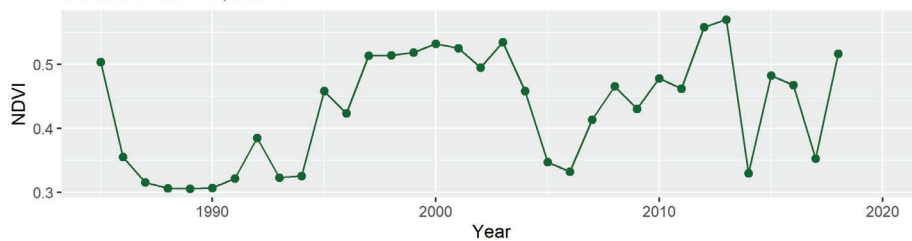
Linear Correlation

R (Avg DTW and NDVI) = 0.034

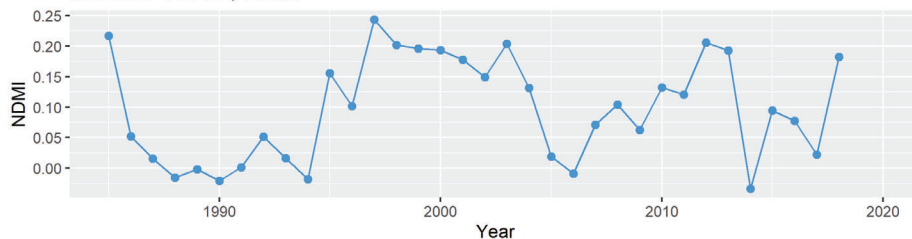
R (Avg DTW and NDMI) = -0.069



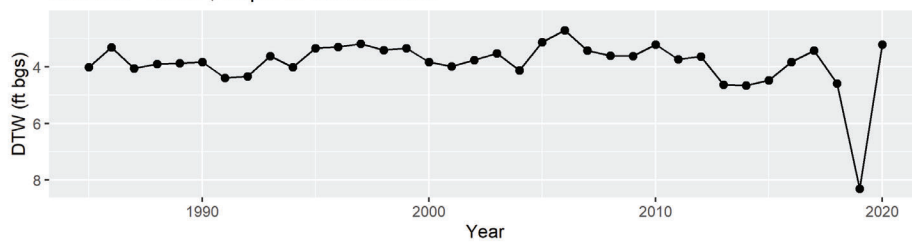
GDE ID: 11015 , NDVI



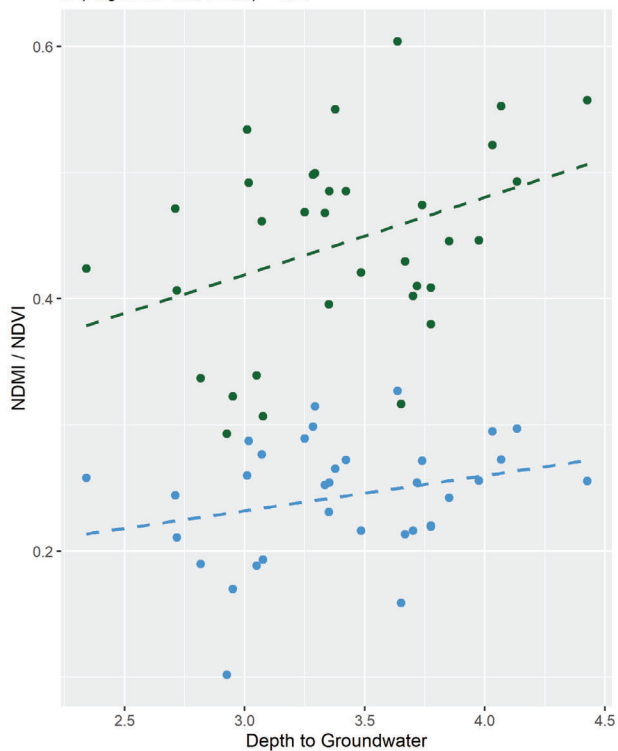
GDE ID: 11015 , NDMI



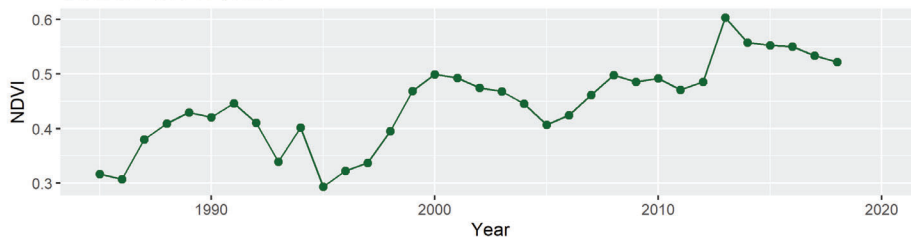
GDE ID: 11015 , Depth to Groundwater



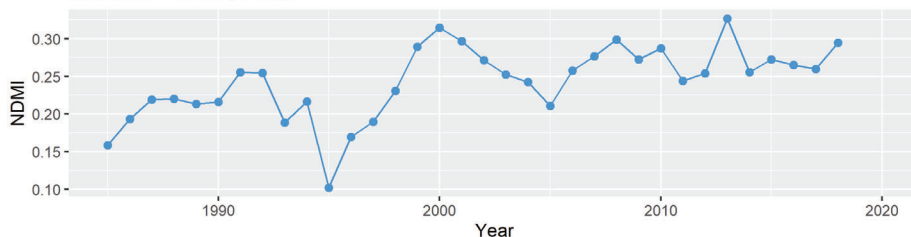
Linear Correlation ● NDVI ● NDMI
R (Avg DTW and NDVI) = 0.37 (p <= 0.05)
R (Avg DTW and NDMI) = 0.27



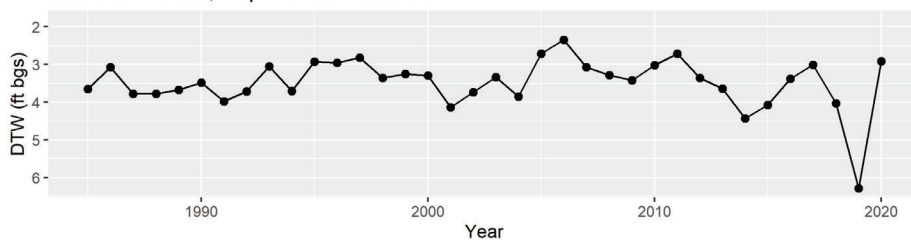
GDE ID: 11018 , NDVI



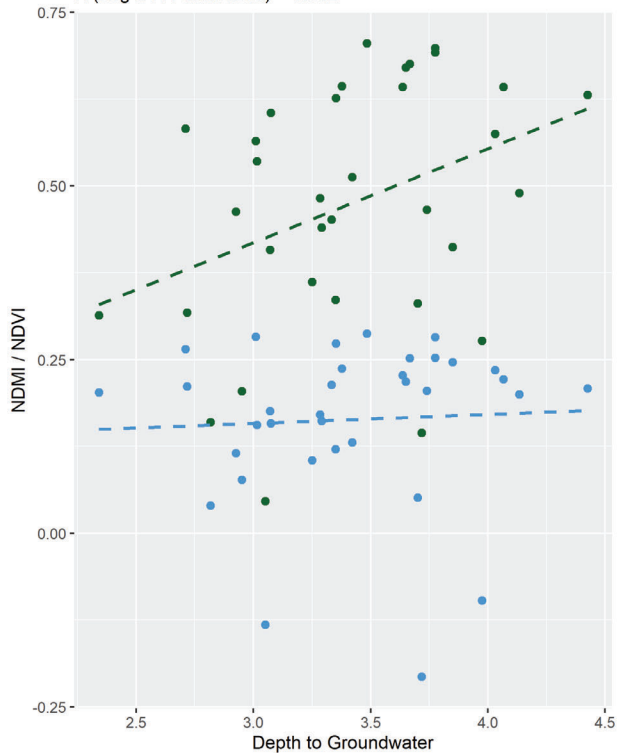
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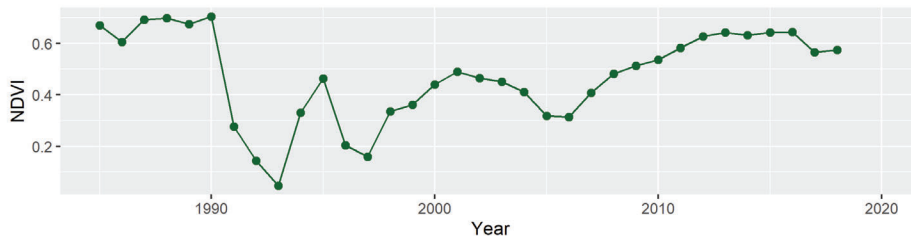
GDE ID: 11018 , Depth to Groundwater



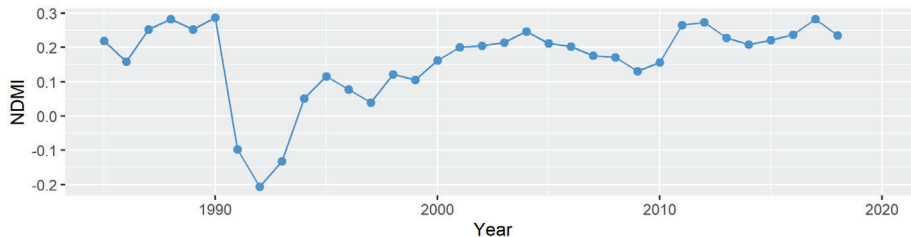
Linear Correlation ● NDVI ● NDMI
R (Avg DTW and NDVI) = 0.36 (p <= 0.05)
R (Avg DTW and NDMI) = 0.052



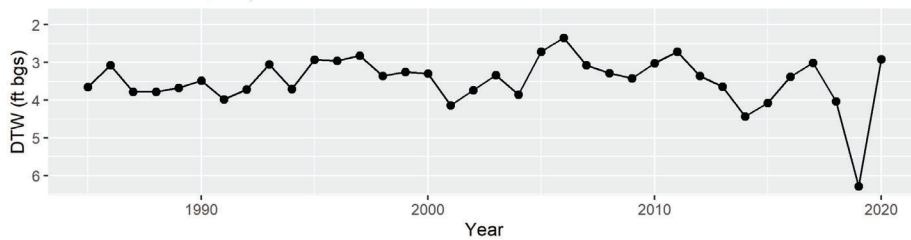
GDE ID: 11020 , NDVI

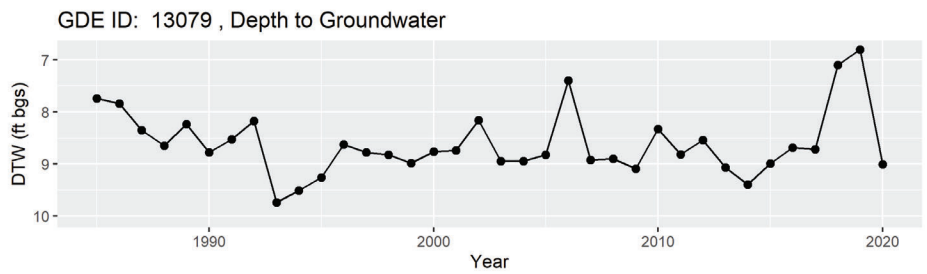
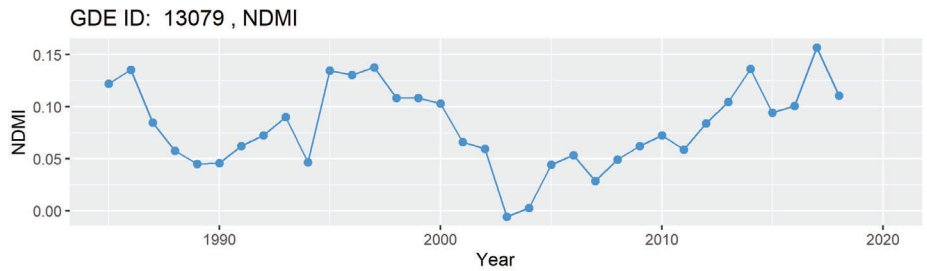
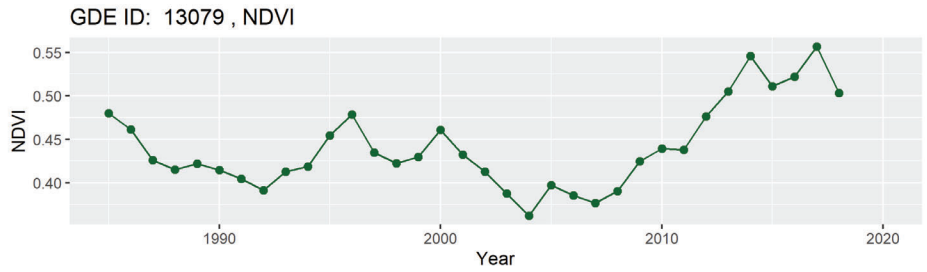
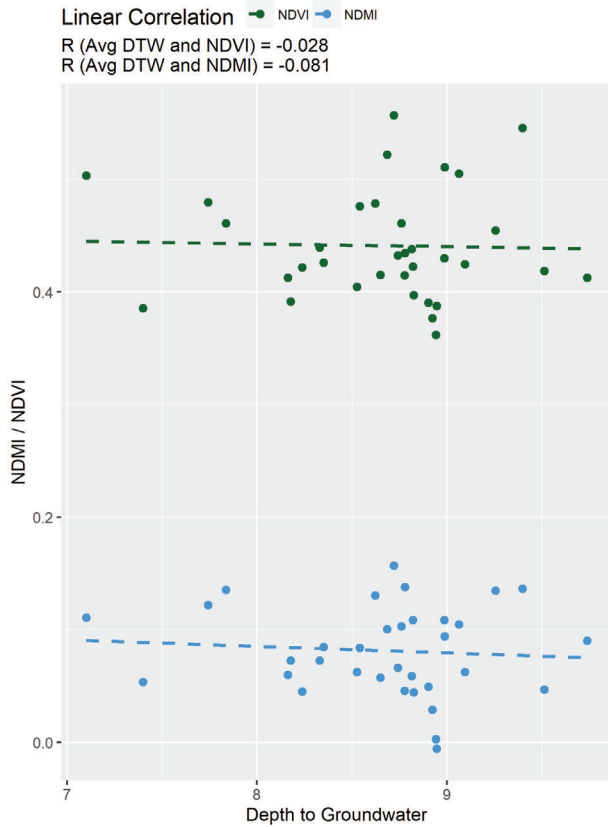
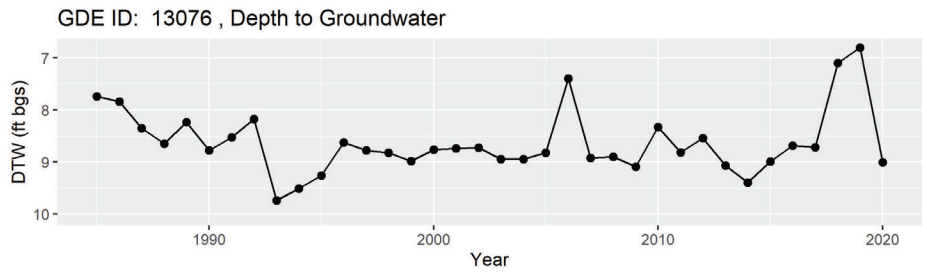
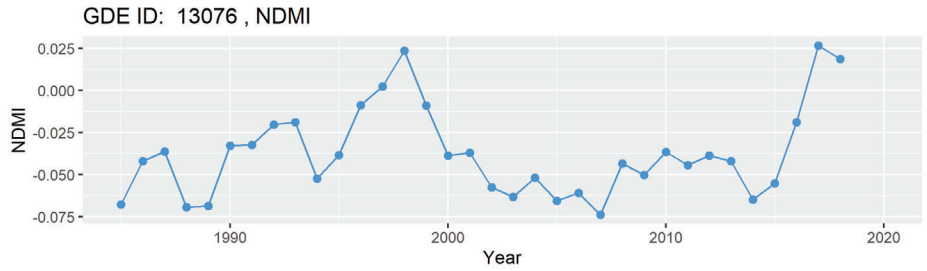
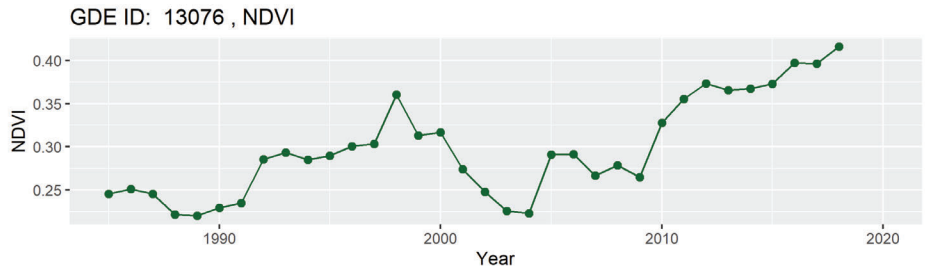
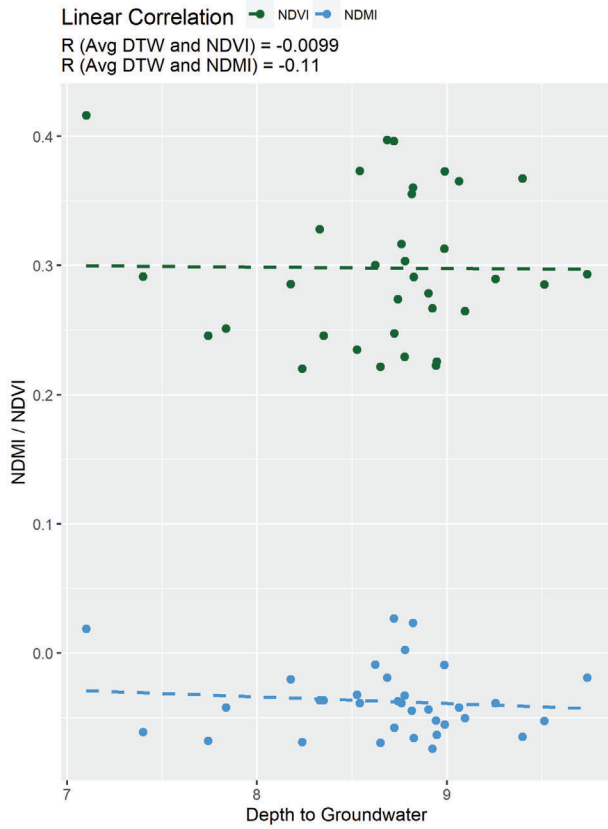


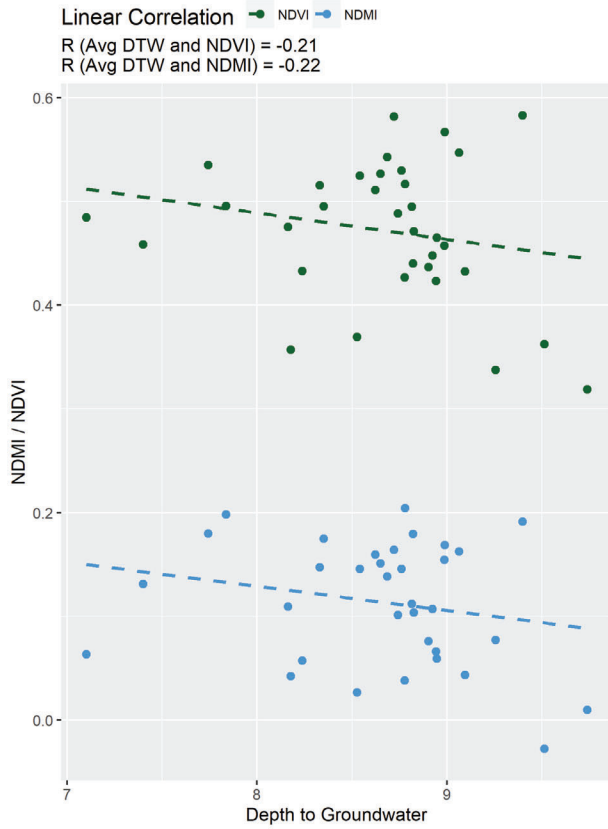
GDE ID: 11020 , NDMI



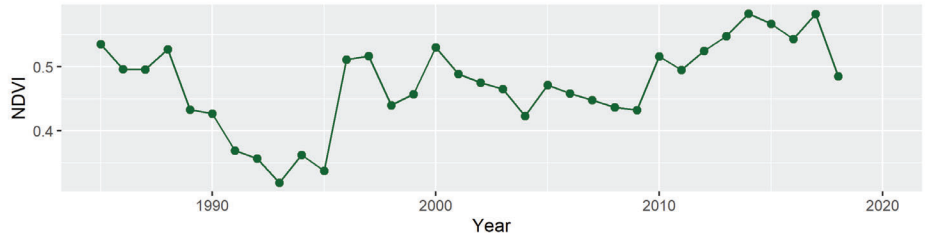
GDE ID: 11020 , Depth to Groundwater



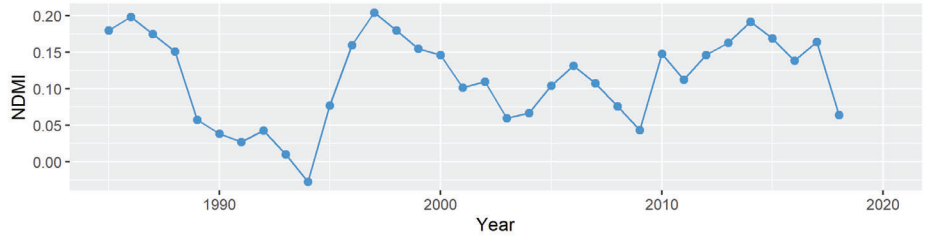




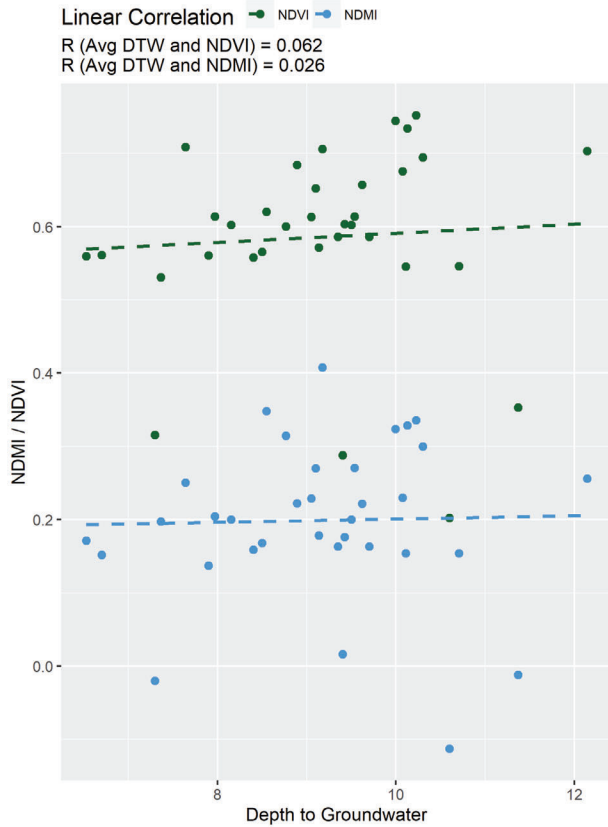
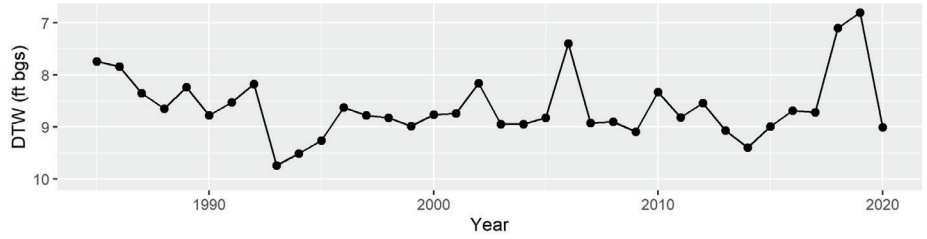
GDE ID: 13083 , NDVI



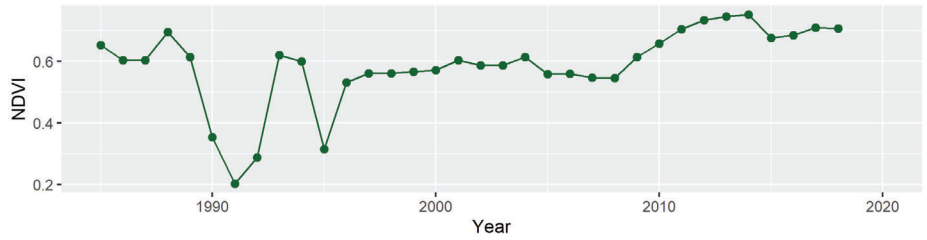
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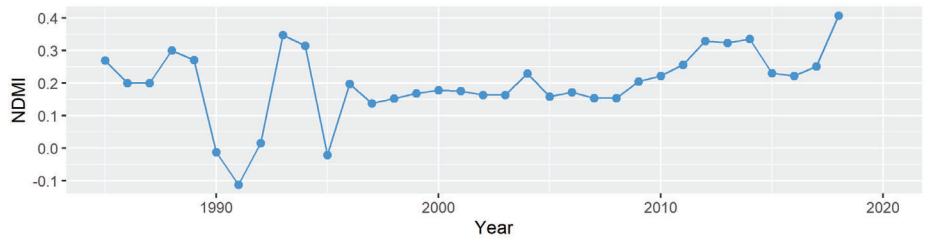
GDE ID: 13083 , Depth to Groundwater



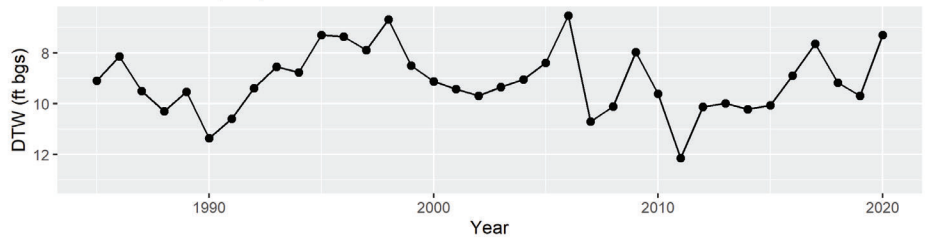
GDE ID: 16760 , NDVI

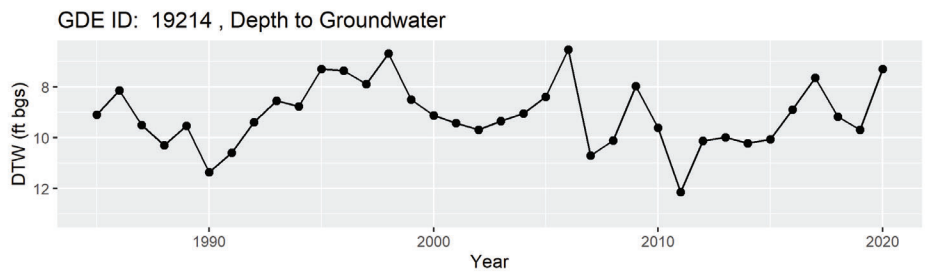
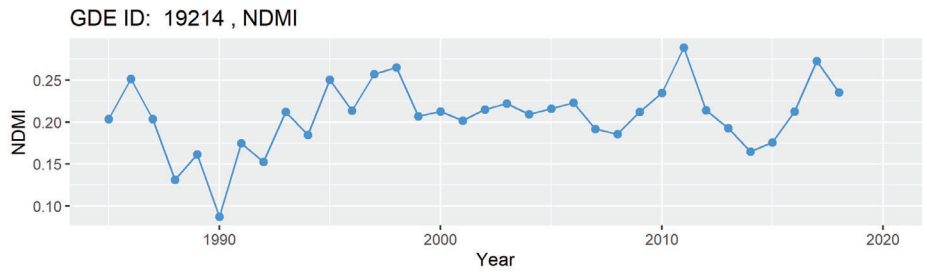
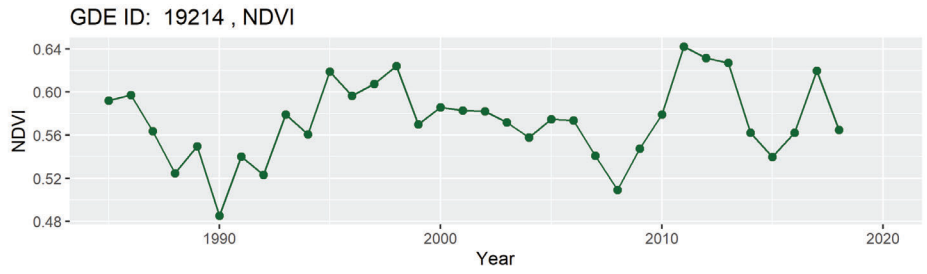
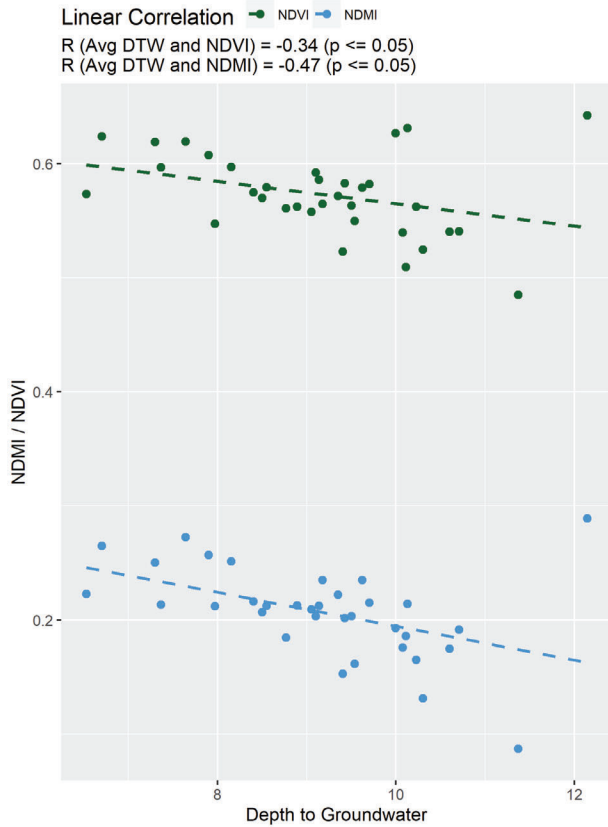
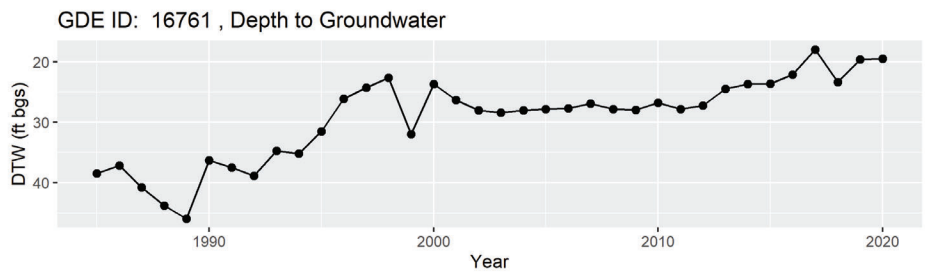
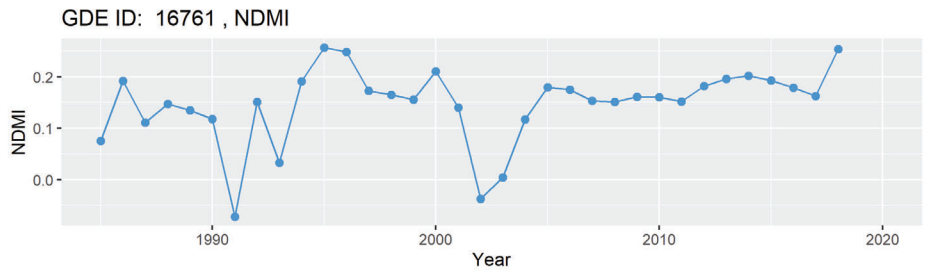
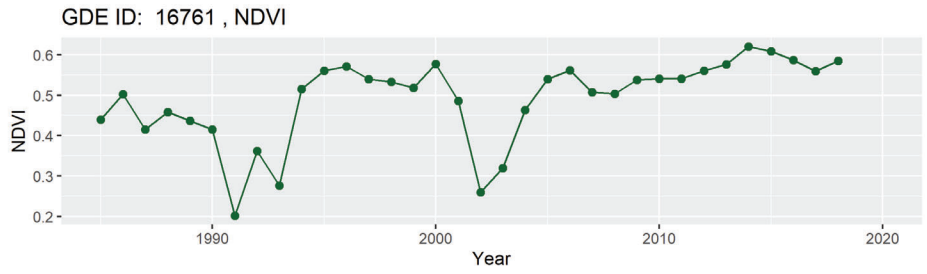
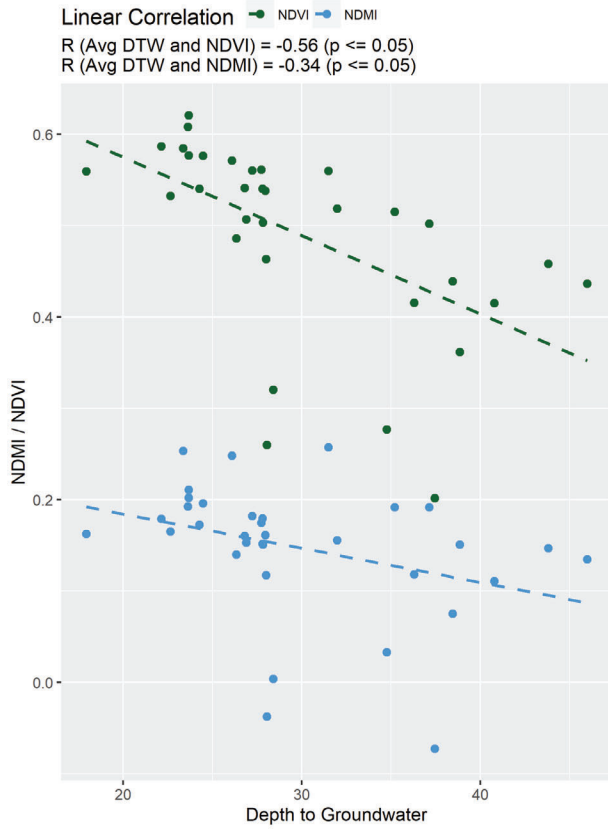


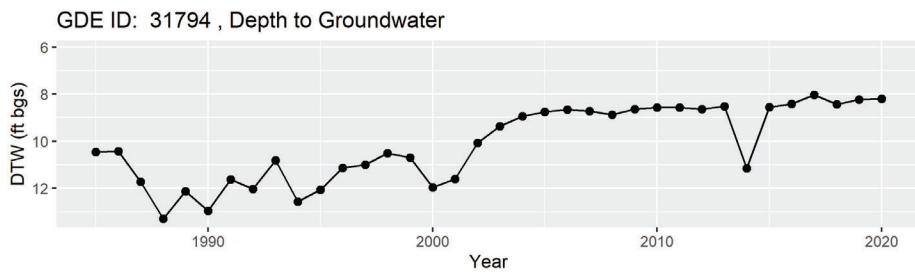
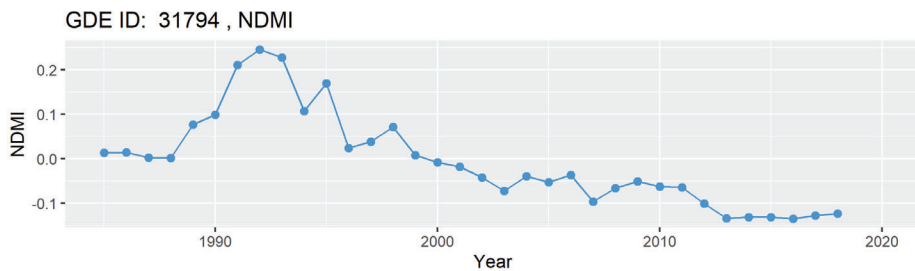
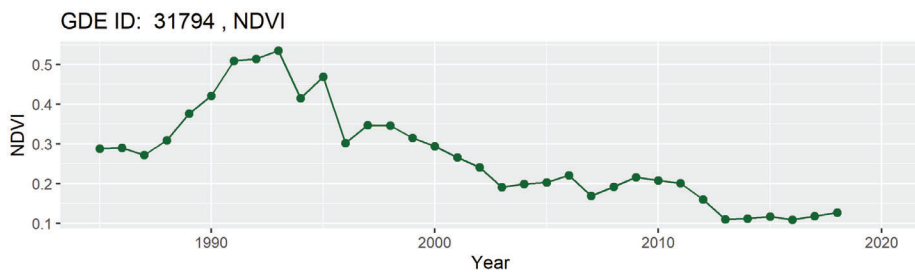
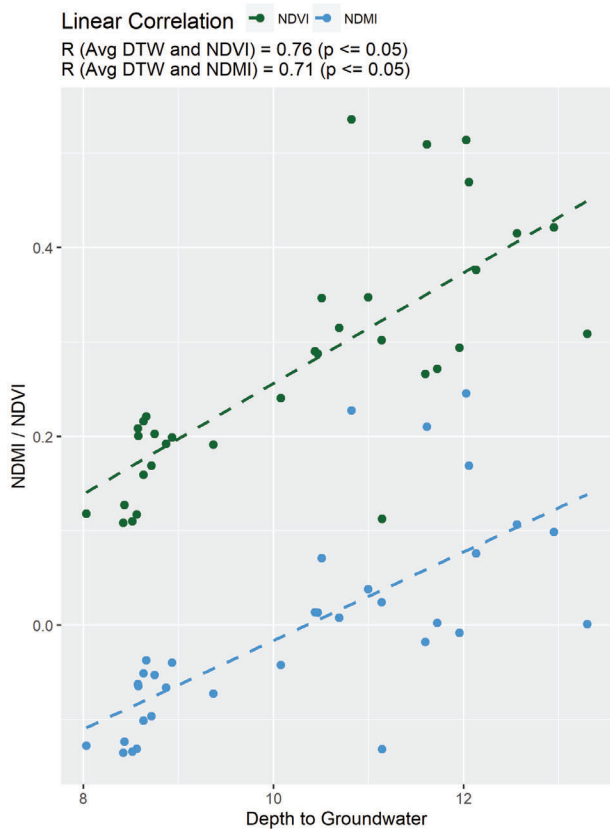
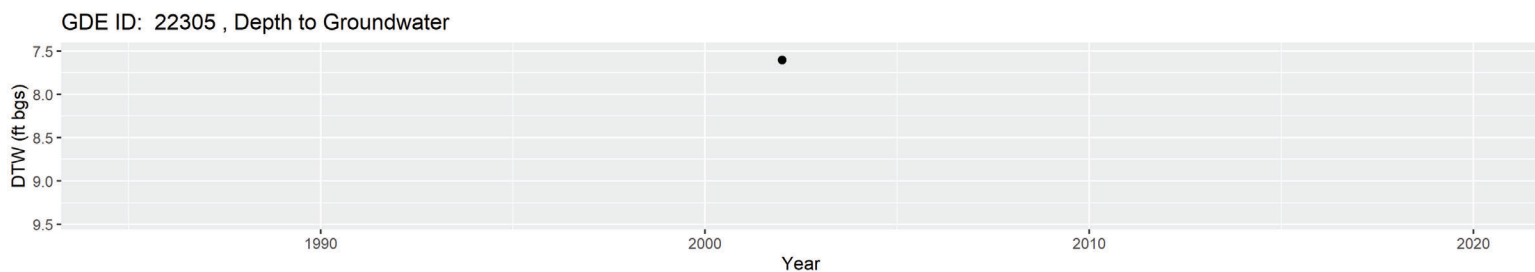
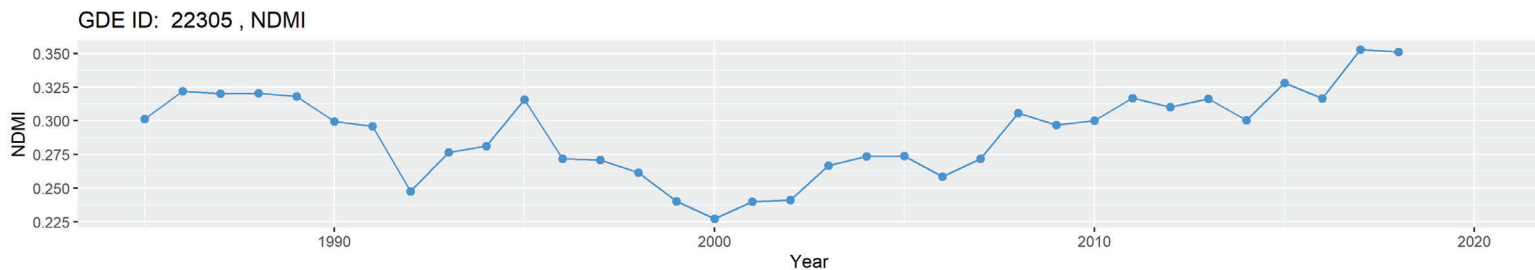
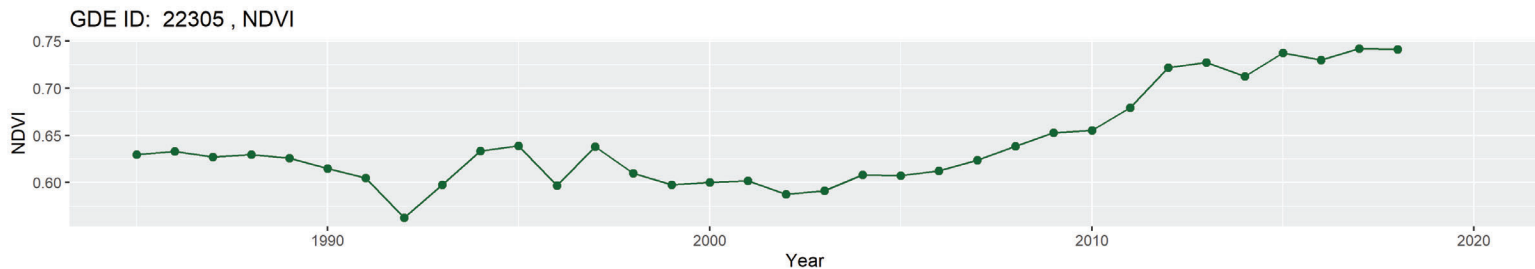
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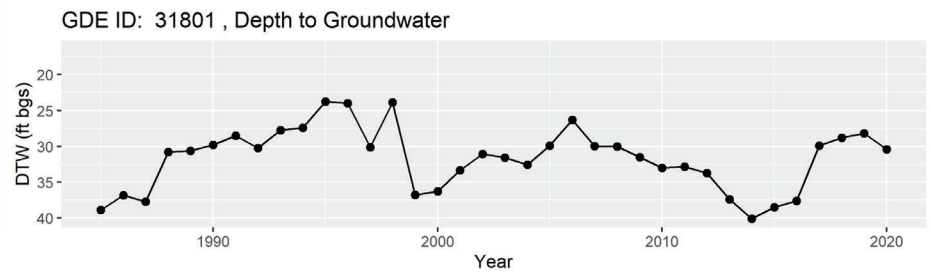
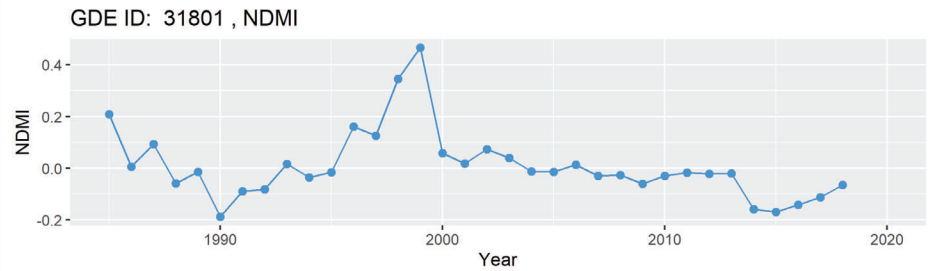
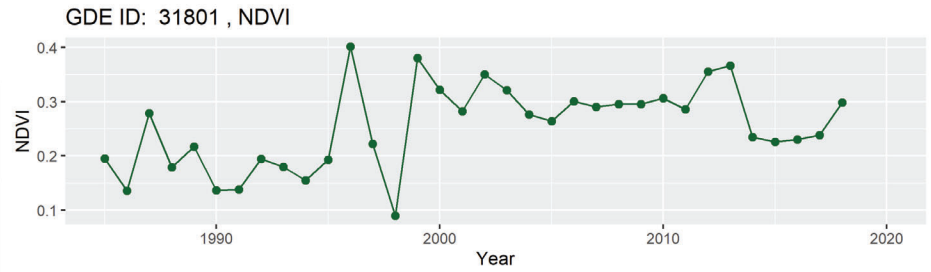
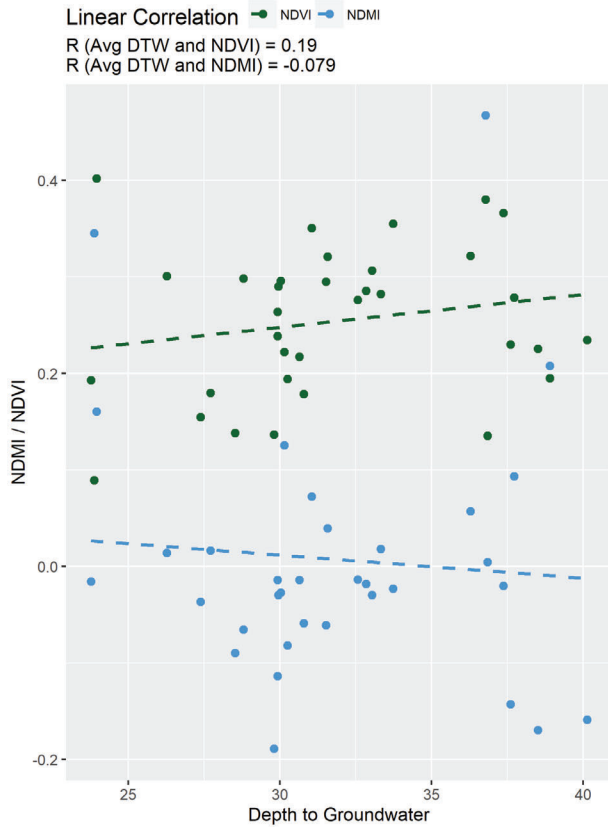
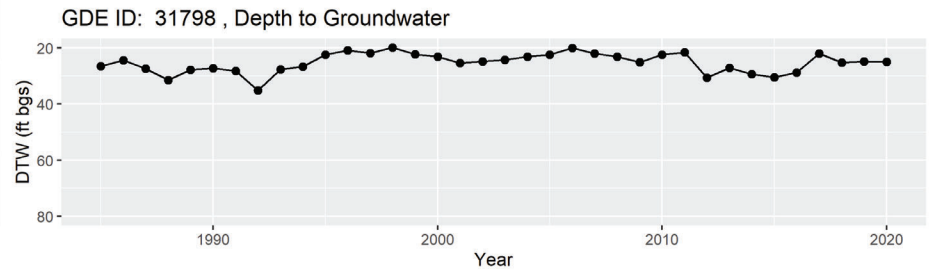
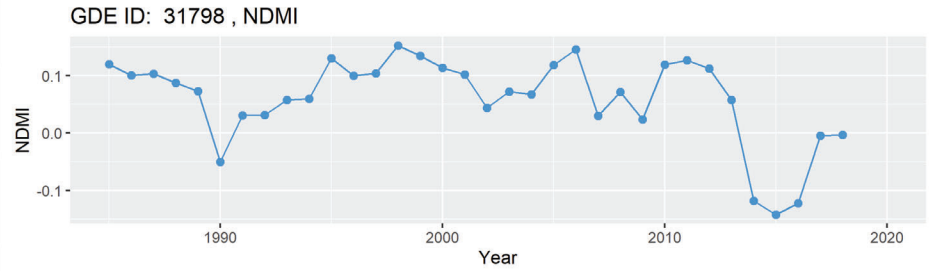
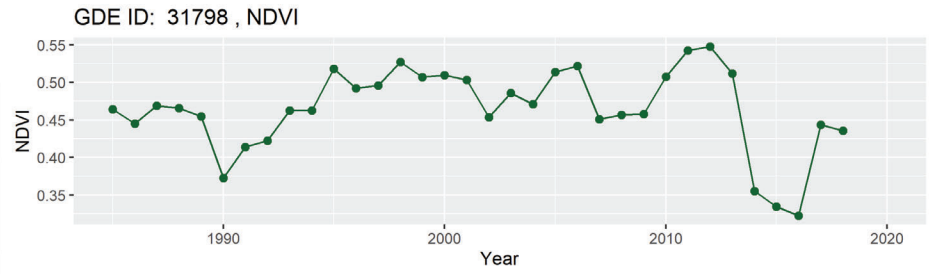
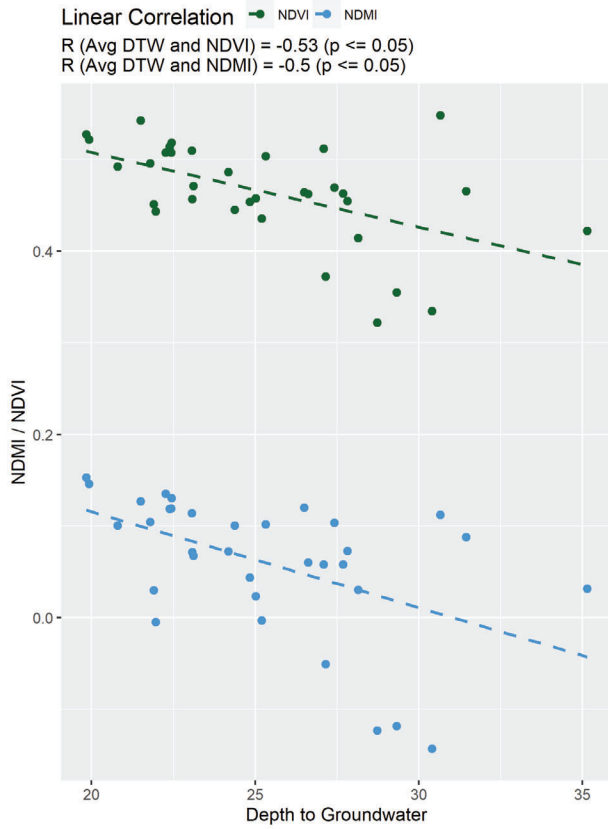


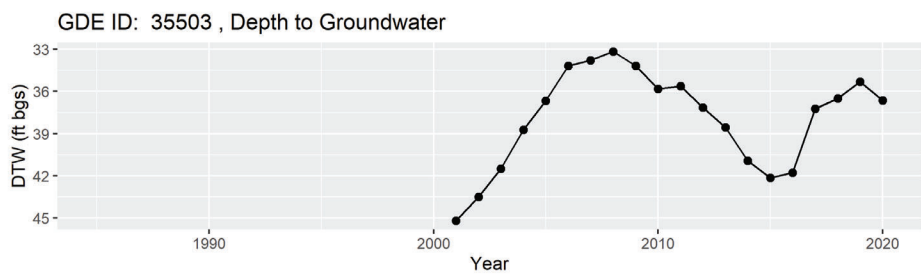
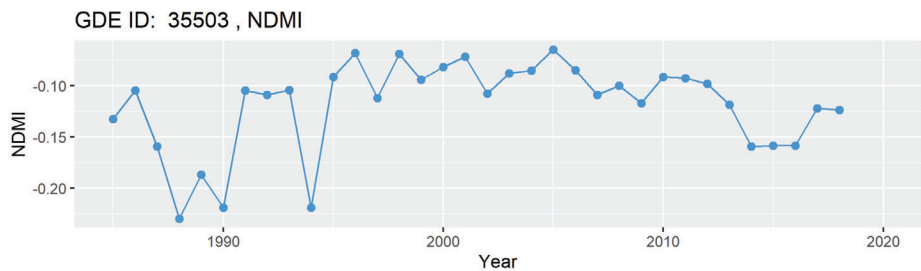
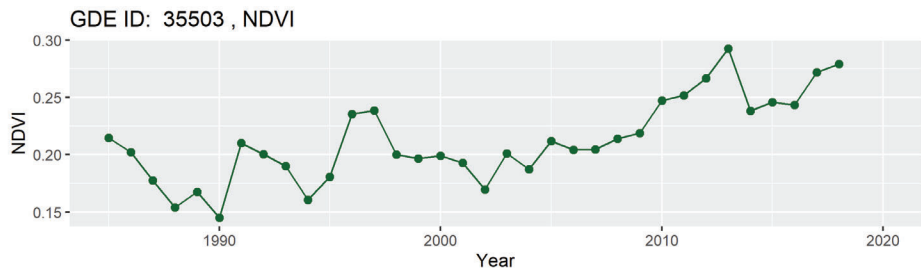
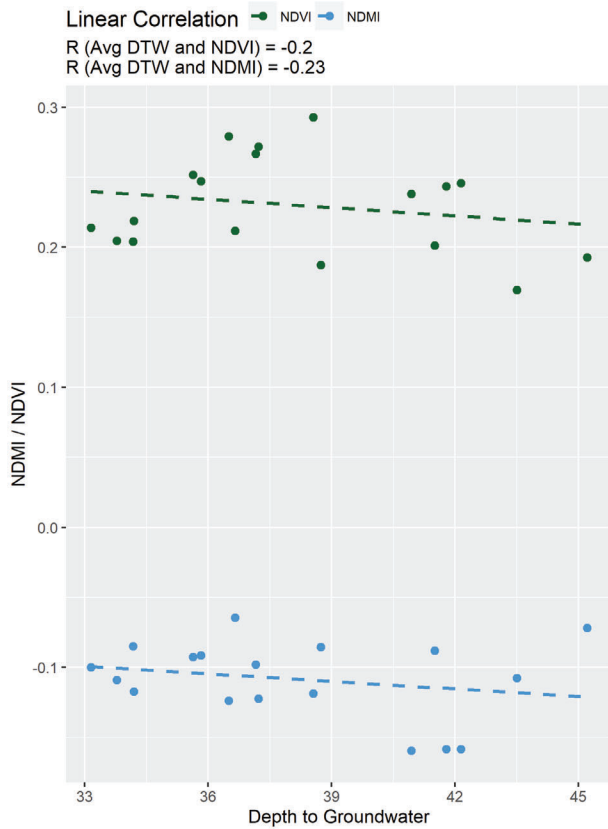
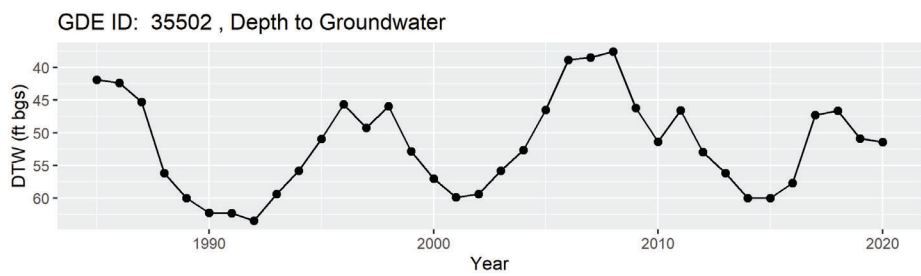
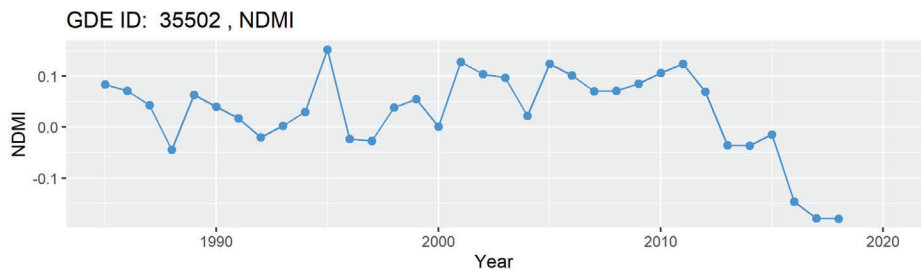
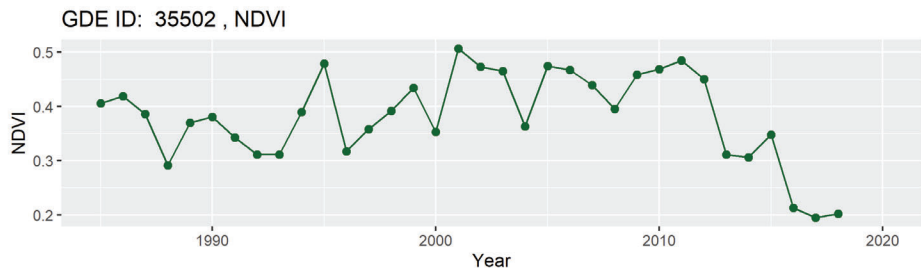
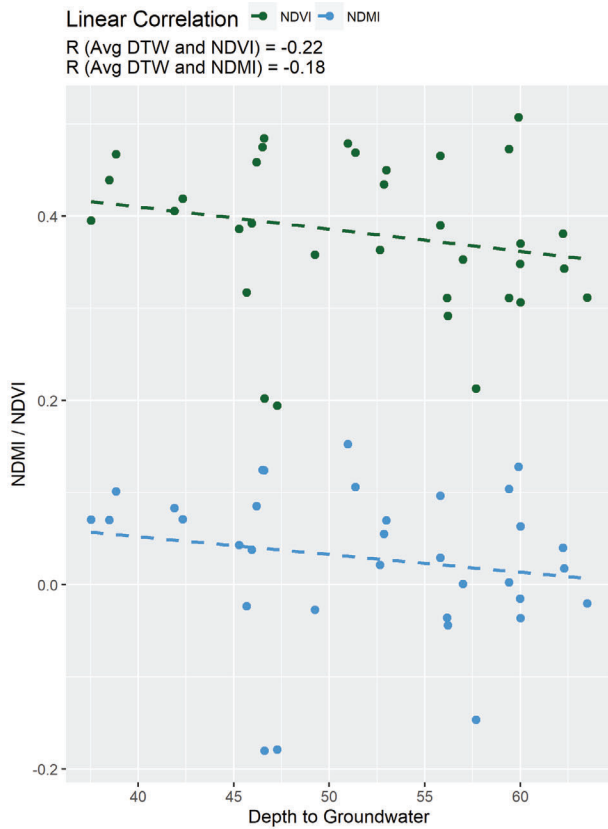
GDE ID: 16760 , Depth to Groundwater

