Evaluation of Potential Groundwater Recharge Areas in West Placer County, California

Prepared for:

Placer County

October 31, 2017

Prepared by

GEI Consultants

Consulting Engineers and Scientists

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GROUNDWATER RECHARGE POTENTIAL AREAS
WEST PLACER COUNTY

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Abbreviations and Acronyms

AF	Acre-feet
ASR	Aquifer Storage and Recovery
County	Placer County
DWR	Department of Water Resources
PCWA	Placer County Water Agency
NID	Nevada Irrigation District
SAGBI	Soil Agricultural Groundwater Banking Index
SSWD	South Sutter Water District
Subbasin	North American Subbasin
SSURGO	Soil Survey Geographic Database
UC	University of California
WPC	West Placer County

1 Introduction

In 2014, Placer County received grant funding from the California Department of Water Resources (DWR) though the Proposition 1, Sustainable Groundwater Planning – Counties with Stressed Basins Grant Agreement, DWR Grant No. 4600011504, for the Western Placer County Groundwater Assessment Project. The Project Work Plan includes four tasks:

1. Develop a summary of land use authorities and forecast of future demand
2. Develop a Groundwater Sustainability Agency organization structure
3. Develop a well extraction facilities inventory database and website
4. Perform water quality sampling at six selected wells

Addendum 1 to the Grant reallocated scope and budget to include preliminary evaluation of potential areas where groundwater recharge occurs which could be used to enhance recharge to groundwater aquifers. This report provides a description of the groundwater recharge areas and identifies potential lands in West Placer County (WPC) that could be used for groundwater recharge to the North American Subbasin (Subbasin). **Figure 1** shows the location of WPC in the Subbasin.

This assessment included identifying potential direct and indirect groundwater recharge methods and their feasibility. The assessment identified potential recharge projects at a conceptual level, and did not include any field investigations or design drawings. General locations of conceptual groundwater recharge projects were identified and a list of tasks that should be completed to further evaluate the feasibility of each recharge location was compiled.