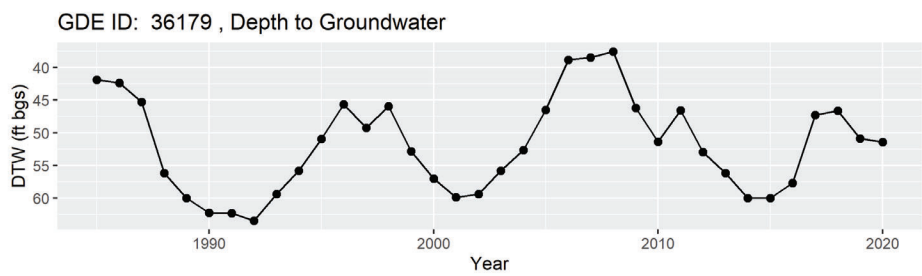
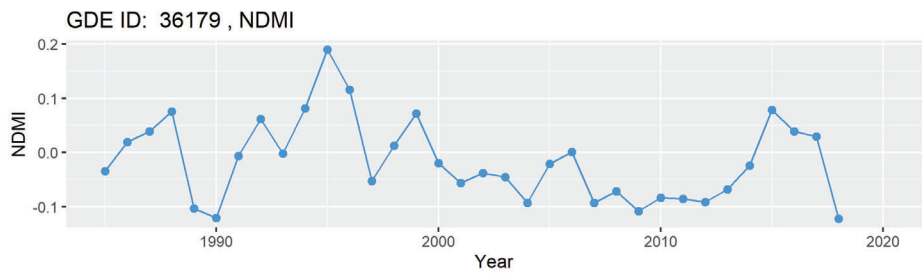
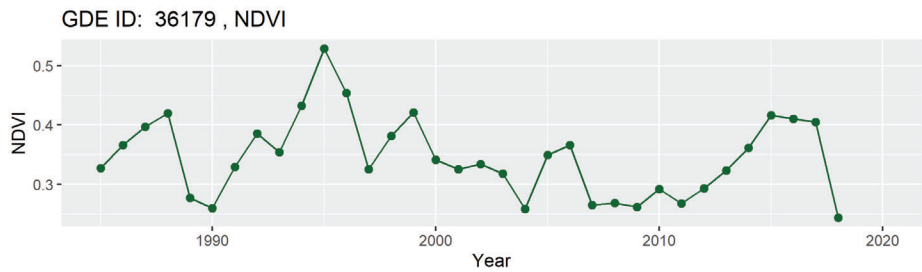
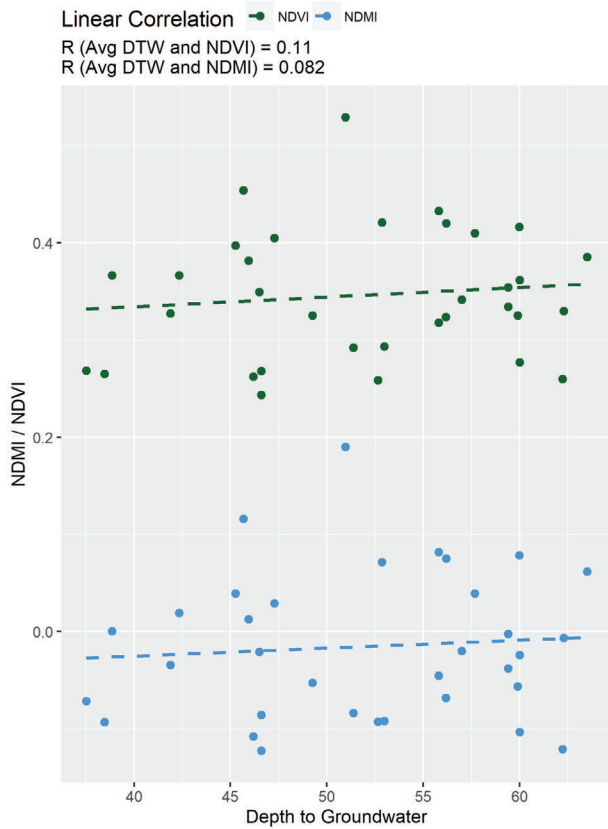
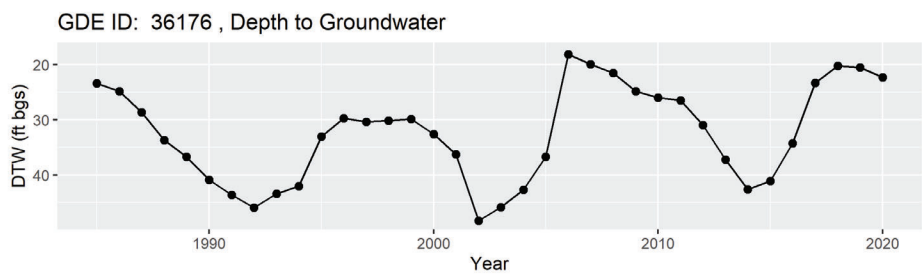
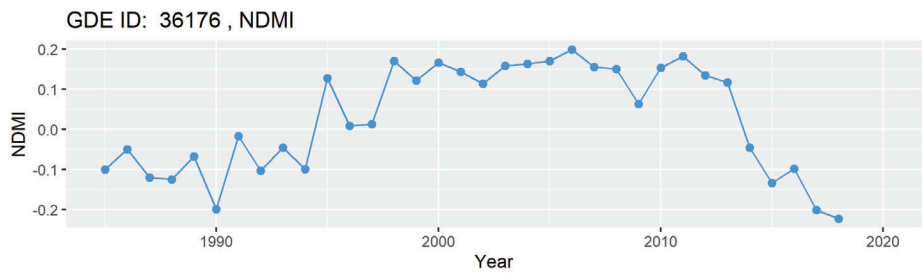
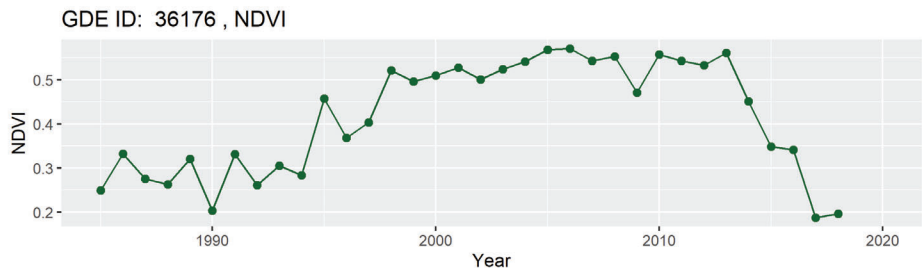
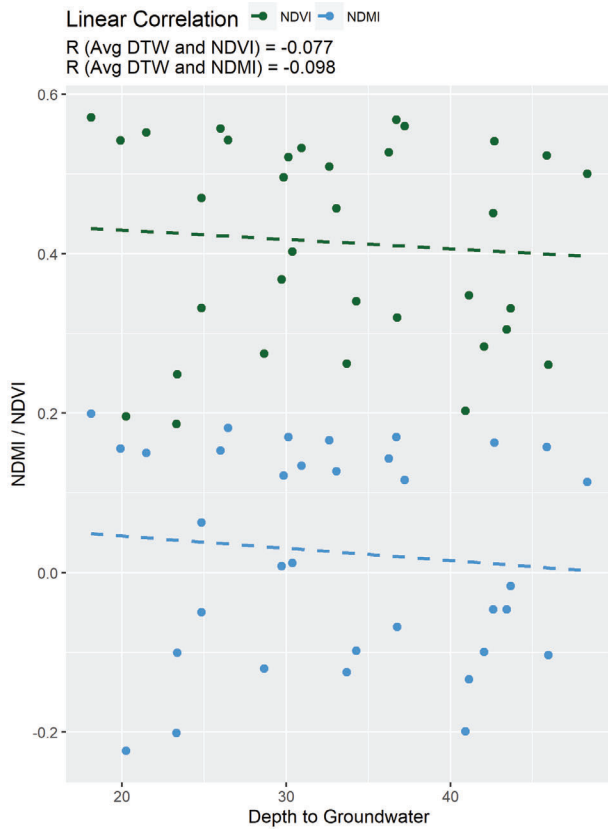


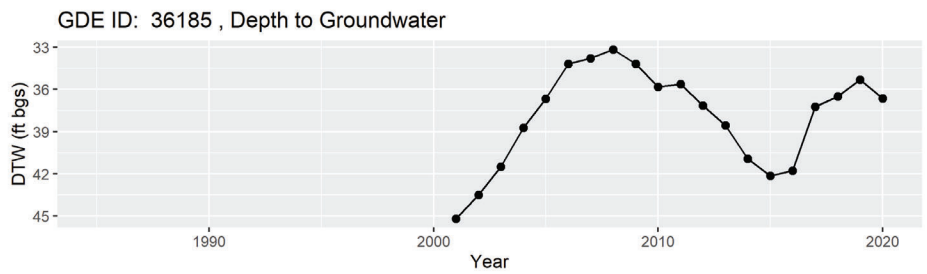
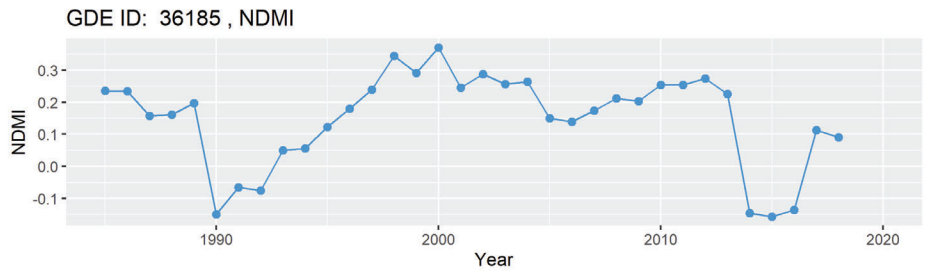
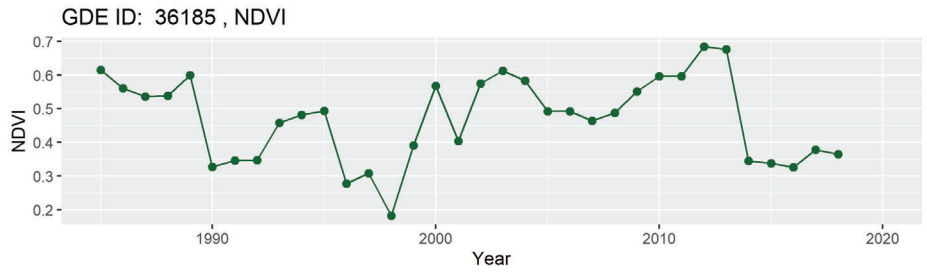
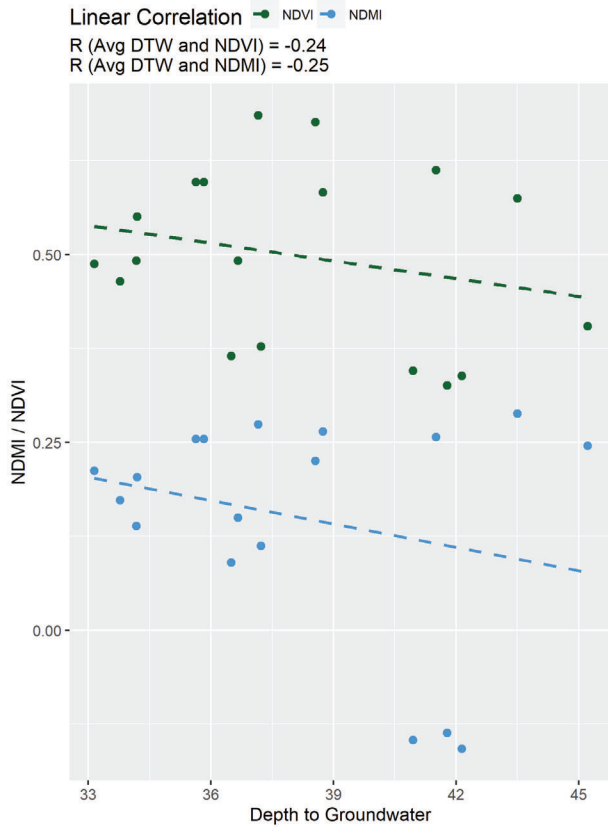
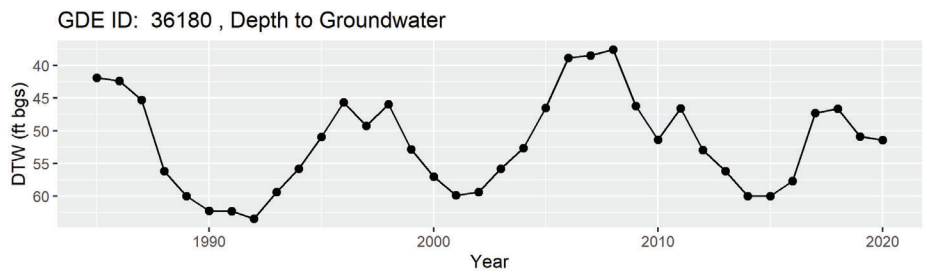
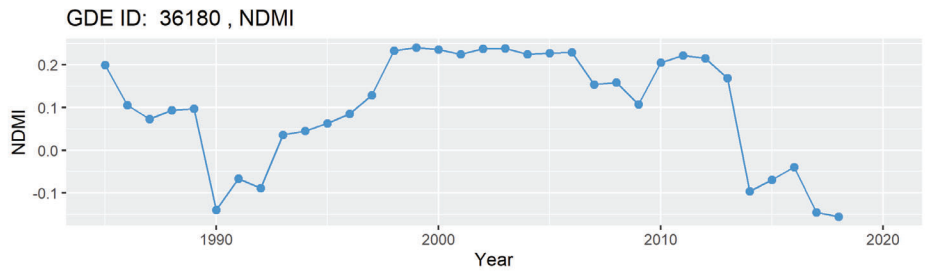
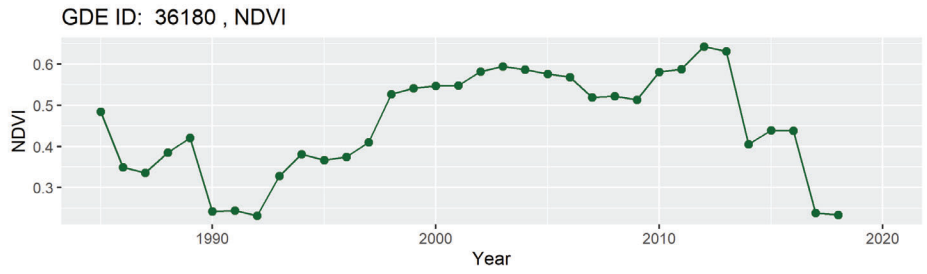
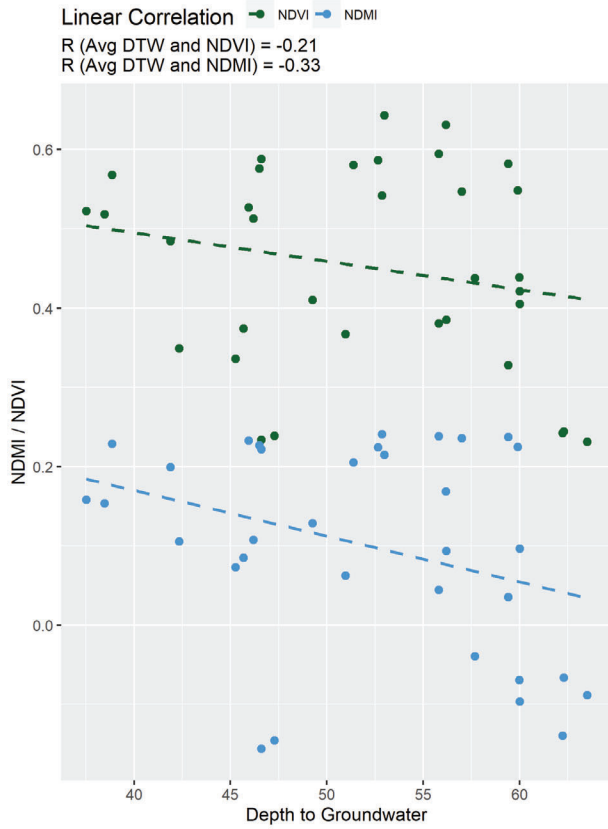


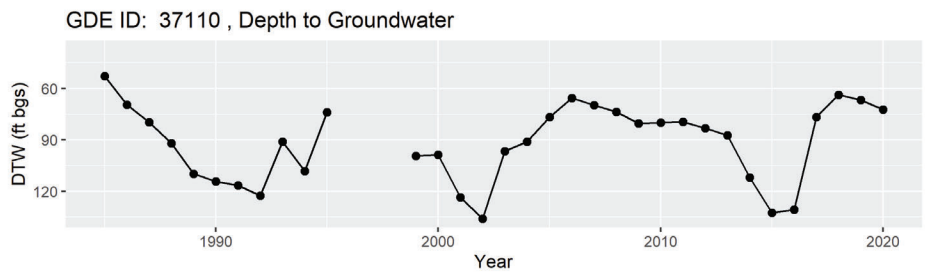
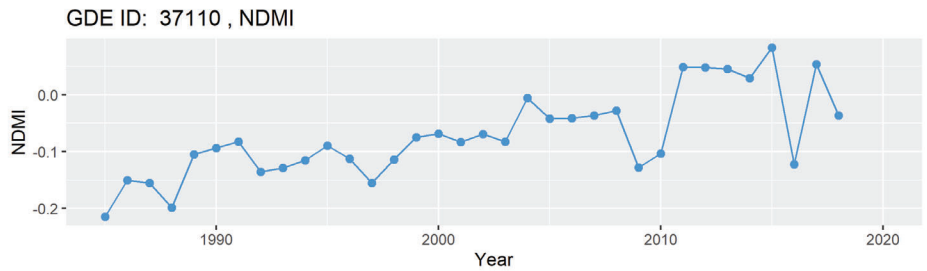
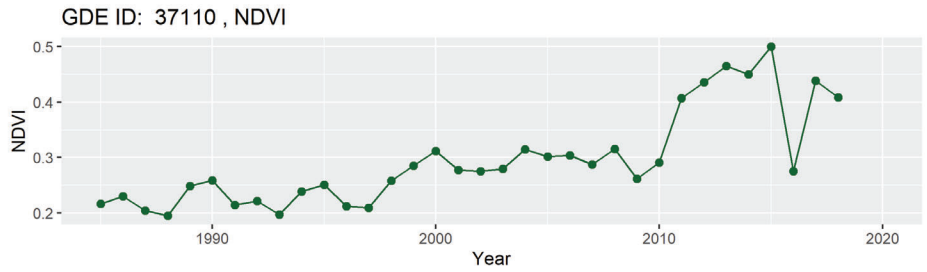
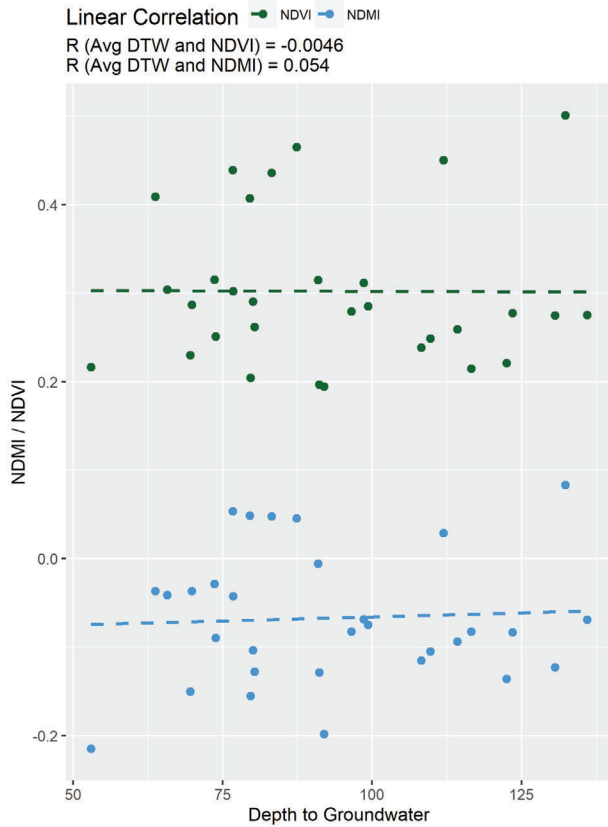
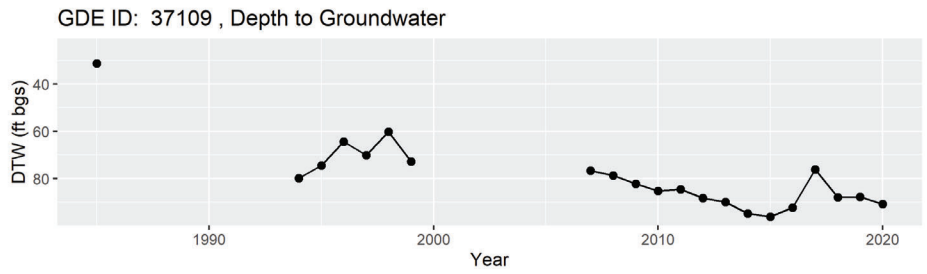
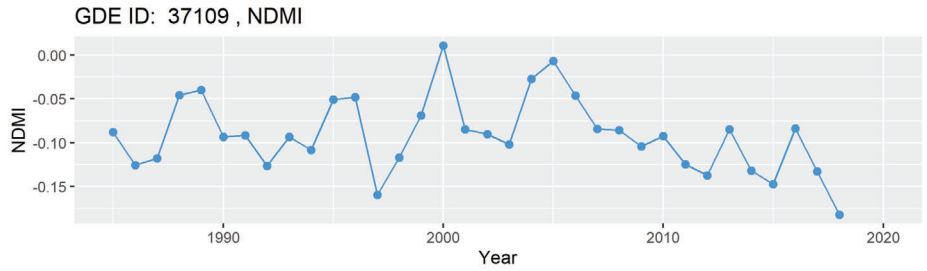
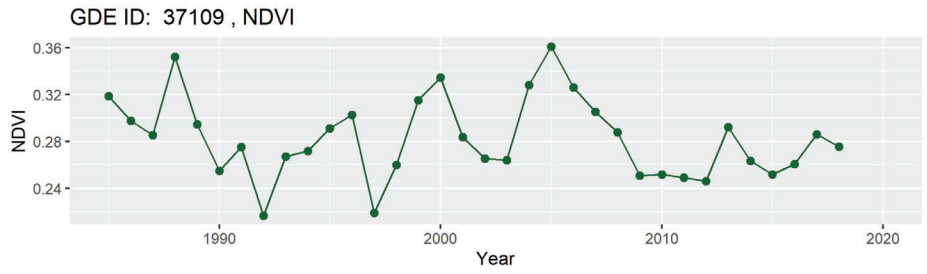
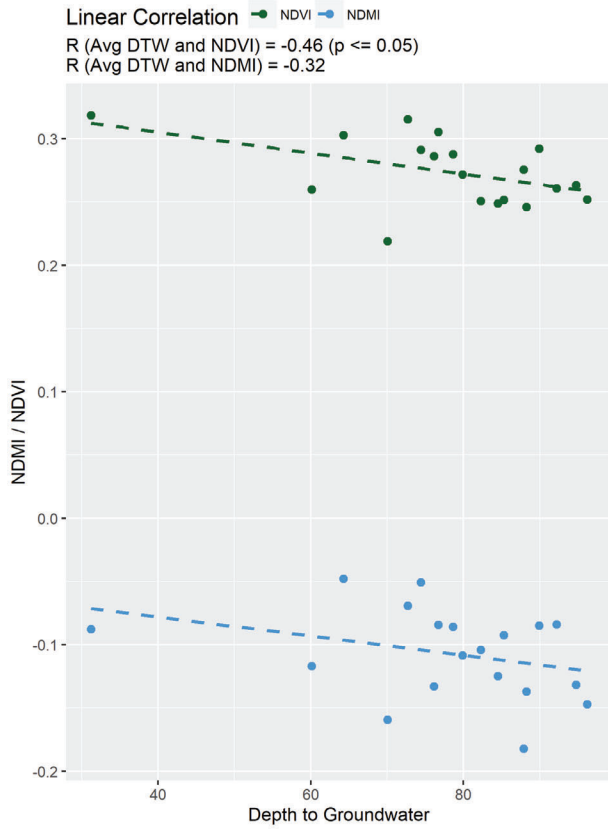


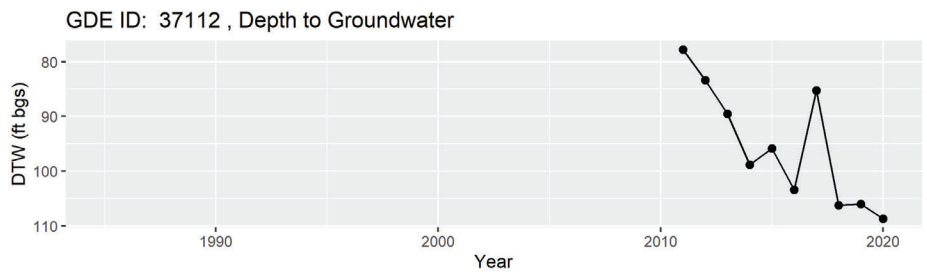
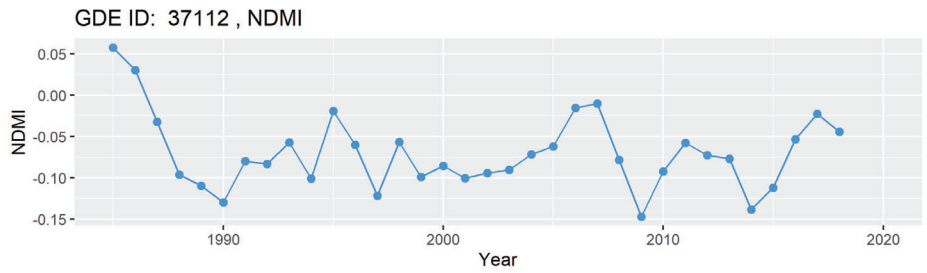
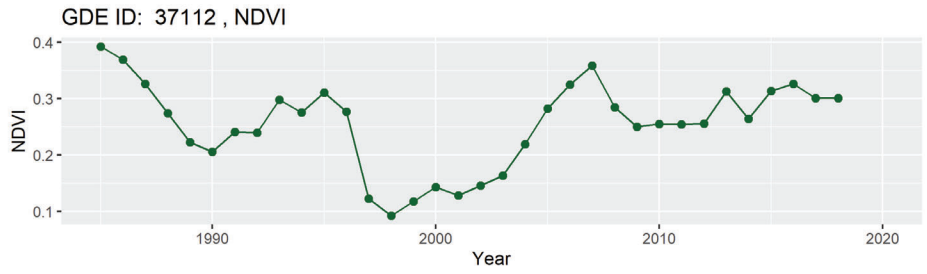
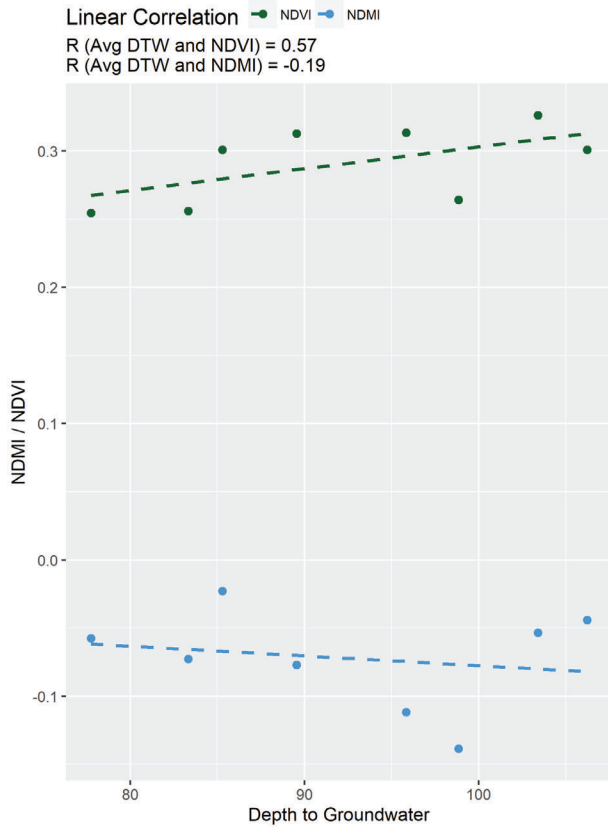
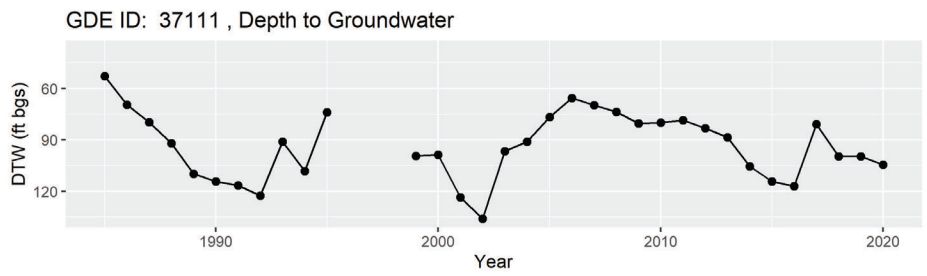
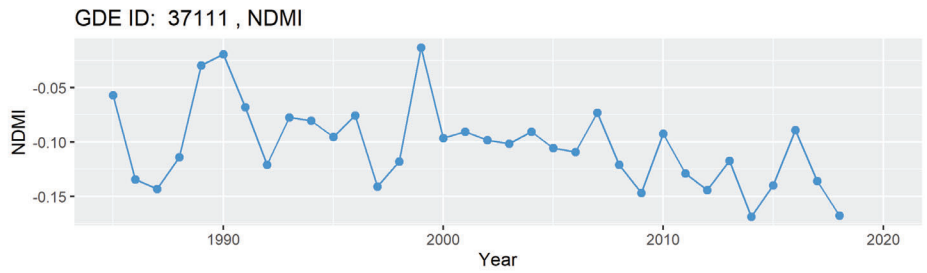
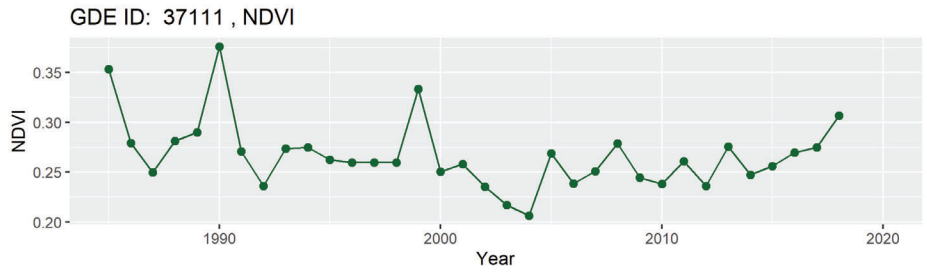
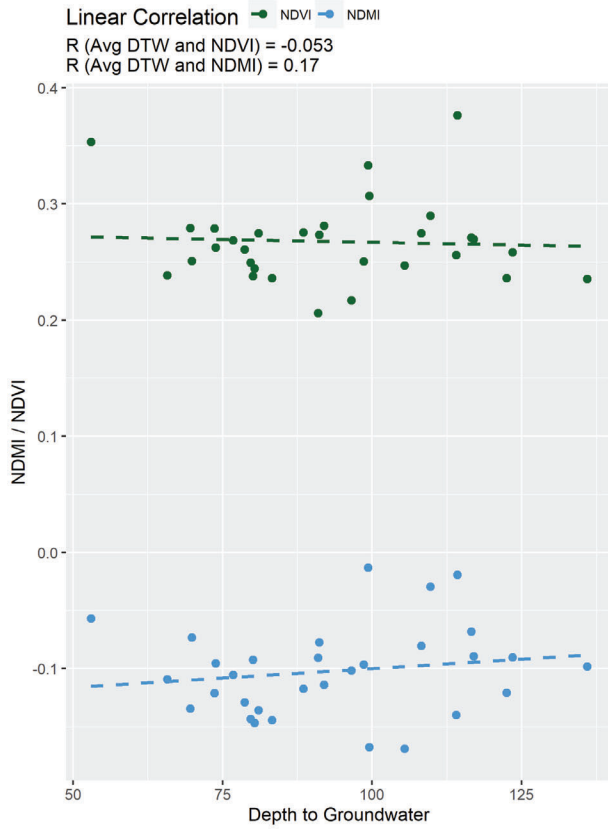


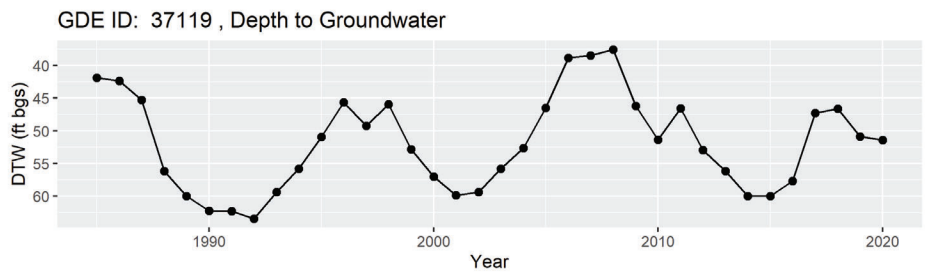
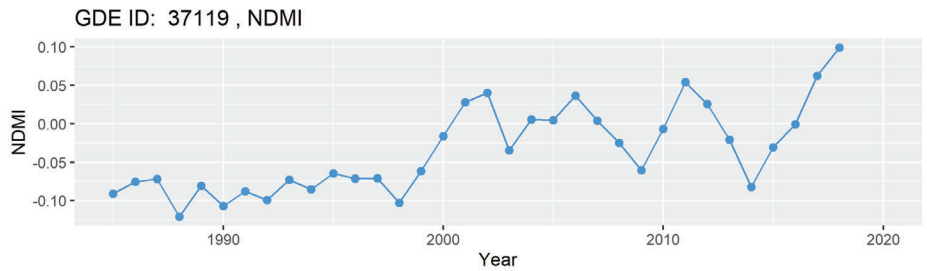
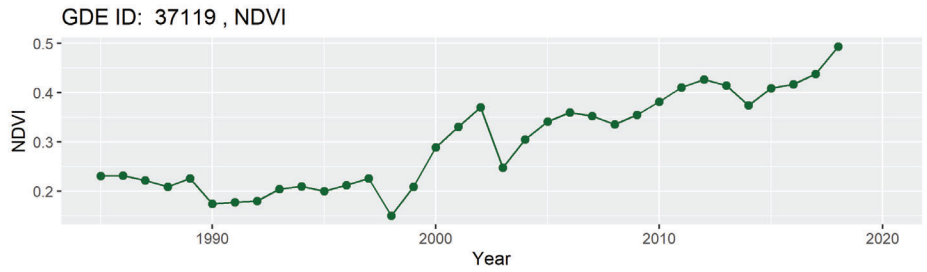
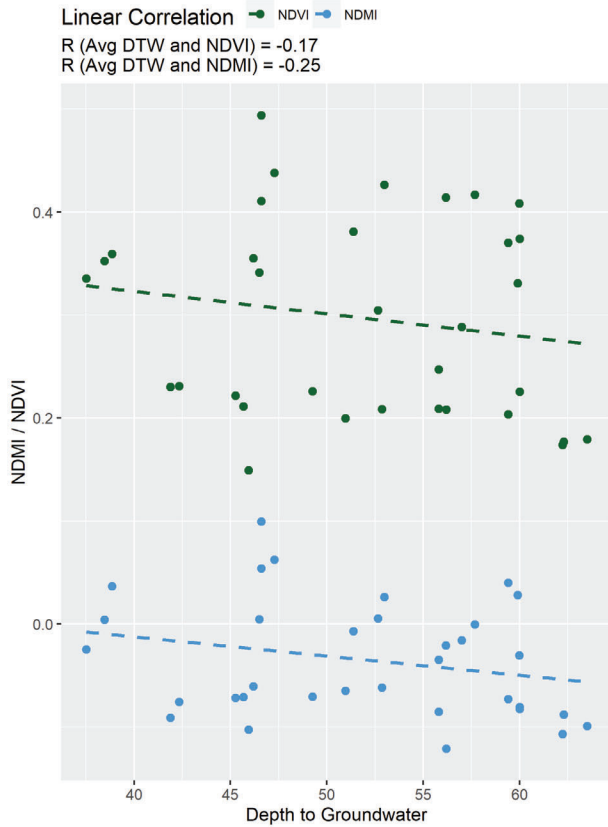
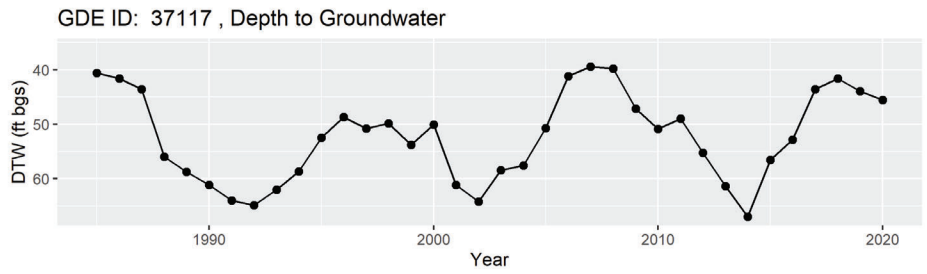
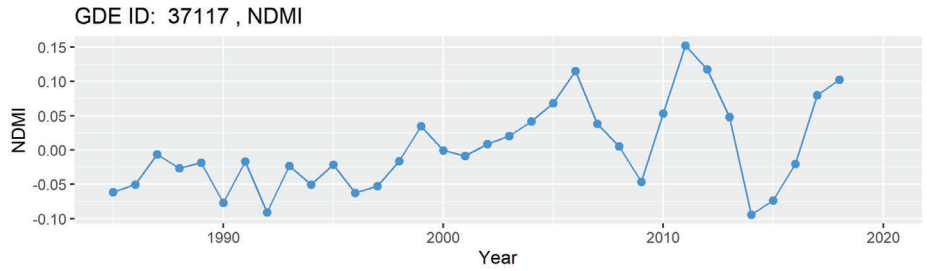
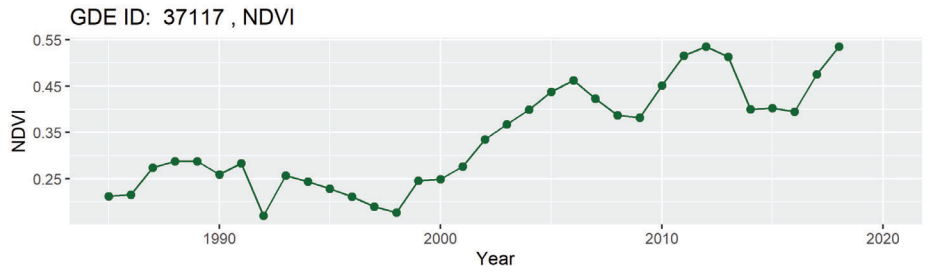
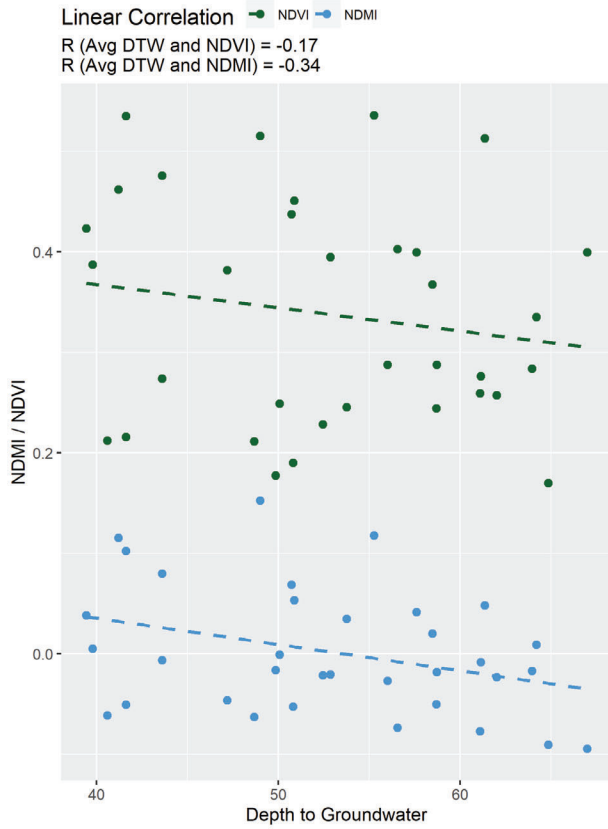


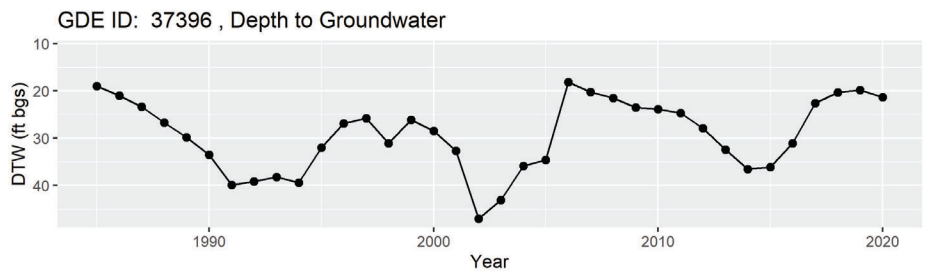
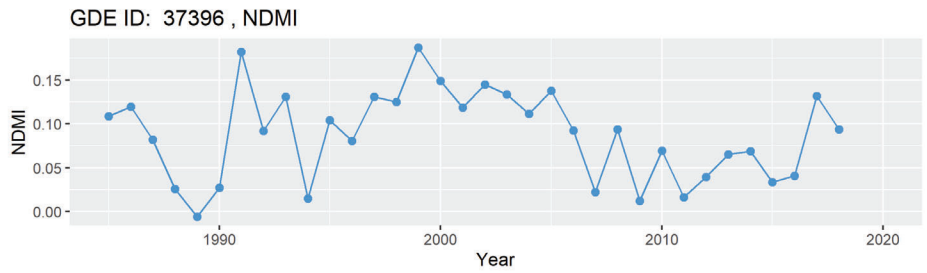
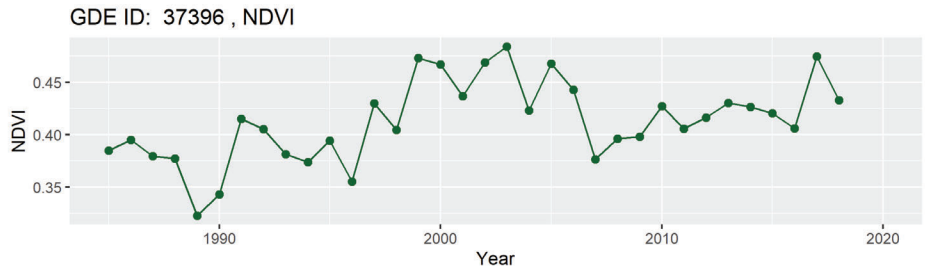
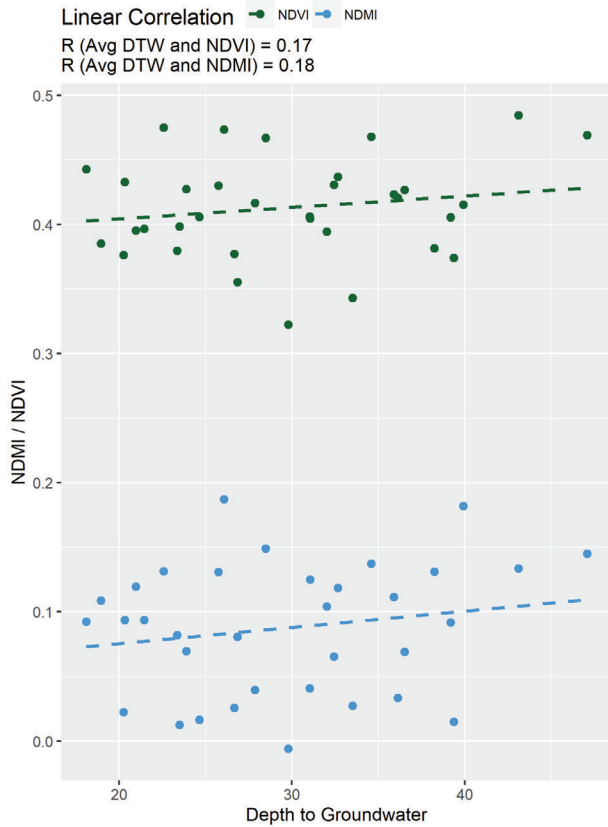
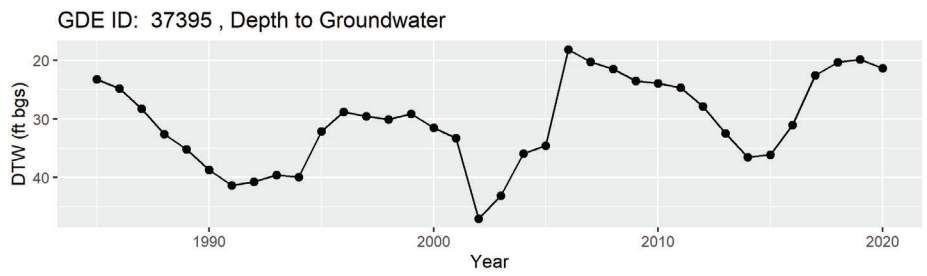
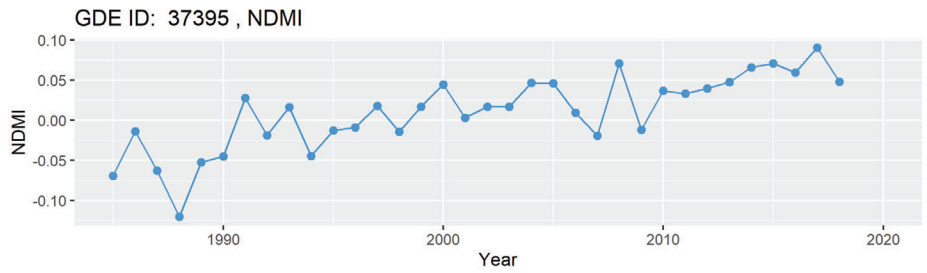
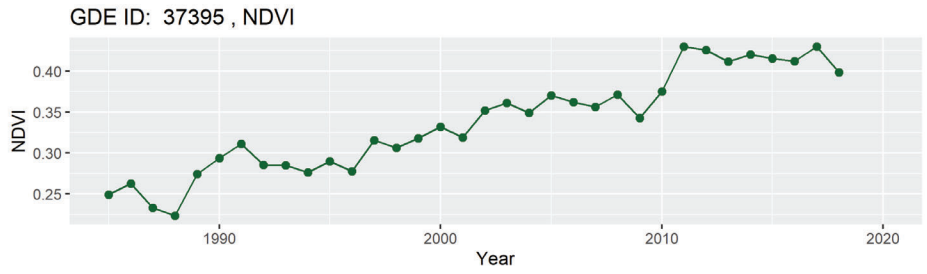
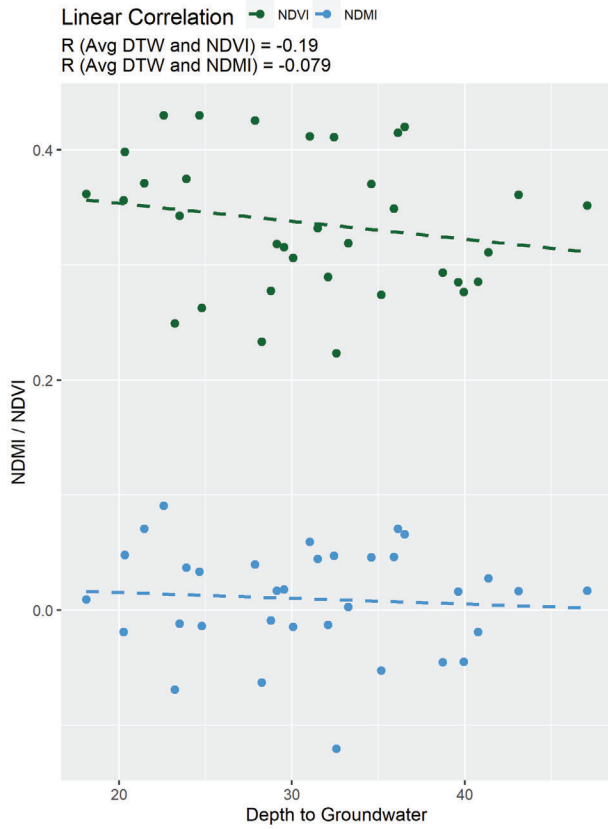


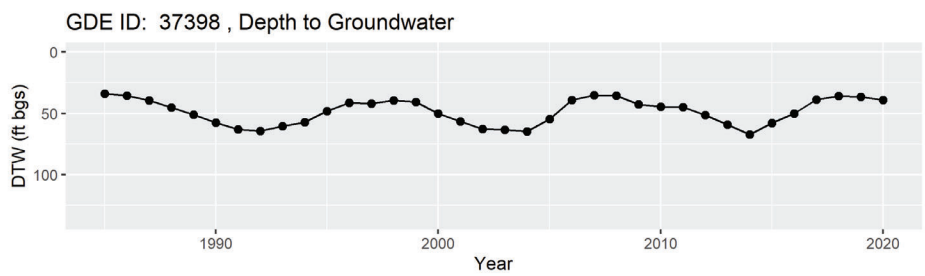
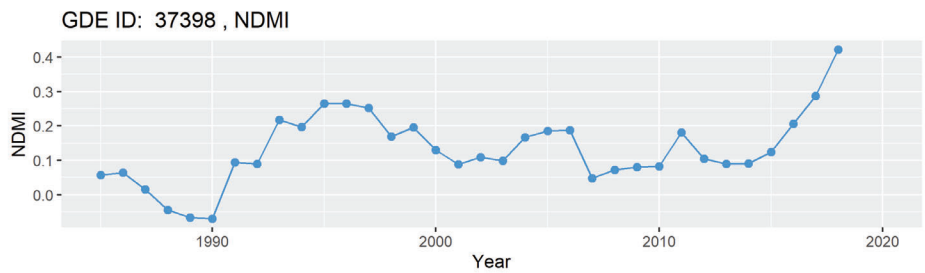
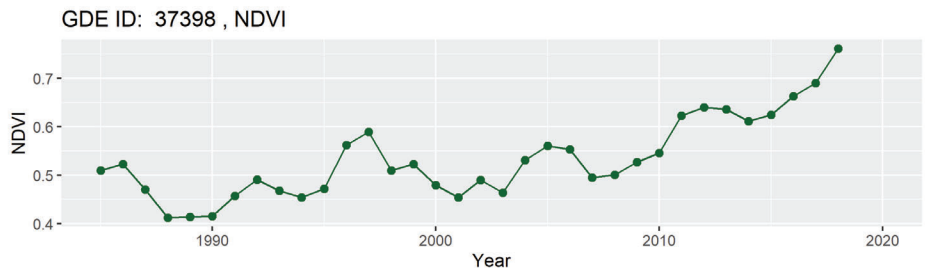
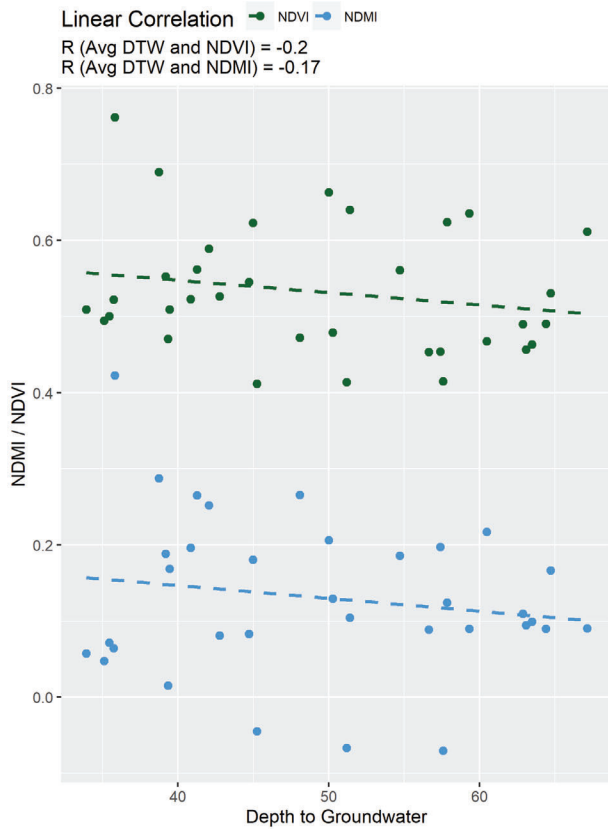
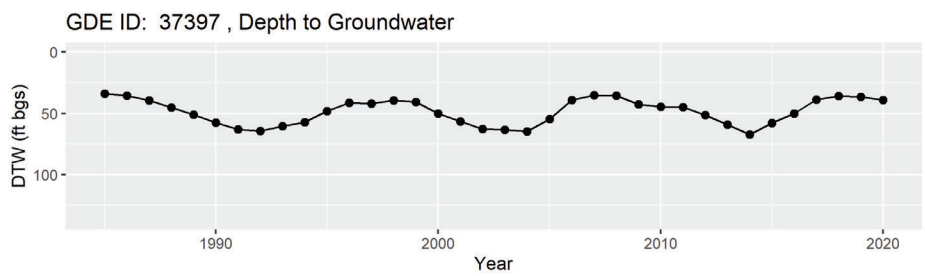
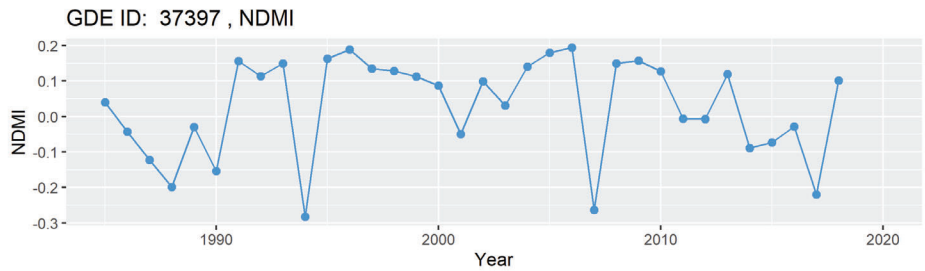
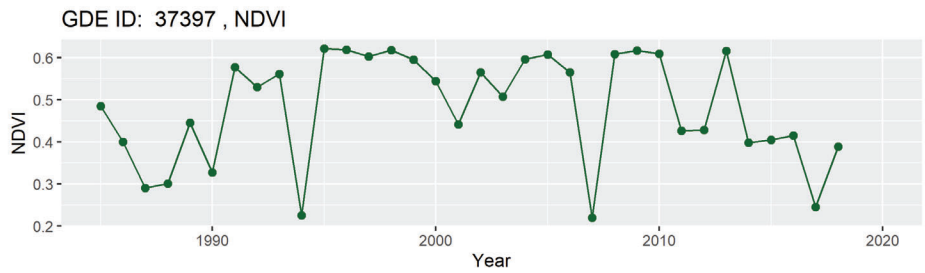
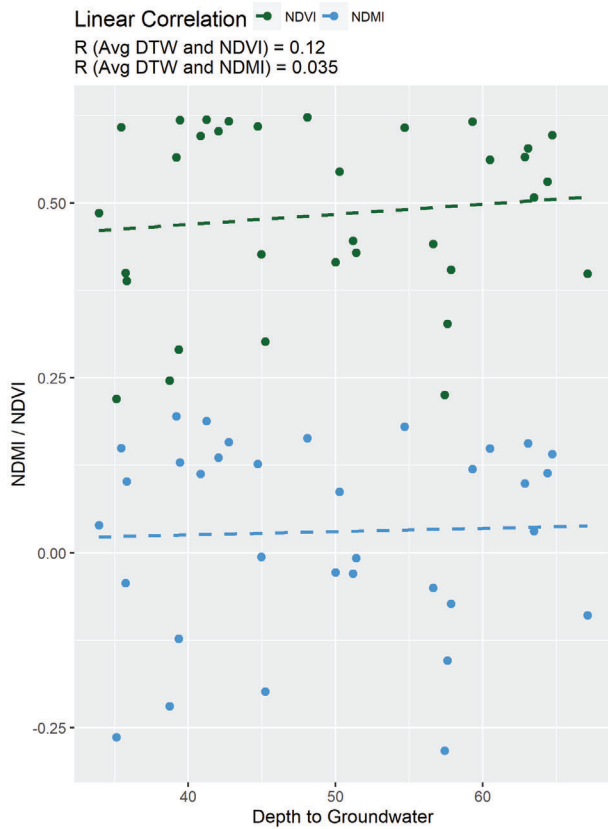


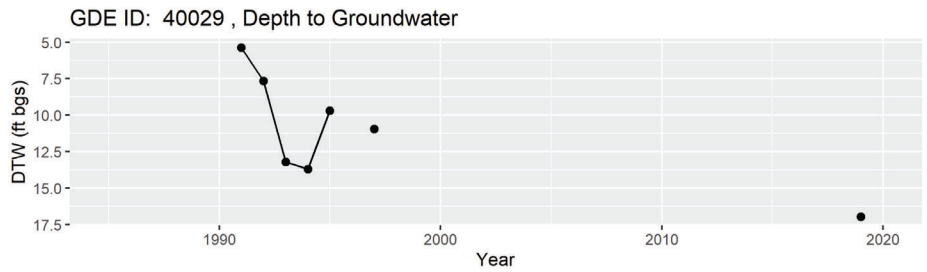
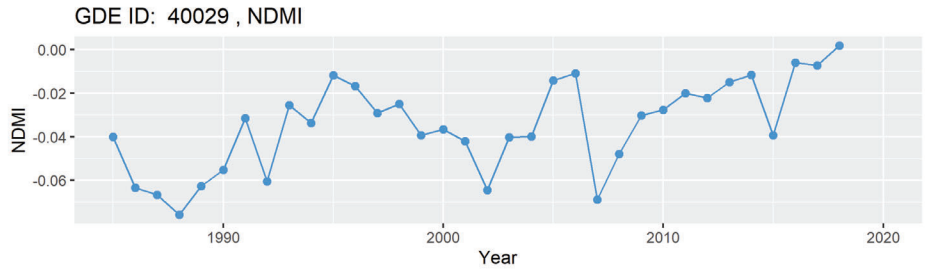
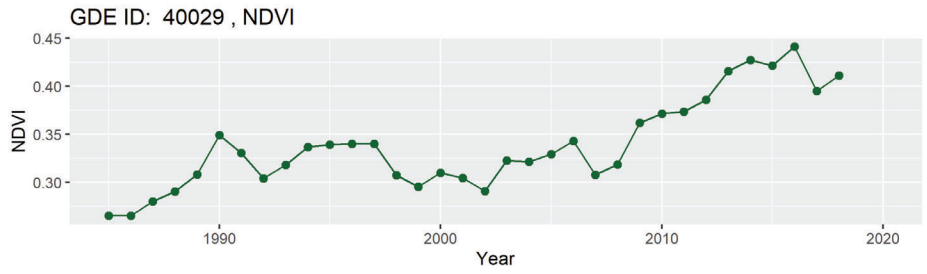
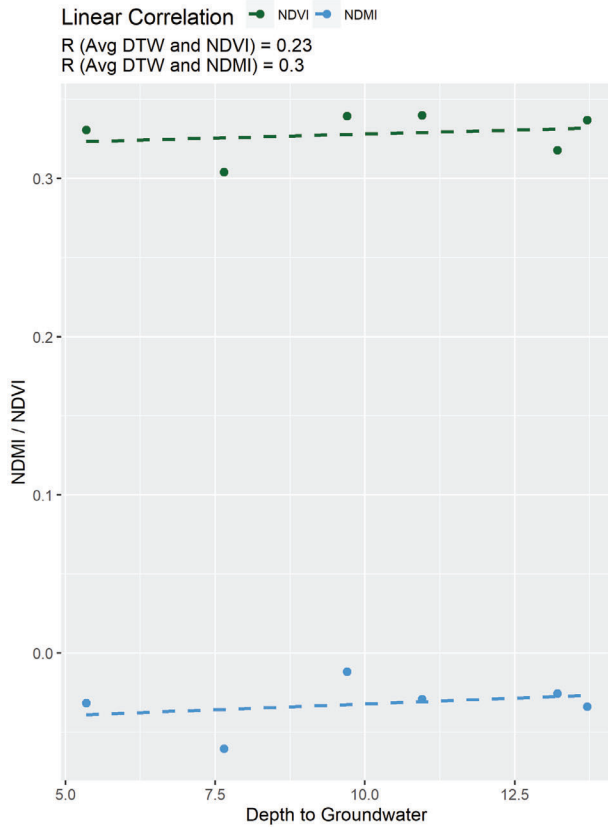
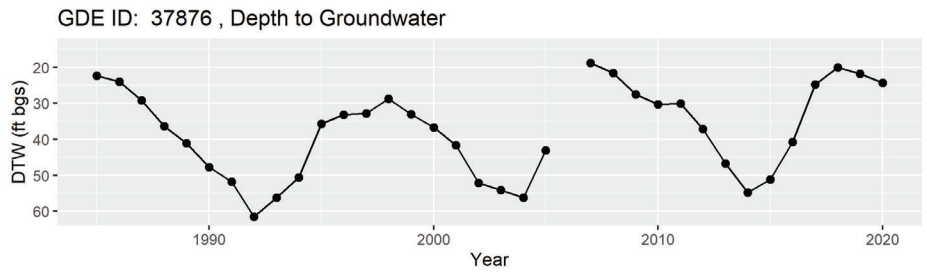
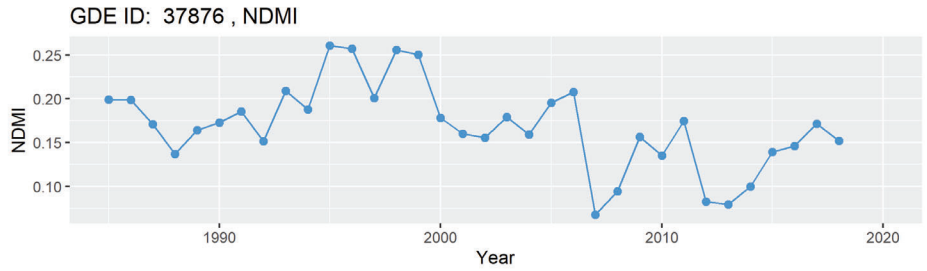
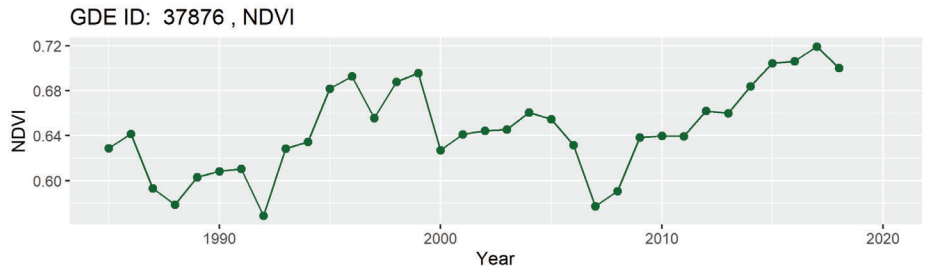
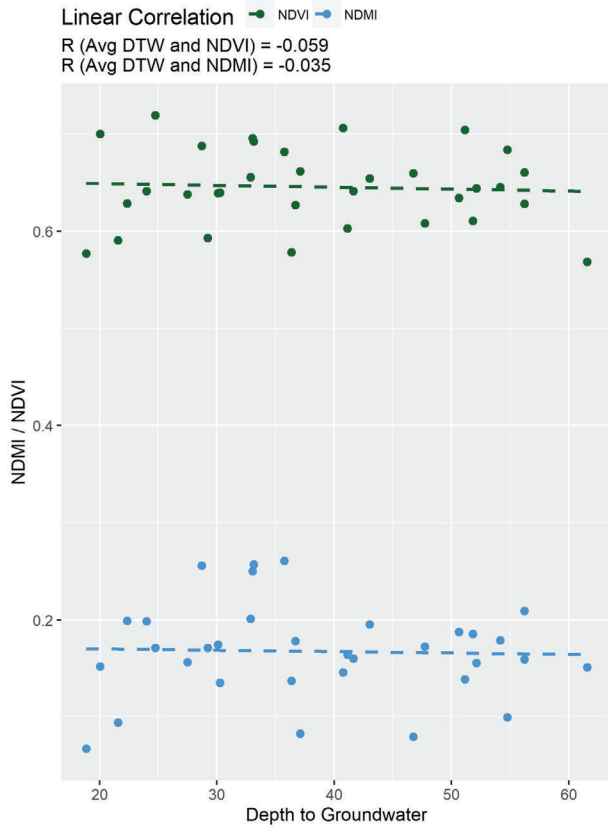


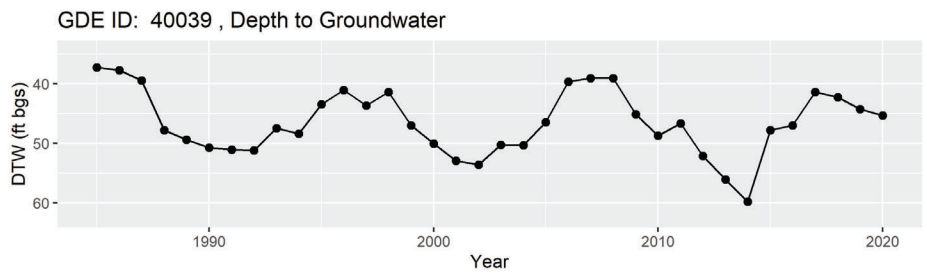
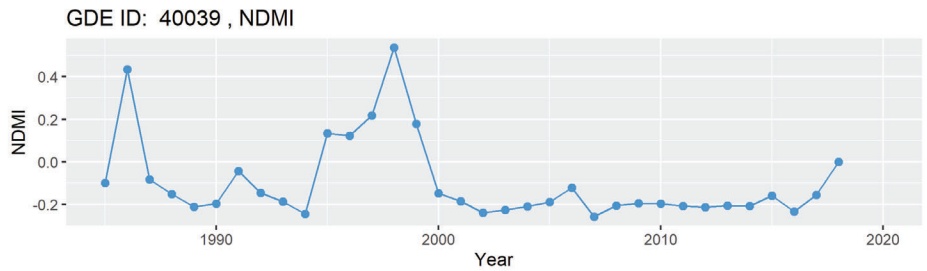
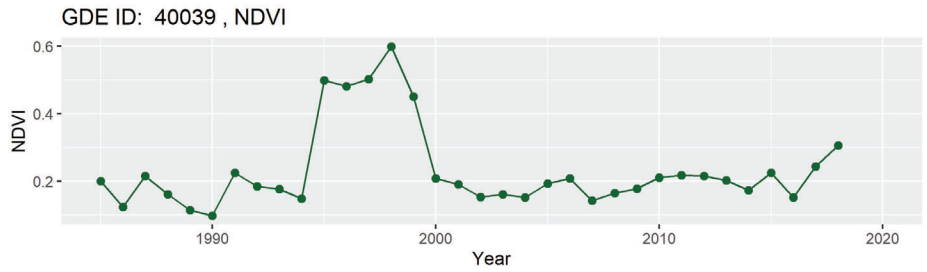
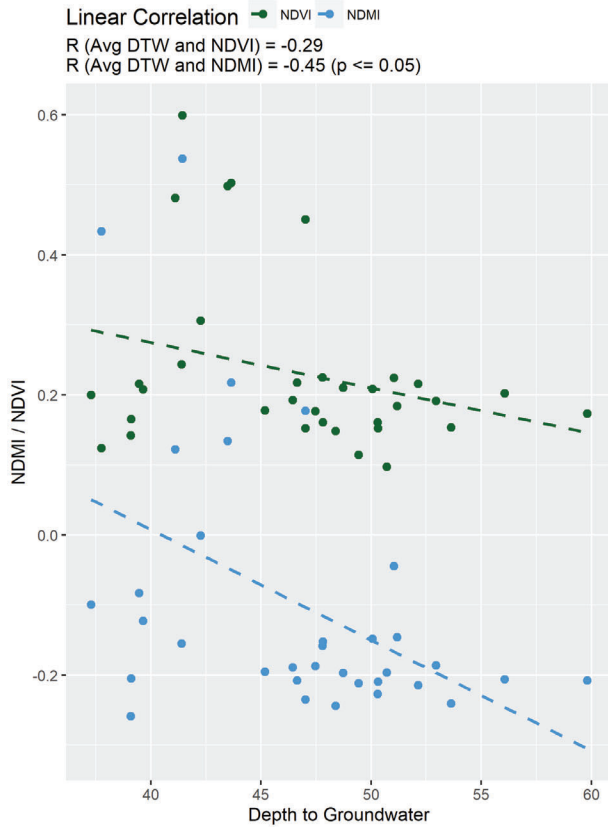
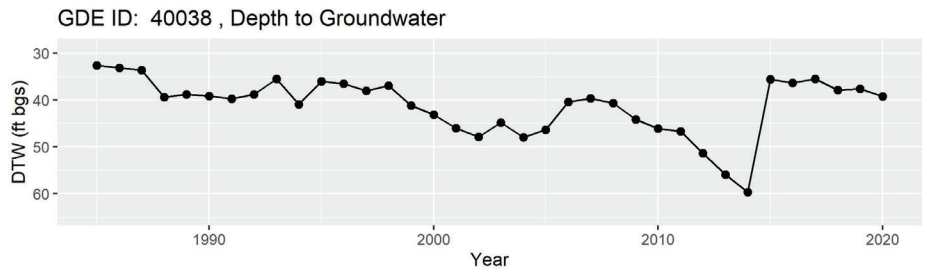
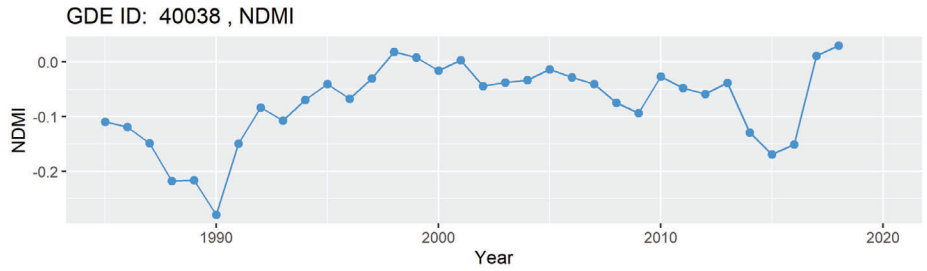
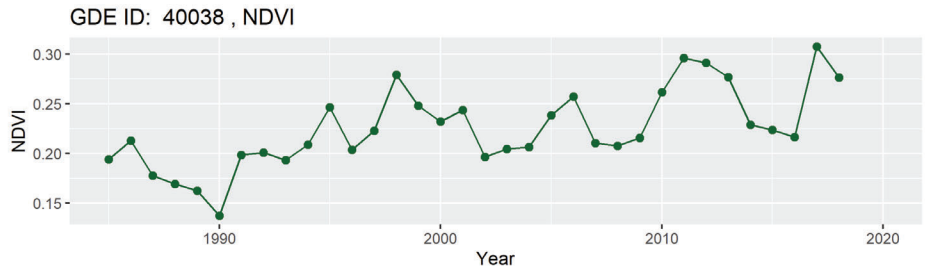
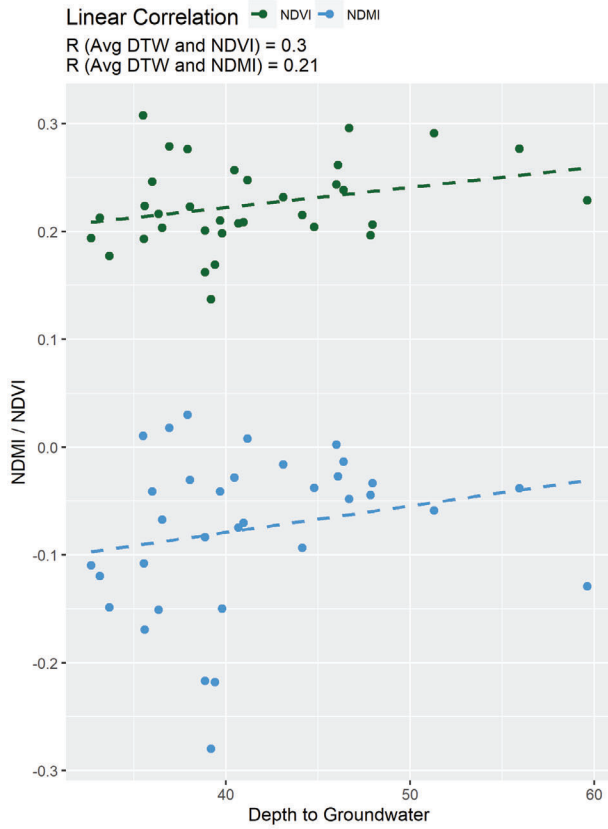


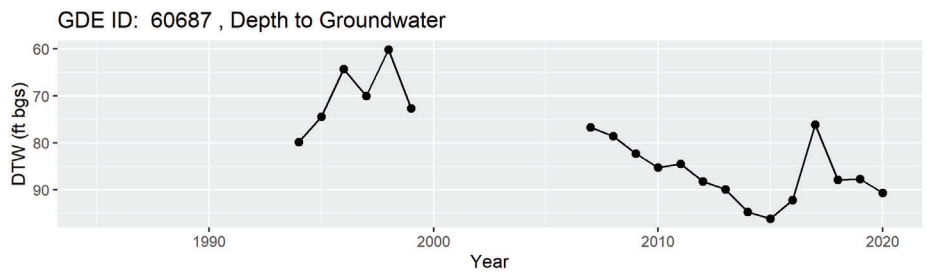
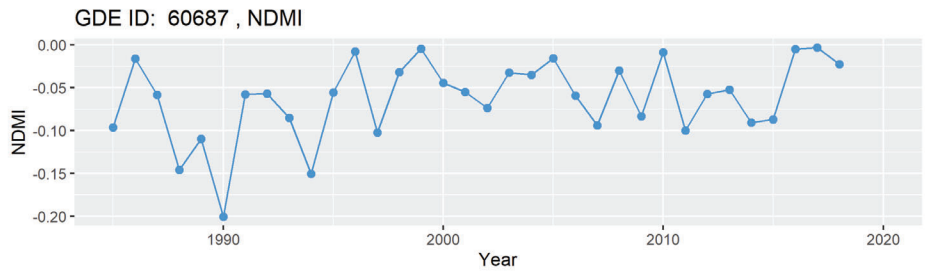
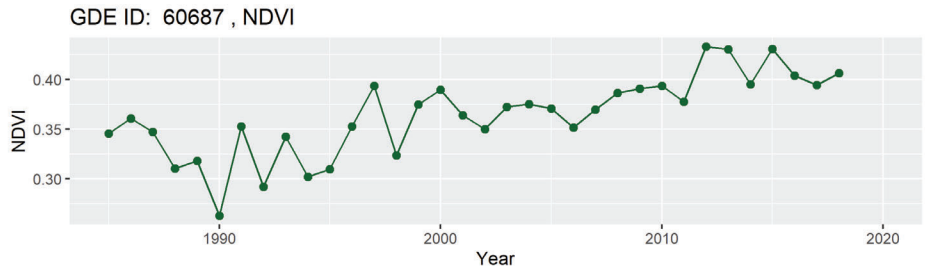
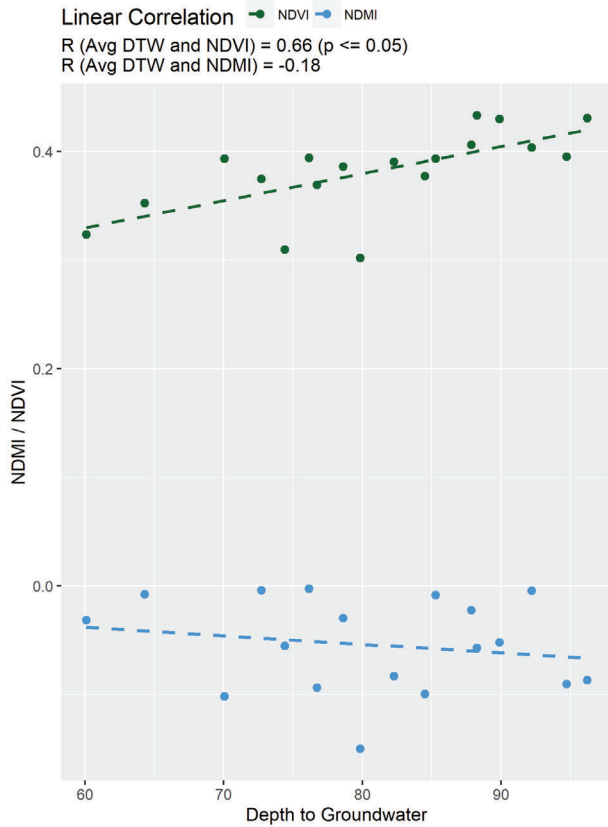
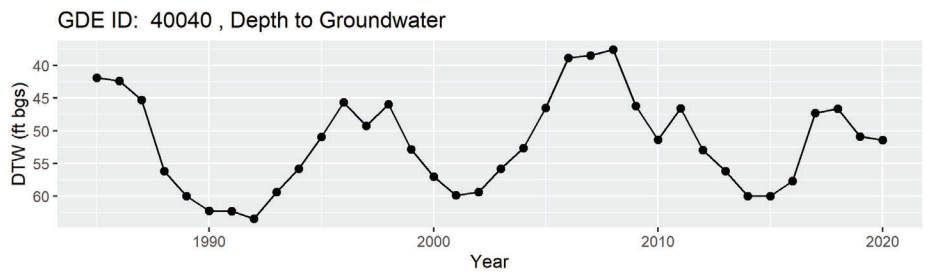
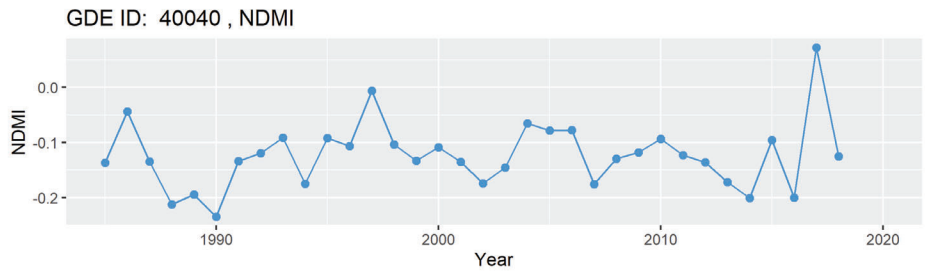
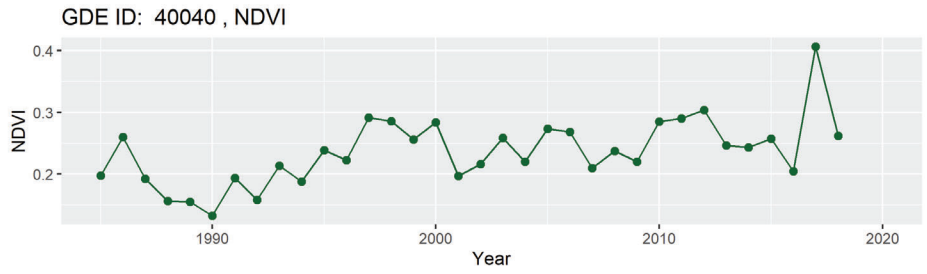
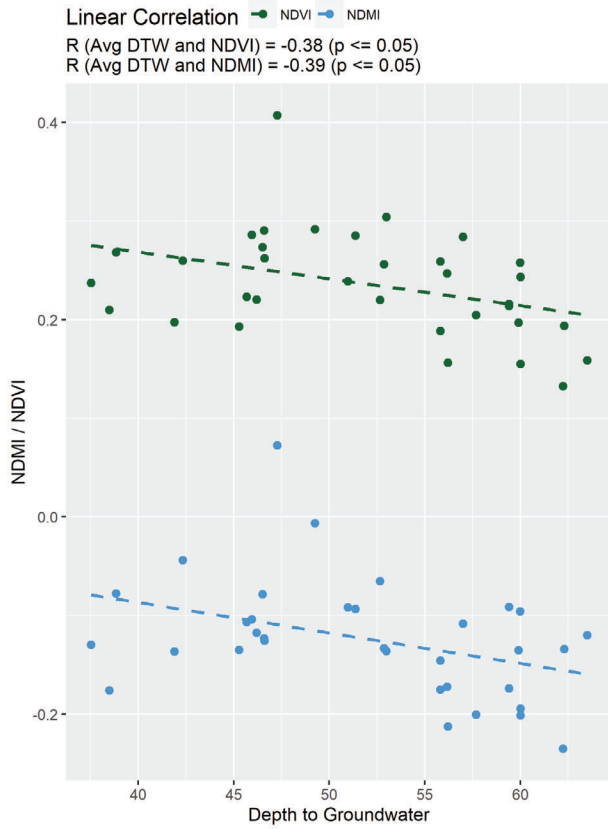








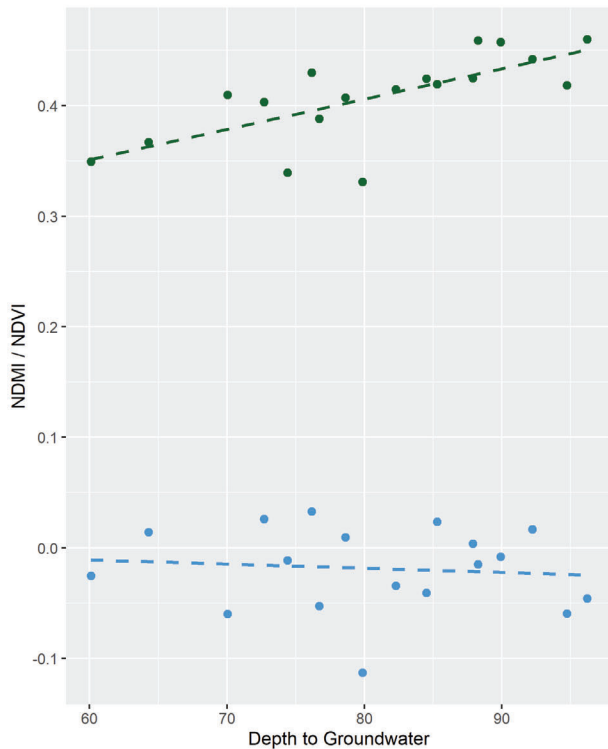




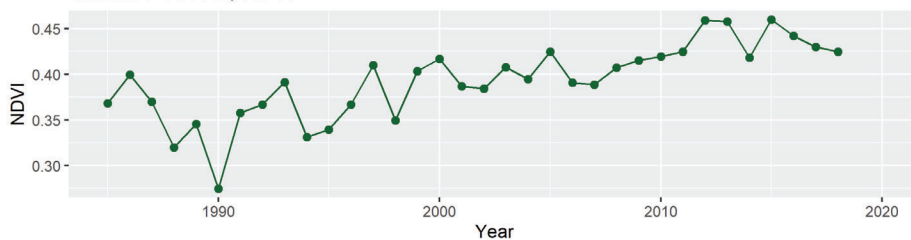
Linear Correlation

- NDVI
- NDMI

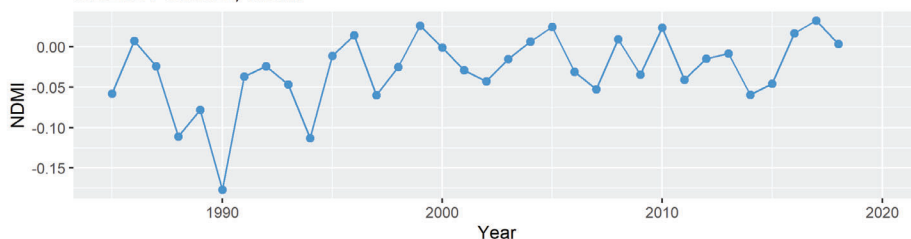
R (Avg DTW and NDVI) = 0.71 ($p \leq 0.05$)
R (Avg DTW and NDMI) = -0.1



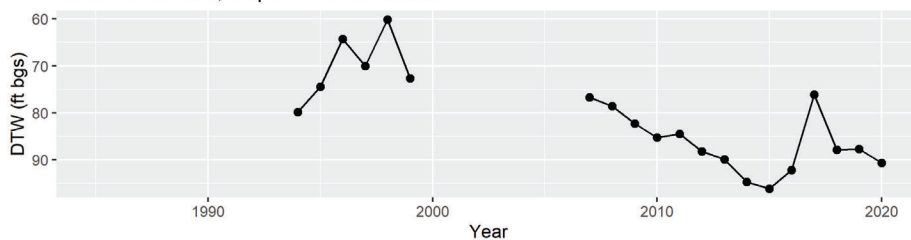
GDE ID: 60692 , NDVI



GDE ID: 60692 , NDMI



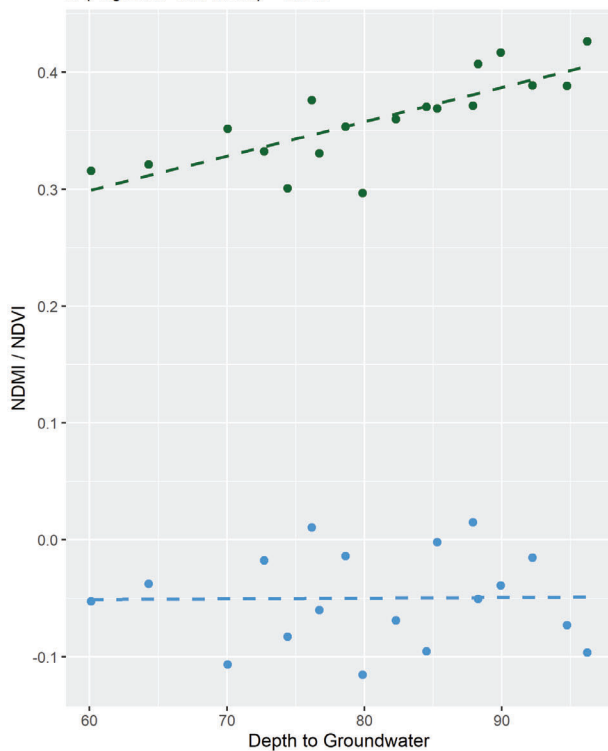
GDE ID: 60692 , Depth to Groundwater



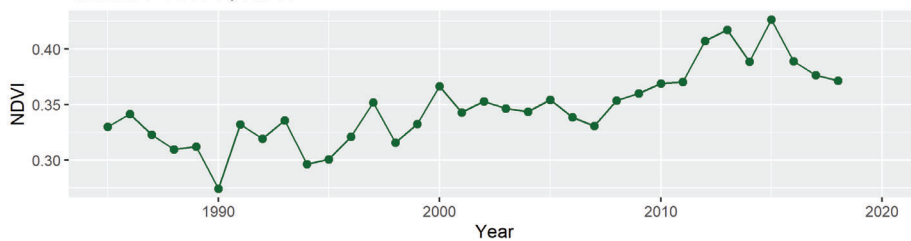
Linear Correlation

- NDVI
- NDMI

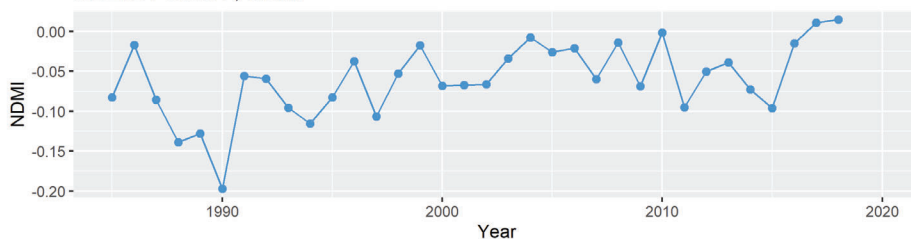
R (Avg DTW and NDVI) = 0.78 ($p \leq 0.05$)
R (Avg DTW and NDMI) = 0.013



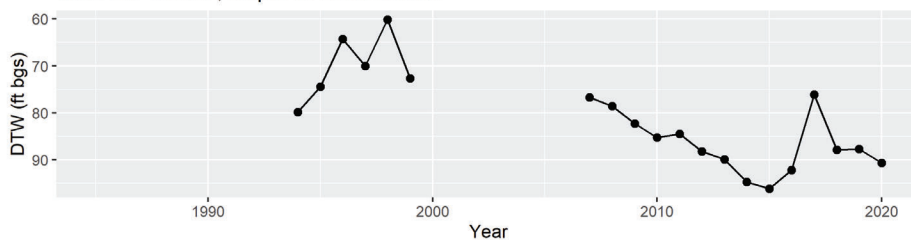
GDE ID: 60694 , NDVI

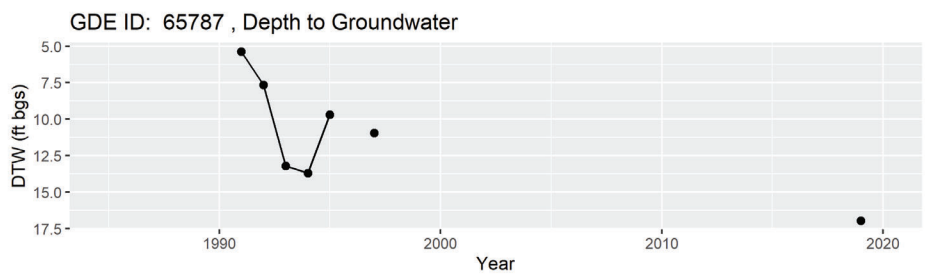
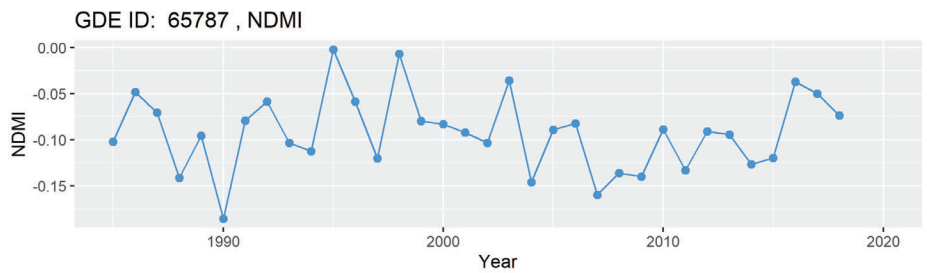
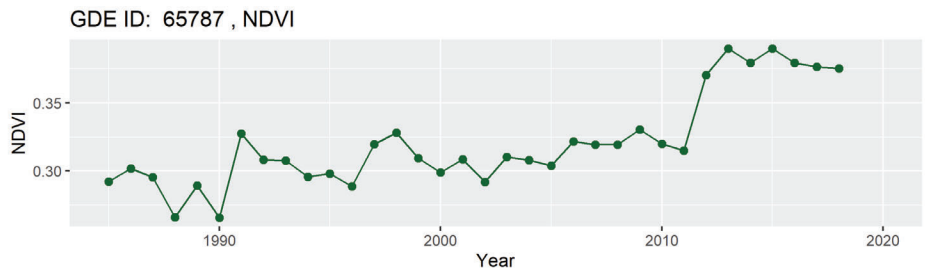
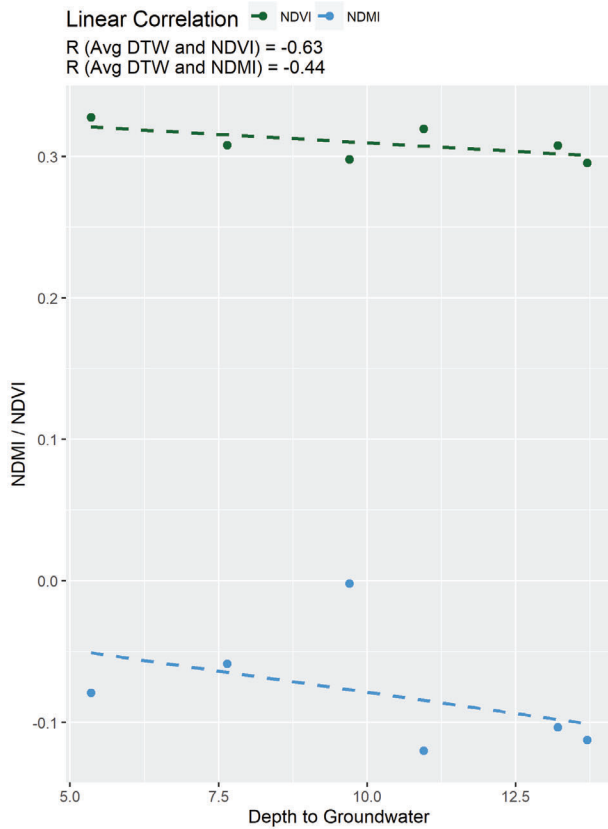
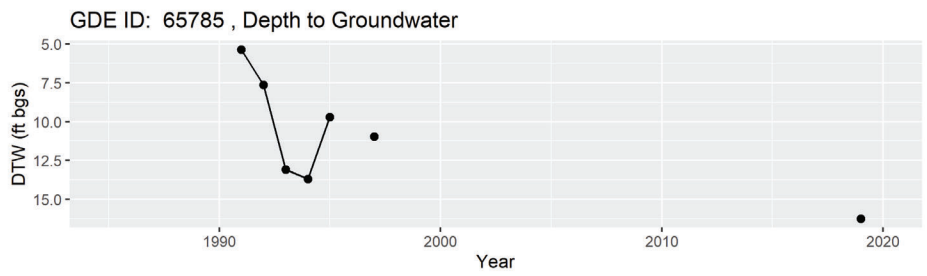
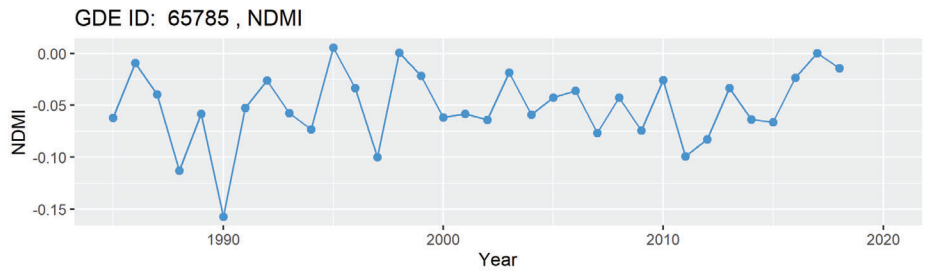
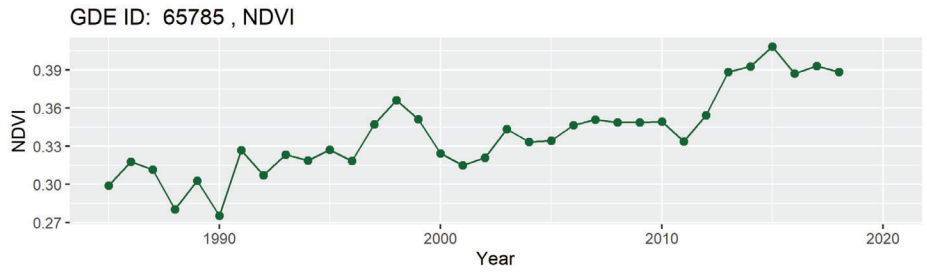
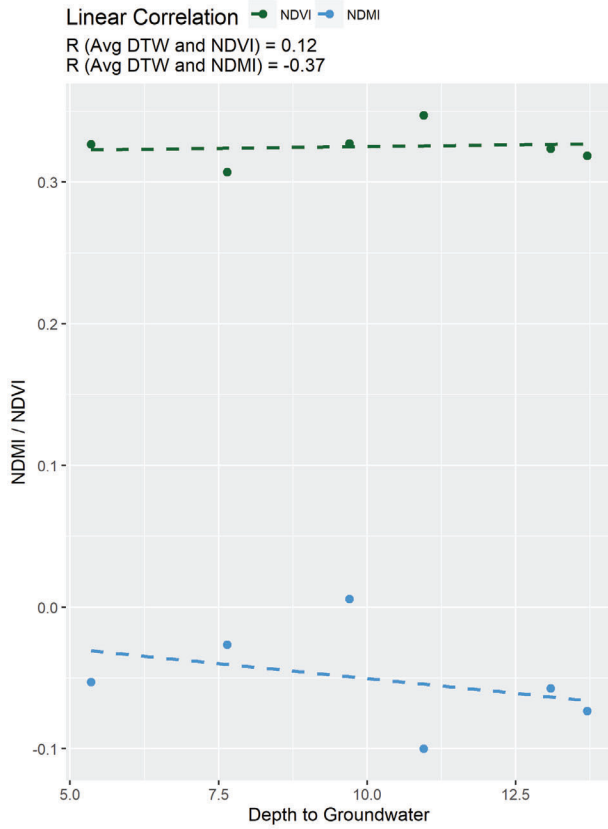


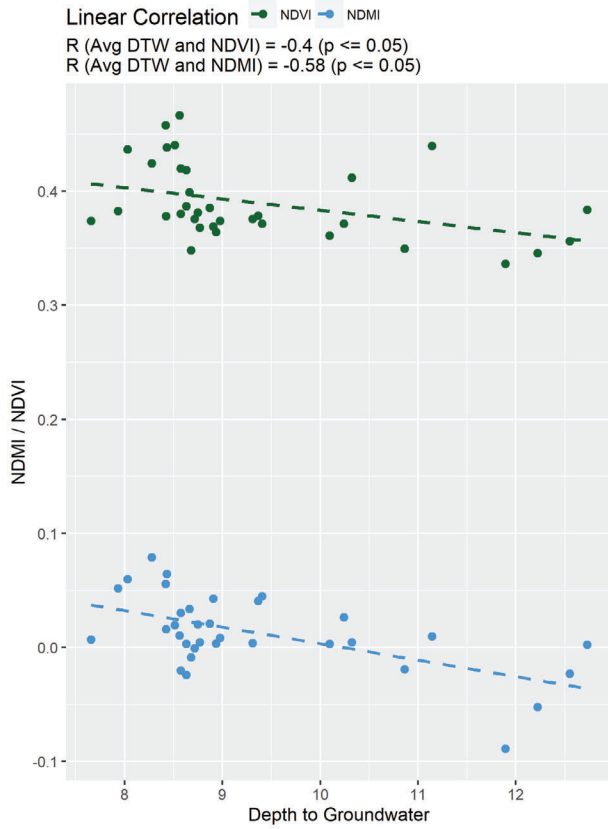
GDE ID: 60694 , NDMI



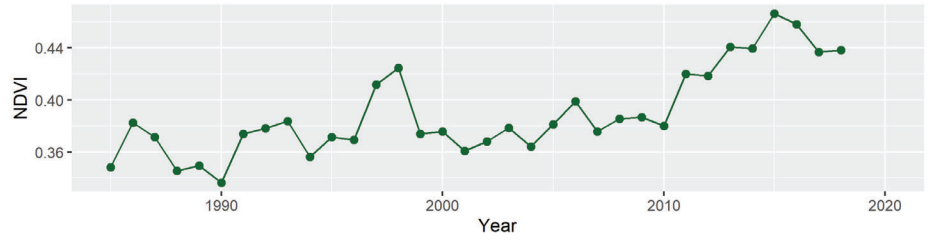
GDE ID: 60694 , Depth to Groundwater



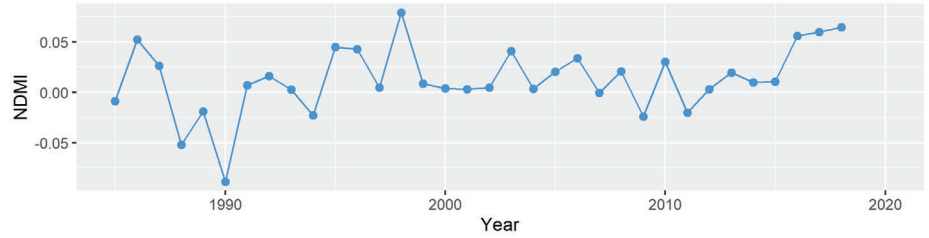




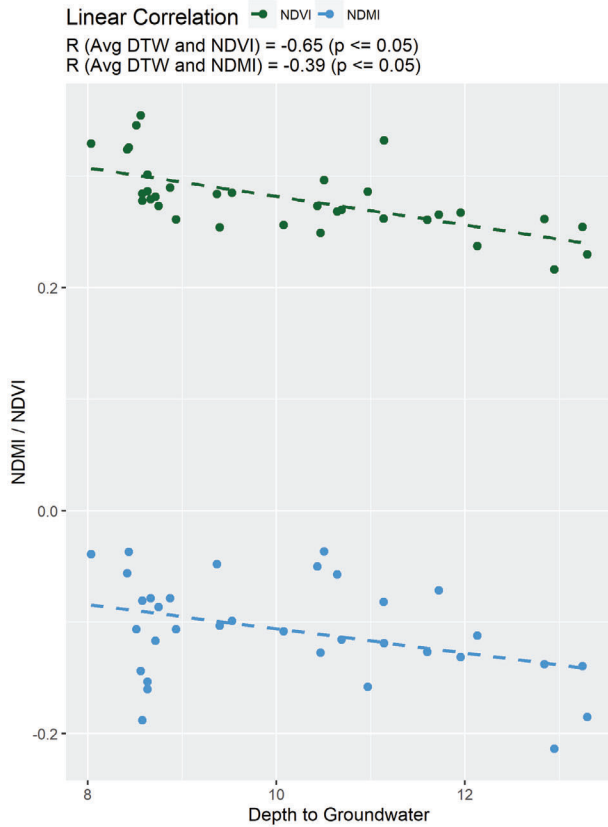
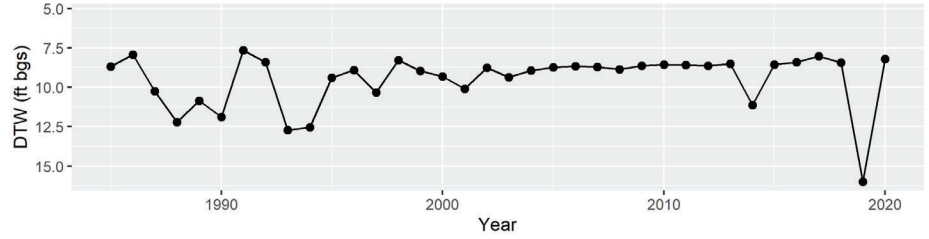
GDE ID: 65792 , NDVI



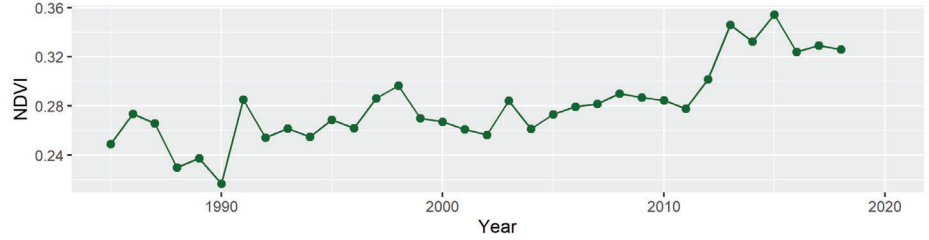
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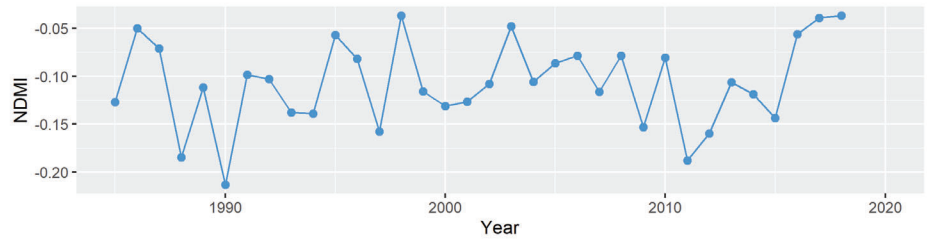
GDE ID: 65792 , Depth to Groundwater



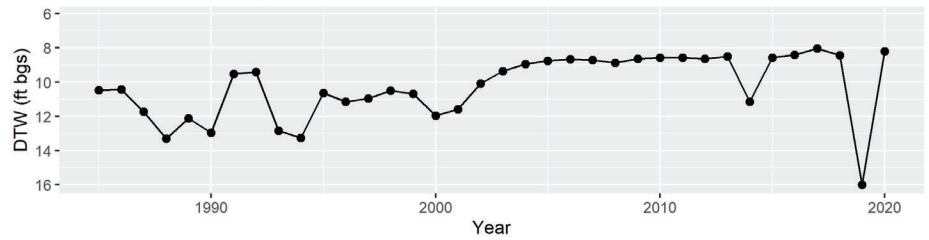
GDE ID: 65793 , NDVI

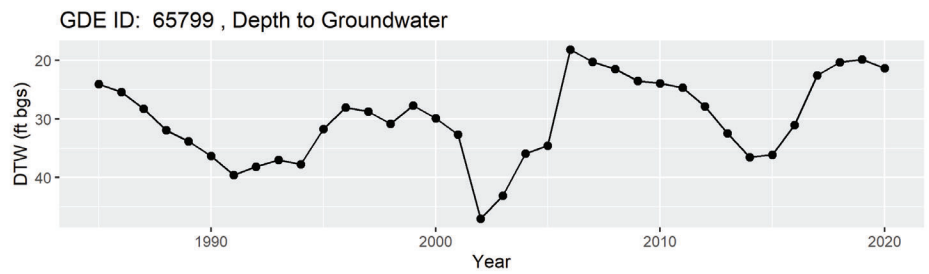
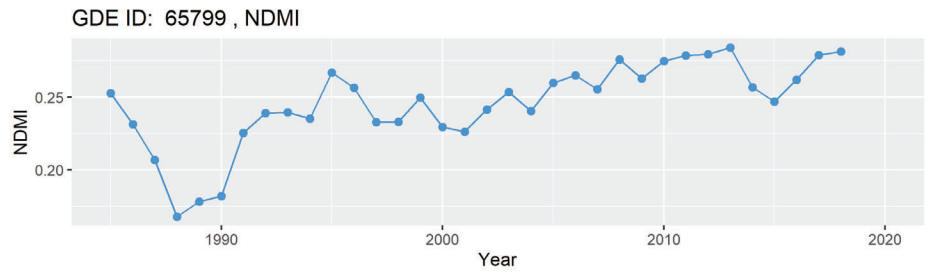
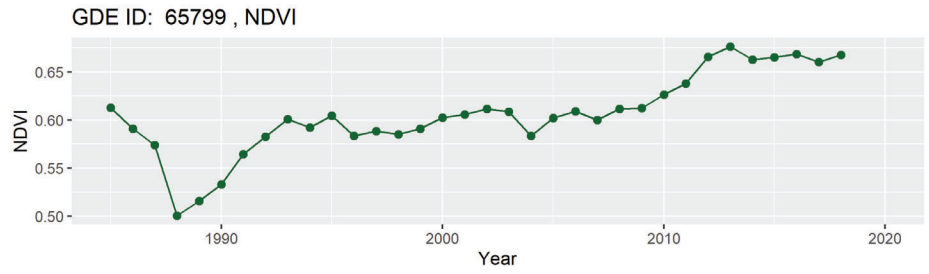
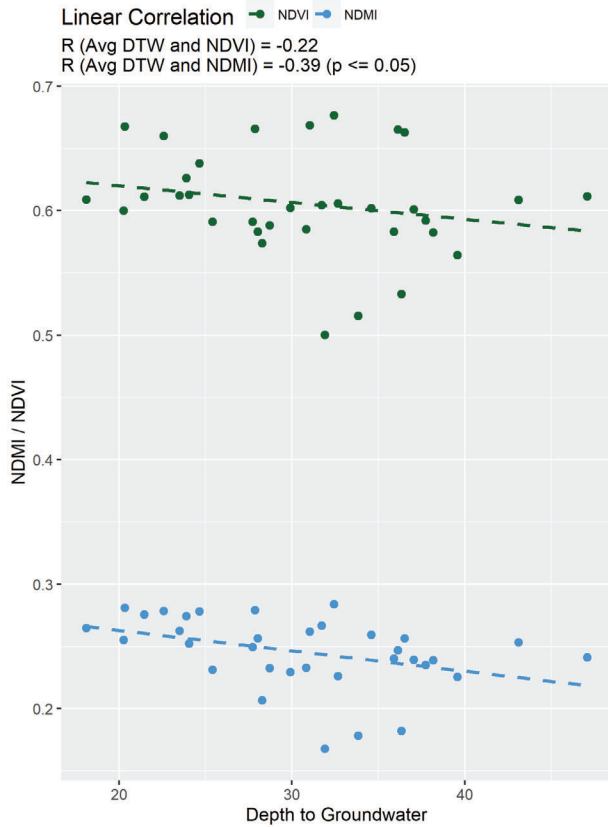
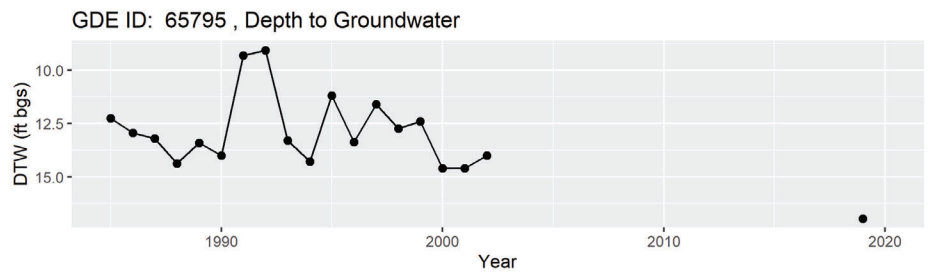
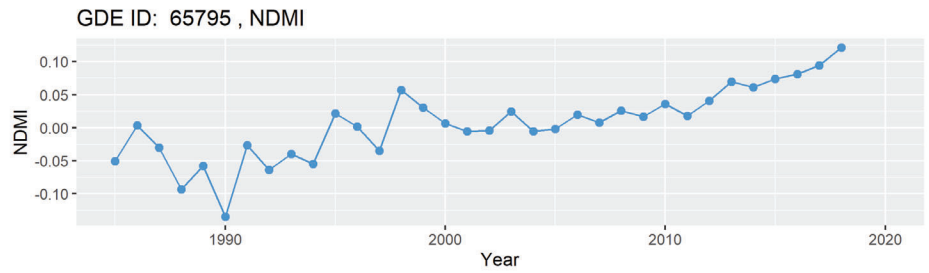
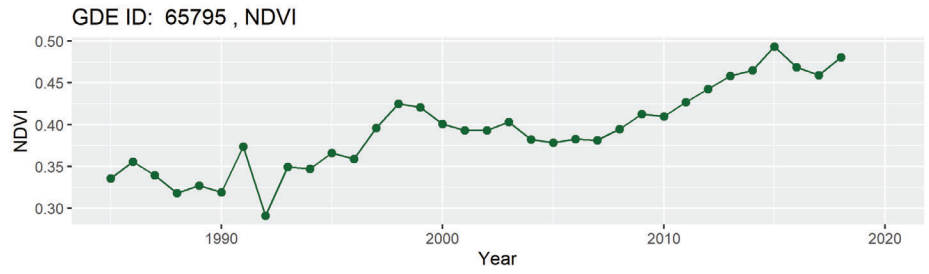
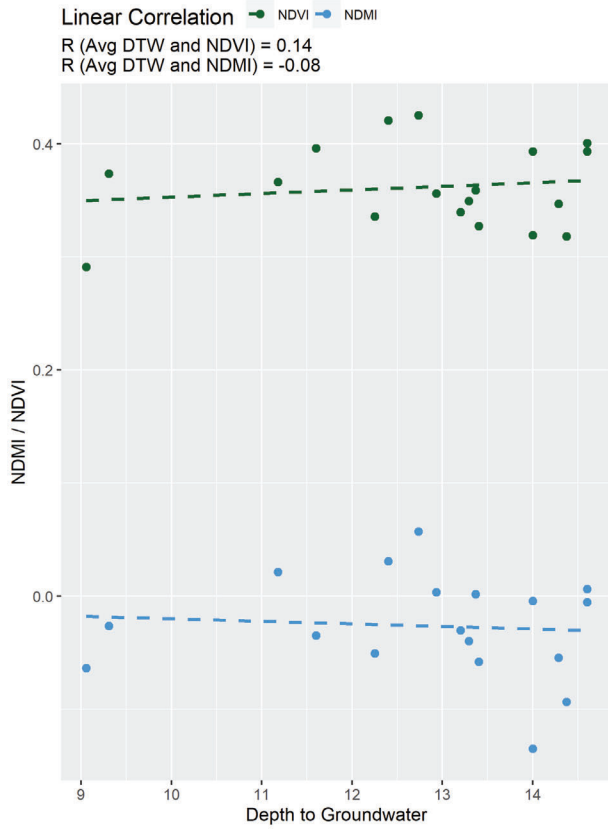


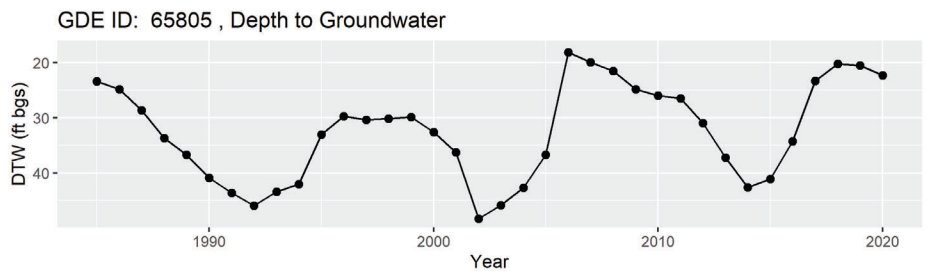
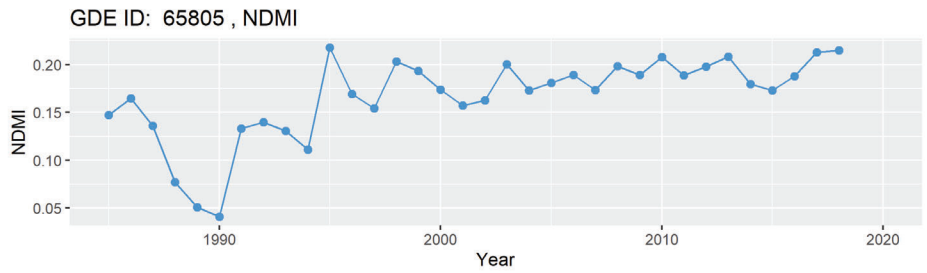
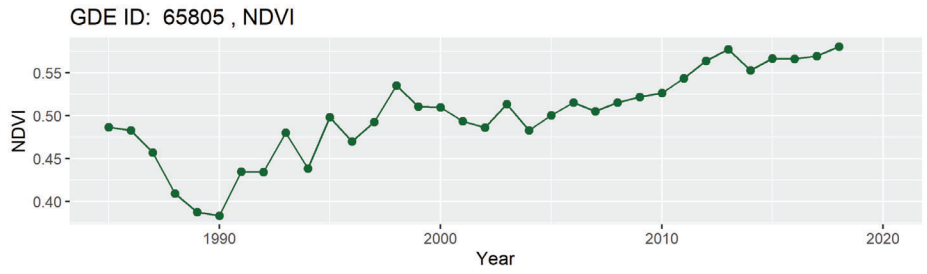
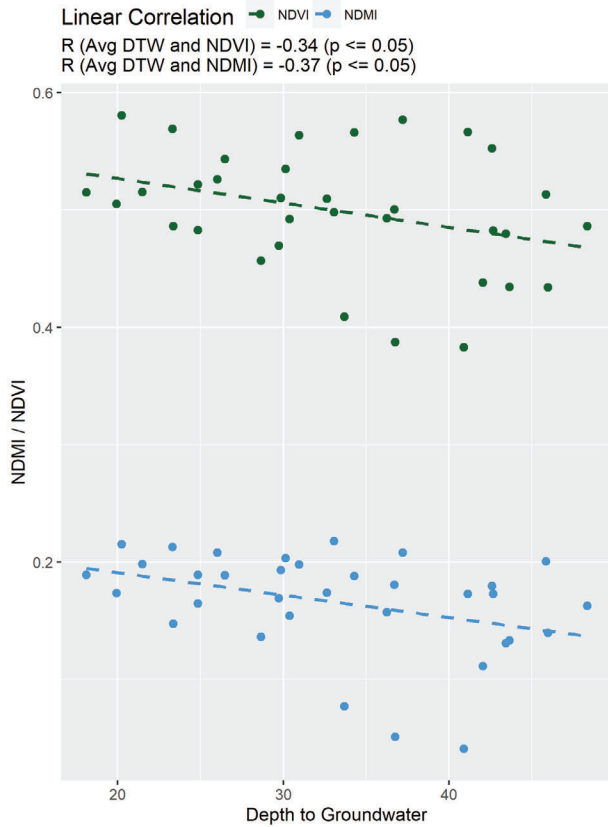
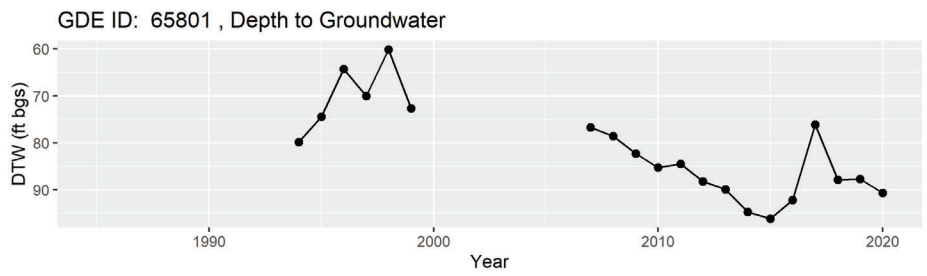
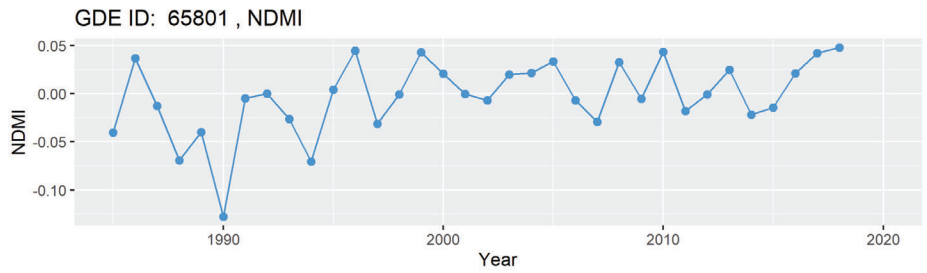
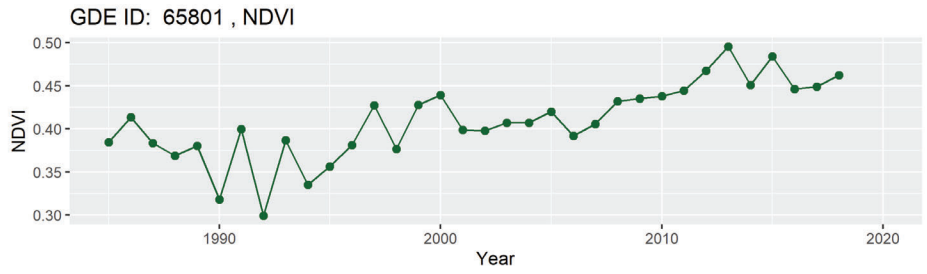
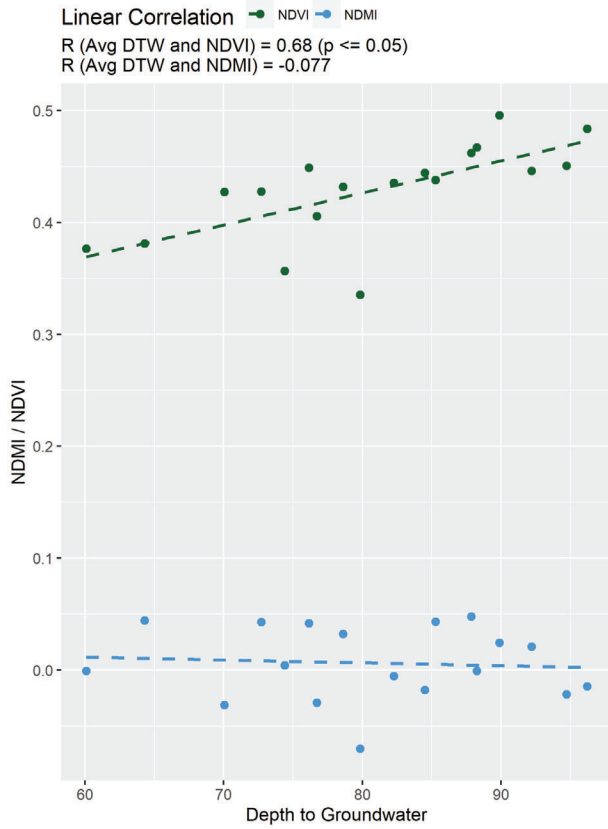
GDE ID: 65793 , NDMI

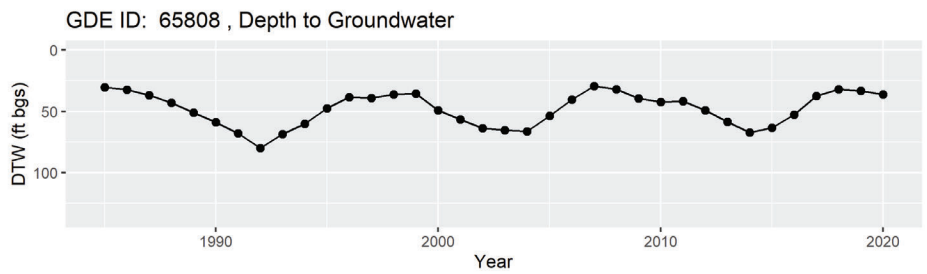
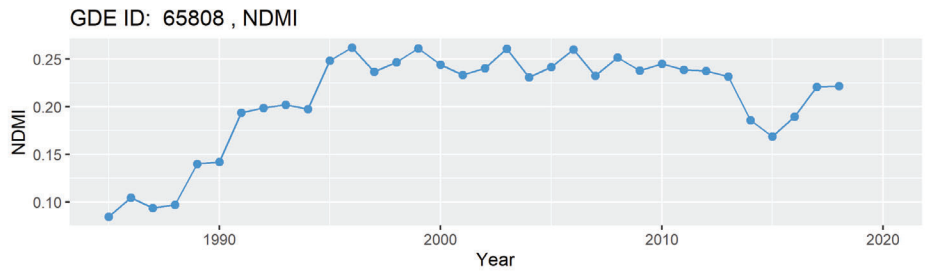
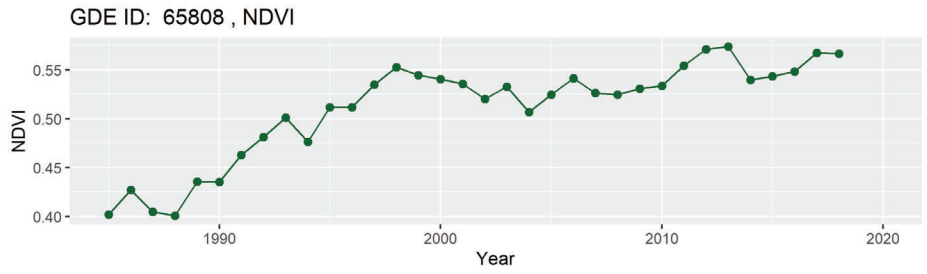
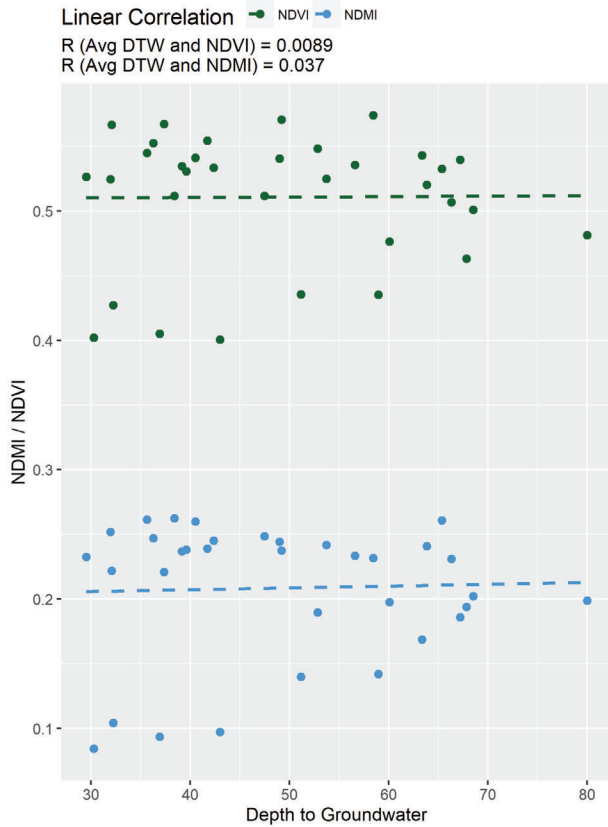
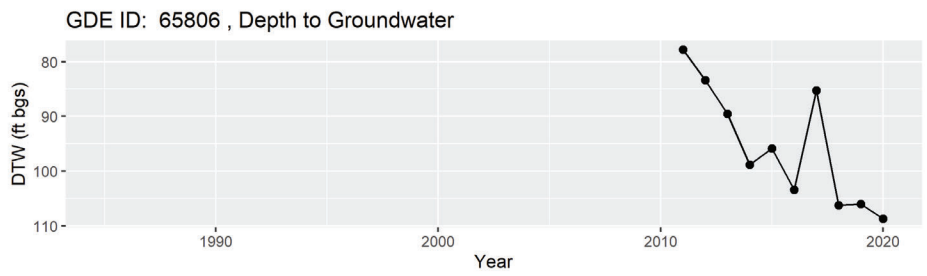
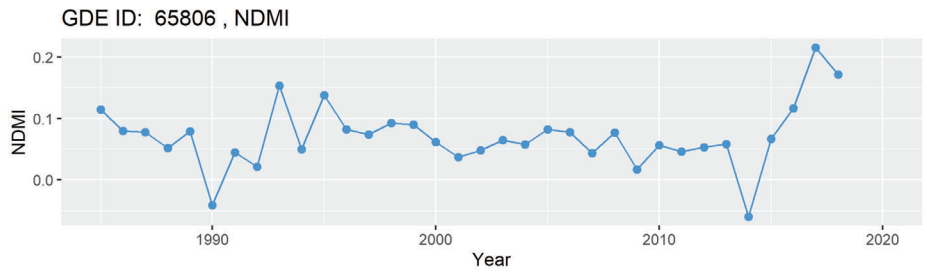
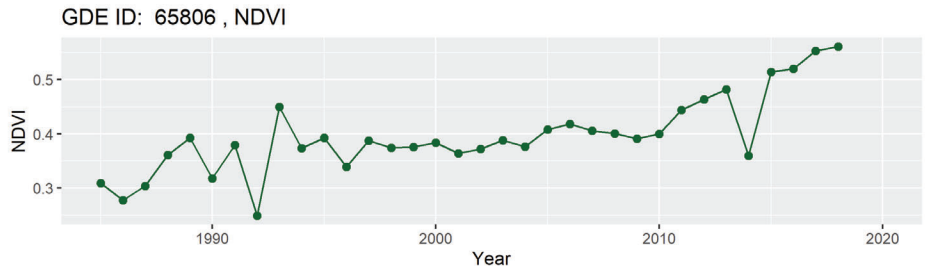
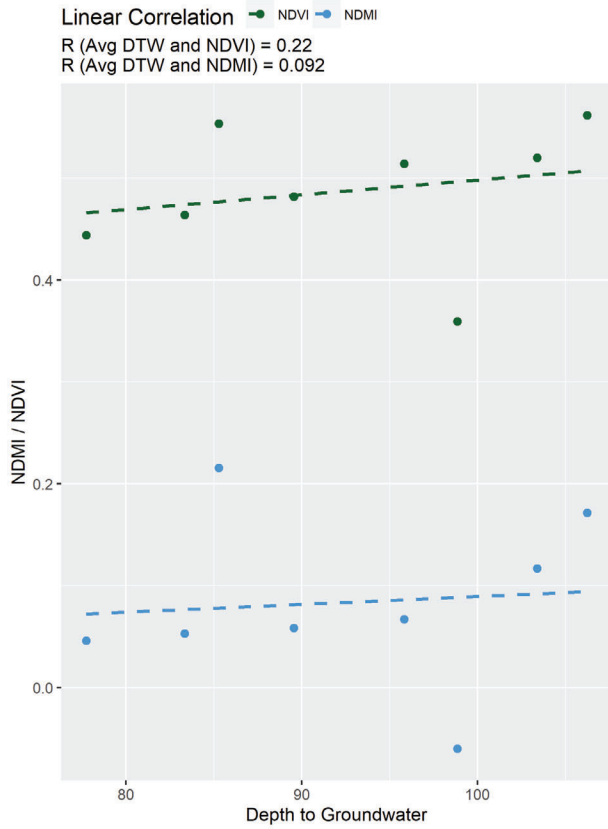


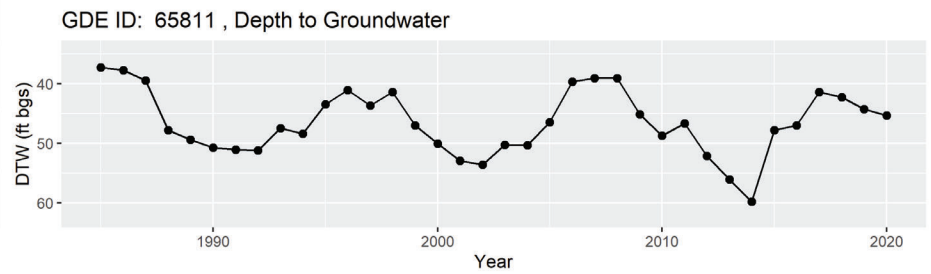
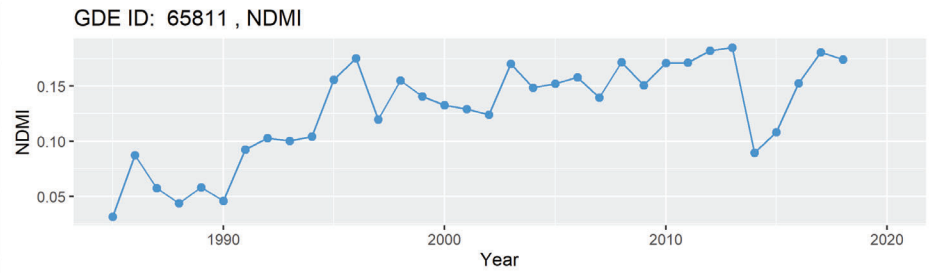
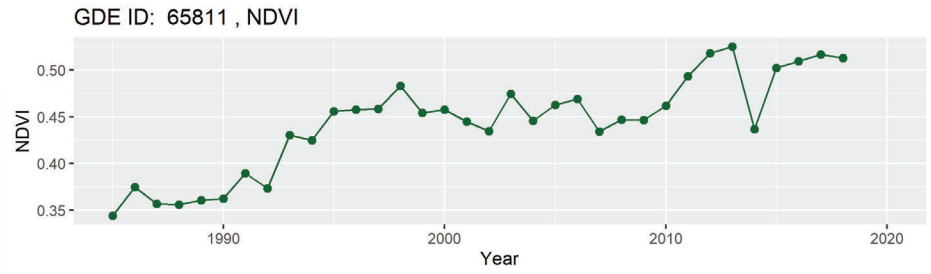
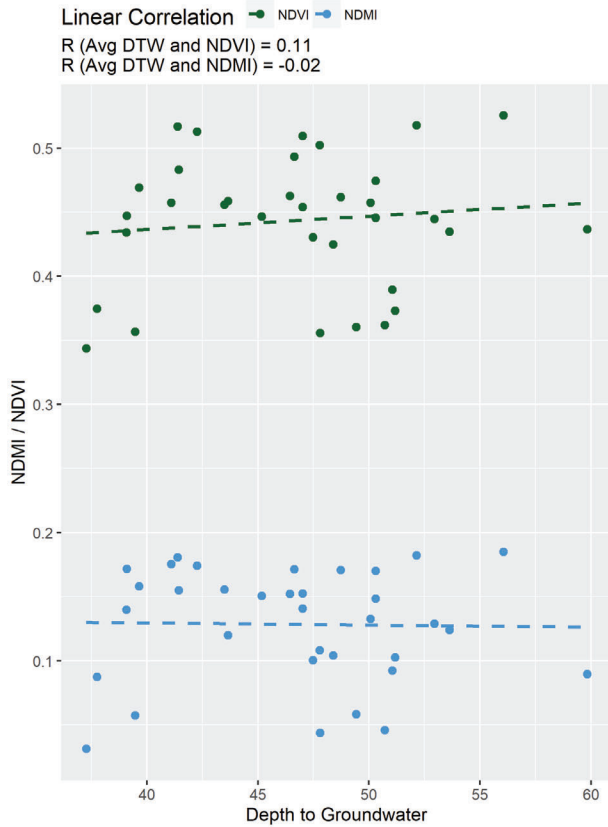
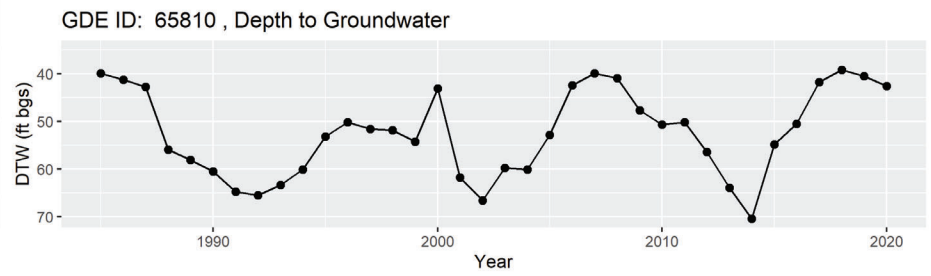
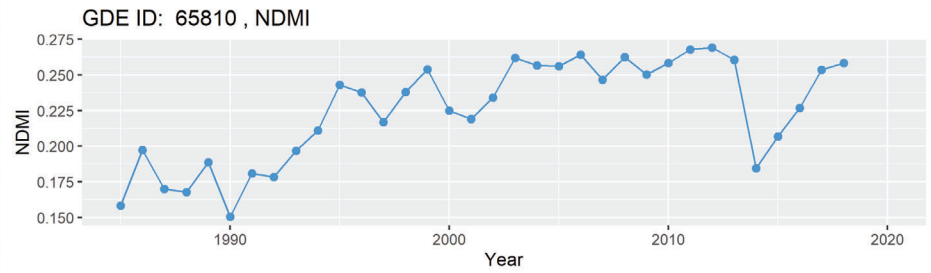
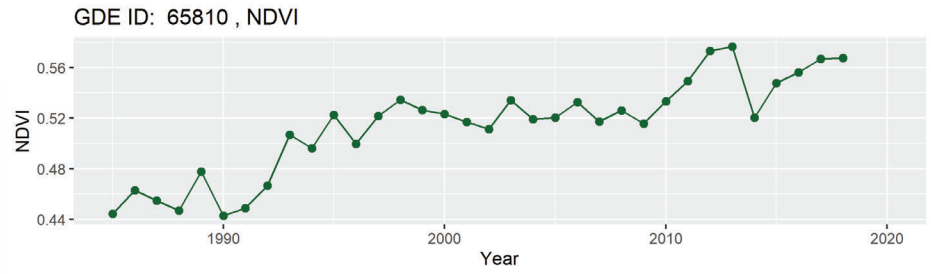
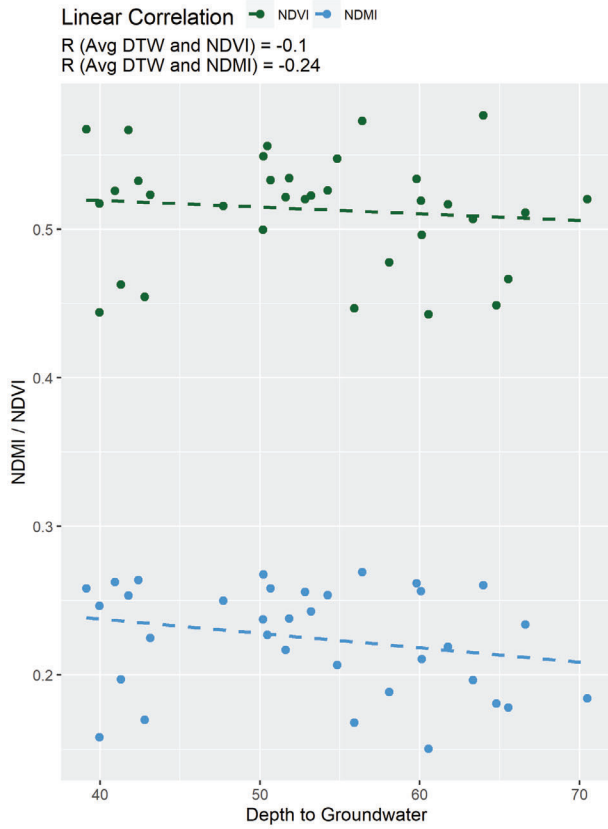
GDE ID: 65793 , Depth to Groundwater

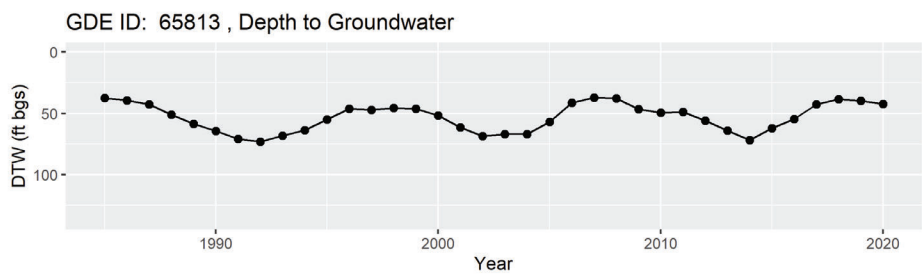
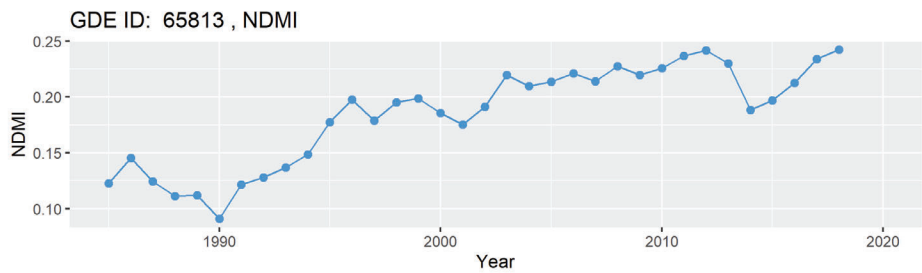
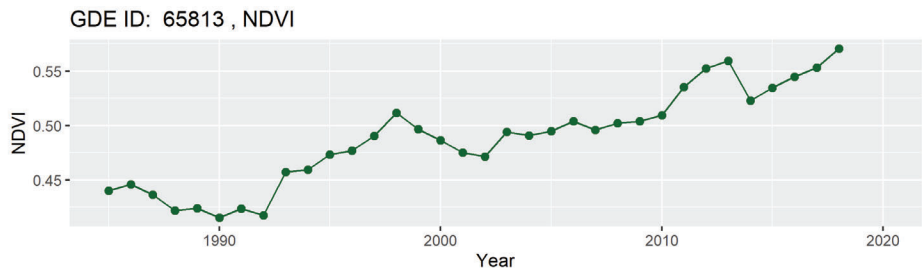
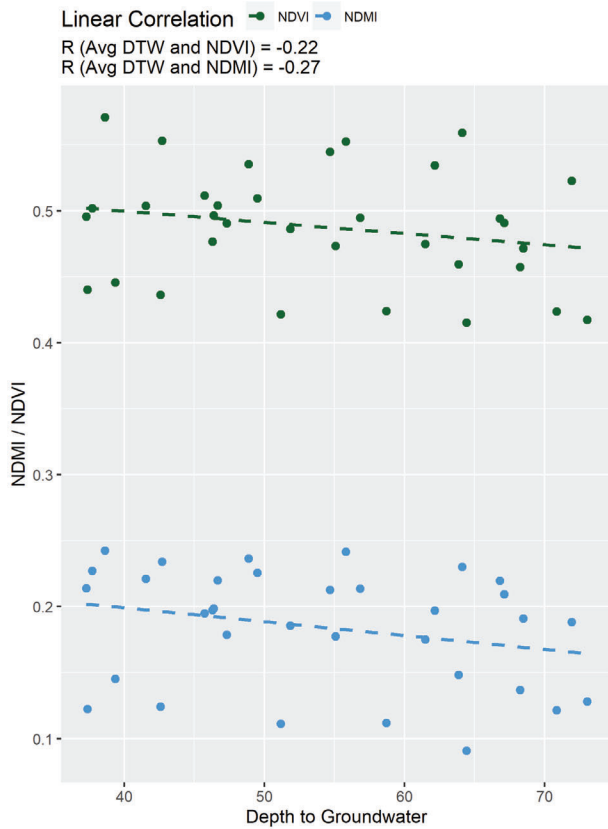
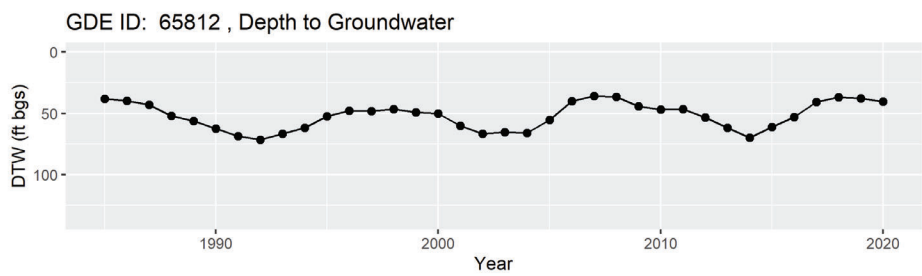
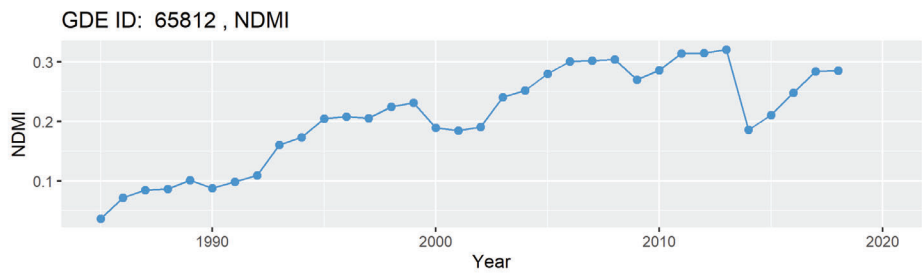
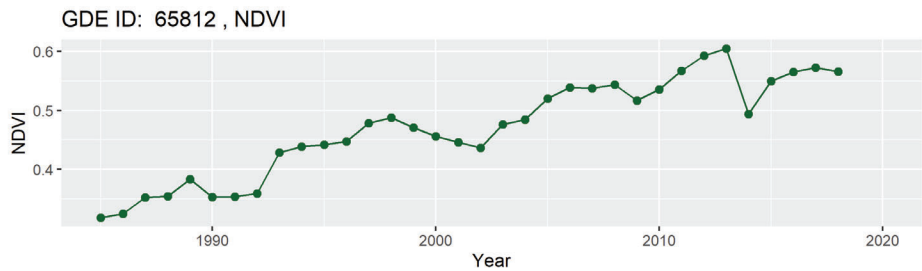
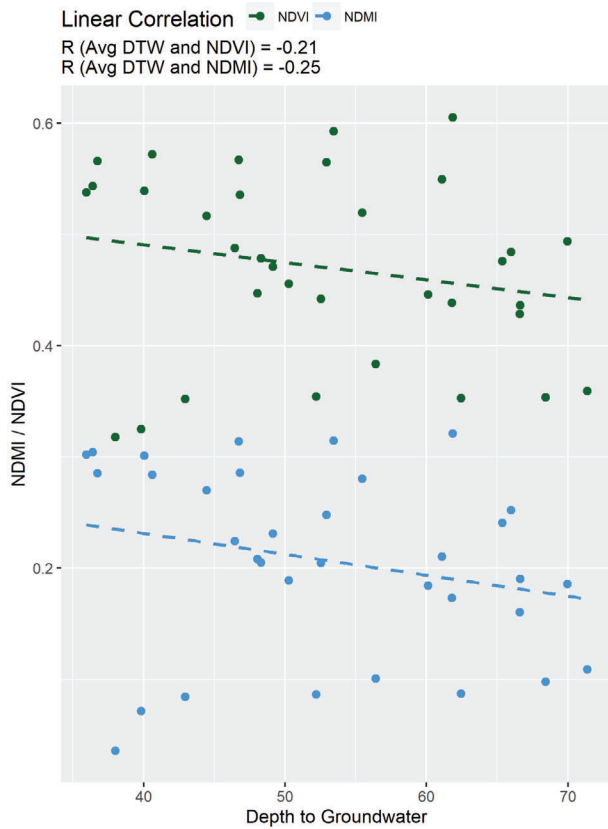


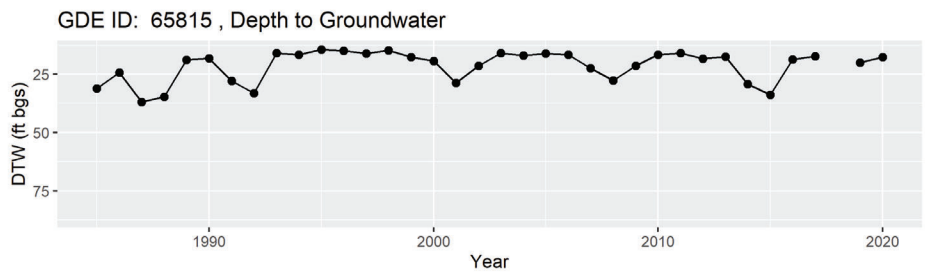
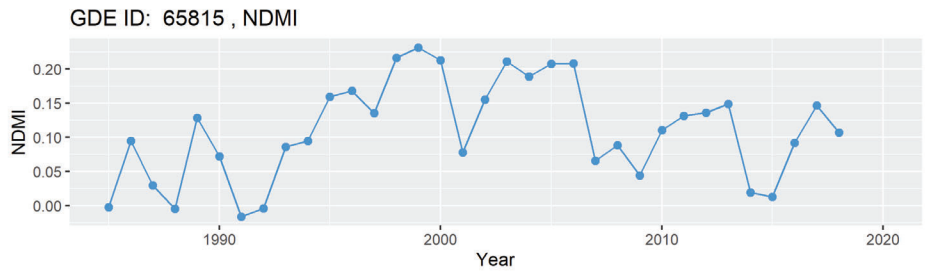
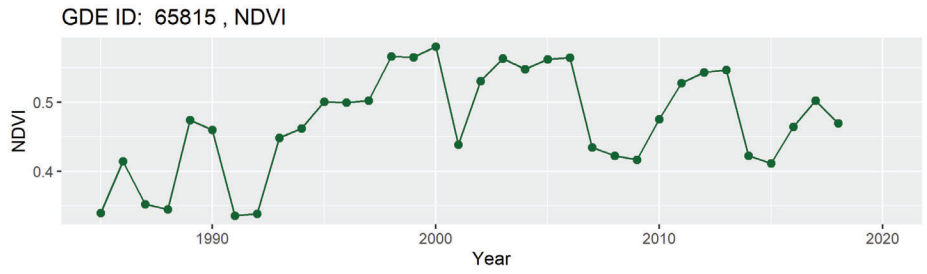
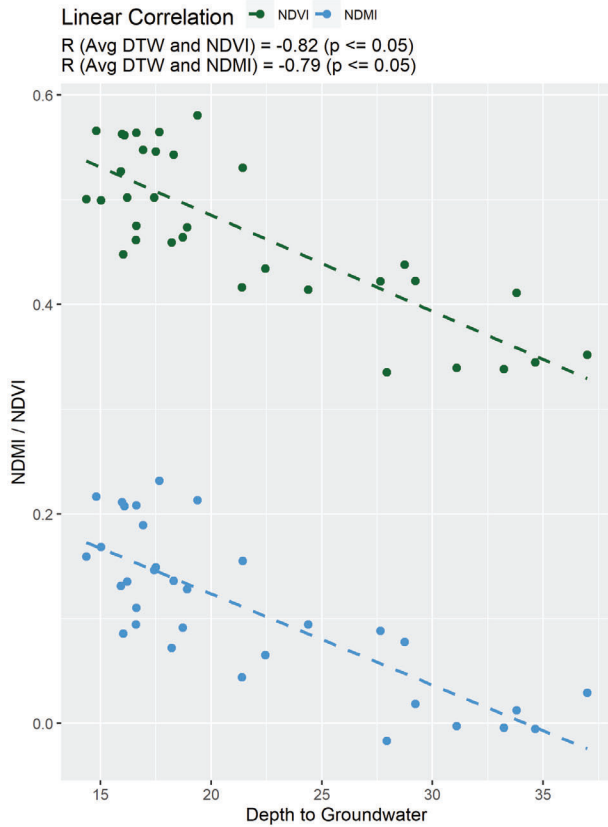
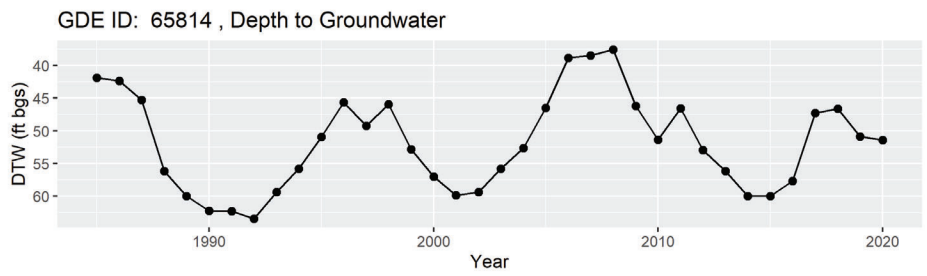
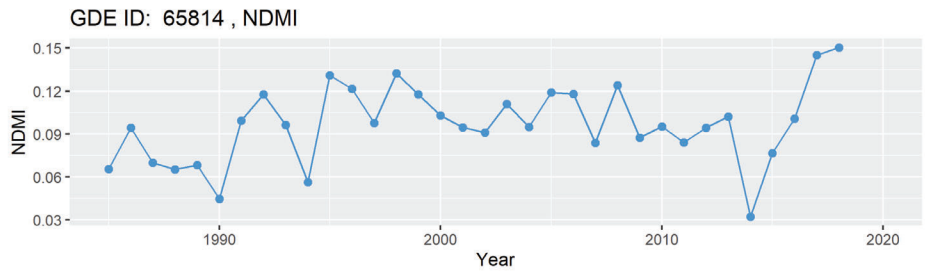
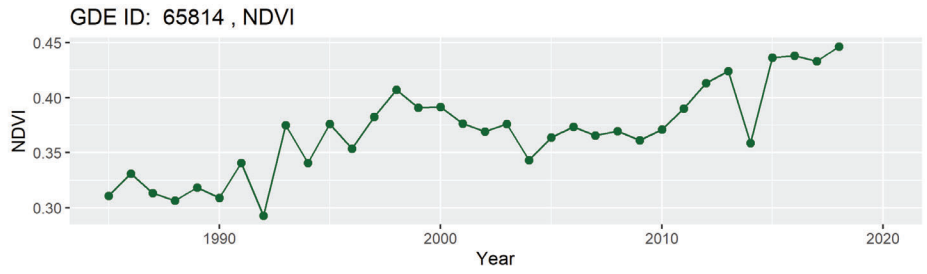
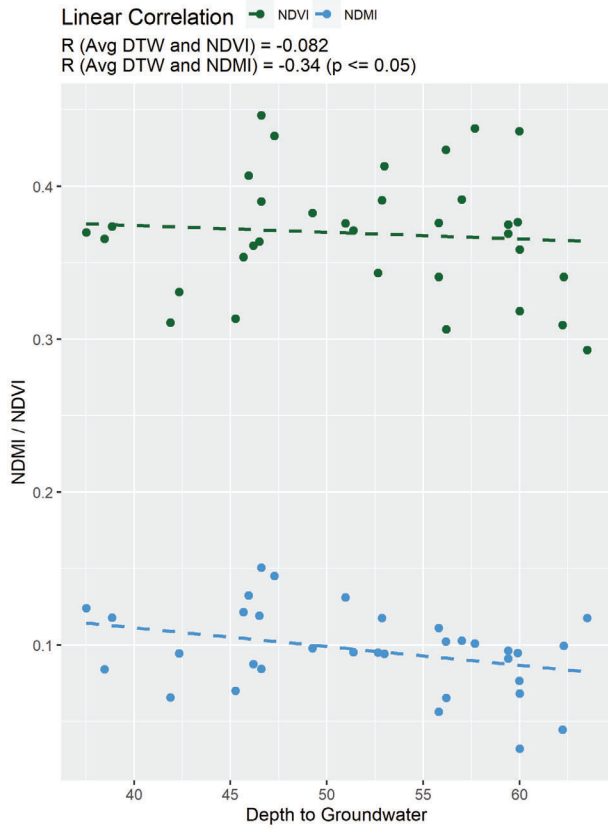


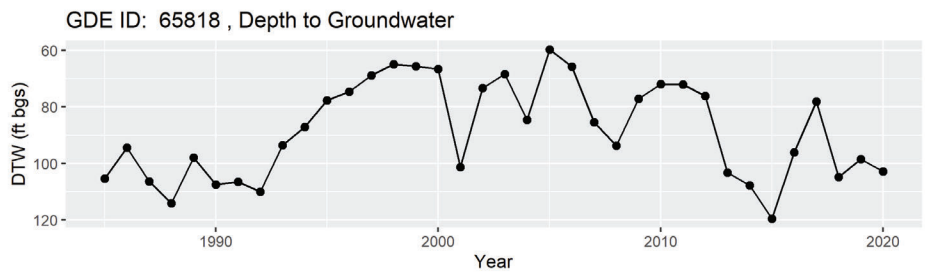
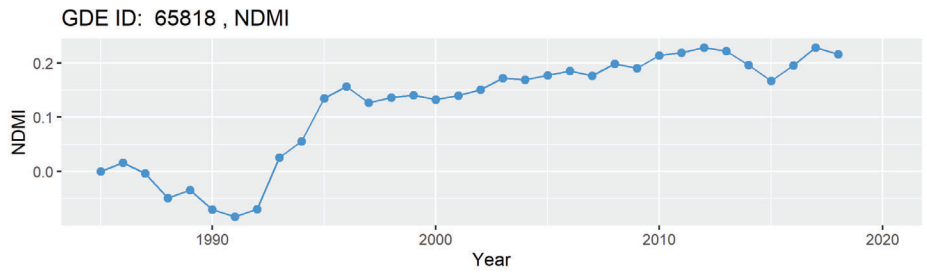
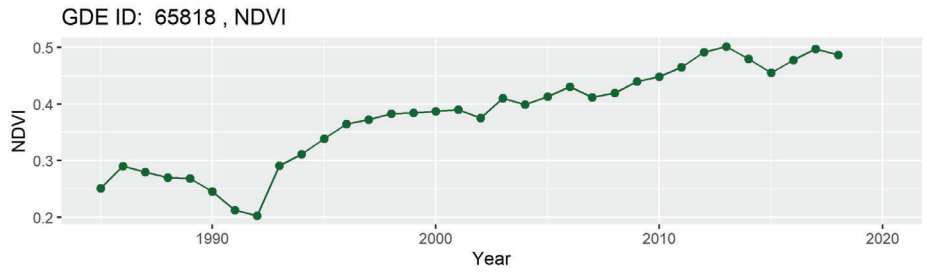
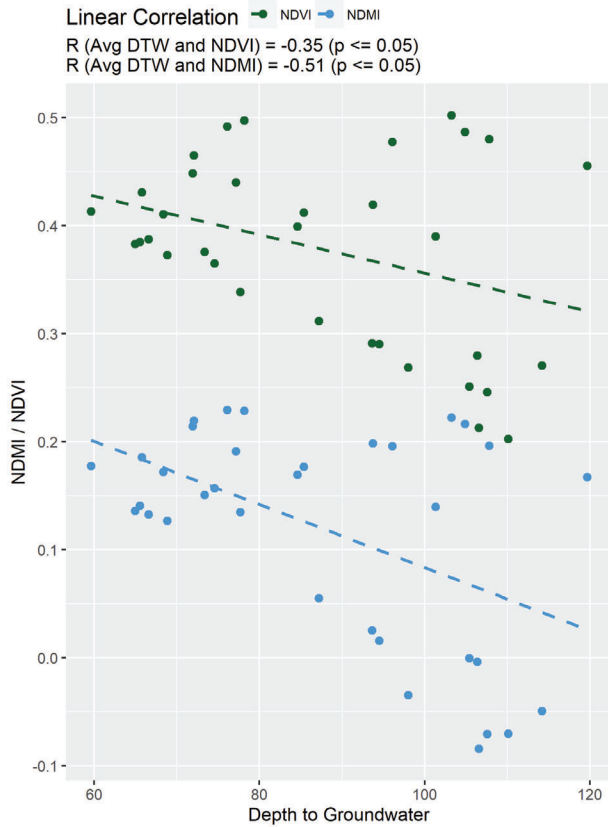
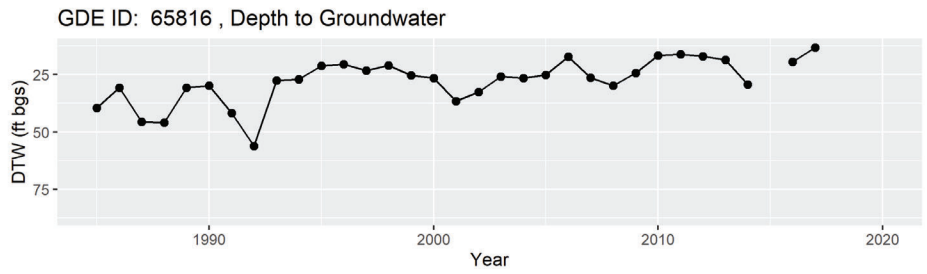
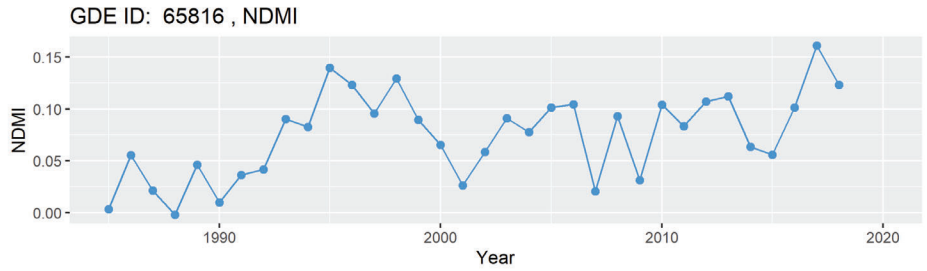
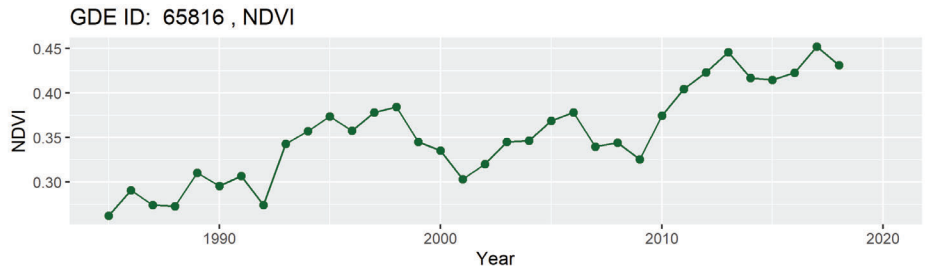
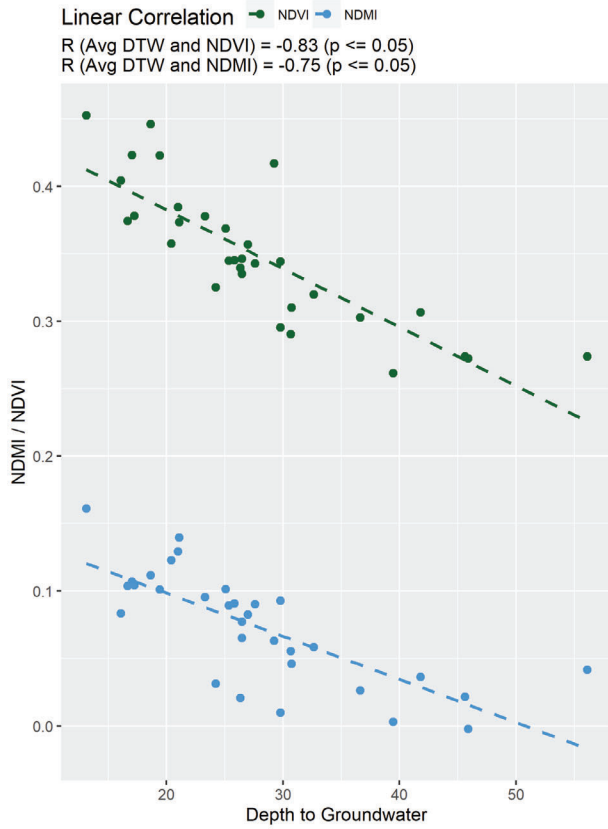


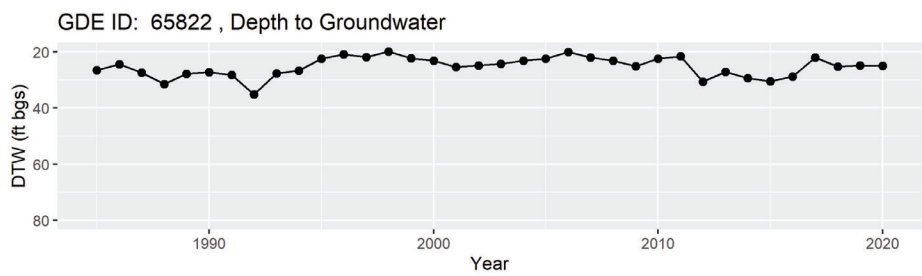
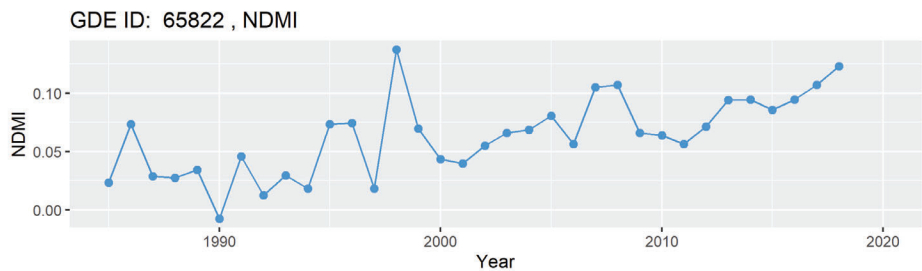
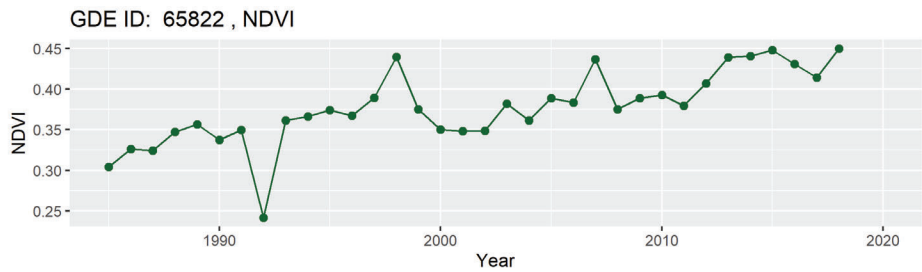
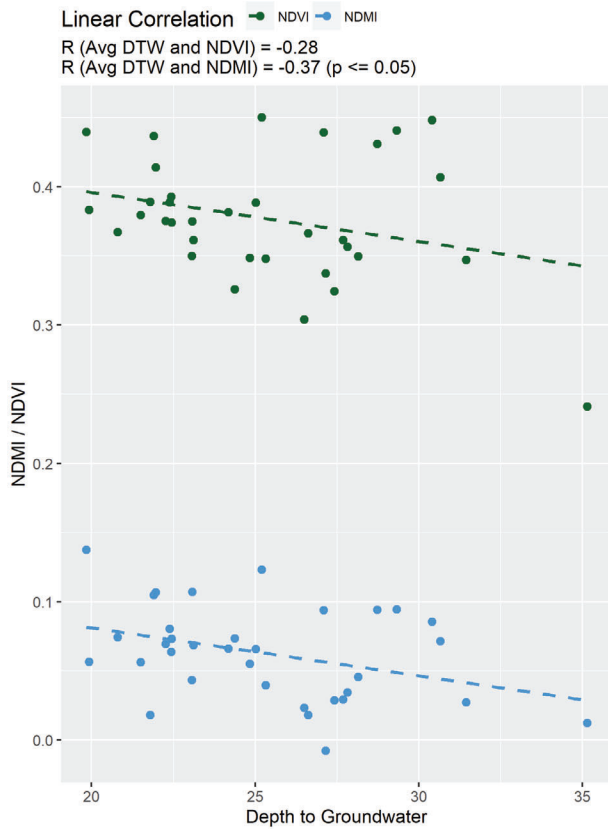
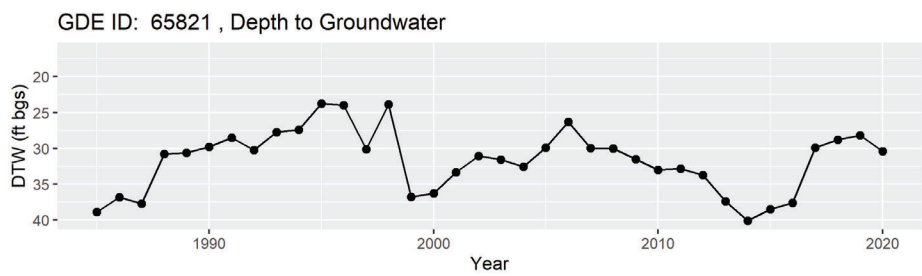
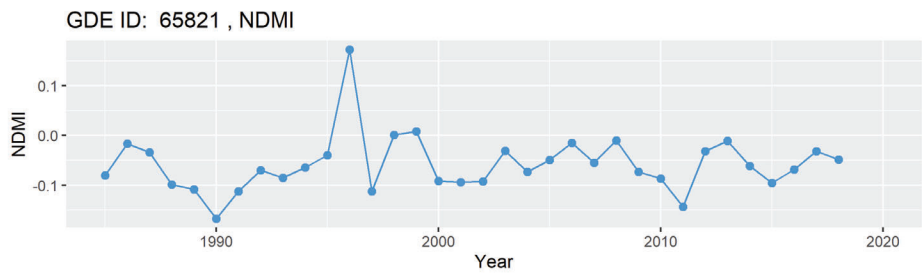
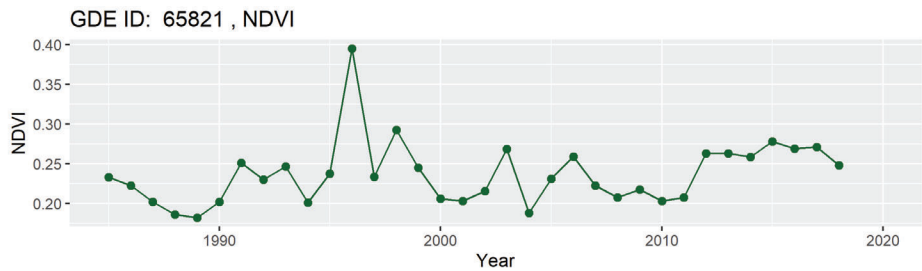
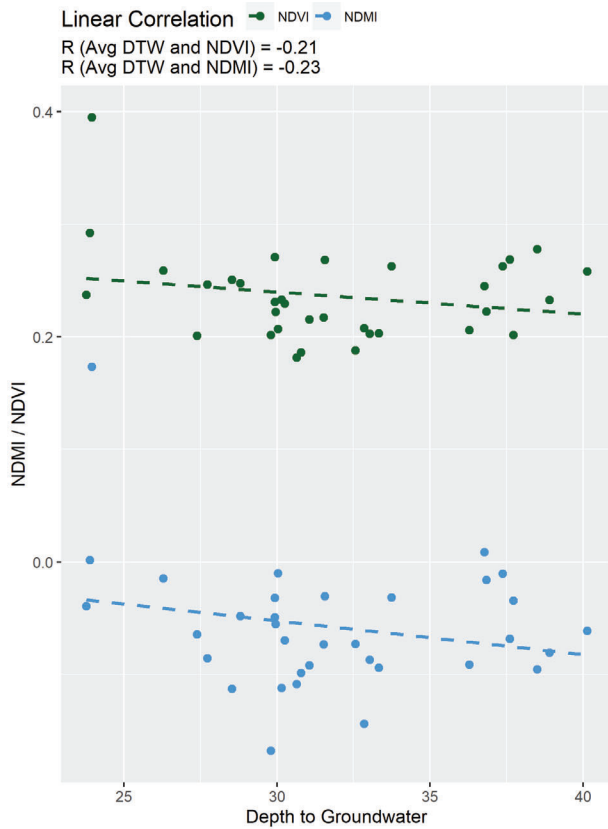


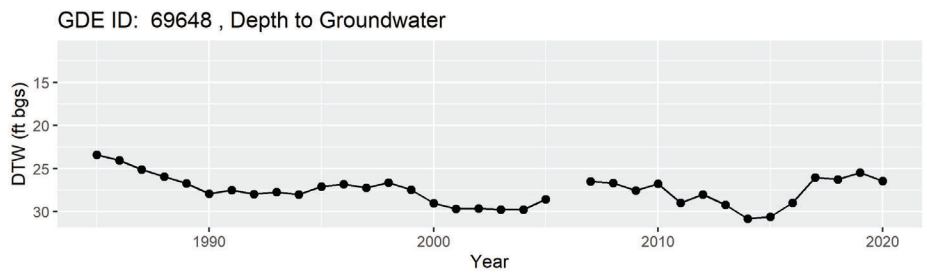
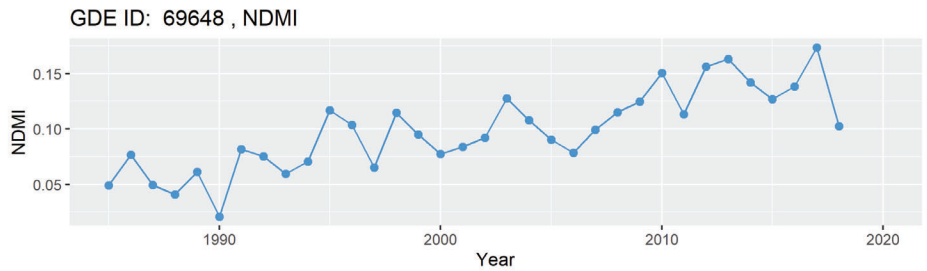
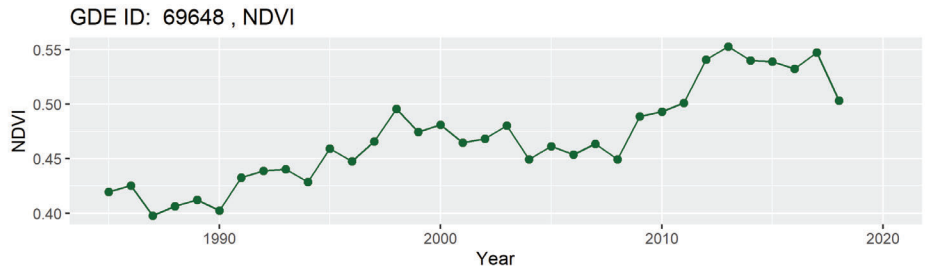
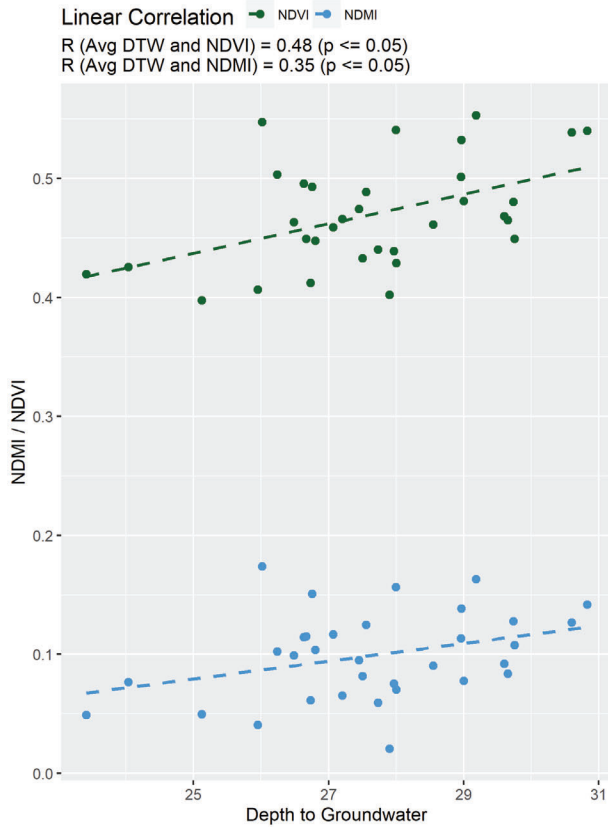
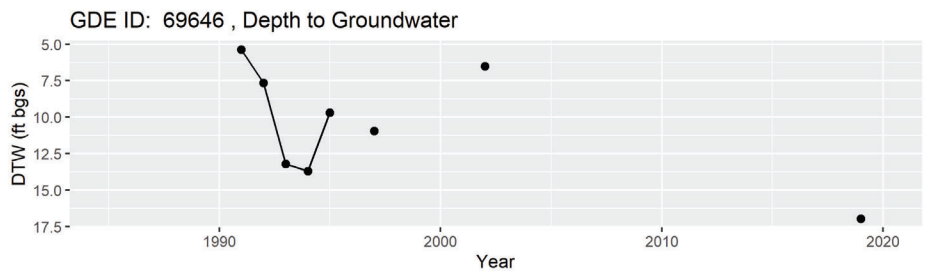
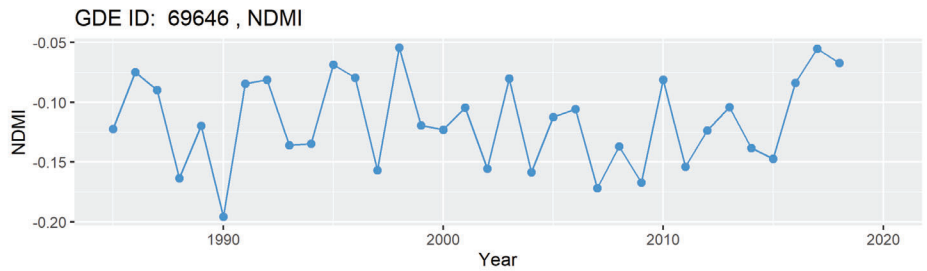
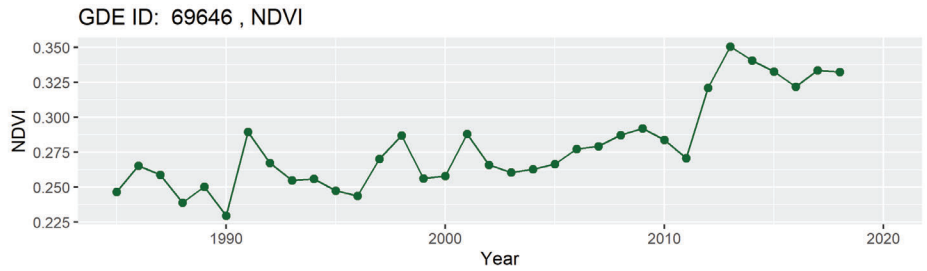
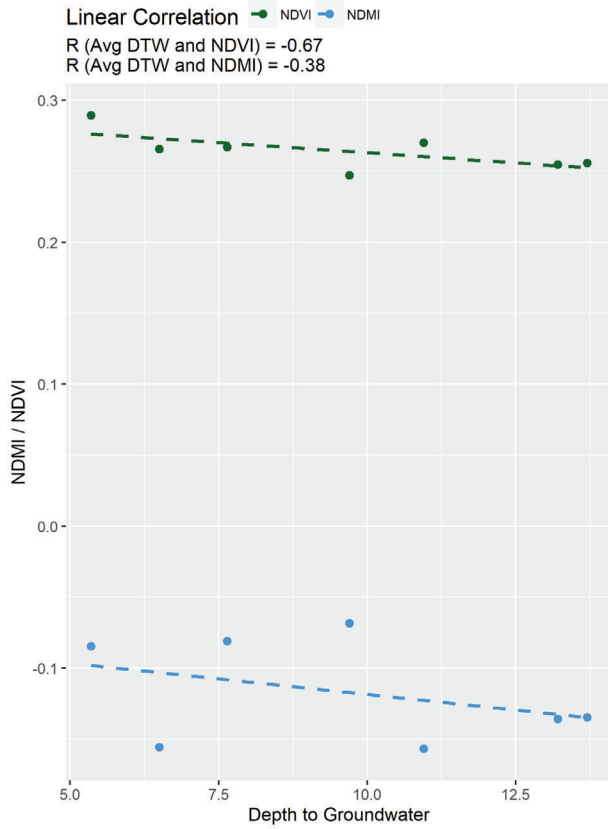


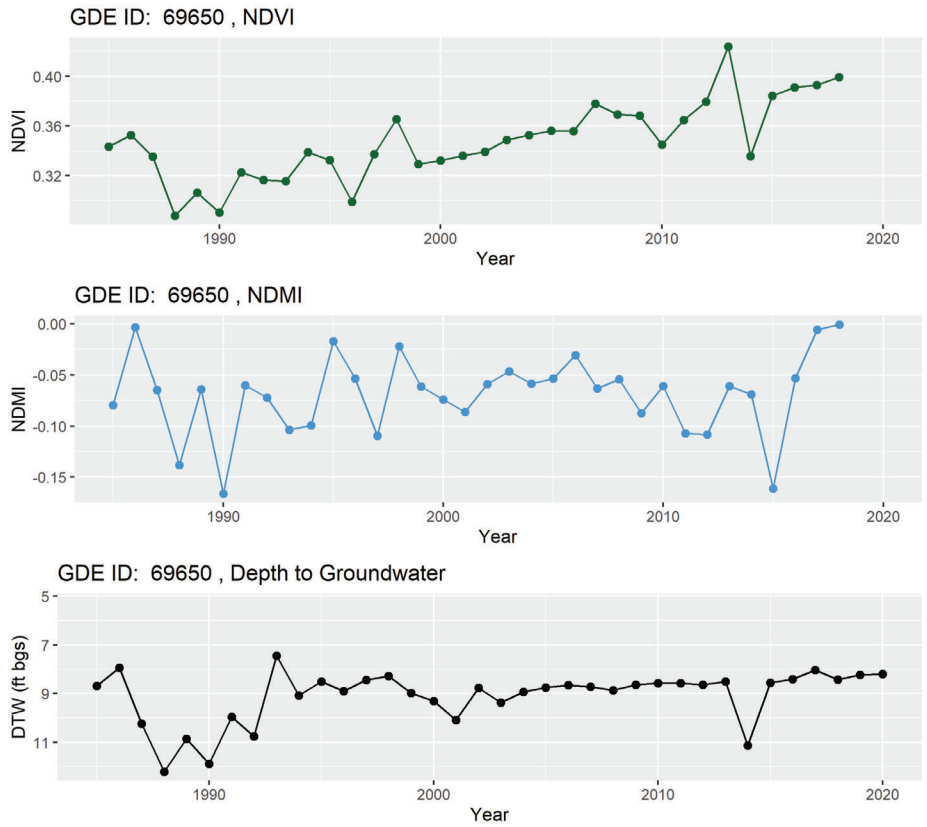
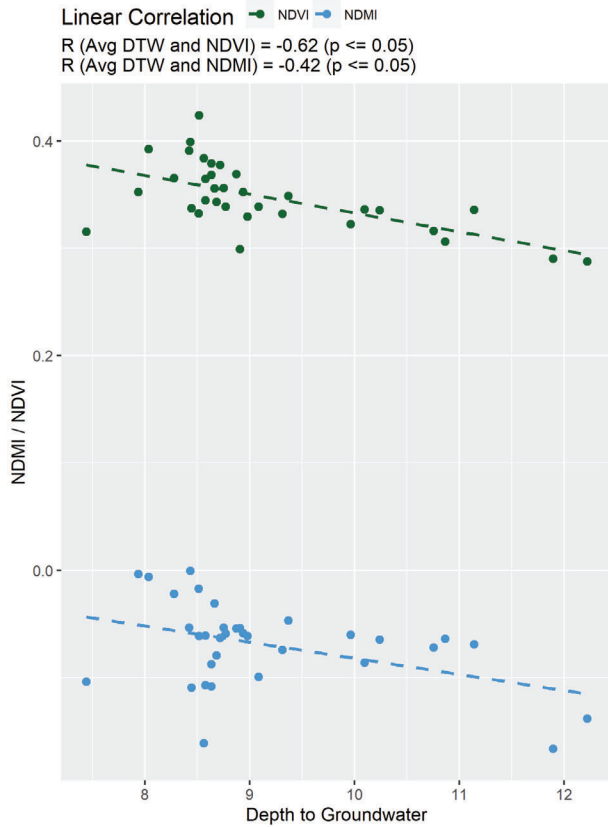
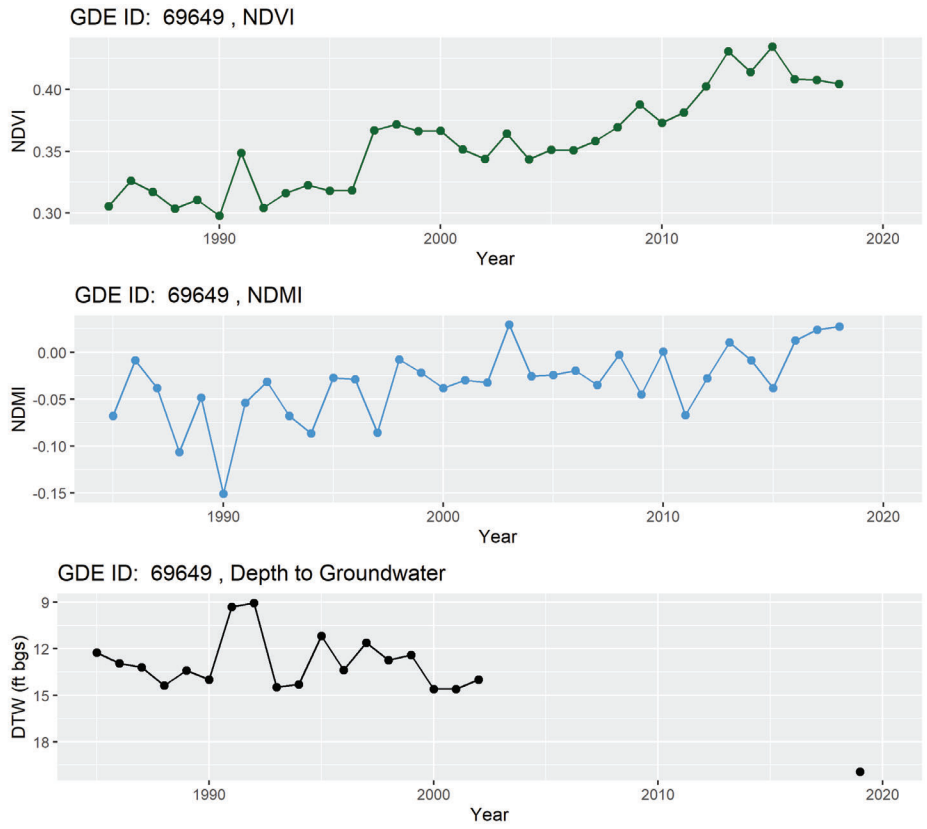
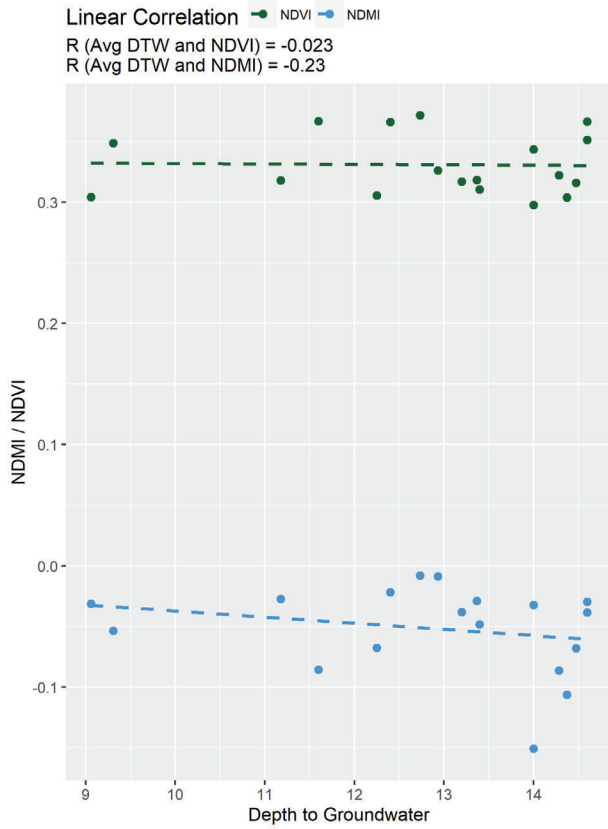


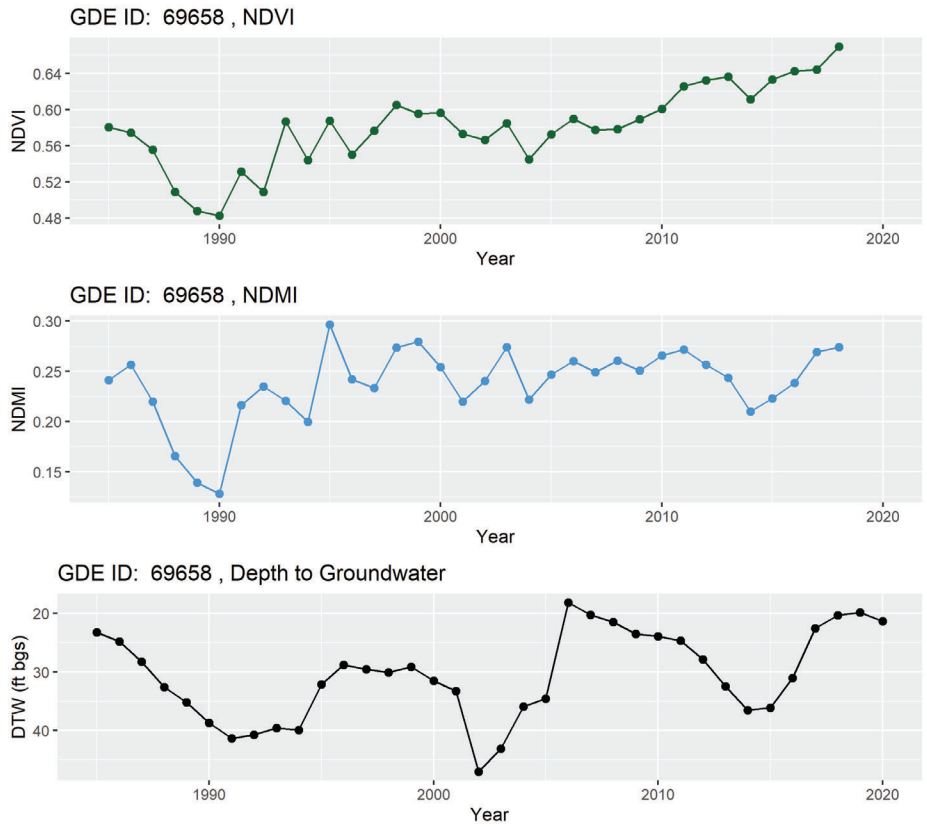
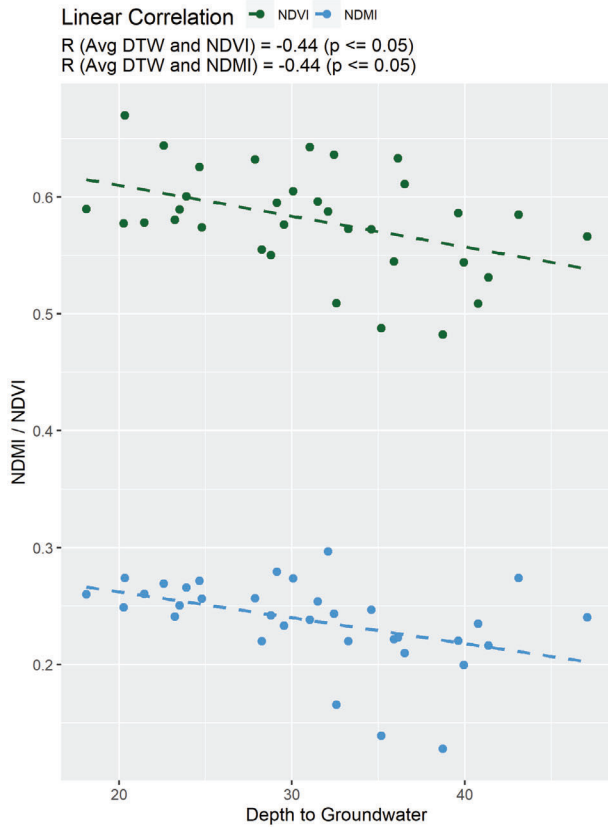
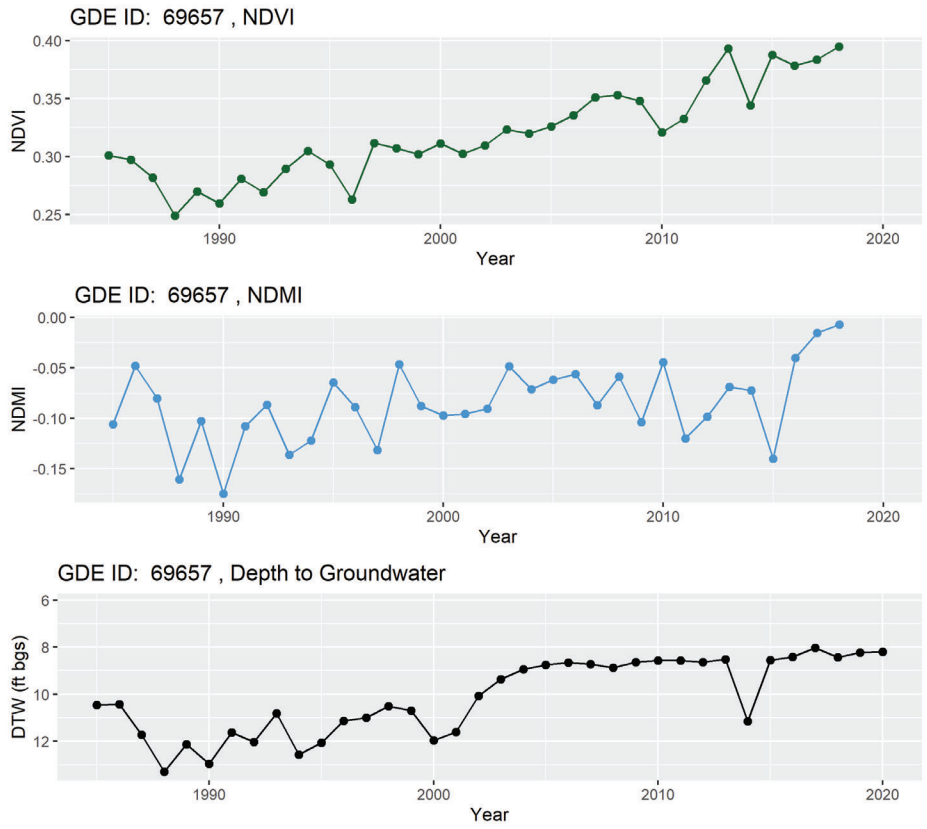
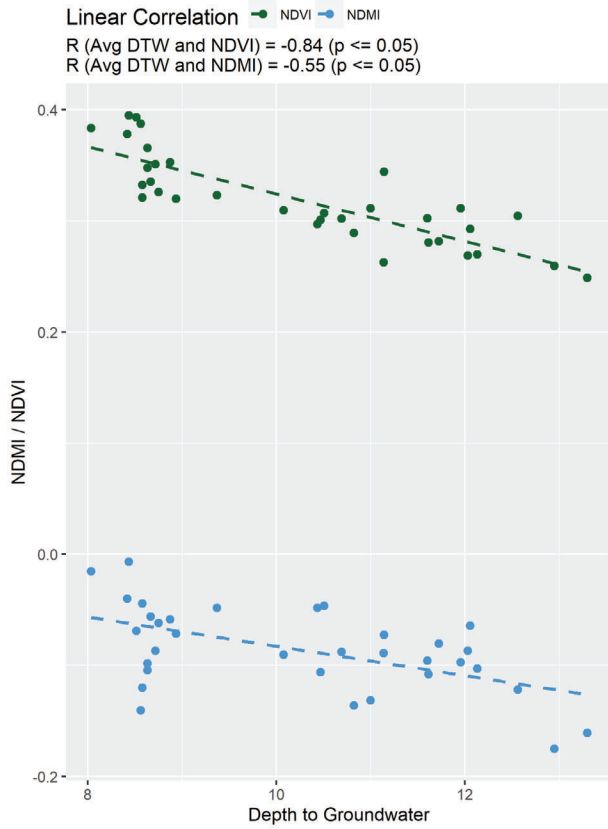


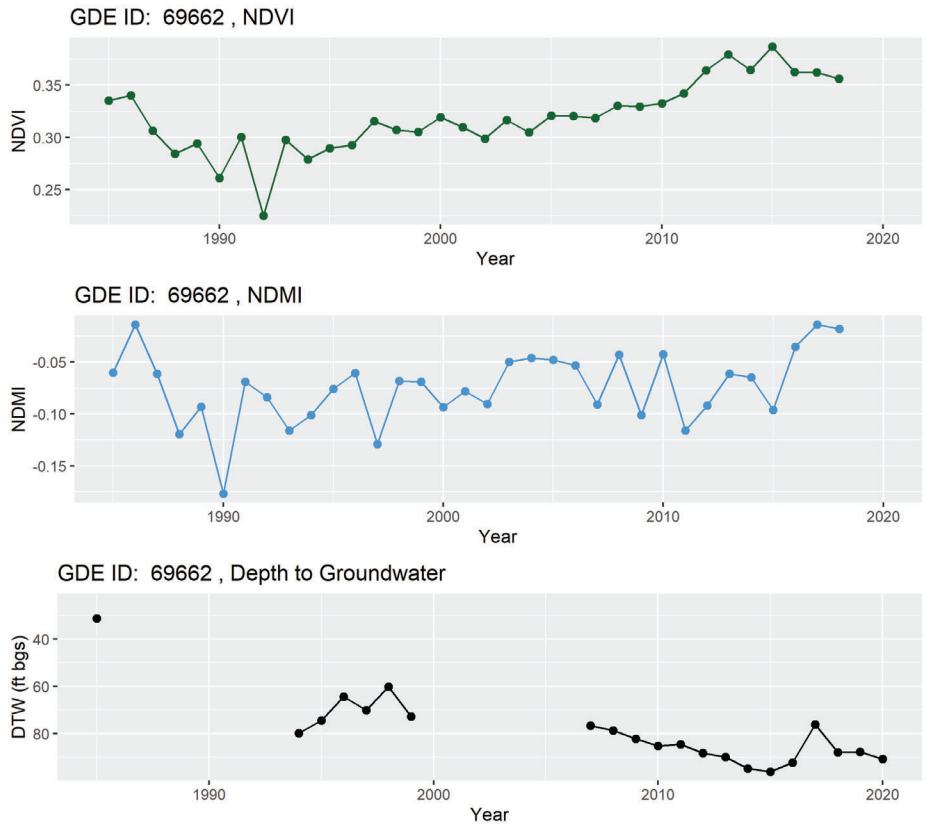
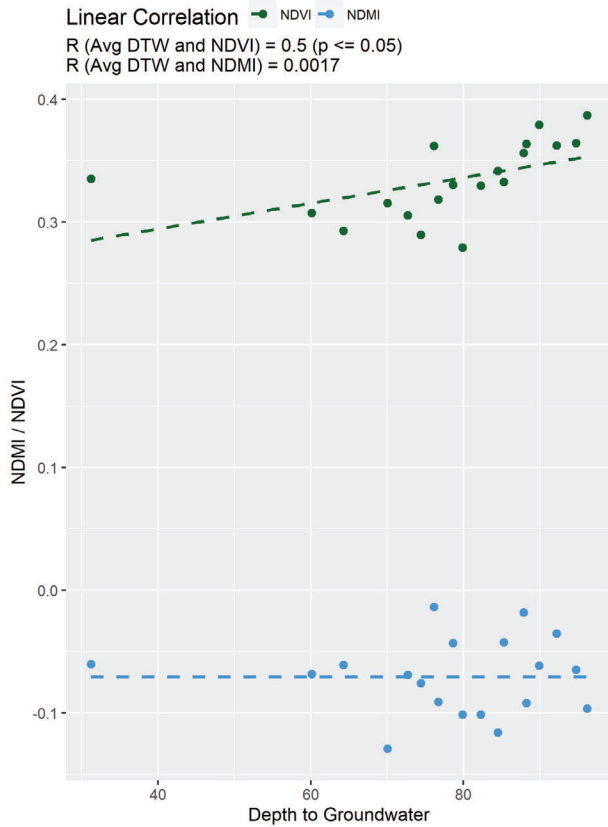
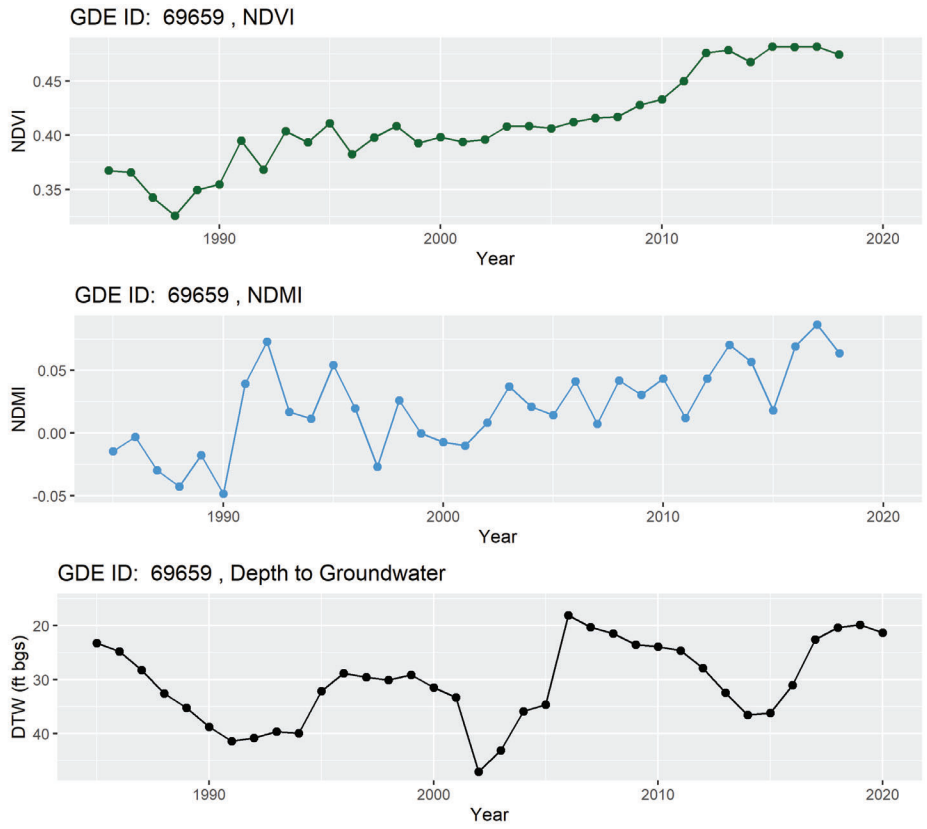
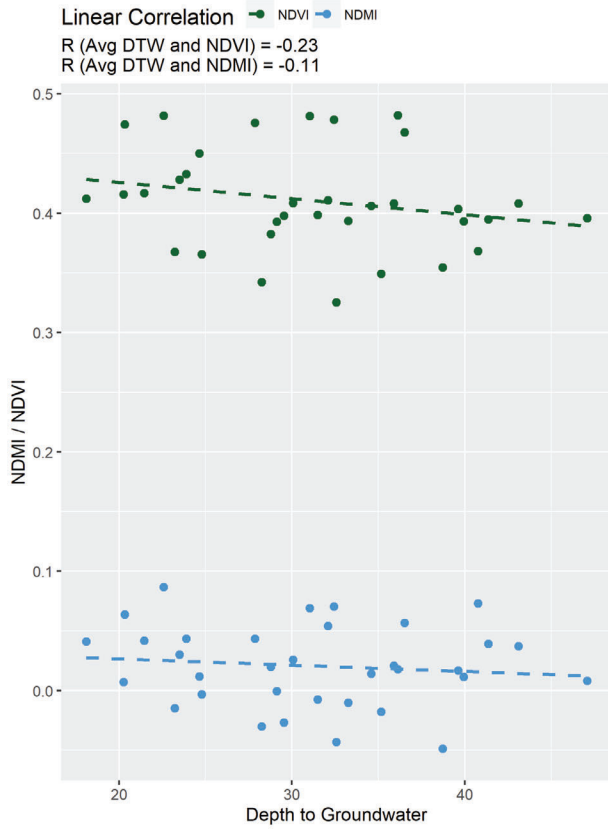






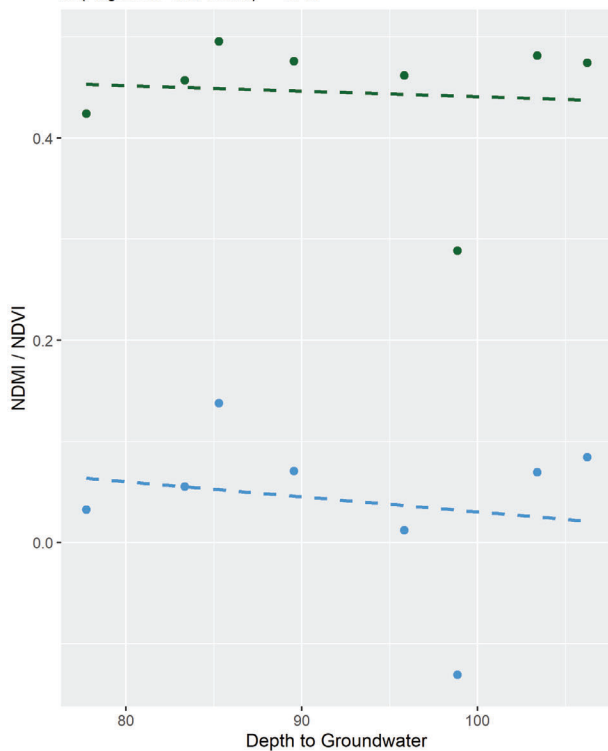




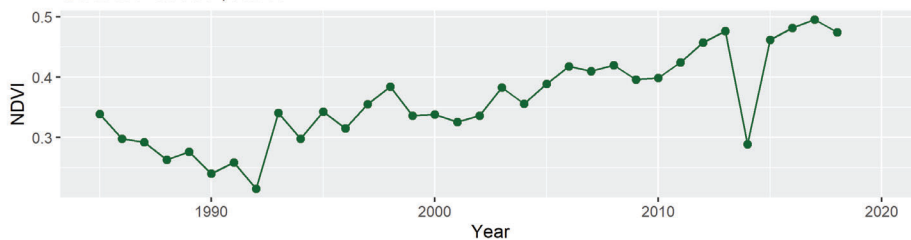


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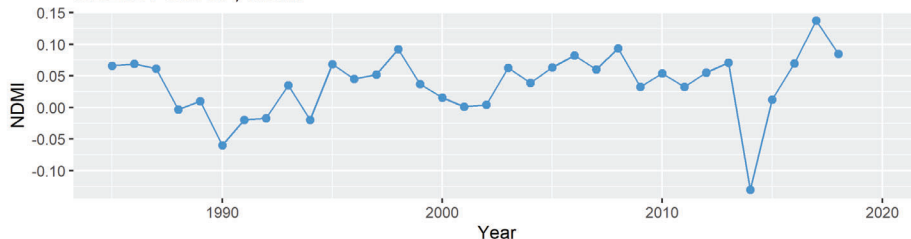
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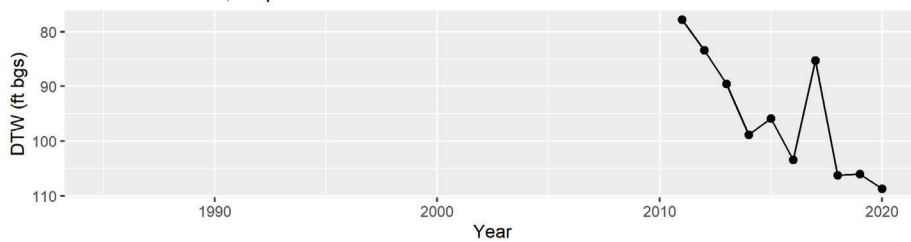
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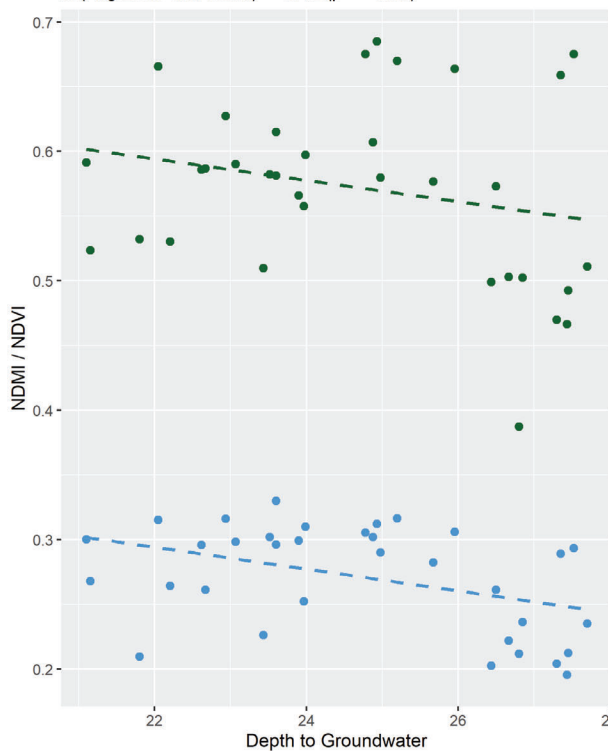


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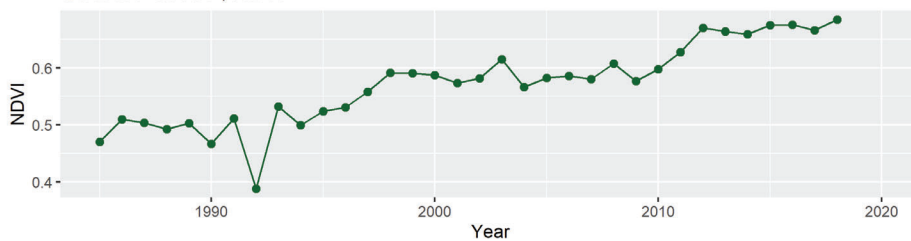


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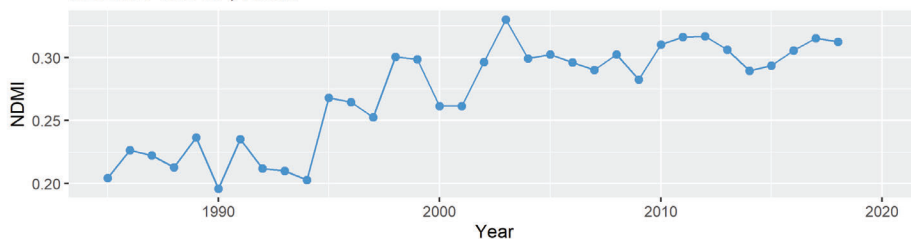
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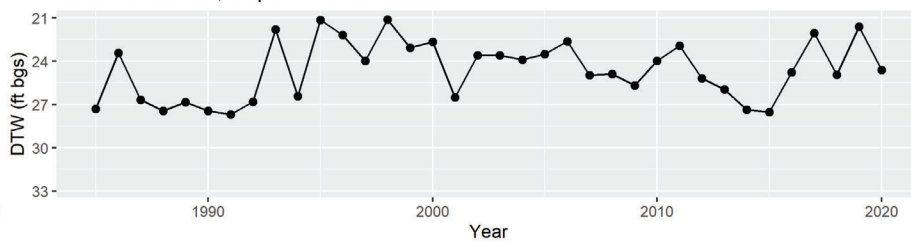
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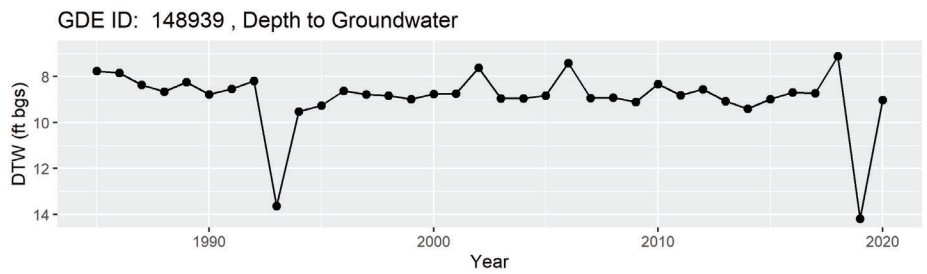
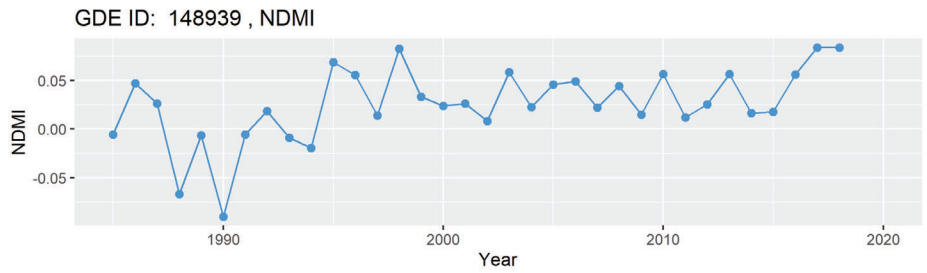
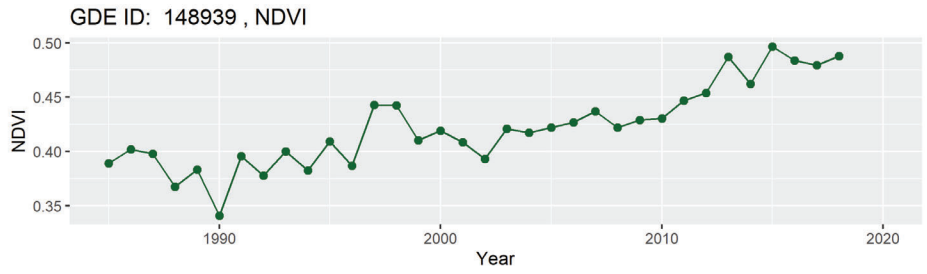
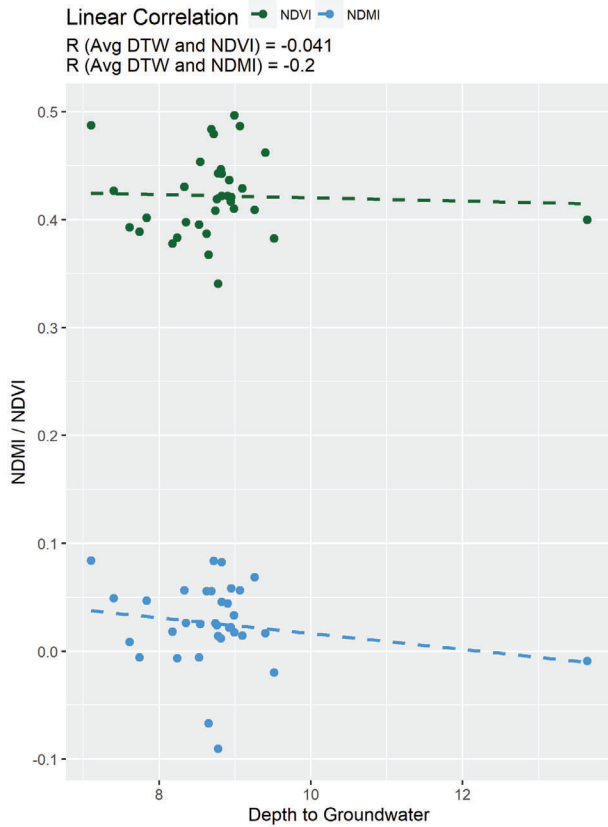
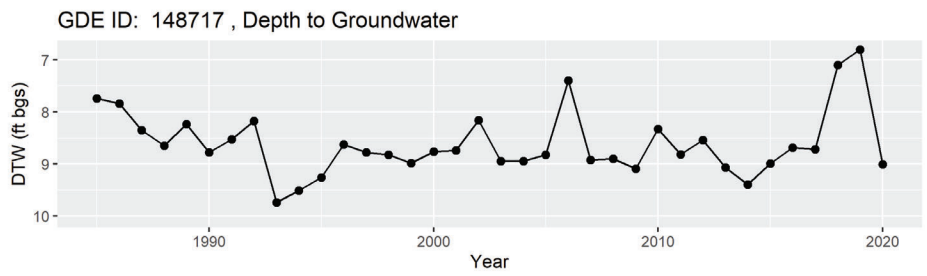
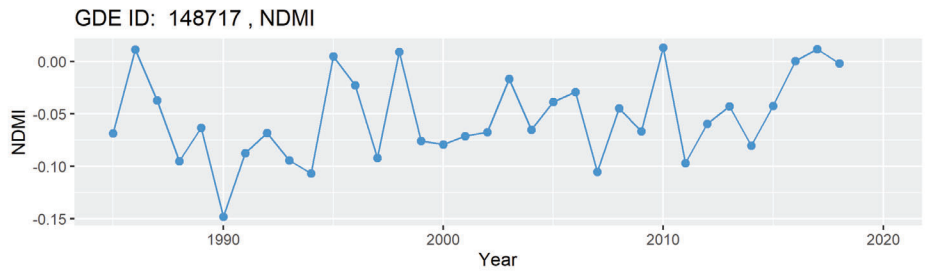
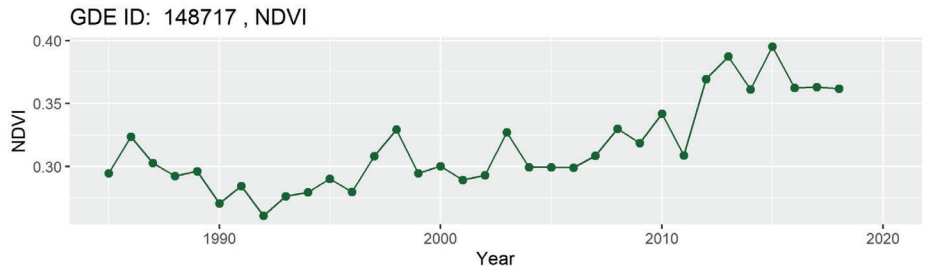
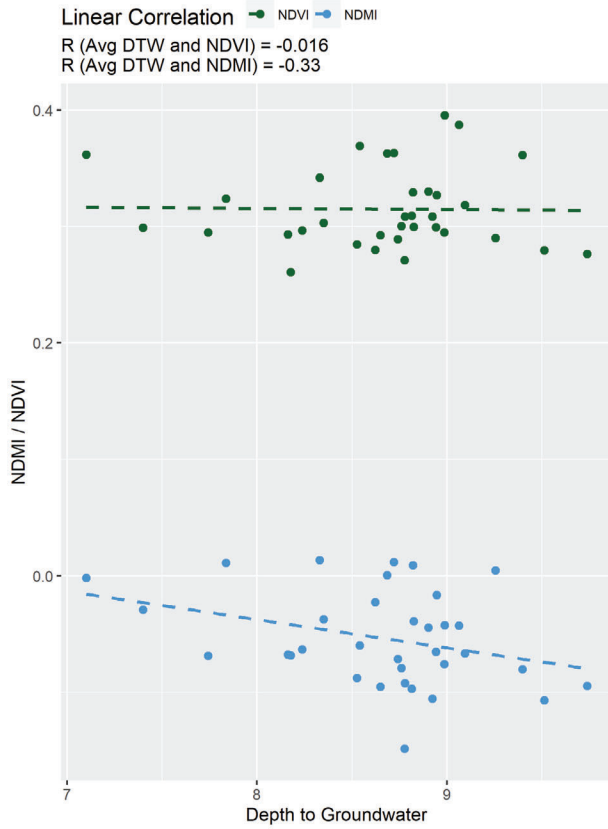


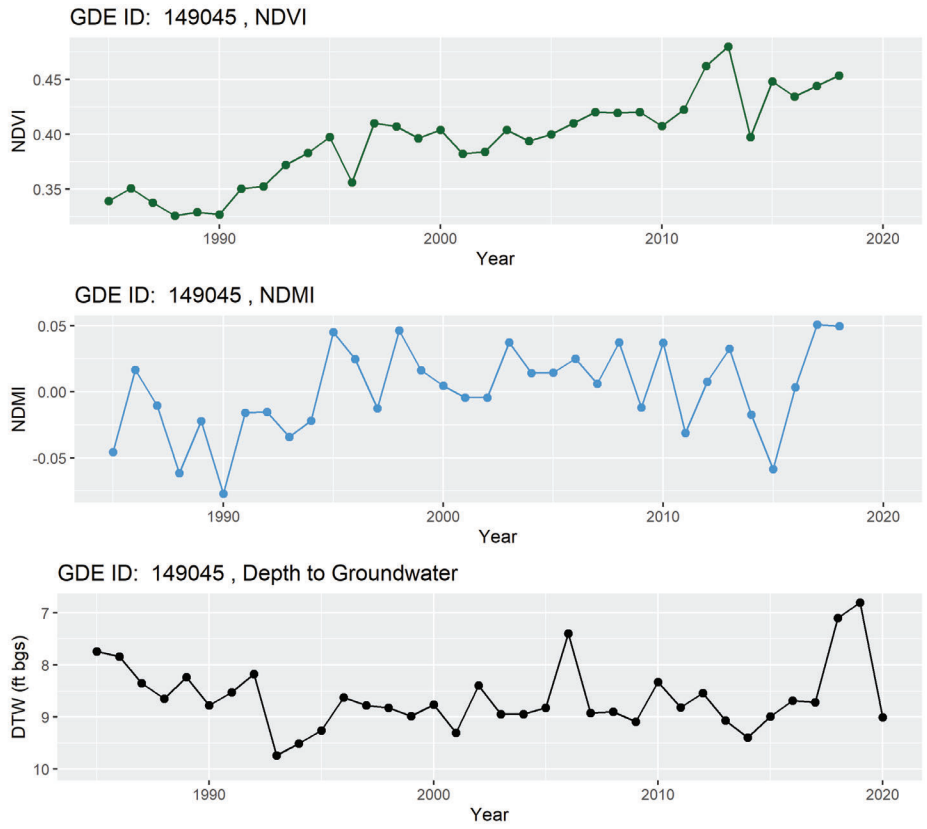
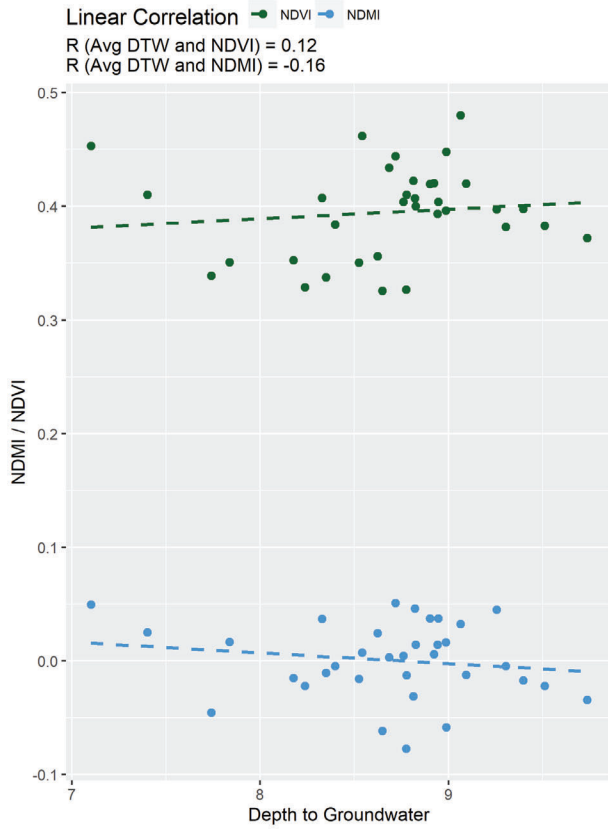
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GDE ID: 69666 , Depth to Groundwater







**Attachment B: Technical Memorandum from Stillwater:
Groundwater Dependent Ecosystems of Livermore
Valley Groundwater Basin**

DRAFT TECHNICAL MEMORANDUM • MAY 2021

Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin



PREPARED FOR

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PREPARED BY

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Suggested citation:

Stillwater Sciences. 2021. Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin. Prepared by Stillwater Sciences, Berkeley, California for EKI Environment & Water, Inc., Burlingame, California

Cover photo: Riparian vegetation along Arroyo Las Positas, Livermore, CA.

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1 INTRODUCTION

This technical memorandum is anticipated to be included as an attachment to the 2022 Alternative Groundwater Sustainability Plan (Alt GSP) for the Livermore Valley Groundwater Basin. This memorandum identifies groundwater dependent ecosystems (GDEs) in the Livermore Valley Groundwater Basin. The Livermore Valley Groundwater Basin is managed by the Zone 7 Water Agency, which is the exclusive Groundwater Sustainability Agency (GSA) within its boundaries. Under the California Sustainable Groundwater Management Act (SGMA), GSAs are required to identify GDEs and other beneficial uses and users of groundwater and consider impacts to GDEs and beneficial users when developing their GSPs as codified in the California Code of Regulations (CCR) sections 23 CCR § 354.16(g), Water Code § 10723.2(e), and Water Code § 10727.4 (State of California 2021). SGMA defines GDEs as “ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface” (23 CCR § 351(m)). As described in The Nature Conservancy’s (TNC) guidance for GDE analysis (Rohde et al. 2018), a GDE’s dependence on groundwater refers to reliance of GDE species and/or ecological communities on groundwater for all or a portion of their water needs. Mapping GDEs requires mapping vegetation that can tap groundwater through their root systems, assessing where the depth of groundwater is within the rooting depth of that vegetation, and mapping the extent of surface water that is interconnected with groundwater (Rohde et al. 2018). Once the GDEs are mapped, the occurrence of special-status species can be used to assess the sensitivity of GDEs in the basin.

Based on the 2016 Alternative Groundwater Sustainability Plan (Zone 7 Water Agency 2016), the Livermore Valley Groundwater Basin is divided into three management areas (Figure 1):

- **The Main Basin Management Area** includes the major aquifer in the Livermore Valley Groundwater Basin and is comprised of deep alluvial sediments (Zone 7 Water Agency 2016).
- **The Fringe Management Area** makes up the northern and eastern portions of the Livermore Valley Groundwater Basin and does not provide a large source of groundwater to the basin due to poor water quality and low well yields (Zone 7 Water Agency 2016). The Fringe Management Area contains the Springtown Alkali Sink which supports several special status species and GDEs (Zone 7 Water Agency 2016).
- **The Upland Management Area** primarily makes up the southern portion of the groundwater basin and is underlain by the Livermore Formation, which is not extensively used for groundwater pumping due to poor water yields (Zone 7 Water Agency 2016).

Although groundwater pumping volumes in the Fringe and Upland Management Areas are small, potential GDEs were identified in these areas to provide a baseline inventory of GDEs in the basin and to inform future monitoring efforts rather than to develop sustainable management criteria for the 2022 Alt GSP Update.

This assessment was conducted in coordination with EKI Environment & Water, Inc. (EKI) and the Zone 7 Water Agency, as described below.

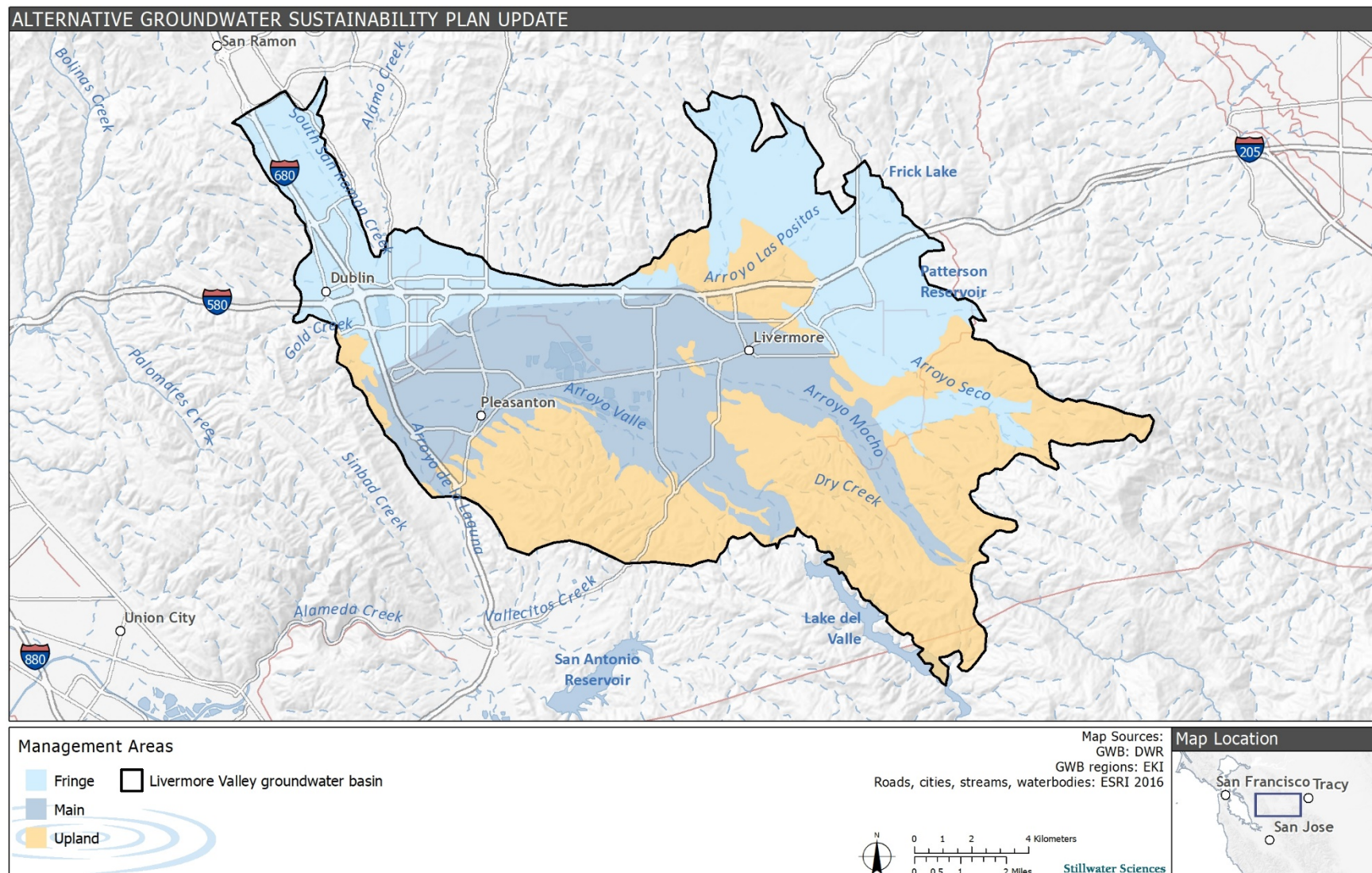


Figure 1. Livermore Valley Groundwater Basin Management Areas.

2 METHODS

2.1 GDE Identification

The procedure used for identifying GDEs is summarized below, and the steps are described in detail in the following sections.

1. **Data sources:** Potential GDEs in the Livermore Valley Groundwater Basin were identified using the California Department of Water Resources' (DWR) indicators of groundwater dependent ecosystems (iGDE) database. The database, which is published online¹ and referred to as the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset (Klausmeyer et al. 2018), includes the location and spatial extent of vegetation and wetland natural communities. This database uses statewide vegetation and wetland mapping coupled with information on the potential groundwater dependence of those communities to identify potential GDEs. This map can be refined by including additional or updated vegetation map sources. The vegetation data sources must then be prioritized (based on data resolution, quality and age) to produce an initial vegetation map of the groundwater basin.
2. **Procedure:** Once the maps are assembled, groundwater dependent vegetation communities are identified through a decision tree based on literature review and wetland status (Lichvar et al. 2016) of dominant species.
3. **Refine potential GDE map:** Potential groundwater dependent vegetation communities were initially identified where depths to groundwater were less than 30 feet (ft) anytime between 2015-2020. Where groundwater depth was unknown (e.g., in portions of the Fringe and Upland Management Areas) the vegetation community was not removed. Where potential GDEs did not reflect current conditions, obvious errors in the vegetation mapping (i.e., polygon boundaries) were corrected using aerial imagery. In addition, the potential GDE map incorporated results of a correlation analysis on depth to groundwater and GDE health-indicating indices provided by EKI. The potential GDE maps were further revised based on input from Zone 7 and EKI.
4. **Field visit:** Where the presence of potential GDE communities was uncertain, Stillwater botanists visited several sites to assess groundwater dependence in the field. Updates based on field observations were incorporated into the final GDE assessment.

2.1.1 Data sources

This section includes brief descriptions of the vegetation community data and other information sources used to identify and aggregate potential GDEs into final GDE units. The Indicators of Groundwater Dependent Ecosystems (iGDE) database (Klausmeyer et al. 2018) was reviewed in a geographic information system (GIS) and used to generate a preliminary map to serve as a guide for initial identification of potential GDEs in the Livermore Valley Groundwater Basin.

For more precise identification of potential GDEs, we developed a refined vegetation map by combining the Classification and Assessment with Landsat of Visible Ecology Groupings (CalVeg) dataset with several more recent datasets. Our refined vegetation map incorporates the following datasets:

¹ <https://gis.water.ca.gov/app/NCDatasetViewer/> [Accessed April 28, 2021]

- Classification and Assessment with Landsat of Visible Ecological Groupings (CalVeg) – United States Department of Agriculture - Forest Service (USDA 2014). *Central Coast region: Imagery date: 1997–2013; Minimum mapping unit (MMU): 2.5-acre.*
- Urban Creeks Council 2014 CalVeg update for third-order and higher channels. *Minimum mapping unit (MMU): ~0.5 acre.* Urban Creeks Council (2014).
- Springtown Alkali Sink Preserve Wetlands Mapping Project, Aerial Information Systems, Inc. (AIS 2009). *Minimum mapping unit (MMU): as low as 200 ft sq in wetland areas, 1.2-acre in general study area.*
- Sycamore Alluvial Woodland Tree Survey in Arroyo Mocho and Arroyo Valley, Alameda County, CA, Zone 7 Water Agency, San Francisco Estuary Institute, H.T. Harvey & Associates (SFEI and H.T. Harvey 2017).

AIS (2009) was considered the highest quality vegetation mapping due to its high resolution. The sycamore woodland mapping was also considered high quality but is of limited extent. Because of the recent date, we next used the UCC (2014) along the channels underlain by the original CalVeg mapping (Figure 2).

Table 1 and Figure 2 show, respectively, the acreage and extent of each dataset.

Table 1. Vegetation and wetland data sources for the Livermore Valley Groundwater Basin.

Data source	Mapped area (acres)
CalVeg	36,254
CalVeg – UCC updates	22,906
AIS Springtown Mapping	10,329
Zone 7 Sycamore Survey	40
Total¹	69,531

¹ Totals may not appear to sum exactly due to rounding error.

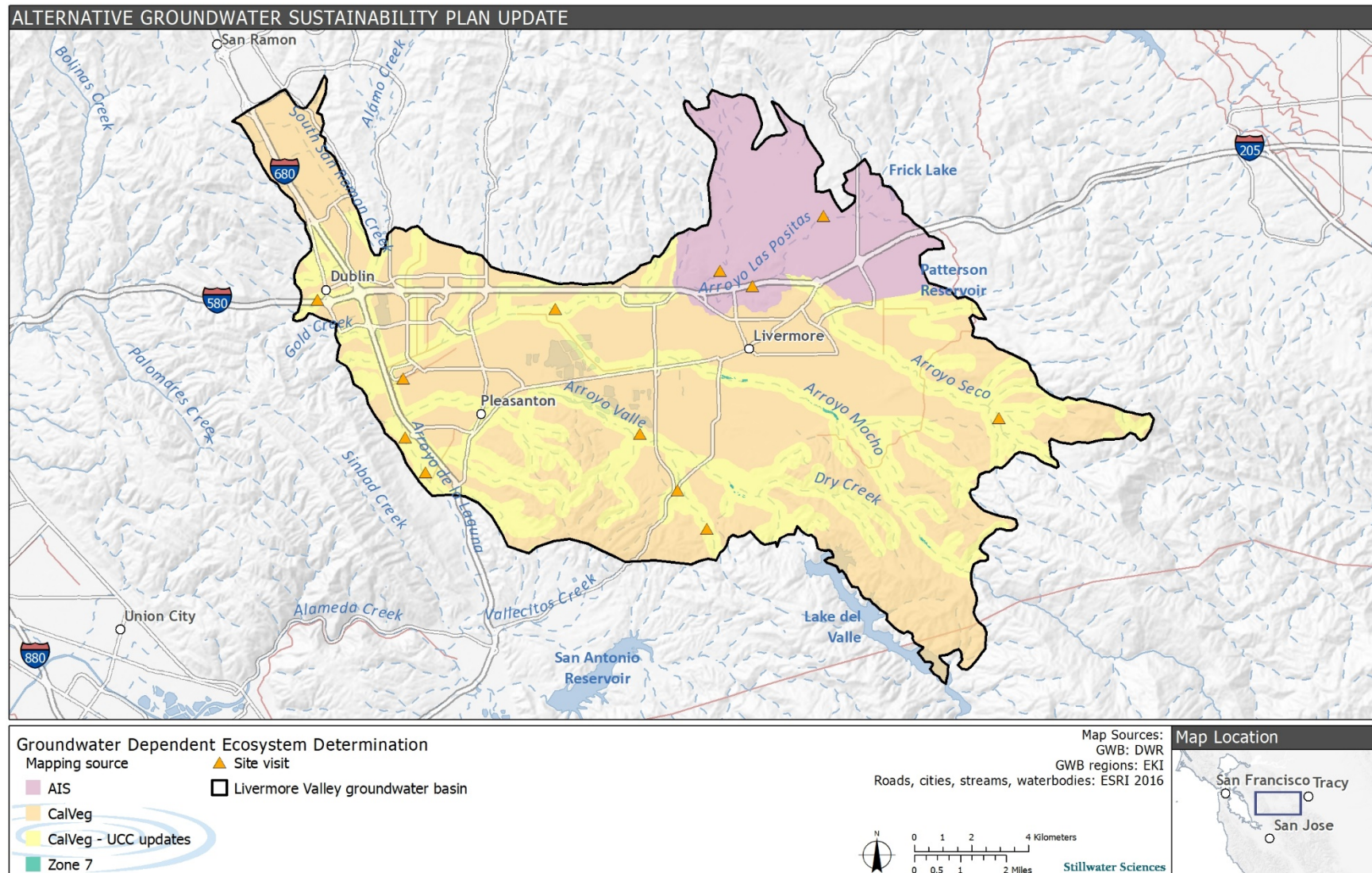


Figure 2. Extent of vegetation mapping data sources.

2.1.2 Procedure

The steps for defining and mapping GDEs outlined in Rohde et al. (2018) were used as a guideline for this process. A decision tree was applied to determine when species or biological communities were considered groundwater dependent based on definitions found in 23 CCR § 351(m) (State of California 2021) and Rohde et al. (2018). This decision tree, created to systematically and consistently address the range of conditions encountered, is summarized below; the term “unit” refers to an area with consistent vegetation and hydrology:

The unit is a GDE if groundwater is likely:

1. An important hydrologic input to the unit during some time of the year, AND
2. Important to survival and/or natural history of inhabiting species, AND
3. Associated with a regional aquifer used as a regionally important source of groundwater.

The unit is not a GDE if its hydrologic regime is primarily controlled by:

1. Surface discharge or drainage from a(n) upslope human-made structure(s), such as a mining pit, irrigation canal, irrigated fields, reservoir, cattle pond, or water treatment pond/facility.
2. Precipitation inputs directly to the unit surface. This excludes vernal pools from being GDEs where units are hydrologically supplied by direct precipitation and very local shallow subsurface flows from the immediately surrounding area.

Rohde et al. (2018) recommend that maps of potential GDEs be compared with local groundwater elevations to determine where groundwater is within the rooting depth of potential GDEs. Given uncertainties in extrapolating well measurements to GDEs and differences in surface elevation of wells and GDEs, Rohde et al. (2018) recommend assigning GDE status to vegetation communities either where groundwater is within 30 ft of the ground surface or where interconnected surface waters are observed.

2.1.3 Refine potential GDE map

The basin-wide vegetation and wetland map was reviewed, and each community was assigned a groundwater dependence category based on rankings for likelihood of connection to groundwater (i.e., unlikely or likely). This determination was based on species composition and the groundwater dependency of dominant species, whether they were considered groundwater dependent by the iGDE database (DWR 2021), and wetland indicator status (Lichvar et al. 2016).

These potential GDEs were then compared with groundwater depth (where known). Depth to groundwater contours for the Main Basin and Fringe Management Areas were provided by Zone 7 and EKI. In the Main Basin and Fringe Management Areas, phreatophytes that occur where groundwater is within 30 ft of the ground surface were identified as likely GDEs. Initial GDE maps used areas with groundwater depth less than 30 ft in a wet period, Spring 2019, using data provided by Zone 7 (Zone 7 2020). The map was revised to include areas where groundwater depths are less than 30 ft anytime between 2015-2020 using raster data of groundwater depth subsequently provided by EKI (EKI 2021).

Groundwater contours or rasters were not available for the Upland Management Area of the Livermore Valley Groundwater Basin due to the general lack of monitoring and production wells in this portion of the Basin. Where well data was available in the Upland Management Area, EKI

evaluated potential groundwater dependence for GDEs that occurred within one kilometer (approximately 0.6 miles) of the well and had minimum depth to water observations less than 30 ft between 2015 and 2020. These potential GDEs were evaluated in the field to assess groundwater dependence.

The southern portion of the Upland Management Area contains extensive valley oak (*Quercus lobata*) and blue oak (*Quercus douglasii*) communities (Figure 3). Valley oaks are included as phreatophytes in California by Klausmeyer et al. (2018) suggesting that they can rely on groundwater for part of their water needs. Klausmeyer et al. (2018) did not include blue oaks in their list of phreatophytes, but focused studies in blue oak woodlands suggest they can depend on groundwater to meet their water needs (e.g., Miller et al. 2010). Though these oaks are deep-rooted (maximum rooting depths range from 30-80 ft, depending on the species) and occur where depth to groundwater is unknown, they are unlikely to be affected by groundwater management because they occur in hillslopes, where hydraulic gradients are steep and groundwater production is de minimis as evidenced by the lack of wells in the area (Zone 7 Water Agency 2016). As such, these communities were not included in the final GDE map presented in Figure 4.

Zone 7 made additional comments on the preliminary GDE map, noting discrepancies between mapped GDEs and current vegetation as well as recent stream restoration projects which may be connected to groundwater. The vegetation map was subsequently adjusted to ensure that mapped polygons aligned with the current extent of vegetation, with a focus on the restoration project areas identified in comments provided by Zone 7.

EKI performed a correlation analysis between depth to groundwater and two remote sensing indices that indicate GDE's health by GDE unit, the Normalized Derived Moisture Index (NDMI) and the Normalized Derived Vegetation Index (NDVI), which indicate the vegetation moisture and vegetation greenness, respectively. The premise of the analysis is that, since the NDMI and NDVI indices can quantify changes in the rates and patterns of vegetation growth and moisture levels in plants over time, the relationship between these two indices and the depth to groundwater can be evaluated to examine whether these measures of GDE "health" have a relationship to shallow groundwater conditions. The preliminary GDE map was subsequently revised based on the results of the correlation analysis provided by EKI.

The occurrence and extent of interconnected surface water is uncertain in the Livermore Valley Groundwater Basin. Potential reaches of interconnected surface water were identified by EKI based on analysis of streambed elevations relative to recent depth to groundwater observations. These reaches generally overlapped with mapped GDEs and were not evaluated separately. Man-made open water areas (e.g., Chain of Lakes and golf course ponds) were removed from the final GDE map.

2.1.4 Field visit

Stillwater Sciences and EKI identified 12 sites to examine in the field based on uncertainties in the preliminary GDE maps, as shown on Figure 2. These sites included gaps in the GDE map where vegetation appeared similar to GDEs that occurred immediately upstream and downstream of the site, riparian vegetation along channels, and mapped GDEs underlain by thick clay layers. Additionally, Stillwater scientists assessed potential GDEs where groundwater data was sparse (near Sycamore Park) and near Springtown. Groundwater dependence of these sites was determined by assessing various local water sources and the width of the riparian zone. Where riparian zones were narrow and relatively sparse, other water sources likely support the vegetation. Where existing vegetation and wetland areas extend beyond a narrow strip along the

channel, groundwater dependence was considered likely. The results of the field investigation are shown in Table 2 and Figure 3, and the Final likely GDE map is presented in Figure 4.

2.2 Special-status Species

As part of the ecological inventory, special-status species and sensitive natural communities that are potentially associated with GDEs in the Livermore Valley Groundwater Basin were identified. For the purposes of this document, special-status species are defined as those:

- Listed, proposed, or under review as endangered or threatened under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA);
- Designated by California Department of Fish and Wildlife (CDFW) as a Species of Special Concern;
- Designated by CDFW as Fully Protected under the California Fish and Game Code (Sections 3511, 4700, 5050, and 5515);
- Designated as Bureau of Land Management (BLM) sensitive;
- Designated as rare under the California Native Plant Protection Act (CNPPA); and/or
- Included on CDFW's most recent Special Vascular Plants, Bryophytes, and Lichens List (CDFW 2020b) with a California Rare Plant Rank (CRPR) of 1, 2, 3, or 4.

2.2.1 Data sources

Stillwater ecologists queried databases on regional and local occurrences and spatial distributions of special-status species within the Livermore Valley Groundwater Basin. Spatial database queries included potential GDEs plus a 1-mile buffer. Databases queried include:

- California Natural Diversity Database (CNDDDB) (CDFW 2020);
- California Native Plant Society (CNPS) Manual of California Vegetation (2020);
- eBird (2021); and
- TNC freshwater species lists generated from the California Freshwater Species Database (CAFSD) (TNC 2020).

2.2.2 Procedure

Stillwater reviewed the database query results and identified special-status species and vegetation communities that may occur within or be associated with the vegetation and aquatic communities in or immediately adjacent to potential GDEs. Stillwater ecologists then consolidated these special-status species and sensitive community types into a list, along with summaries of habitat preferences, potential groundwater dependence, and reports of any known occurrences.

Wildlife species were evaluated for potential groundwater dependence using determinations from the Critical Species Lookbook (Rohde et al. 2019) or by evaluating known habitat preferences, life histories, and diets. Species GDE associations were assigned one of three categories:

- Direct—species directly dependent on groundwater for some or all water needs (e.g., cottonwood with roots in groundwater, juvenile steelhead in dry season)
- Indirect—species dependent upon other species that rely on groundwater for some or all water needs (e.g., riparian birds)

- No known reliance on groundwater

Sensitive natural communities were classified as either likely or unlikely to depend on groundwater based on species composition using the same methodology as vegetation communities (Section 2.1.3). Plant species were evaluated for potential groundwater dependence based on their habitat (Jepson Flora Project 2020) and association with vegetation communities classified as GDEs. Special-status plant GDE associations were assigned one of three categories: likely, possible, or unlikely. The “possible” category was included to classify plant species with limited habitat data or where a species may have an association with a vegetation community identified as a GDE (e.g., Coast live oak, California sagebrush).

Database query results for local and regional special-status species occurrences were combined with their known habitat requirements to develop a list of groundwater dependent special-status species (Section 3.2) that satisfy the following criteria: (1) documented to occur within the GDE unit, or (2) known to occur in the region and suitable habitat present in the GDE unit.

3 RESULTS

3.1 Comparison with iGDE Database

The differences between the iGDE map (DWR 2021) and the final GDE map are shown in Figure 3. The primary differences are the addition of GDEs in the northeast portion of the basin where the AIS mapping occurred and removal of man-made open water polygons along Chain of Lakes (along Arroyo Valle) and near Dublin. Some changes reflect differences between the UCC update to the CalVeg map and Stillwater's edits to the map along Arroyo Mocho and Arroyo Valle. In particular, the width of the riparian vegetation along both rivers increased in places. The reclassification near Lake Boris on Arroyo Valle (downstream of Site I) reduced the extent of GDEs downstream of the lake. In addition, several changes were made based on the site visit (Figure 3, Table 2). The vegetation was removed along Arroyo Del Laguna and west of Pleasanton (Sites B, C, and D). These sites occur above a thick clay layer (known colloquially as the Overburden layer) that precludes connection to the aquifer. Observations during the field visit suggested that the riparian vegetation at Sites B–D was likely dependent on surface water rather than groundwater due to the relatively narrow riparian zone. Site L (Figure 3) was also removed since the very sparse riparian vegetation suggested the area was not connected to groundwater. Wetlands mapped within man-made lakes and ponds (e.g., Frick Lake in the eastern part of the basin) were also removed. The final GDE map is presented in Figure 4.

Table 2. Likely groundwater dependence of field sites.

Site	Site description	Groundwater dependence
A	Mature trees including oaks (<i>Quercus</i> spp.), redwood (<i>Sequoia sempervirens</i>), tree of heaven (<i>Ailanthus altissima</i>), eucalyptus (<i>Eucalyptus</i> spp.)	Likely, kept
B	Flood control channel with planted willows (<i>Salix</i> spp.)	Unlikely, removed
C	Narrow band of willows, cottonwoods (<i>Populus</i> spp.), and oaks; channel incised up to 30 ft	Unlikely, removed
D	Narrow band of willows, cottonwoods, and valley oaks (<i>Quercus lobata</i>)	Unlikely, removed
E	Narrow band of sparse riparian vegetation	Unlikely, removed
F	Valley oak, live oak (<i>Quercus agrifolia</i>) and willow	Likely, kept
G	Willows, live oak, eucalyptus; may have perennial flow	Likely, kept
H	Near Springtown; likely groundwater dependent	Likely, added
I	Similar to upstream and downstream GDEs	Likely, added
J	Mature riparian trees, little surface water	Likely, added
K	Sycamore Park; closed canopy, mature riparian trees	Likely, added
L	Sparse valley oaks along incised, intermittent channel	Unlikely, removed

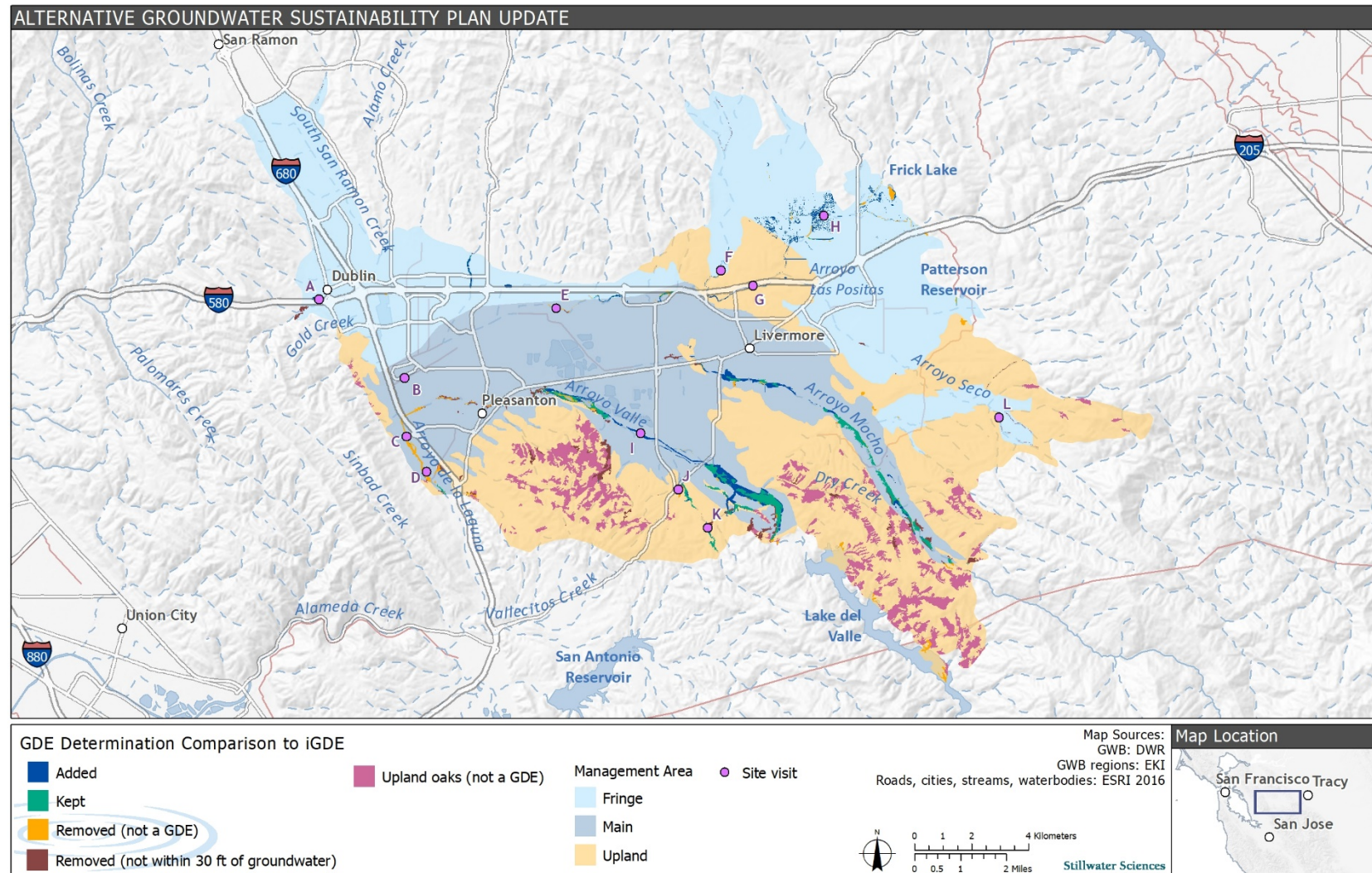


Figure 3. Comparison of the GDE map with the iGDE database (DWR 2021).

Note: The reasons for GDE removal are discussed in Section 3.1 and Table 2.

3.2 GDEs in the Livermore Valley Groundwater Basin

The Livermore Valley Groundwater Basin contains 1062 acres of likely GDEs, approximately 2% of the total basin area (Figure 4). The Main Basin Management Area contains approximately 69% of the total likely GDE area, the Fringe Management Area approximately 20%, and the Upland Management Area contains the remaining 11% of the GDEs. The most prevalent vegetation communities across all likely GDE units are the riparian mixed hardwood alliance and California sycamore alliance, which respectively comprise 40% and 30% of likely GDE area in the basin and are located almost entirely in the Main Basin Management Area. The Alkaline mixed grasses and forbs alliance comprises 10% of total likely GDE area and is located almost entirely in the Fringe Management Area.

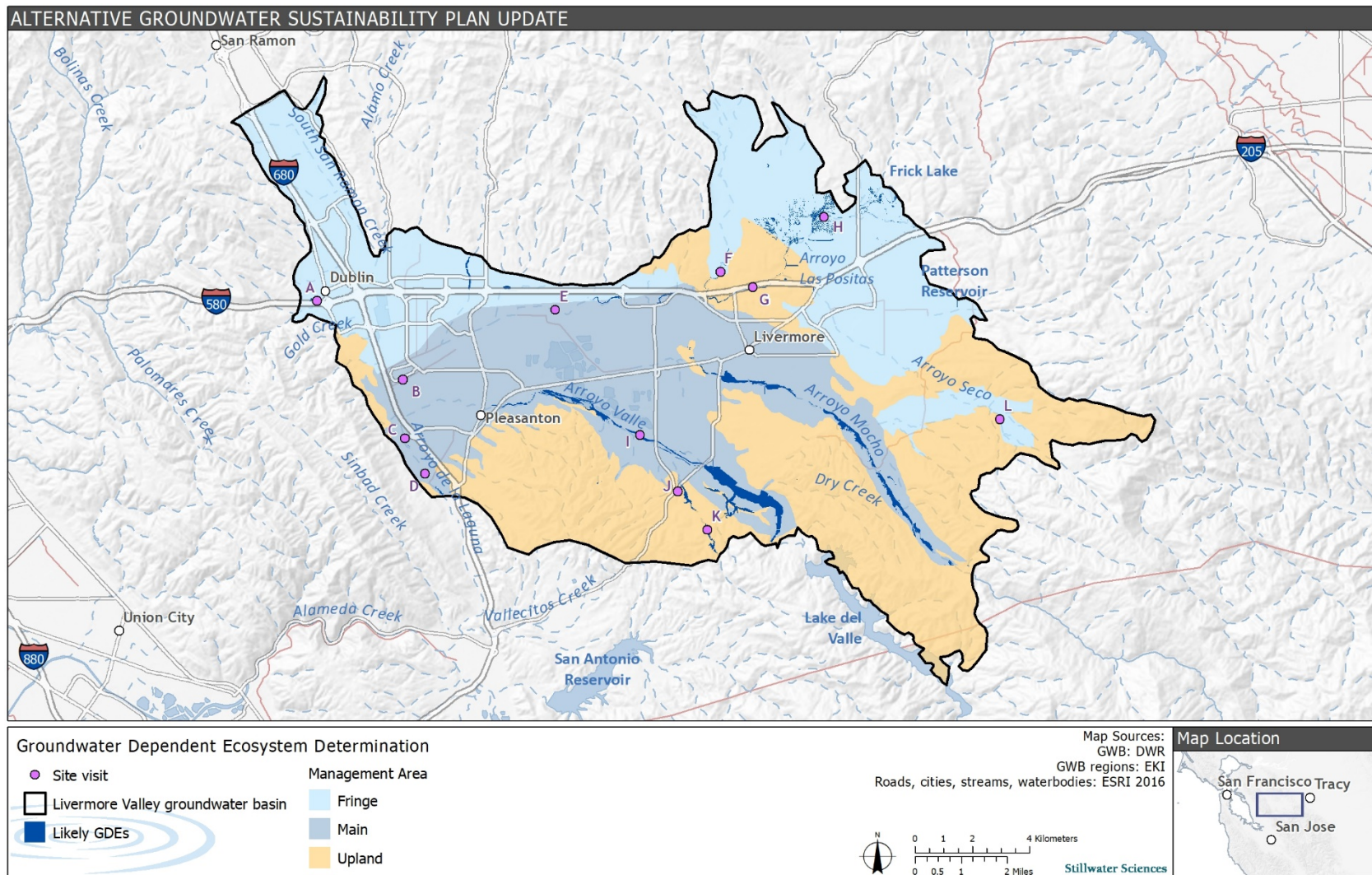


Figure 4. Groundwater dependent ecosystems in the Livermore Basin.

The Main Basin Management Area contains 737 acres of likely GDEs. The most prevalent vegetation communities are the California sycamore alliance (250 acres), riparian mixed hardwood alliance (239 acres), and valley oak alliance (212 acres) (Figure 5). GDEs typically occur along riparian zones, particularly Arroyo Mocho, Arroyo Valle, and Arroyo Las Positas. Additional GDEs occur in Sycamore Park in the upper extent of Arroyo Valle. The valley oak alliance is mostly found in the upstream portions of Arroyo Mocho within the main basin.

The riparian mixed hardwood alliance is comprised of willows (*Salix* spp.) and Fremont cottonwoods (*Populus fremontii*), which have maximum reported rooting depths in the literature of about 7 ft (The Nature Conservancy 2018) but can occur at relative elevations of 10–15 ft in some cases (Stillwater Sciences 2007). Maximum rooting depths for California sycamore (*Platanus racemosa*) are not reported in the literature, but American sycamore (*Platanus occidentalis*) has a maximum reported rooting depth of about 9 ft (The Nature Conservancy 2018). The valley oaks (*Quercus lobata*) that make up the valley oak alliance have the deepest rooting depth of the riparian vegetation found in the main basin measured maximum rooting depths up to 24 ft (The Nature Conservancy 2018).

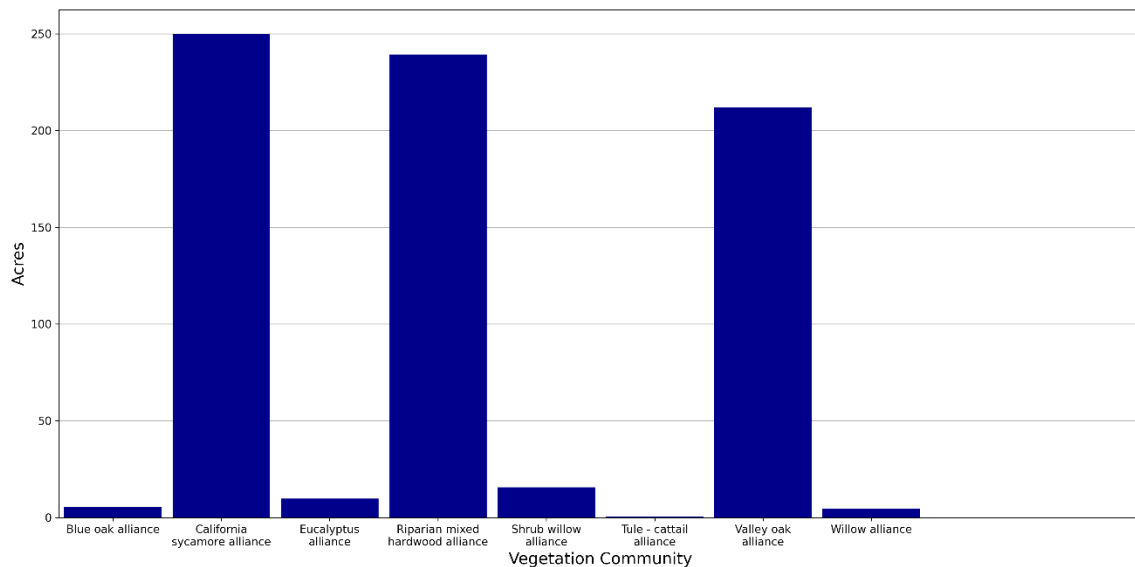


Figure 5. Likely GDE vegetation communities in the Main Basin Management Area, by acreage. Only eight likely GDE vegetation communities occur in the management area.

The Fringe Management Area contains 210 acres of likely GDEs. The most prevalent vegetation community is the alkaline mixed grasses and forbs alliance (100 acres). Other alkaline communities are also prevalent: alkaline mixed scrub alliance (29 acres) and alkaline flats (15 acres) (Figure 6). The GDEs in the Fringe Management Area occur along Arroyo Las Positas and the smaller spring-fed channels and wetlands in the northeast portion of the Fringe Management Area near Springtown (the northeasternmost site visit marker in Figure 4). Of the 144 acres of alkaline likely GDE vegetation communities, 54 acres occur in the Springtown Alkali Sink, as defined in the Zone 7 Alternative GSP (2016). The rooting depth of species in the alkaline mixed grasses and forbs alliance is unknown but is likely shallow (< 2 ft). The dominant species of the alkaline mixed scrub alliance is iodine bush (*Allenrolfea occidentalis*), which has reported maximum rooting depths of 2 ft. The dominant species of the tule-cattail alliance include sedges (*Carex* spp.), tules (*Scirpus* spp.), cattails (*Typha* spp.), and spikerushes (*Eleocharis* spp.). The

rooting depth of these genera is typically less than 1 ft. The riparian mixed hardwood alliance has maximum rooting depths of about 7 ft (see above).

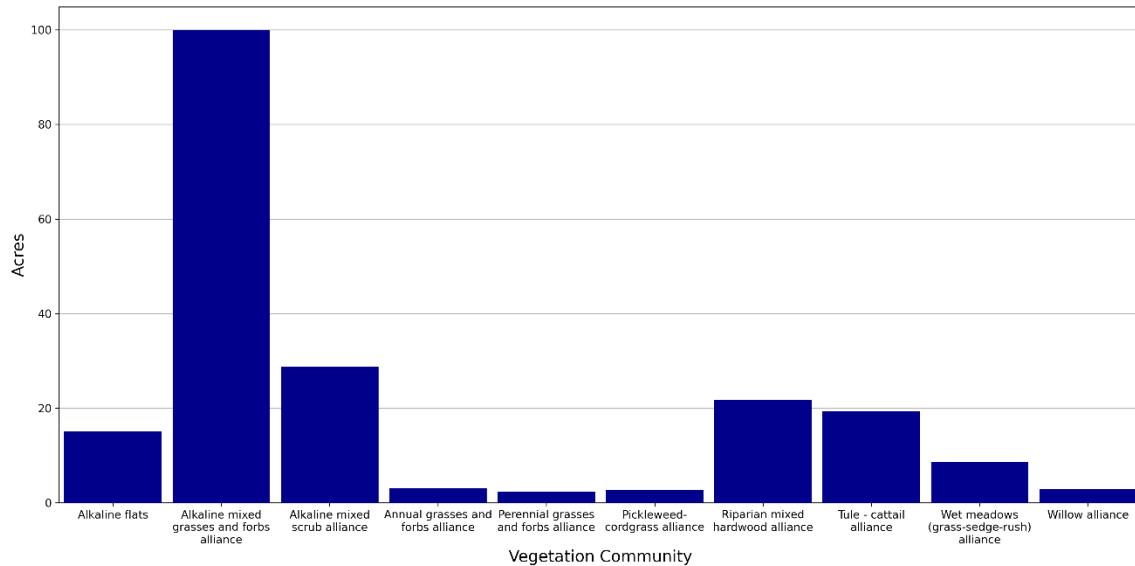


Figure 6. Ten most common likely GDE vegetation communities in the Fringe Management Area, by acreage.

The Upland Management Area contains 101 acres of likely GDEs. The most prevalent vegetation community is the riparian mixed hardwood alliance (74 acres) (Figure 7). GDEs in this unit occur in the riparian zones of smaller tributaries. The riparian mixed hardwood alliance is comprised of willows (*Salix* spp.) and Fremont cottonwoods (*Populus fremontii*), which have maximum reported rooting depths in the literature of about 7 ft (The Nature Conservancy 2018) but can occur at relative elevations of 10–15 ft in some cases (Stillwater Sciences 2007).

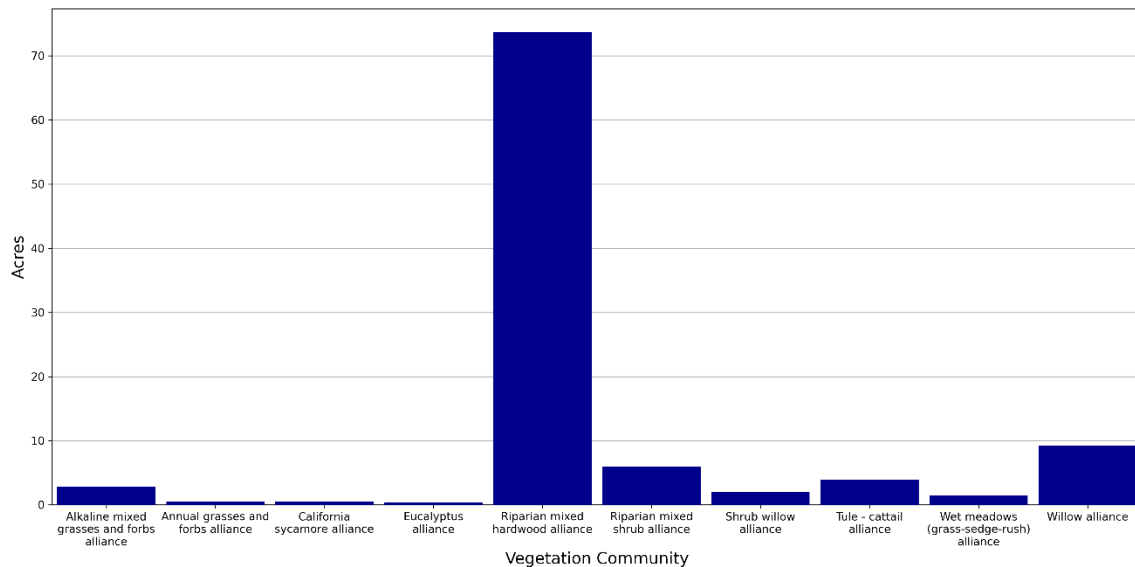


Figure 7. Ten most common likely GDE vegetation communities in the Upland Management Area, by acreage.

3.3 Special-status Species

3.3.1 Critical habitat

The Livermore Valley Groundwater Basin includes United States Fish and Wildlife Service (USFWS) designated critical habitat for four federally listed species: Alameda whipsnake (*Masticophis lateralis euryxanthus*) (936 acres), California red-legged frog (*Rana draytonii*) (7,273 acres), California tiger salamander (*Ambystoma californiense*) (0.5 acres), and vernal pool fairy shrimp (*Branchinecta lynchi*) (1,337 acres) (USFWS 2006a, USFWS 2010, USFWS 2005, USFWS 2006b). The locations of critical habitat for each species within the Livermore Valley Groundwater Basin are shown in Figure 8. Of the designated critical habitat, most of the habitat for the vernal pool fairy shrimp is co-located with mapped GDEs, but this species relies on vernal pools, which are dependent on rainfall, rather than groundwater and is therefore unlikely to be groundwater dependent. Most of the critical habitat for California red-legged frogs and Alameda whipsnake occurs outside of the defined GDEs, with approximately 2 acres of their critical habitat overlapping with a riparian GDE at the upstream end of Arroyo Mocho.

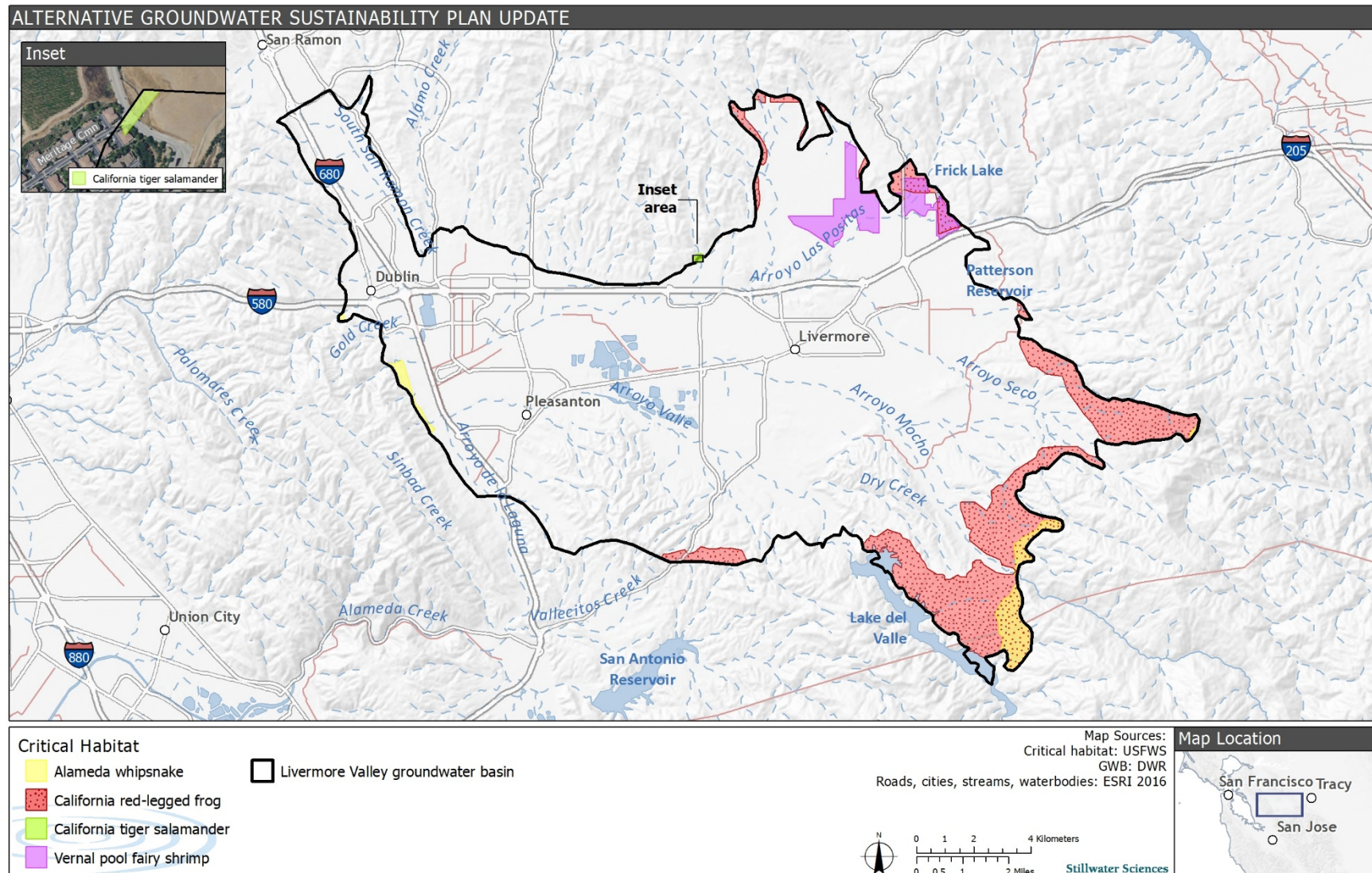


Figure 8. Designated critical habitat within the Livermore Valley Groundwater Basin.

3.3.2 Plants

Twenty-two special-status plants occur within the basin (Table 3). Of these, 12 were likely dependent upon groundwater, four were possibly dependent on groundwater, one was unlikely to be groundwater dependent, and five were not groundwater dependent (Table 3). All 12 special-status plants likely dependent on groundwater occurred in the Fringe Management Area, and three of the 12 also occurred in the Upland Management Area. The likely groundwater dependent special-status plants in the Fringe Area mostly were observed in or around the Springtown Alkali Sink.

Table 3. Groundwater dependance of special-status plant species in the Livermore Valley Groundwater Basin.

Common name <i>Scientific name</i>	Status ¹	Association with GDE	Documented occurrence location	Query source ²
Alkali milk-vetch <i>Astragalus tener</i> var. <i>tener</i>	G2T1, S1, 1B.2	Likely	Fringe	CNDDB
Heartscale <i>Atriplex cordulata</i> var. <i>cordulata</i>	G3T2, S2, 1B.2	Likely	Fringe	CNDDB
Brittlescale <i>Atriplex depressa</i>	G2, S2, 1B.2	Likely	Fringe	CNDDB
Lesser saltscale <i>Atriplex minuscula</i>	G2, S2, 1B.1	Possible	Fringe	CNDDB
Big-scale balsamroot <i>Balsamorhiza macrolepis</i>	G2, S2, 1B.2	Not a GDE	Uplands	CNDDB
Big tarplant <i>Blepharizonia plumosa</i>	G1G2, S1S2, 1B.1	Not a GDE	Outside of basin	CNDDB
Congdon's tarplant <i>Centromadia parryi</i> subsp. <i>congdonii</i>	G3T1T2, S1S2, 1B.1	Possible	Fringe, Uplands	CNDDB
Hispid salty bird's-beak <i>Chloropyron molle</i> subsp. <i>hispidum</i>	G2T1, S1, 1B.1	Likely	Fringe	CNDDB
Palmate-bracted bird's-beak <i>Chloropyron palmatum</i>	G1, S1, 1B.1	Likely	Fringe, Uplands	CNDDB
Livermore tarplant <i>Deinandra bacigalupii</i>	G1, S1, 1B.1	Likely	Fringe	CNDDB
Hospital Canyon larkspur <i>Delphinium californicum</i> subsp. <i>interius</i>	G3T3, S3, 1B.2	Not a GDE	Main, Uplands	CNDDB

Common name <i>Scientific name</i>	Status ¹	Association with GDE	Documented occurrence location	Query source ²
Jepson's coyote-thistle <i>Eryngium jepsonii</i>	G2, S2, 1B.2	Likely	Fringe	CNDDB
San Joaquin spearscale <i>Extriplex joaquinana</i>	G2, S2, 1B.2	Possible	Fringe	CNDDB
Stinkbells <i>Fritillaria agrestis</i>	G3, S3, 4.2	Unlikely	Fringe	CNDDB
Diablo helianthella <i>Helianthella castanea</i>	G2, S2, 1B.2	Possible	Fringe, on the edge of basin	CNDDB
Prostrate vernal pool navarretia <i>Navarretia prostrata</i>	G2, S2, 1B.2	Likely	Fringe	CNDDB
Hairless popcornflower <i>Plagiobothrys glaber</i>	GX, SX, 1A	Likely	Fringe, Uplands	CNDDB
California alkali grass <i>Puccinellia simplex</i>	G3, S2, 1B.2	Likely	Fringe, Uplands	CNDDB
Chaparral ragwort <i>Senecio aphanactis</i>	G3, S2, 2B.2	Not a GDE	Outside of Basin	CNDDB
Long-styled sand-spurrey <i>Spergularia macrotheca</i> var. <i>longistyla</i>	G5T2, S2, 1B.2	Likely	Fringe	CNDDB
Saline clover <i>Trifolium hydrophilum</i>	G2, S2, 1B.2	Likely	Fringe	CNDDB

Common name <i>Scientific name</i>	Status ¹	Association with GDE	Documented occurrence location	Query source ²
Caper-fruited tropidocarpum <i>Tropidocarpum capparideum</i>	G1, S1, 1B.1	Not a GDE	Outside of Basin	CNDDDB

¹ Status codes:

G = Global

T = Subspecies or variety

Federal

FT = Listed as threatened under the federal Endangered Species Act

FPT = Proposed as threatened under the federal Endangered Species Act

FD = Federally delisted

State

S = Sensitive

SE = Listed as Endangered under the California Endangered Species Act

ST = Listed as Threatened under the California Endangered Species Act

SSC = CDFW species of special concern

SFP = CDFW fully protected species

Rank

1 Critically Imperiled—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.

2 Imperiled—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

3 Vulnerable—At moderate risk of extinction or elimination due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

4 Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors.

5 Demonstrably Secure—Common; widespread and abundant.

Q Taxonomic questions associated with this name

Ranks such as S2S3 indicate a ranking between S2 and S3

California Rare Plant Rank (CRPR)

1B Plants rare, threatened, or endangered in California and elsewhere

2B Plants rare, threatened, or endangered in California, but more common elsewhere

4 More information needed about this plant, a review list

4 Plants of limited distribution, a watch list

CRPR Threat Ranks:

0.1 Seriously threatened in California (high degree/immediacy of threat)

0.2 Fairly threatened in California (moderate degree/immediacy of threat)

0.3 Not very threatened in California (low degree/immediacy of threats or no current threats known)

GDE Likelihood**Likely** Species habitat includes multiple GDE habitats and the species has a wetland plant rating in the USACE Arid West Regional Supplement (FAC, FACW, or OBL)**Possible** Species habitat range includes at least some GDE habitats (per CNPS and/or Jepson), however the species has an upland plant rating in the USACE Arid West Regional Supplement (FACU, UPL, or NL/UPL [i.e., not listed therefore considered upland])**Unlikely** Species habitat associations do not include a potential GDE and it is associated with upland habitats. However, it has a plant rating in the USACE Arid West Regional Supplement of sometimes occurring in wetlands (e.g., FAC).**Not a GDE** Species habitat associations do not include a potential GDE and it is associated with upland habitats. Also, it has an upland plant rating in the USACE Arid West Regional Supplement.²Query source: CNDDDB: California Natural Diversity Database (CDFW 2020a)

3.3.3 Terrestrial and aquatic wildlife

Thirty-one special-status terrestrial and aquatic wildlife species were identified as having the potential to occur within the Livermore Valley Groundwater Basin. Of these, 14 were potentially groundwater dependent species: two amphibian species, two reptile species, seven bird species, and three mammal species. Additional information on these groundwater dependent species, including regulatory status and habitat associations, is provided in Table 4. Ten of the groundwater dependent special status species are likely to occur in the Main Basin, eight of the groundwater-dependent special status species are likely to occur in the Fringe Management Area, and 13 of the groundwater-dependent special status species are likely to occur in the Upland Management Area.

Table 4. Groundwater-dependence of special-status terrestrial and aquatic wildlife species with potential to occur or suitable habit in the Livermore Valley Groundwater Basin.

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
<i>Invertebrates</i>						
Longhorn fairy shrimp <i>Branchinecta longiantenna</i>	FE/–	Likely	Main, Fringe, Uplands	CNDDDB, CAFSD	No known reliance on groundwater	Vernal pools; also found in sandstone rock outcrop pools, grass-bottomed pools, and claypan pools.
Vernal pool fairy shrimp <i>Branchinecta lynchi</i>	FT/–	Likely (critical habitat)	Fringe	CNDDDB, CAFSD	No known reliance on groundwater	Vernal pools; also found in sandstone rock outcrop pools. The Livermore Valley Groundwater Basin includes 1,337 acres of USFWS designated critical habitat.
Crotch bumble bee <i>Bombus crotchii</i>	–/SCE	Likely	Fringe, Uplands	CNDDDB	No known reliance on groundwater	Inhabits open grassland and scrub habitats in Coastal California east towards the Sierra-Cascade Crest. Nests are often located underground in abandoned rodent burrows, or above ground in tufts of grass, rock piles, or tree cavities.
Western bumble bee <i>Bombus occidentalis</i>	–/SCE	Likely	Fringe, Uplands	CNDDDB	No known reliance on groundwater	Uses flowering plants in meadows and forested openings; abandoned rodent burrows are used for nest and hibernation sites for queens.

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
Amphibian						
California red-legged frog <i>Rana draytonii</i>	FT/SSC	Likely (Critical Habitat)	Main, Fringe, Uplands	CNDDDB, CAFSD	Direct	Breeds in still or slow-moving water with emergent and overhanging vegetation, including wetlands, wet meadows, ponds, lakes, and low-gradient, slow moving stream reaches with permanent pools; uses adjacent uplands for dispersal and summer retreat. Relies on surface water that may be supported by groundwater (Rohde et al. 2019). The Livermore Valley Groundwater Basin includes 7,273 acres of USFWS designated critical habitat.
California tiger salamander <i>Ambystoma californiense</i>	FT/ST	Likely (Critical Habitat)	Fringe, Uplands	CNDDDB, CAFSD	No known reliance on groundwater	Grassland, oak savannah, or edges of woodland that provide subterranean refuge (typically mammal burrows); breeds in nearby temporary ponds, vernal pools, or slow-moving parts of streams. The Livermore Valley Groundwater Basin includes 0.5 acres of USFWS designated critical habitat.
Foothill yellow- legged frog <i>Rana boylei</i>	BLMS/SE	Likely	Main, Uplands	CNDDDB	Direct	Shallow tributaries and mainstems of perennial streams and rivers, typically associated with cobble or boulder substrate; occasionally found in isolated pools, vegetated backwaters, and deep, shaded, spring-fed pools. The frog is reliant on surface water that may be fed by groundwater.
Western spadefoot <i>Spea hammondi</i>	BLMS/SSC	Likely	Fringe, Uplands	CNDDDB, CAFSD	No known reliance on groundwater	Areas with sparse vegetation and/or short grasses in sandy or gravelly soils; primarily in washes, river floodplains, alluvial fans, playas, alkali flats, among grasslands, chaparral, or pine-oak woodlands; breeds in ephemeral rain pools with no predators.

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
Reptile						
Alameda whipsnake <i>Masticophis lateralis euryxanthus</i>	FT/ST	Likely (Critical Habitat)	Uplands	CNDDDB	Indirect	Chaparral (northern coastal sage scrub and coastal sage) and rocky outcrops; may venture into adjacent habitats, including grassland, oak savanna, and woodlands. Relies on native vegetation that may be groundwater dependent vegetation (e.g., <i>Quercus</i> spp.) (Rohde et al. 2019). The Livermore Valley Groundwater Basin includes 936 acres of USFWS designated critical habitat.
Coast horned lizard <i>Phrynosoma blainvillii</i>	BLMS/SSC	Likely	Main, Fringe	CNDDDB	No known reliance on groundwater	Open areas with sandy soil and/or patches of loose soil and low/scattered vegetation in scrublands, grasslands, conifer forests, and woodlands; frequently found near ant hills. Feeds on ants and other small invertebrates (e.g., spiders, beetles, and grasshoppers).
Northern California legless lizard <i>Anniella pulchra</i>	–/SSC	Possible	Outside of basin	CNDDDB	No known reliance on groundwater	Occurs in moist, warm, loose soil with plant cover and in sparsely vegetated areas of chaparral, pine-oak woodlands, desert scrub, and stream terraces with sycamores, cottonwoods, or oaks. Forages in loose soil, sand, and leaf litter for larval insects, beetles, termites, and spiders.
San Joaquin coachwhip <i>Masticophis flagellum ruddocki</i>	–/SSC	Likely	Uplands	CNDDDB	No known reliance on groundwater	Open, dry, treeless areas, including grassland and saltbush scrub; uses rodent burrows, shaded vegetation, and surface objects as refuge.
Southwestern pond turtle <i>Actinemys pallida</i>	BLMS/SSC	Likely	Main, Fringe, Uplands	CNDDDB, CAFSD	Direct	Ponds, lakes, rivers, streams, creeks, marshes, and irrigation ditches with basking sites. Feeds on aquatic plants, invertebrates, worms, frog and salamander eggs and larvae, crayfish, and occasionally frogs and fish. Relies on surface water that may be supported by groundwater (Rhode et al. 2019).

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
Bird						
American peregrine falcon <i>Falco peregrinus anatum</i>	–/SFP	Likely	Main, Fringe, Uplands	CNDDDB, eBird	No known reliance on groundwater	Wetlands, woodlands, cities, agricultural lands, and coastal area with cliffs (and rarely broken-top, predominant trees) for nesting; often forages near water. Prey includes birds (e.g., shorebirds, ducks, grebes, gulls, pigeons, and songbird) and bats.
American White Pelican <i>Pelecanus erythrorhynchos</i>	–/SSC	Likely	Main, Fringe, Uplands	CAFSD, eBird	Indirect	Salt ponds, large lakes, and estuaries; loafs on open water during the day; roosts along water's edge at night. Forages for small fish in shallow water on inland marshes.
Bald eagle <i>Haliaeetus leucocephalus</i>	BGEPA, BLMS/SE, SFP	Likely	Main, Fringe, Uplands	CNDDDB, CAFSD, eBird	Indirect	Large bodies of water or rivers with abundant fish, uses snags or other perches; nests in advanced-successional conifer forest near open water (e.g., lakes, reservoirs, rivers). Bald eagles are reliant on surface water that may be supported by groundwater and/or groundwater-dependent vegetation (Rhode et al. 2019).
Burrowing owl <i>Athene cunicularia</i>	BLMS/SSC	Likely	Main, Fringe, Uplands	CNDDDB	No known reliance on groundwater	Level, open, dry, heavily grazed or low-stature grassland or desert vegetation with available burrows. Preys on invertebrates and vertebrates.
Golden eagle <i>Aquila chrysaetos</i>	BGEPA, BLMS/SFP	Likely	Main, Fringe, Uplands	CNDDDB, eBird	No known reliance on groundwater	Open woodlands and oak savannahs, grasslands, chaparral, sagebrush flats; nests on steep cliffs or medium to tall trees. Primary prey are small to medium mammals and birds; also scavenges and catches fish.
Grasshopper sparrow <i>Ammodramus savannarum</i>	–/SSC	Likely	Main, Uplands	CNDDDB	No known reliance on groundwater	Grasslands. Ground forager that feeds on insects, including grasshoppers.

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
Loggerhead shrike <i>Lanius ludovicianus</i>	–/SSC	Likely	Main, Fringe, Uplands	CNDDDB, eBird	No known reliance on groundwater	Open shrubland or woodlands with short vegetation and and/or bare ground for hunting; some tall shrubs, trees, fences, or power lines for perching; typically nests in isolated trees or large shrubs. Feeds on insects, amphibians, reptiles, small mammals, and birds.
Redhead <i>Aythya americana</i>	–/SSC	Likely	Main, Fringe, Uplands	CAFSD, eBird	Indirect	Freshwater emergent wetlands with dense stands of cattails (<i>Typha</i> spp.) and bulrush (<i>Schoenoplectus</i> spp.) interspersed with areas of deep, open water; forages and rests on large, deep bodies of water. Summer resident in southern California.
Swainson's hawk <i>Buteo swainsoni</i>	–/ST	Likely	Main, Fringe, Uplands	CNDDDB, eBird	Indirect	Nests in oaks or cottonwoods in or near riparian habitats; forages in grasslands, irrigated pastures, and grain fields. Swainson's hawks rely on groundwater-dependent vegetation in riparian woodland areas for nesting (Rohde et al 2019). Preys on mammals and insects.
Tricolored blackbird <i>Agelaius tricolor</i>	–/ST	Likely	Main, Fringe, Uplands	CNDDDB, CAFSD, eBird	Indirect	Feeds in grasslands and agriculture fields; nesting habitat components include open accessible water with dense, tall emergent vegetation, a protected nesting substrate (including flooded or thorny vegetation), and a suitable nearby foraging space with adequate insect prey.
White-tailed kite <i>Elanus leucurus</i>	BLMS/SFP	Likely	Main, Fringe, Uplands	CNDDDB, eBird	Indirect	Lowland grasslands and wetlands with open areas; nests in trees near open foraging area. Predominately preys on small mammals, but its diet also includes birds and lizards.

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
Willow Flycatcher <i>Empidonax traillii</i>	–/SE	Likely	Main, Uplands	CAFSD, eBird	Indirect	Dense brushy thickets within riparian woodland often dominated by willows and/or alder, near permanent standing water. Reliant on groundwater-dependent riparian vegetation, including for nest sites that are typically located near slow-moving streams, or side channels and marshes with standing water and/or wet soils (Rohde et al 2019). Feeds on insects, fruits, and berries.
Mammals						
American badger <i>Taxidea taxus</i>	–/SSC	Likely	Fringe, Uplands	CNDDB	No known reliance on groundwater	Shrubland, open grasslands, fields, and alpine meadows with friable soils.
Pallid bat <i>Antrozous pallidus</i>	BLMS/SSC	Likely	Fringe, Main, Uplands	CNDDB	No known reliance on groundwater	Roosts in rock crevices, tree hollows, mines, caves, and a variety of vacant and occupied buildings; feeds in a variety of open woodland habitats. Habitat and prey (e.g., insects and arachnids) not associated with aquatic ecosystems.
San Joaquin kit fox <i>Vulpes macrotis mutica</i>	FE, BLMS/ST	Likely	Outside of Basin	CNDDB	No known reliance on groundwater	Annual grasslands or open areas dominated by scattered brush, shrubs, and scrub.
San Joaquin pocket mouse <i>Perognathus inornatus</i>	BLMS/–	Possible	Outside of Basin	CNDDB	Indirect	Open grasslands, savanna, and desert shrub communities; often in areas with sandy washes and finely textured soils. Birthing dens are in burrows near the base of shrubs. Predominantly granivorous, eating seeds of annual and perennial grasses, shrubs, and forbs. Also feeds on soft-bodied insects, cutworms, earthworms, and even grasshoppers.

Common name <i>Scientific name</i>	Status ¹ Federal/State	Potential to occur in the Livermore Valley Groundwater Basin ²	Documented occurrence location	Query source ³	GDE . association ⁴	Habitat and documented occurrences in Livermore Valley Groundwater Basin Groundwater Basin
Townsend's big-eared bat <i>Corynorhinus townsendii</i>	BLMS/SSC	Likely	Main, Uplands	CNDDDB	Indirect	Most abundant in mesic habitats, also found in oak woodlands, desert, vegetated drainages, caves or cave-like structures (including basal hollows in large trees, mines, tunnels, and buildings) and riparian communities. Feeds on moths, beetles, and soft-bodied insects and drinks water.
Yuma myotis <i>Myotis yumanensis</i>	BLMS/–	Likely	Main, Uplands	CNDDDB	Indirect	Uses a variety of habitats, including riparian, agriculture, shrub, urban, desert, open forests, and woodlands. Distribution is strongly associated with water; drinks water and forages near or over waterbodies.

¹ Status codes:

Federal

FE = Listed as endangered under the federal Endangered Species Act
 FT = Listed as threatened under the federal Endangered Species Act
 FPE = Federally proposed as endangered
 BGEPA = Federally protected under the Bald and Golden Eagle Protection Act
 BLMS = Bureau of Land Management Sensitive Species

State

SE = Listed as Endangered under the California Endangered Species Act
 ST = Listed as Threatened under the California Endangered Species Act
 SCE = State Candidate Endangered
 SSC = CDFW Species of Special Concern
 SFP = CDFW Fully Protected species

² Potential to Occur:

Likely: the species *has* documented occurrences and the habitat is high quality or quantity

Possible: no documented occurrences and the species' required habitat is moderate to high quality or quantity

Unlikely: no documented occurrences and the species' required habitat is of low to moderate quality or quantity

³ Query source:

CAFSD: California Freshwater Species Database (TNC 2021)
 CNDDDB: California Natural Diversity Database (CDFW 2020a)
 eBird: (eBird 2021)

⁴ Groundwater Dependent Ecosystem (GDE) association:

Direct: Species directly dependent on groundwater for some or all water needs

Indirect: species dependent upon other species that rely on groundwater for some or all water needs (e.g., riparian birds).

No known reliance on groundwater: Species is not known to rely on groundwater. For species associated with vernal pools, it is assumed that the seasonal water in the vernal pools originates from rainfall rather than groundwater.

4 SUMMARY

In the Livermore Valley Groundwater Basin, likely GDEs occur in all three management areas. Likely GDEs in the Main Basin Management Area typically occur along riparian zones along major channels (e.g., Arroyo Valle, Arroyo Mocho, and Arroyo Las Positas). Likely GDEs in the Fringe Management Area include riparian vegetation (willows and cottonwoods) and alkaline-tolerant plants that occur along spring-fed channels and wetlands in Springtown Alkali Sink in the northeast corner of the basin. Likely GDEs in the Upland Management Area occur in riparian zones along smaller tributaries.

Twelve special status plants identified in the basin are likely dependent on groundwater. Groundwater dependent special-status plant species occur primarily in the Fringe and Upland Management Areas. There are 14 groundwater dependent special-status wildlife species likely to occur in the basin. Groundwater dependent special-status wildlife are likely to occur in all three management areas.

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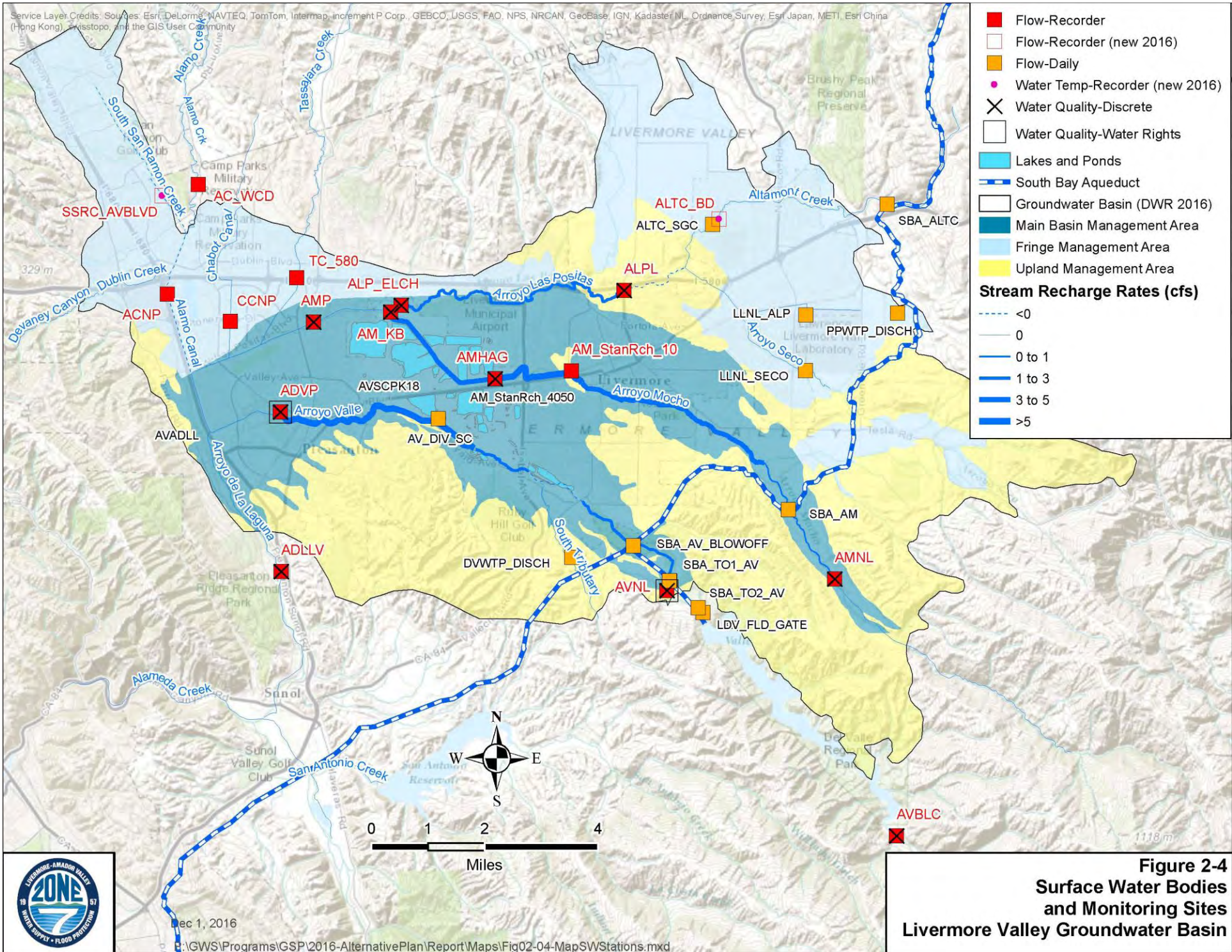
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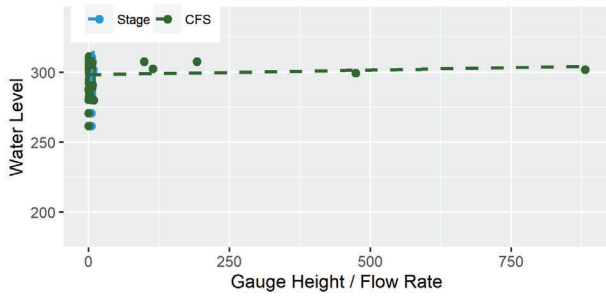
Attachment C: Surface Water Bodies and Monitoring Sites



**Attachment D: Time Series Data and Correlation Plots
by Stream Station**

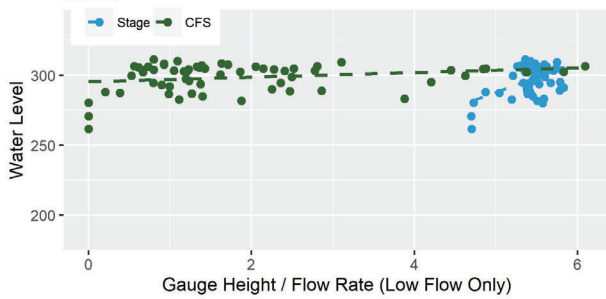
Linear Correlation

Linear Correlation Coefficient (Gauge Height) = 0.327 , p-value = 0.00618
Linear Correlation Coefficient (Flow Rate) = 0.0828 , p-value = 0.499

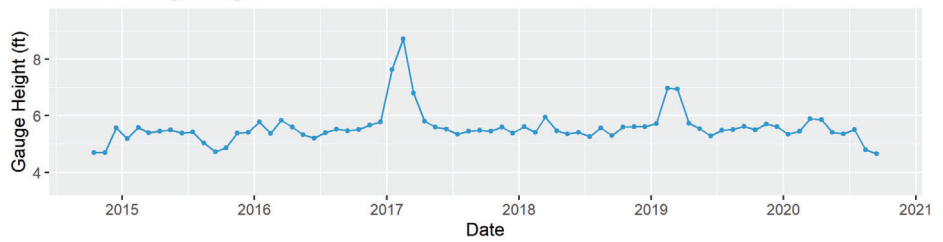


Linear Correlation: Low Flow

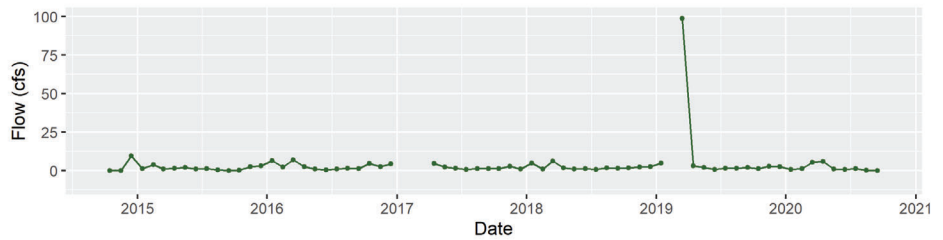
Linear Correlation Coefficient (Gauge Height) = 0.51 , p-value = 2.72e-05
Linear Correlation Coefficient (Flow Rate) = 0.243 , p-value = 0.0594



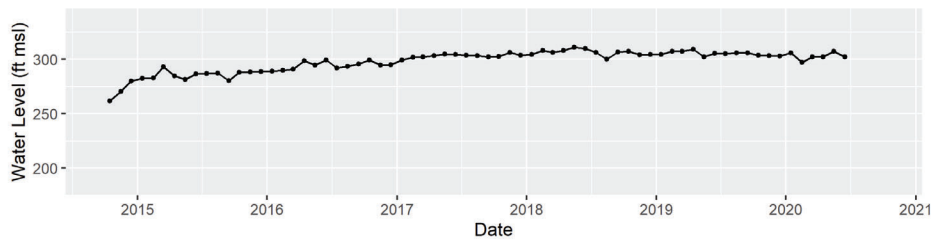
ADVP : Gauge Height



ADVP : Flow Rate

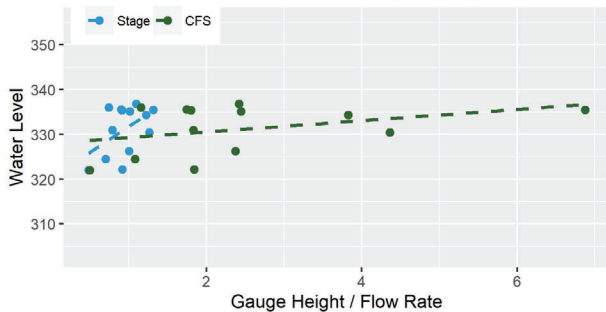


ADVP : Water Level



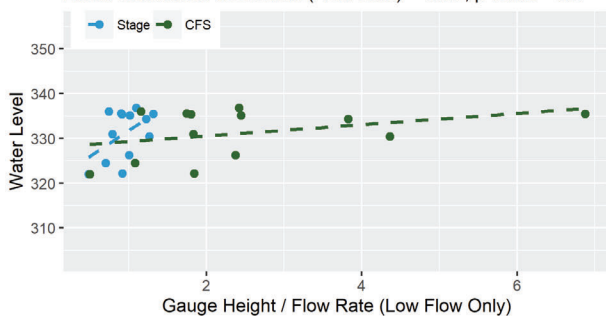
Linear Correlation

Linear Correlation Coefficient (Gauge Height) = 0.496 , p-value = 0.0846
Linear Correlation Coefficient (Flow Rate) = 0.38 , p-value = 0.2

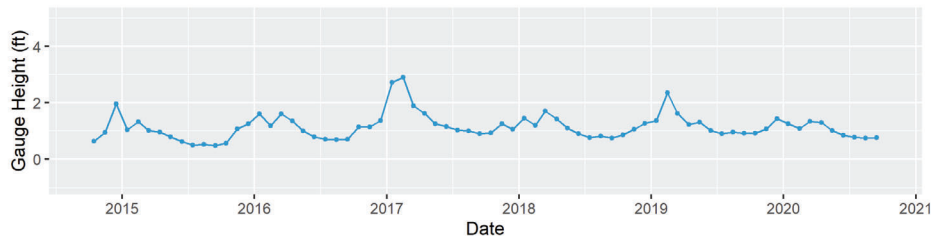


Linear Correlation: Low Flow

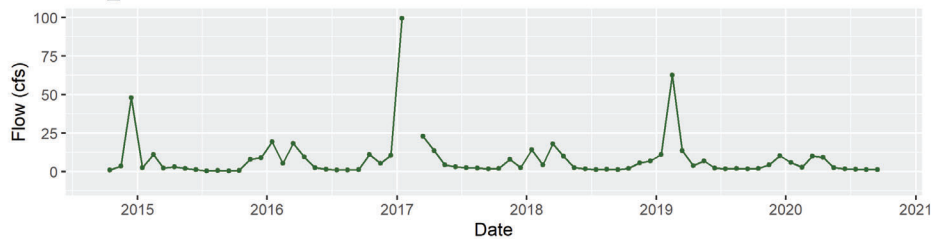
Linear Correlation Coefficient (Gauge Height) = 0.496 , p-value = 0.0846
Linear Correlation Coefficient (Flow Rate) = 0.38 , p-value = 0.2



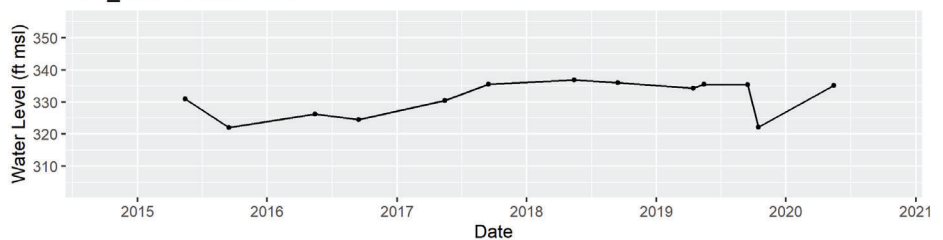
ALP_ELCH : Gauge Height



ALP_ELCH : Flow Rate

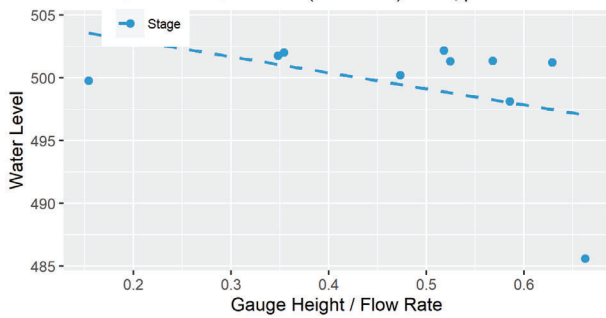


ALP_ELCH : Water Level



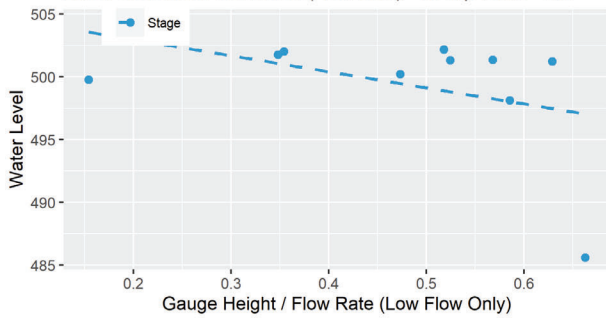
Linear Correlation

Linear Correlation Coefficient (Gauge Height) = -0.399 , p-value = 0.253
Linear Correlation Coefficient (Flow Rate) = NA , p-value = NA

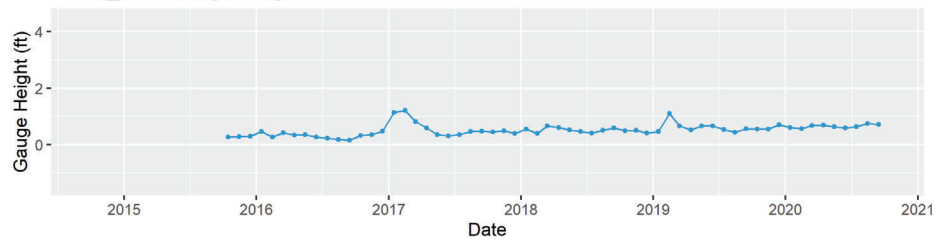


Linear Correlation: Low Flow

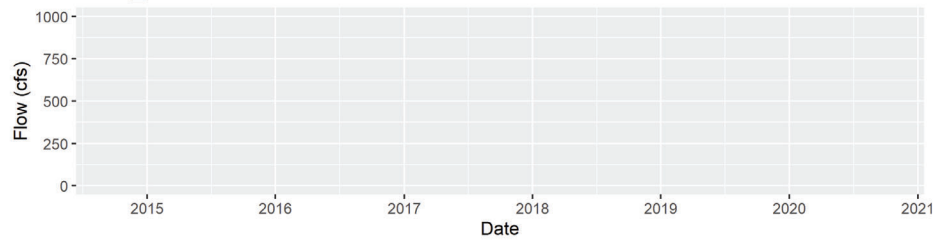
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Linear Correlation Coefficient (Flow Rate) = NA , p-value = NA



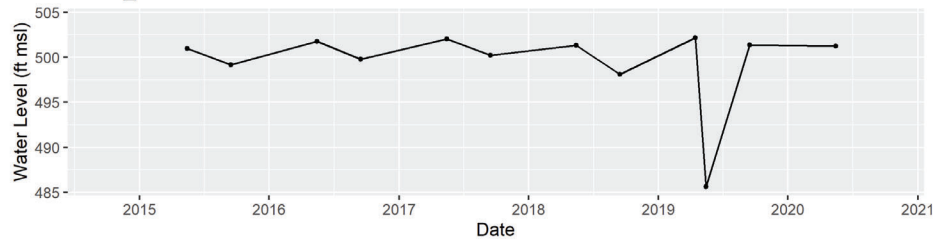
ALTC_BD : Gauge Height



ALTC_BD : Flow Rate

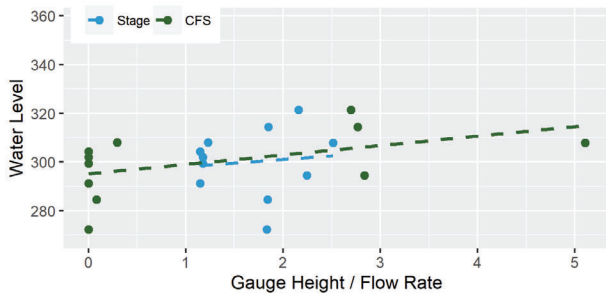


ALTC_BD : Water Level



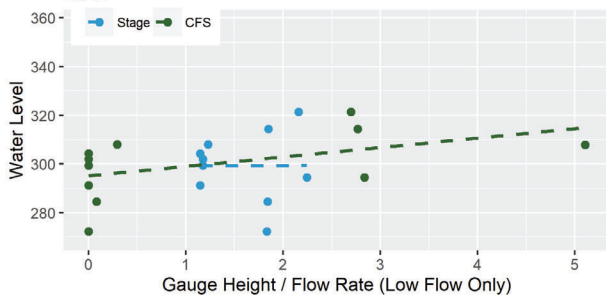
Linear Correlation

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Linear Correlation Coefficient (Flow Rate) = 0.498 , p-value = 0.119

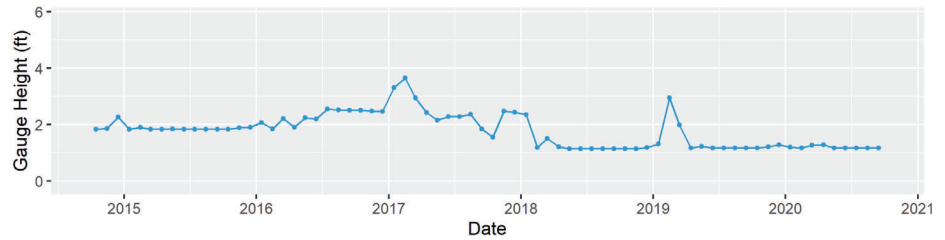


Linear Correlation: Low Flow

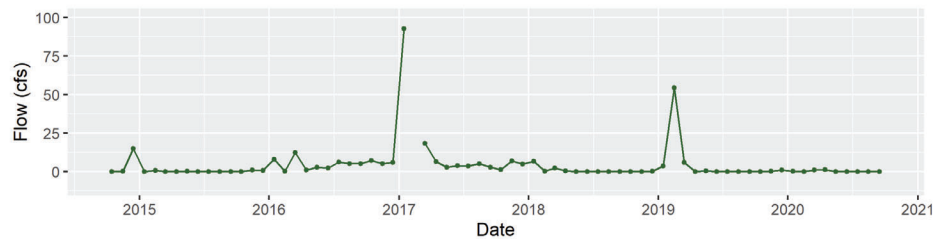
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Linear Correlation Coefficient (Flow Rate) = 0.498 , p-value = 0.119



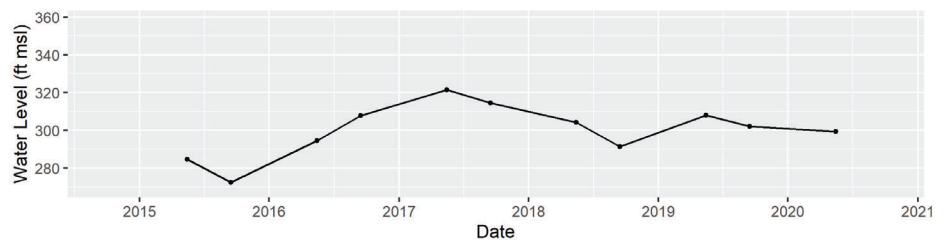
AMHAG : Gauge Height



AMHAG : Flow Rate

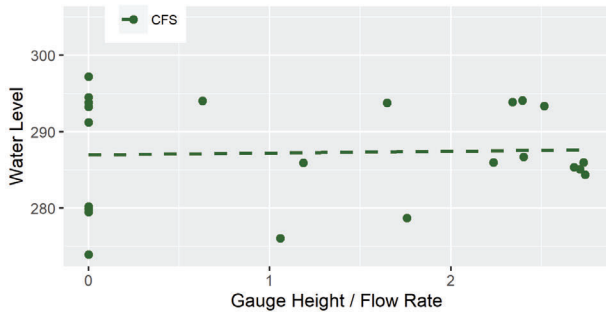


AMHAG : Water Level



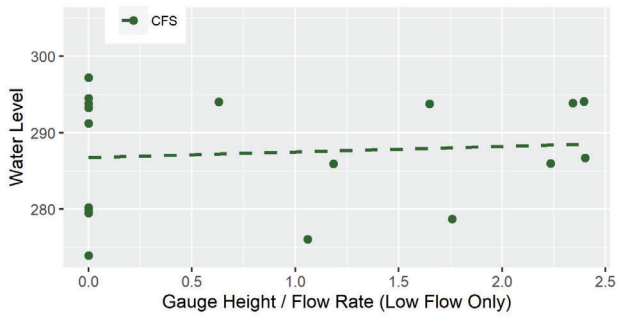
Linear Correlation

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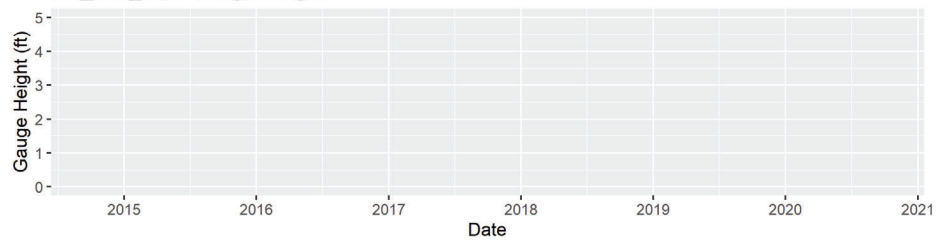


Linear Correlation: Low Flow

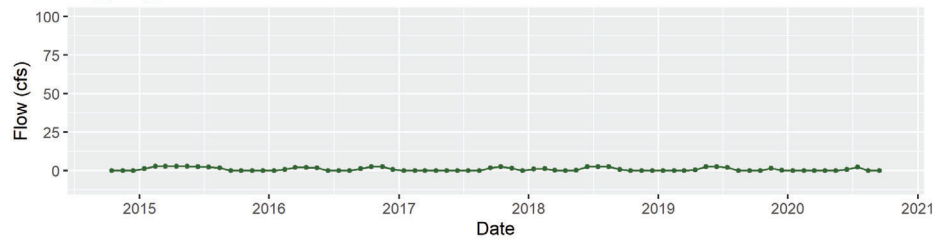
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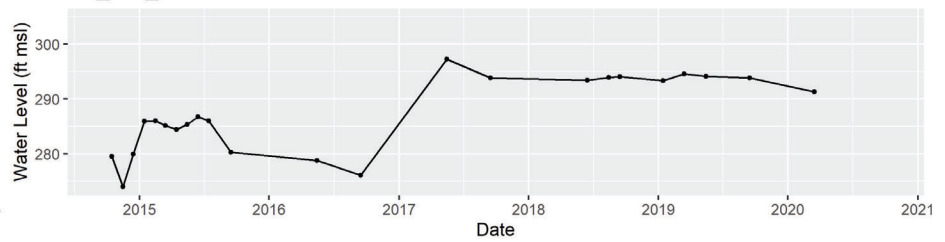
AV_DIV_SC : Gauge Height



AV_DIV_SC : Flow Rate

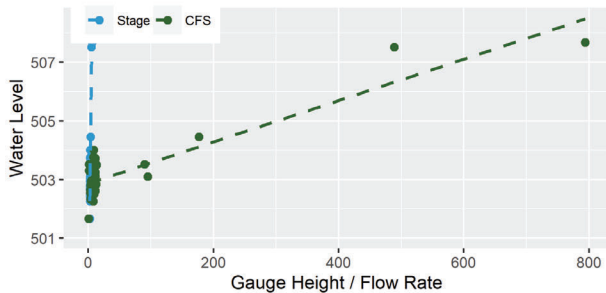


AV_DIV_SC : Water Level



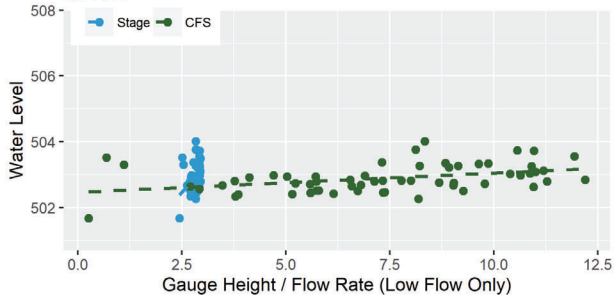
Linear Correlation

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Linear Correlation Coefficient (Flow Rate) = 0.871 , p-value = 9.77e-22

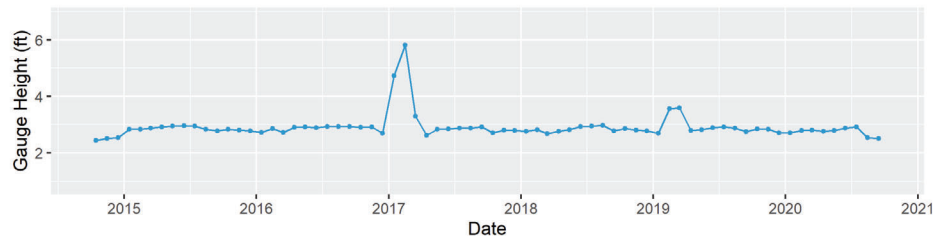


Linear Correlation: Low Flow

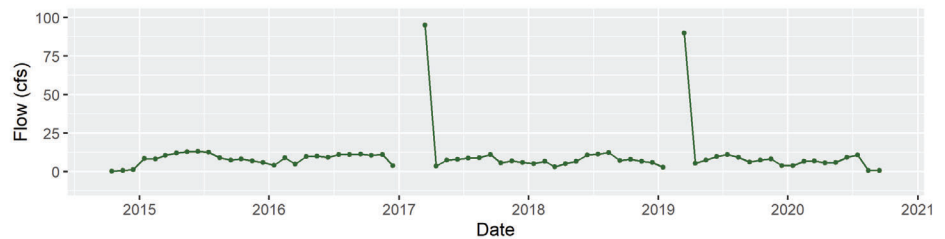
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Linear Correlation Coefficient (Flow Rate) = 0.397 , p-value = 0.00185



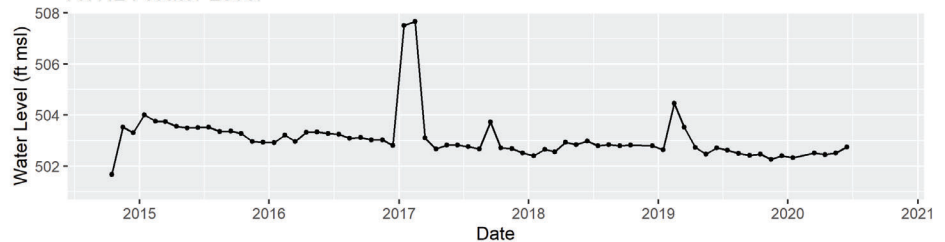
AVNL : Gauge Height



AVNL : Flow Rate

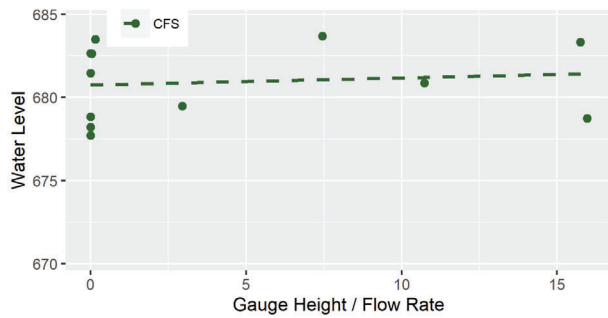


AVNL : Water Level



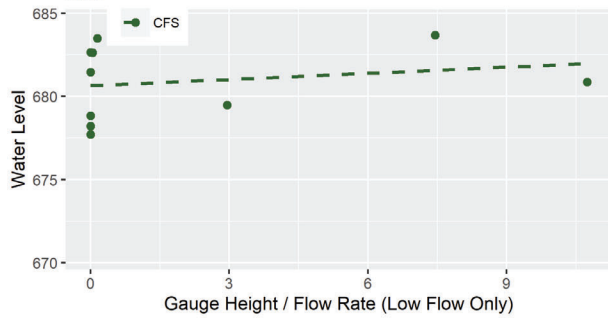
Linear Correlation

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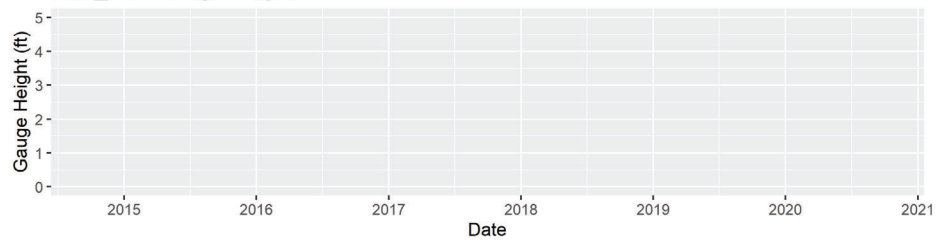


Linear Correlation: Low Flow

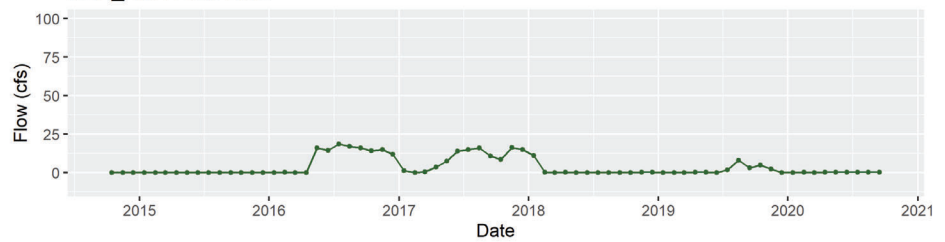
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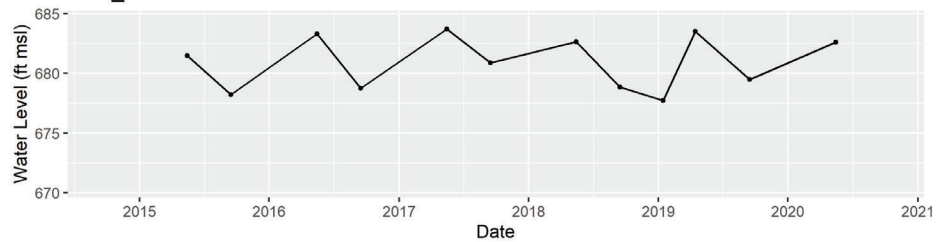
SBA_AM : Gauge Height



SBA_AM : Flow Rate

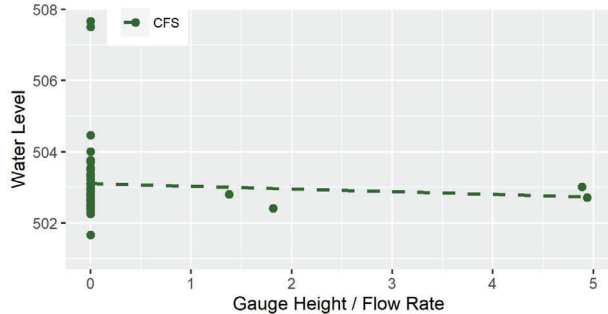


SBA_AM : Water Level



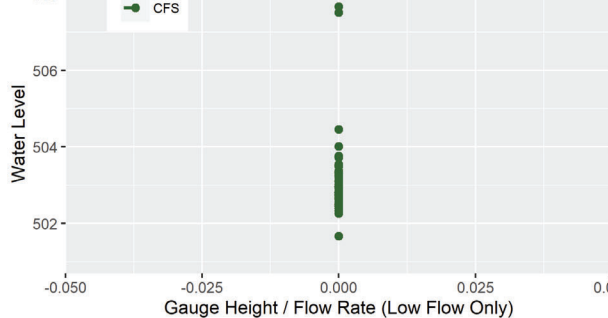
Linear Correlation

Linear Correlation Coefficient (Gauge Height) = NA , p-value = NA
Linear Correlation Coefficient (Flow Rate) = -0.0724 , p-value = 0.56

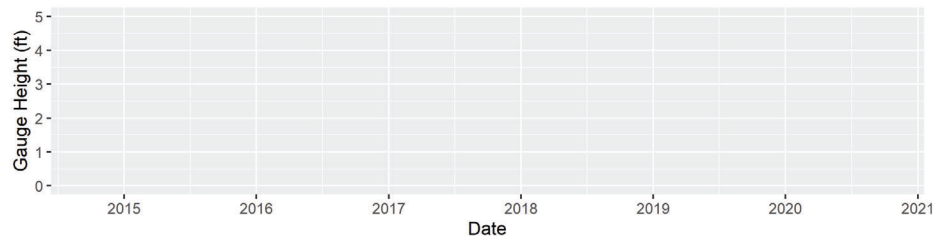


Linear Correlation: Low Flow

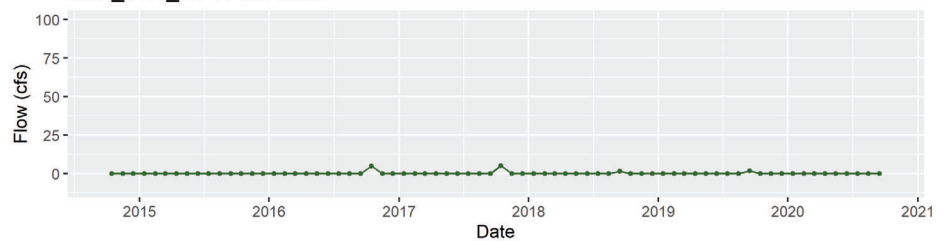
Linear Correlation Coefficient (Gauge Height) = NA , p-value = NA
Linear Correlation Coefficient (Flow Rate) = NA , p-value = NA



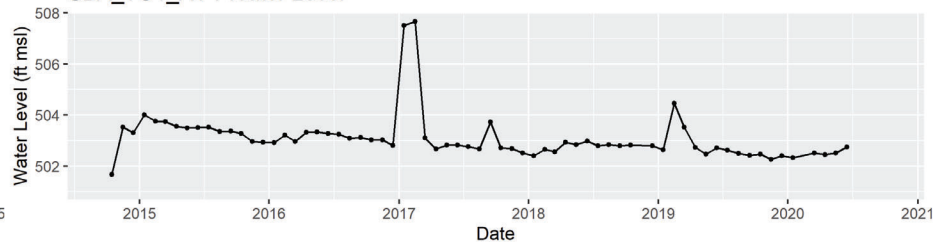
SBA_TO1_AV : Gauge Height



SBA_TO1_AV : Flow Rate

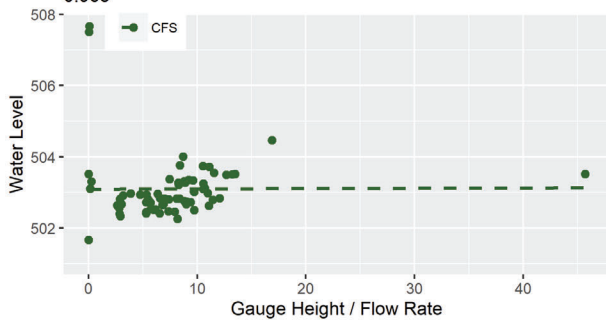


SBA_TO1_AV : Water Level



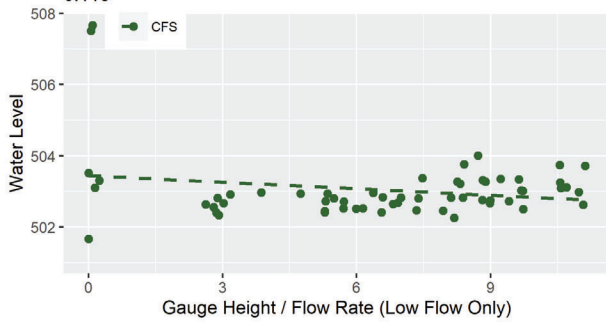
Linear Correlation

Linear Correlation Coefficient (Gauge Height) = NA , p-value = NA
Linear Correlation Coefficient (Flow Rate) = 0.00539 , p-value = 0.965

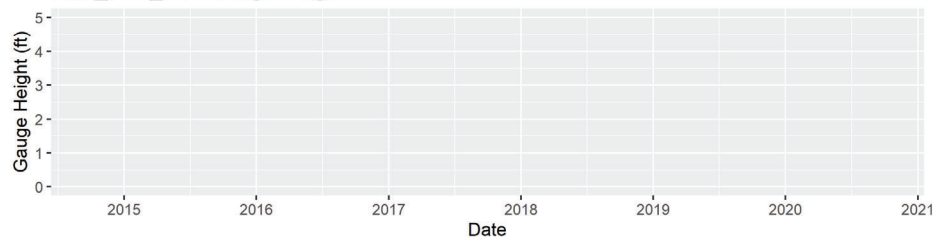


Linear Correlation: Low Flow

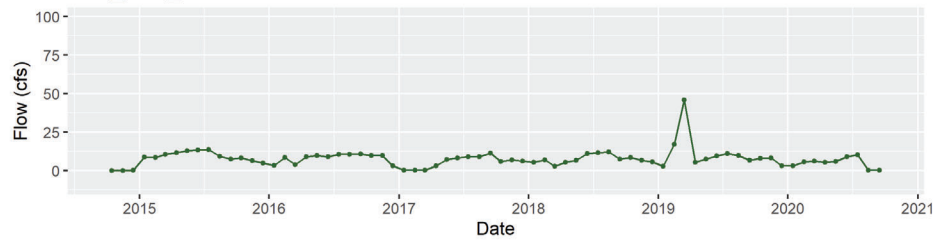
Linear Correlation Coefficient (Gauge Height) = NA , p-value = NA
Linear Correlation Coefficient (Flow Rate) = -0.206 , p-value = 0.118



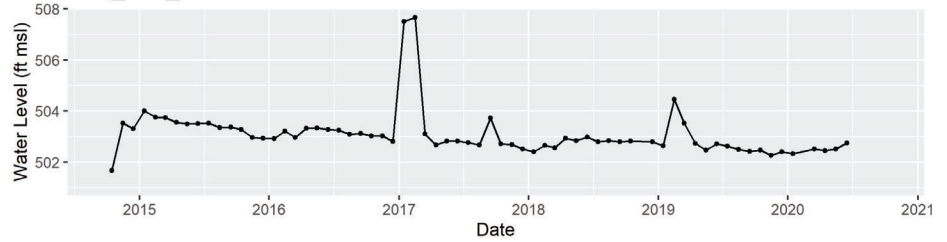
SBA_TO2_AV : Gauge Height



SBA_TO2_AV : Flow Rate



SBA_TO2_AV : Water Level



Attachment E: Change in GDE Area Analysis

Change in GDE Area Analysis

Normalized Derived Vegetation Index (NDVI) is the most widely used vegetation metric in the literature and is a reliable measure of the photosynthetic chlorophyll content in leaves and vegetation cover.¹ The Nature Conservancy (TNC) Groundwater Dependent Ecosystem (GDE) Pulse calculated annual NDVI from surface reflectance corrected multispectral Landsat imagery, and applied a linear fit to the NDVI time series data to estimate the NDVI trends over specific timespan of interest. The NDVI trends can be viewed on the TNC GDE Pulse website (<https://gde.codefornature.org/#/map>).

Since NDVI is used to estimate vegetation greenness and provides a proxy for vegetation growth, change in GDE area can be estimated using TNC GDE Pulse raster data that shows the NDVI trends between 2014 and 2018.^{2,3} Moderate to large increases in NDVI trends represent an increase in the GDE area and moderate to large decreases in NDVI trends represent a decrease in the GDE area. Therefore, the change in GDE area can be estimated by subtracting GDE area with decreasing NDVI trends from GDE area with increasing NDVI trends.

This analysis was performed in ArcGIS.⁴ The statewide raster data that show NDVI trends between 2014 and 2018 were clipped using the likely GDEs' polygon within the Livermore Valley Groundwater Basin (Basin). Raster values of zero mean no change in NDVI trends. Positive and negative raster values mean increasing and decreasing NDVI trends respectively. For the purpose of this analysis, raster values that range from -628 to 628 were assumed to represent little or no change in NDVI trends.⁵ For each likely GDE area within the Basin, the total number of raster pixels that fall within the GDE polygon boundary, the number of pixels that show increasing NDVI trends, and the number of pixels that show decreasing NDVI trends were summarized, as shown in **Table 1**. Change in area for each likely GDE was then calculated by dividing the difference between the increasing and decreasing NDVI trends' pixel counts by the total pixel count.

Percentages of GDE area reduction in 2014 compared to 2018 by likely GDEs are shown in **Table 1**. Figures included below show the raster data of NDVI trends by likely GDEs within the Basin. Compared to the 2018 GDE area, reductions in GDE area that range from -14% to 63% were observed, with an area weighted average of 40% (i.e., on average the GDE area in 2014 was 40% less than the GDE area in 2018).

¹ <https://gde.codefornature.org/#/methodology>

² Statewide raster data that show NDVI trends are provided by TNC on 30 August 2021.

³ Since the Plan is not required to address undesirable results that occurred before, and have not been corrected by January 1, 2015 (Water Code Section 10727.2 (b)(4)), 2014 is selected as the start of the analysis timeframe. 2018 is selected as the end of the analysis timeframe since it is a recent wet year when GDE conditions might be above average.

⁴ <https://www.esri.com/en-us/arcgis/about-arcgis/overview>

⁵ The range of -628 to 628 is approximately two percent of the raster values' total range. It was selected by visually comparing raster pixels that fall within this range with the "little or no change" NDVI trend category from the TNC GDE Pulse website. Therefore, raster values larger than 628 represent moderate or large increase in NDVI trends, and raster values smaller than -628 represent moderate or large decreasing in NDVI trends.

Table 1. Change in GDE Area (2014-2018)

Likely GDEs	Total Pixel Count	Pixel Count of Increasing NDVI Trends	Pixel Count of Decreasing NDVI Trends	GDE Area Reduction in 2014 (a)
Arroyo Mocho - Riparian Mixed Hardwood & Sycamore	529	349	33	60%
Arroyo Mocho - Valley Oak	999	185	290	-11%
Arroyo Valle - Riparian Mixed Hardwood	769	527	46	63%
Arroyo Valle - Sycamore Grove	1954	1134	94	53%
Springtown Alkali Sink	971	633	42	61%
Upland - Riparian Mixed Hardwood	210	41	71	-14%
Arroyo Las Positas - Mixed Vegetation	303	88	86	1%
Potential GDEs to be Further Evaluated	203	127	20	53%
Area Weighted Average (%)				40%

Abbreviations:

GDE = Groundwater Dependent Ecosystem

NDVI = Normalized Derived Vegetation Index

TNC = The Nature Conservancy

Notes:

- (a) Positive percentages represent net reduction in GDE area and negative percentages represent net increase in GDE area in 2014 relative to 2018.

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

DWR Basin Boundaries (2018)

□ Livermore Valley Groundwater Basin

NDVI Trend (2014-2018)

■ Large or Moderate Decrease

■ Little or No Change

■ Large or Moderate Increase

ABBREVIATIONS

DWR = California Department of Water Resources

GDE = Groundwater Dependent Ecosystem

NDVI = Normalized Derived Vegetation Index



0 0.25 0.5
Miles

DATE: September 2, 2021

FILE: X:\C00065.00\Map\2021\08\GDE_Pulse_Raster_Working.mxd

Arroyo Mocho - Riparian Mixed Hardwood & Sycamore

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

DWR Basin Boundaries (2018)

□ Livermore Valley Groundwater Basin

NDVI Trend (2014-2018)

■ Large or Moderate Decrease

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ABBREVIATIONS

DWR = California Department of Water Resources

GDE = Groundwater Dependent Ecosystem

NDVI = Normalized Derived Vegetation Index



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Miles

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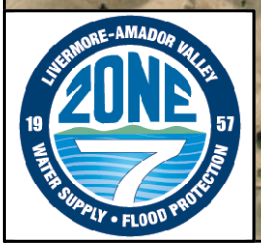
Arroyo Mocho - Valley Oak

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

- DWR Basin Boundaries (2018)**
[Black outline] Livermore Valley Groundwater Basin
- NDVI Trend (2014-2018)**
[Red] Large or Moderate Decrease
[Yellow] Little or No Change
[Blue] Large or Moderate Increase

ABBREVIATIONS
DWR = California Department of Water Resources
GDE = Groundwater Dependent Ecosystem
NDVI = Normalized Derived Vegetation Index



DATE: September 2, 2021

FILE: X:\C00065.00\Map\2021\08\GDE Pulse Raster Working.mxd

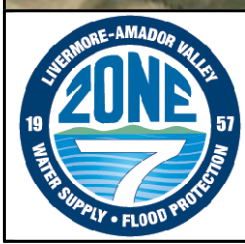
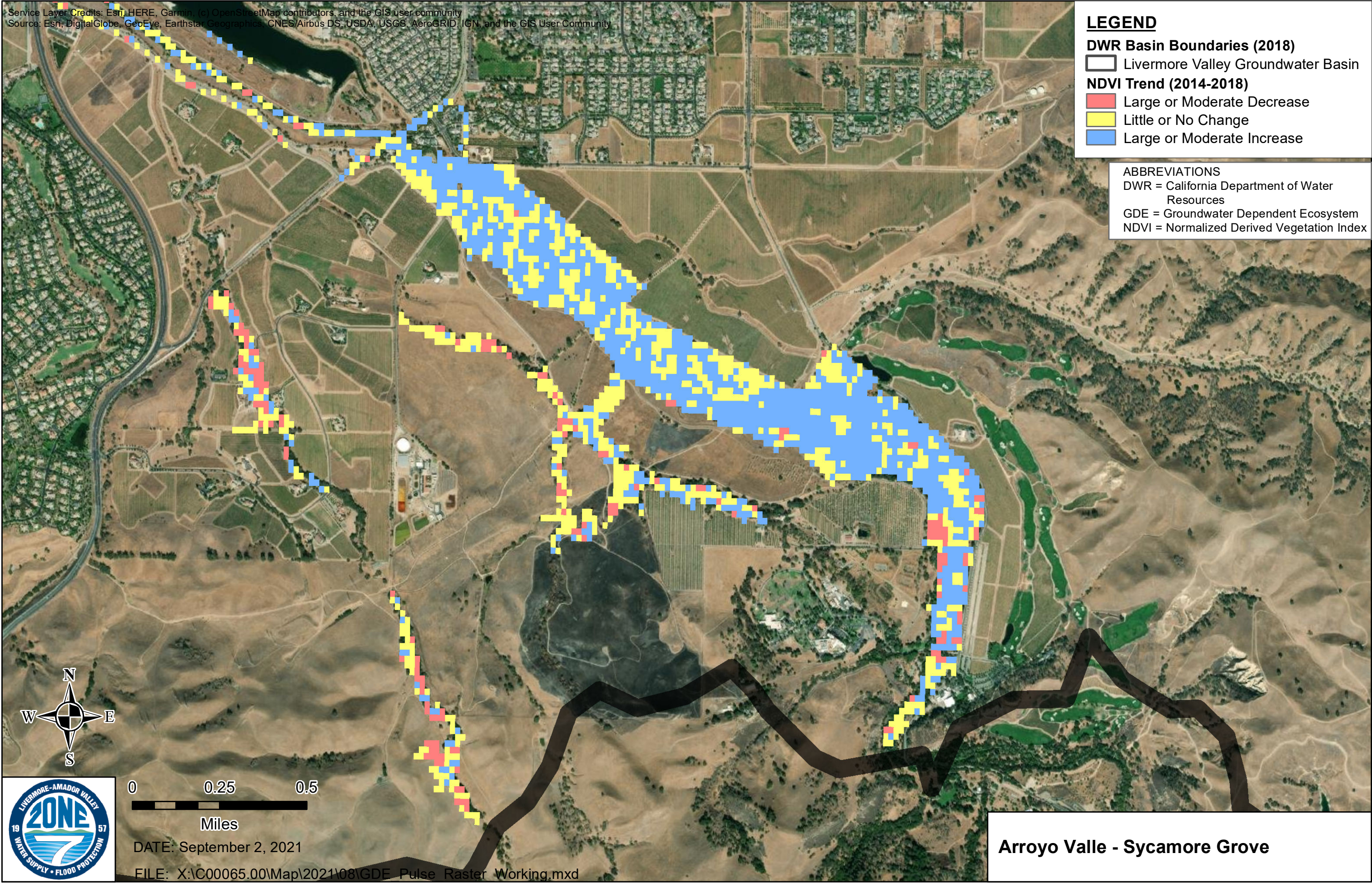
Arroyo Valle - Riparian Mixed Hardwood

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

- DWR Basin Boundaries (2018)**
- Livermore Valley Groundwater Basin
- NDVI Trend (2014-2018)**
- Large or Moderate Decrease
 - Little or No Change
 - Large or Moderate Increase

ABBREVIATIONS
DWR = California Department of Water Resources
GDE = Groundwater Dependent Ecosystem
NDVI = Normalized Derived Vegetation Index



0 0.25 0.5
Miles

DATE: September 2, 2021

FILE: X:\C00065.00\Map\2021\08\GDE Pulse Raster Working.mxd

Arroyo Valle - Sycamore Grove

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

DWR Basin Boundaries (2018)

□ Livermore Valley Groundwater Basin

NDVI Trend (2014-2018)

■ Large or Moderate Decrease

■ Little or No Change

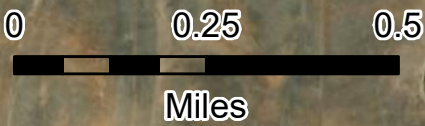
■ Large or Moderate Increase

ABBREVIATIONS

DWR = California Department of Water Resources

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NDVI = Normalized Derived Vegetation Index



DATE: September 2, 2021

FILE: X:\C00065.00\Map\2021\08\GDE Pulse Raster Working.mxd

Springtown Alkali Sink

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

DWR Basin Boundaries (2018)

□ Livermore Valley Groundwater Basin

NDVI Trend (2014-2018)

■ Large or Moderate Decrease

■ Little or No Change

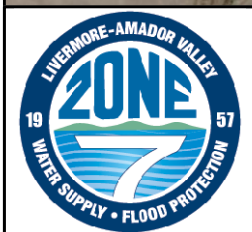
■ Large or Moderate Increase

ABBREVIATIONS

DWR = California Department of Water Resources

GDE = Groundwater Dependent Ecosystem

NDVI = Normalized Derived Vegetation Index



0 0.2 0.4

Miles

DATE: September 2, 2021

FILE: X:\C00065.00\Map\2021\08\GDE Pulse Raster Working.mxd

Upland - Riparian Mixed Hardwood

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND
DWR Basin Boundaries (2018)
[Black outline] Livermore Valley Groundwater Basin
NDVI Trend (2014-2018)
[Red] Large or Moderate Decrease
[Yellow] Little or No Change
[Blue] Large or Moderate Increase

ABBREVIATIONS
DWR = California Department of Water Resources
GDE = Groundwater Dependent Ecosystem
NDVI = Normalized Derived Vegetation Index



DATE: September 2, 2021

FILE: X:\C00065.00\Map\2021\08\GDE_Pulse_Raster_Working.mxd

Arroyo Las Positas -- Mixed Vegetation

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

DWR Basin Boundaries (2018)

□ Livermore Valley Groundwater Basin

NDVI Trend (2014-2018)

■ Large or Moderate Decrease

■ Little or No Change

■ Large or Moderate Increase

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NDVI = Normalized Derived Vegetation Index



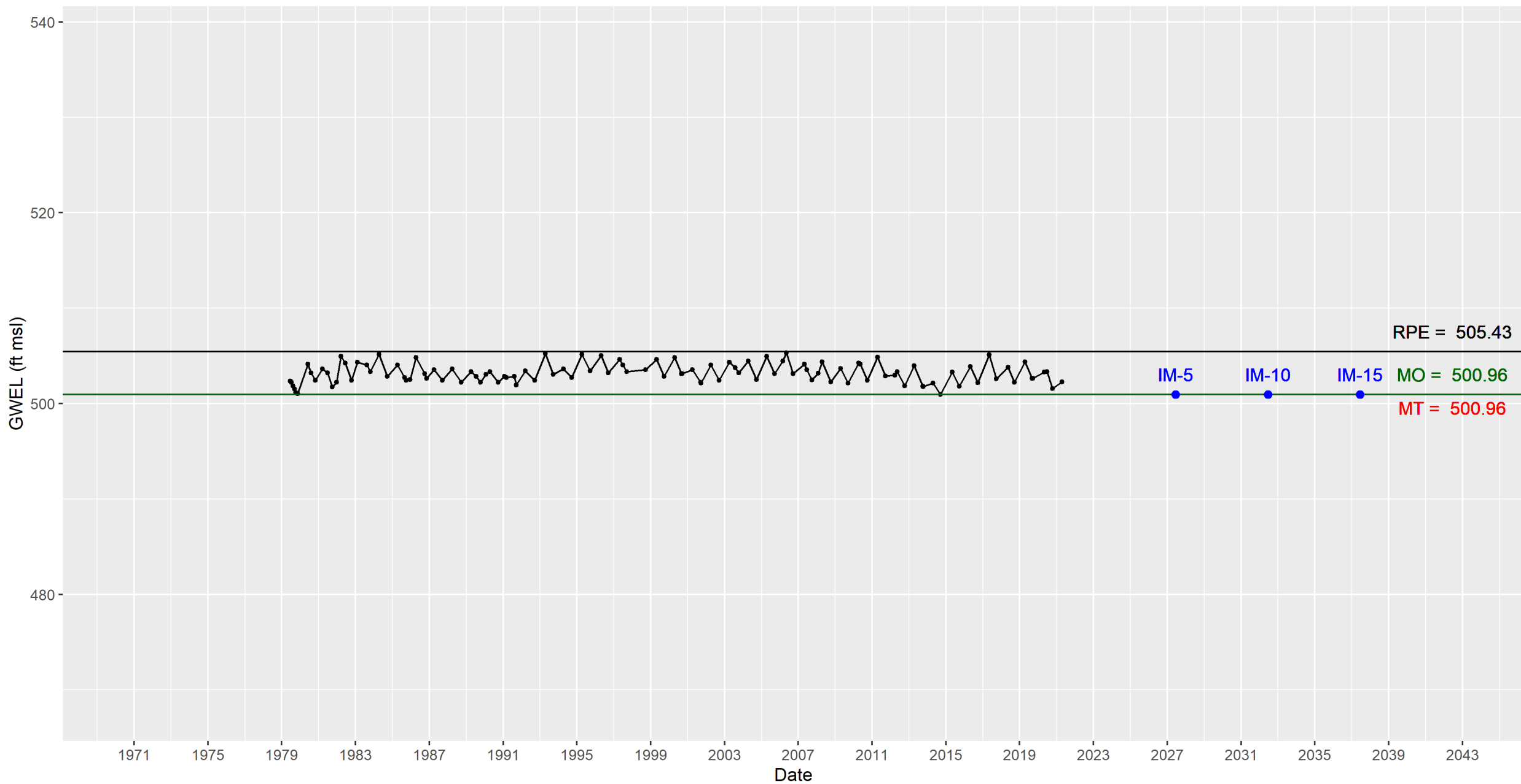
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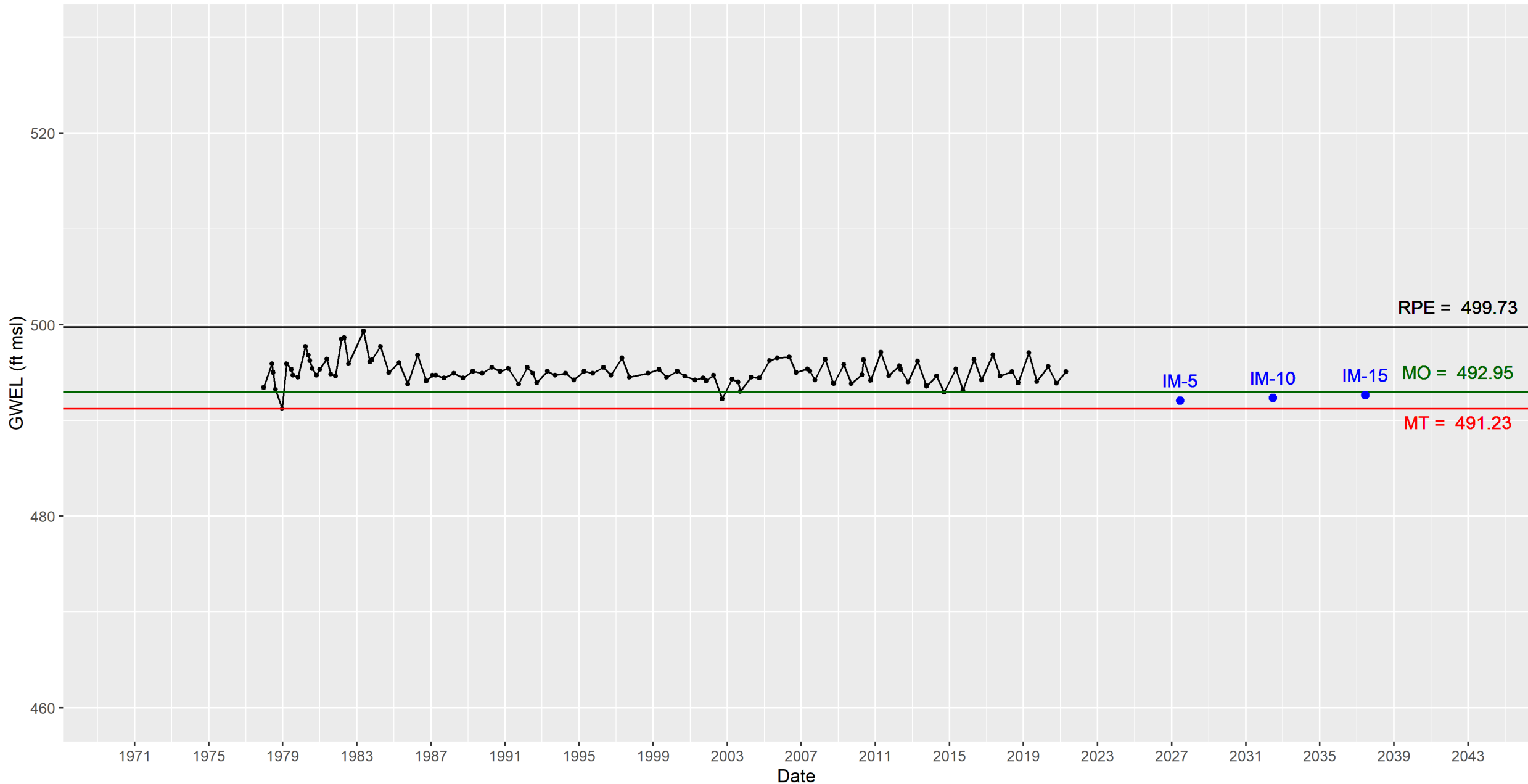
Potential GDEs to be Further Evaluated

Attachment F: Water Levels and SMC Plots by RMW- ICSW

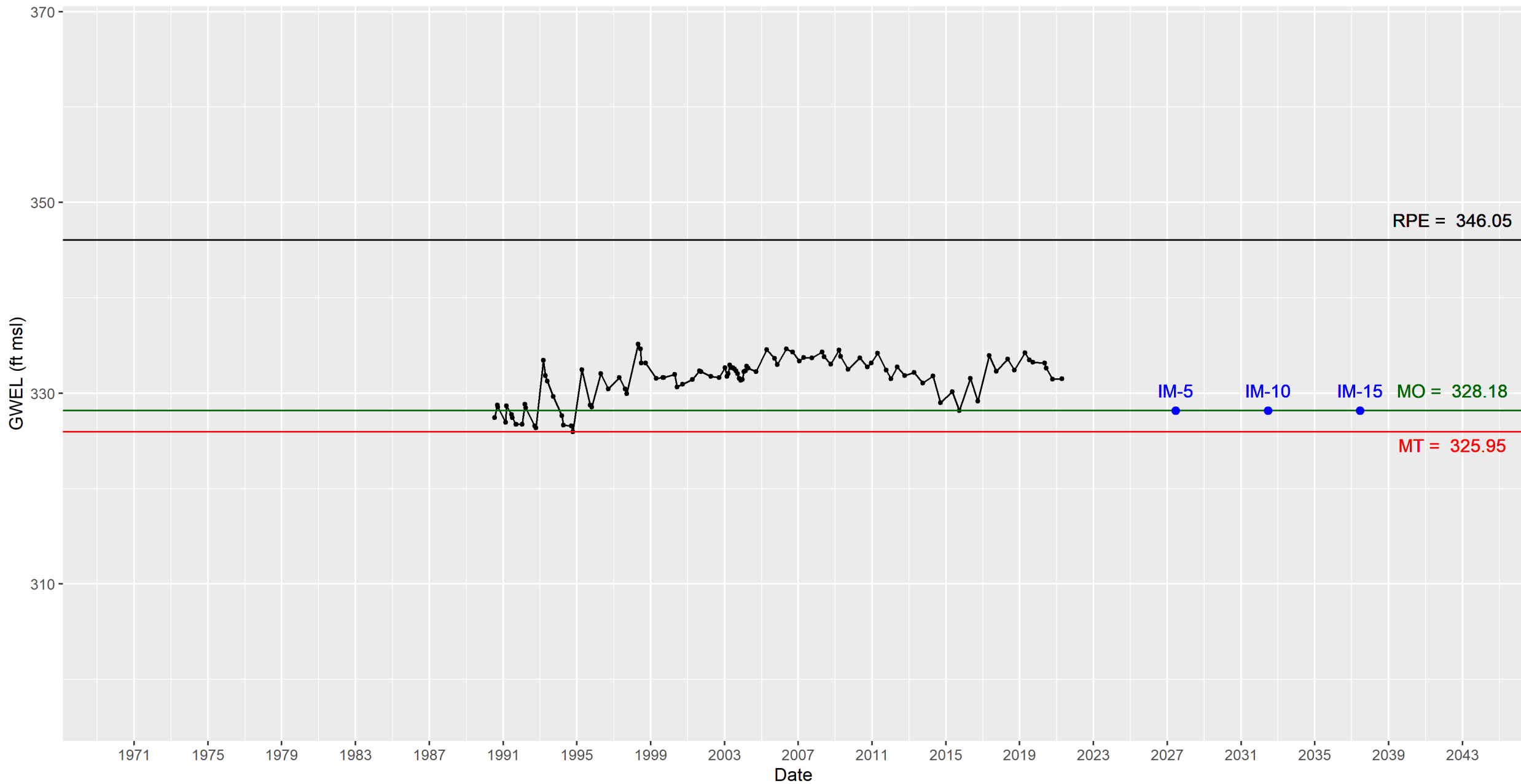
2S2E27P002 : Water Level & SMC



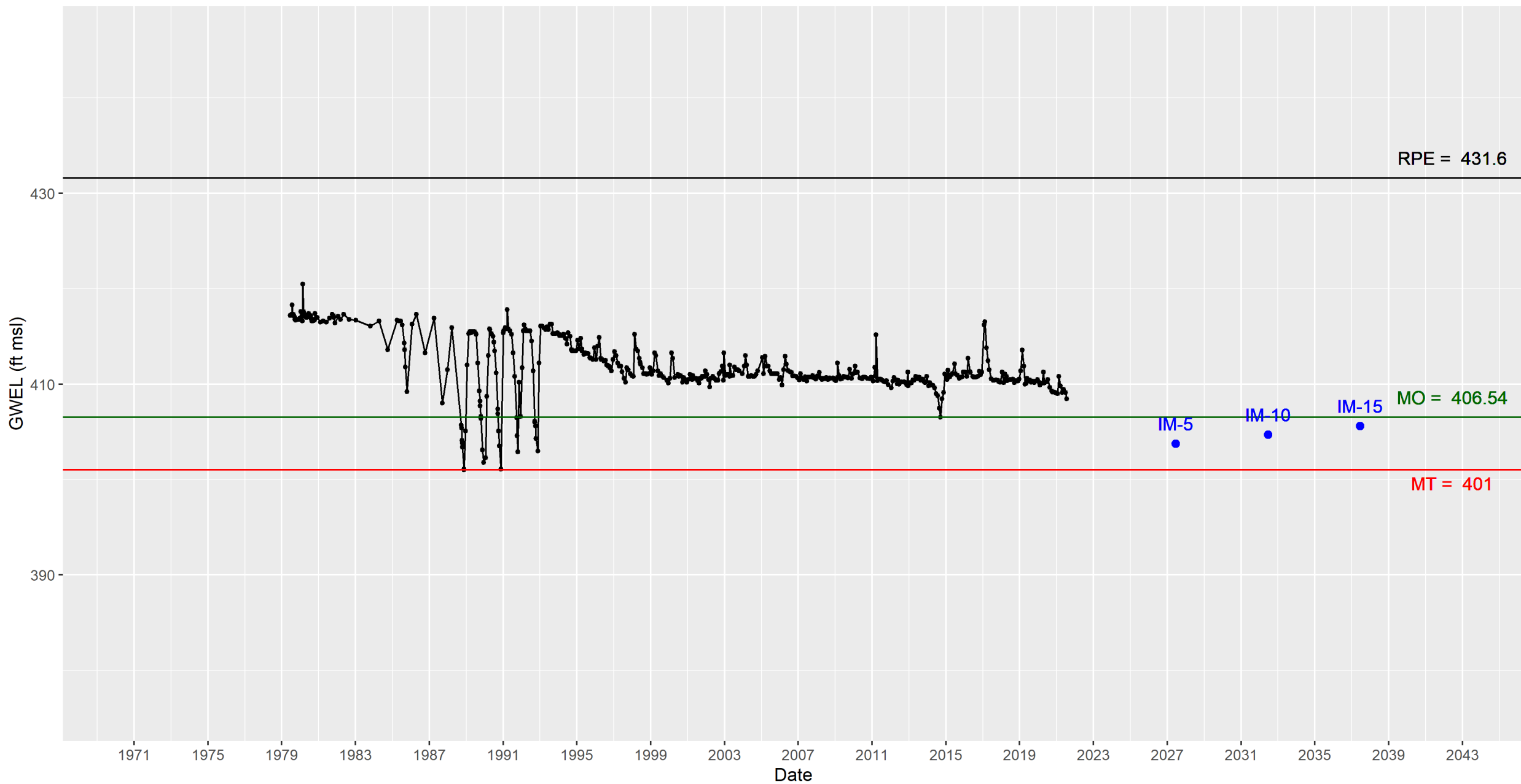
2S2E34E001 : Water Level & SMC



3S1E05K006 : Water Level & SMC



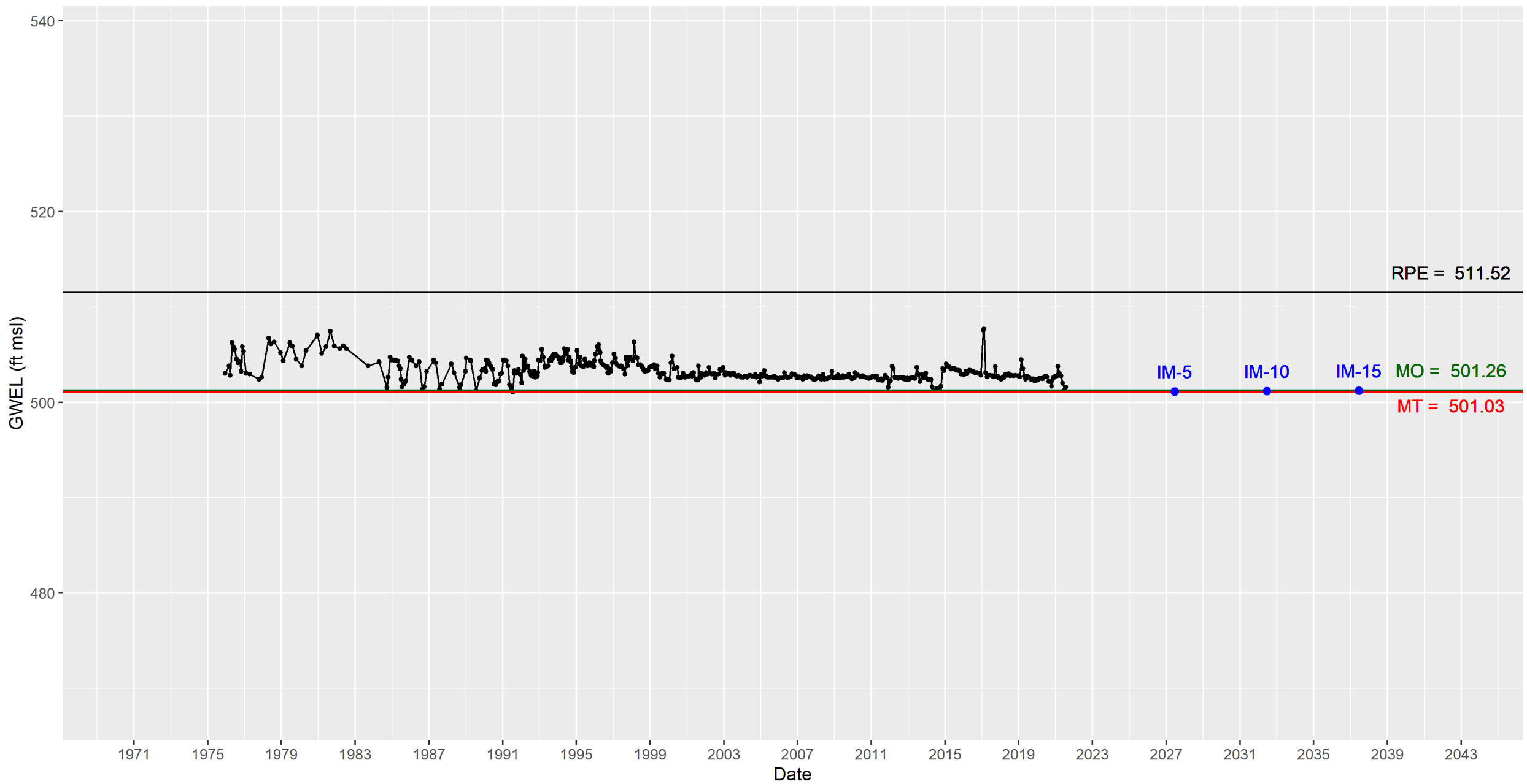
3S2E30D002 : Water Level & SMC



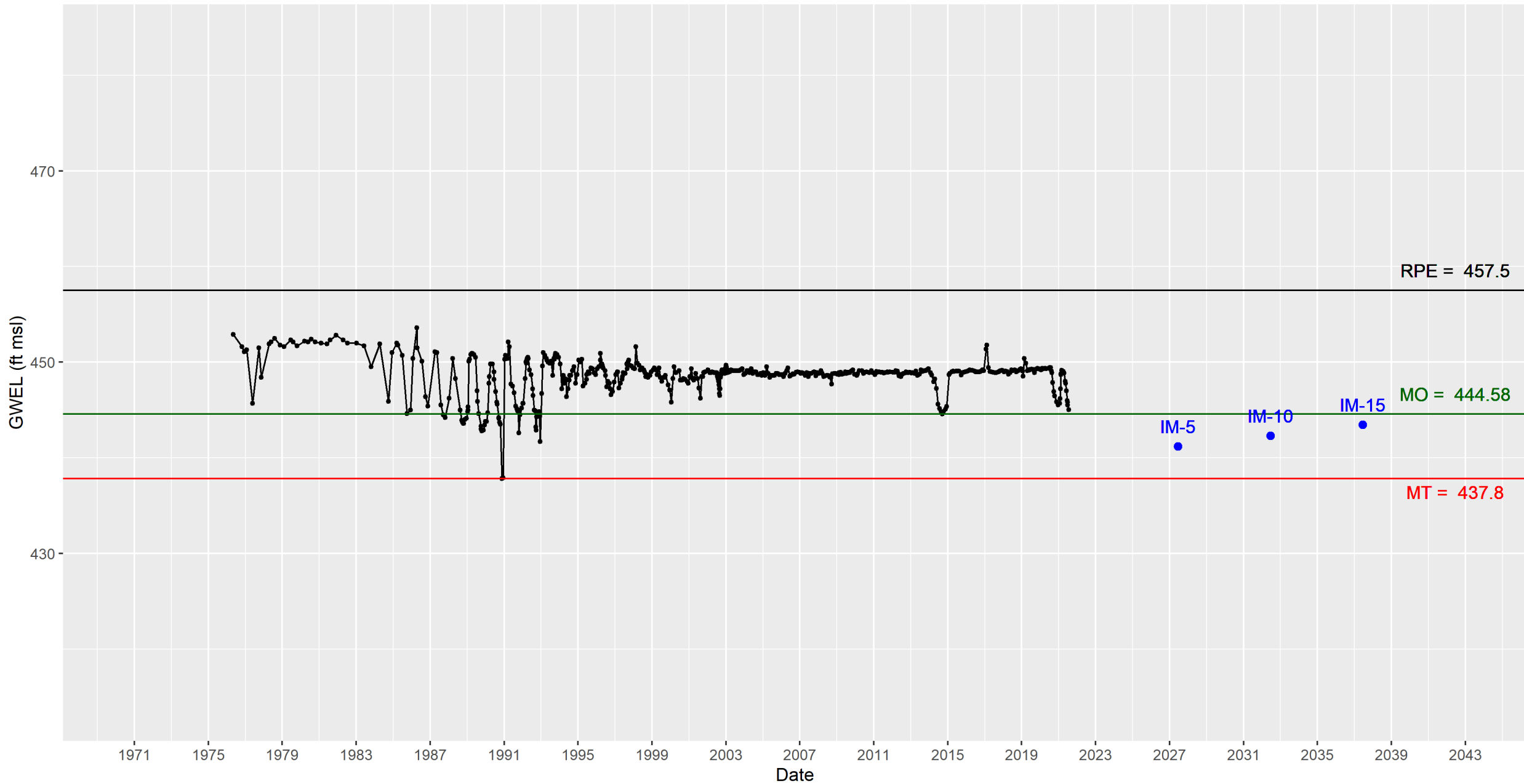
3S1E16P005 : Water Level & SMC



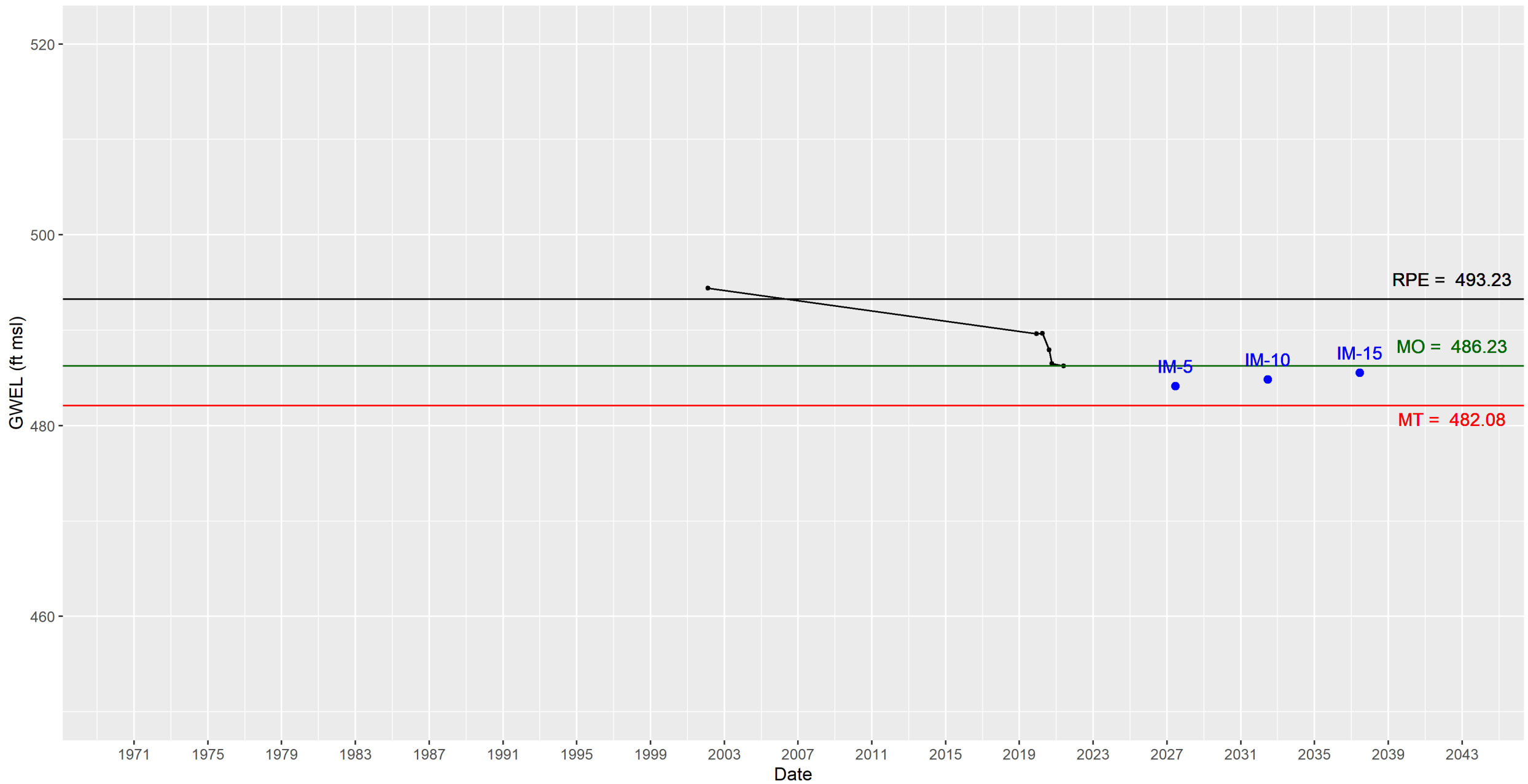
3S2E33G001 : Water Level & SMC



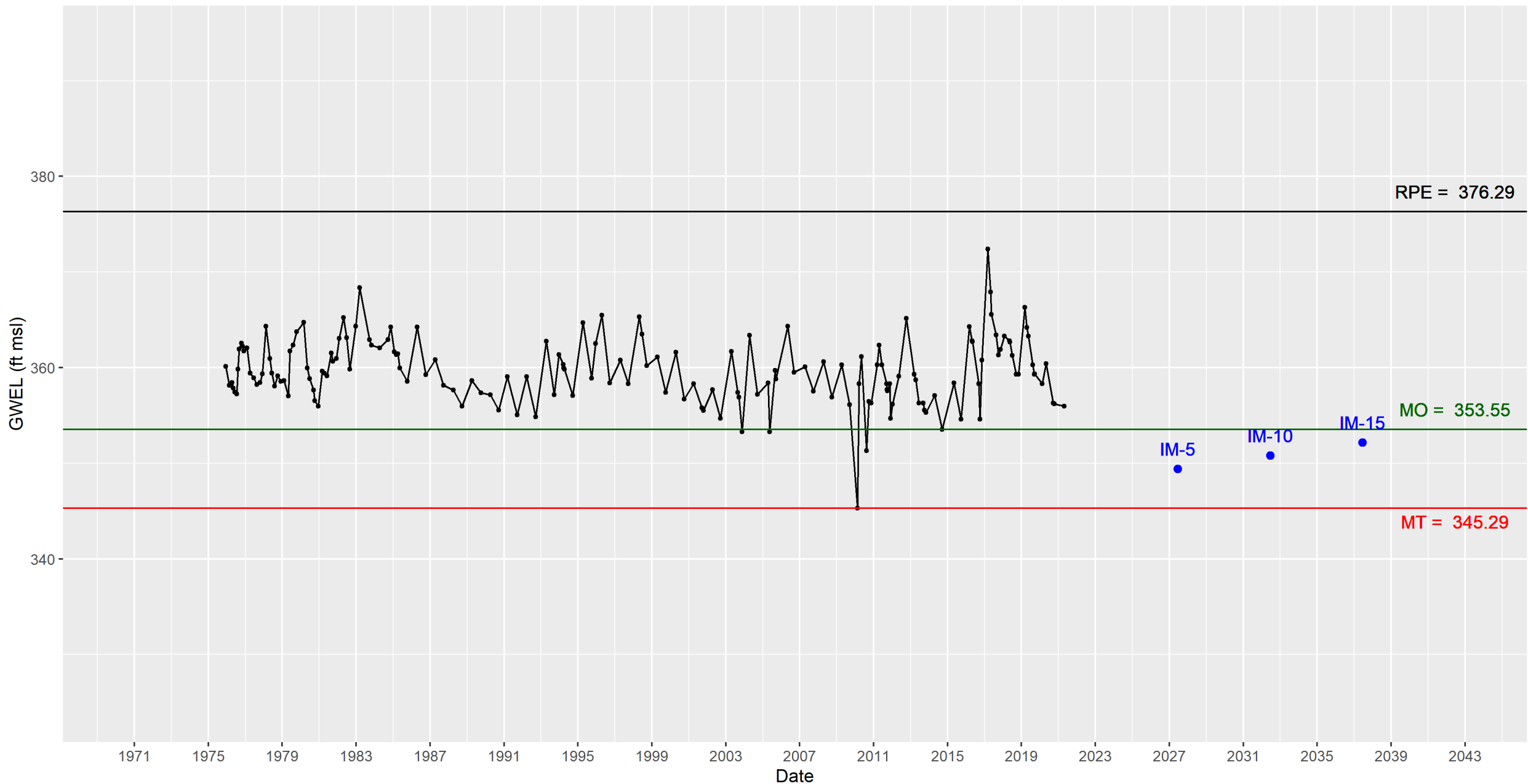
3S2E29F004 : Water Level & SMC



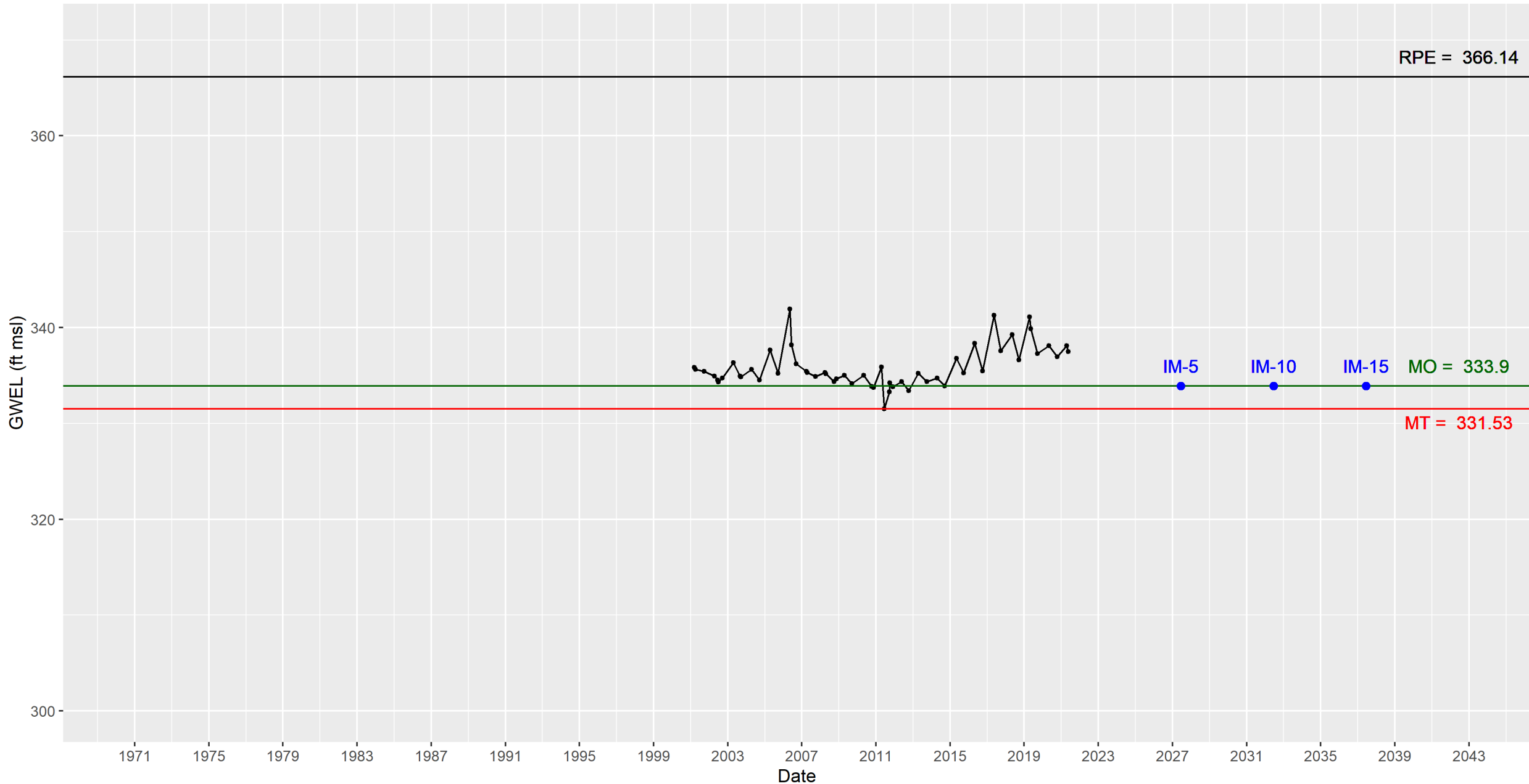
3S2E33C001 : Water Level & SMC



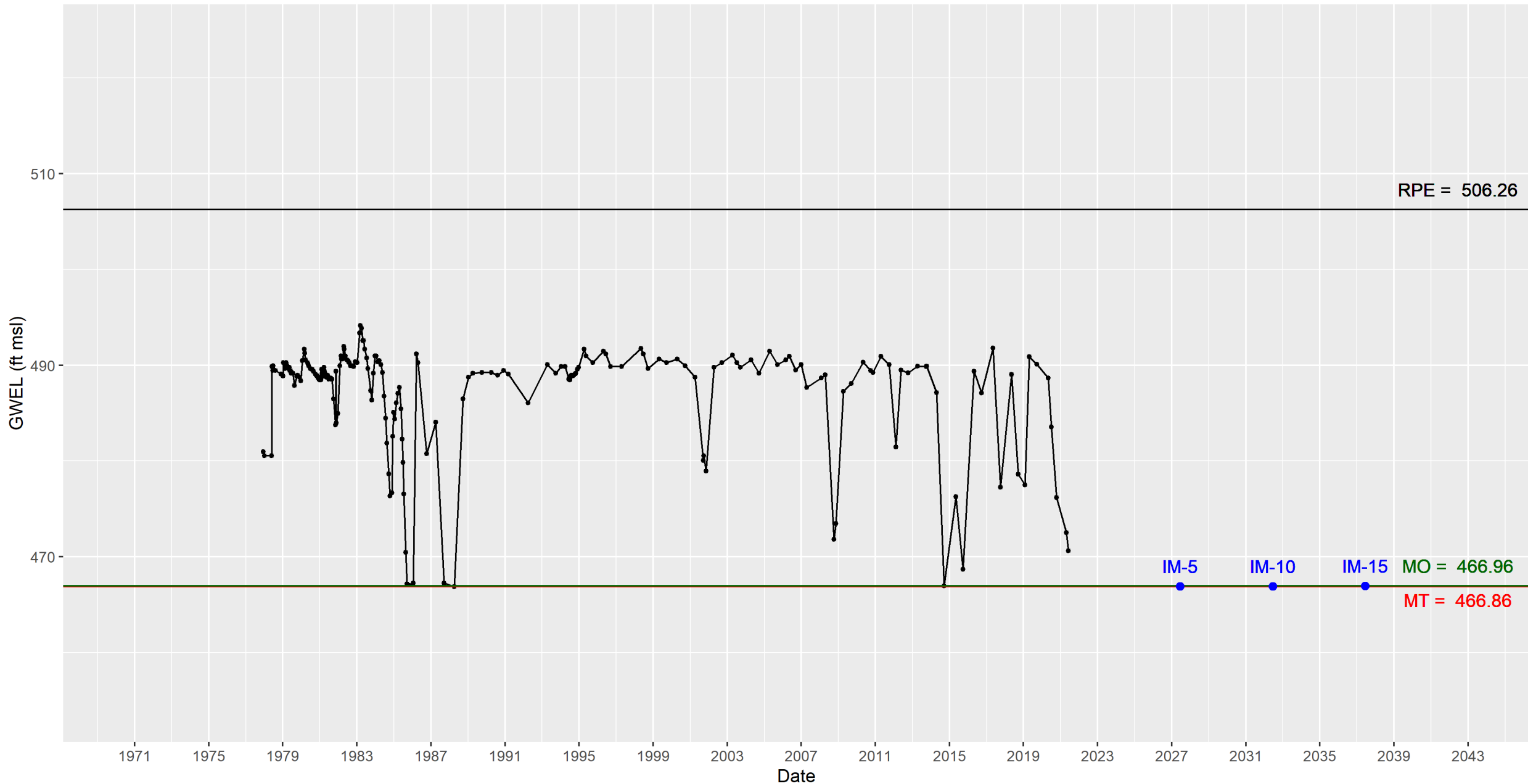
3S1E02R001 : Water Level & SMC



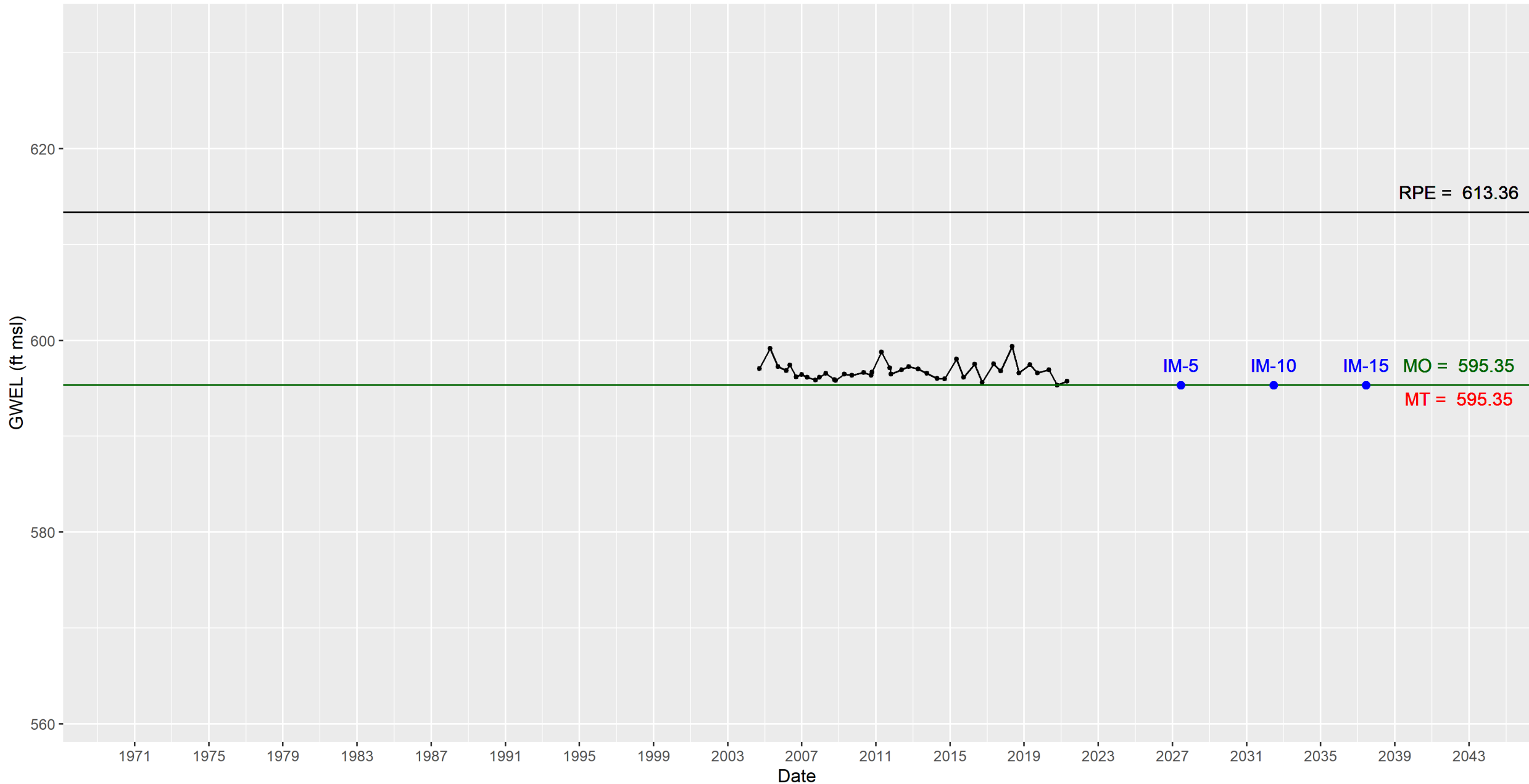
3S1E02N006 : Water Level & SMC



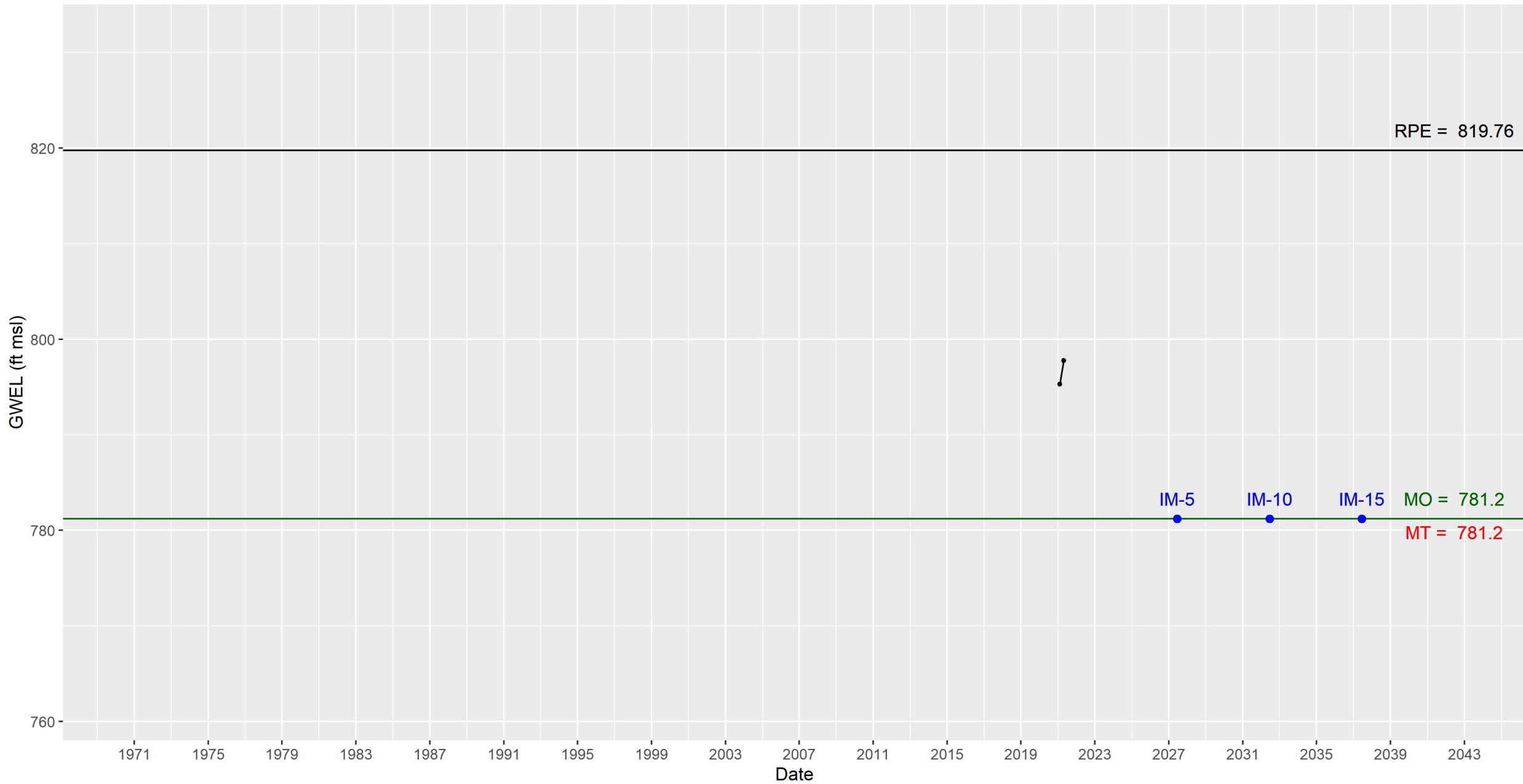
3S2E16E004 : Water Level & SMC



3S2E23E001 : Water Level & SMC



4S2E01A001 : Water Level & SMC



3S2E32E007 : Water Level & SMC

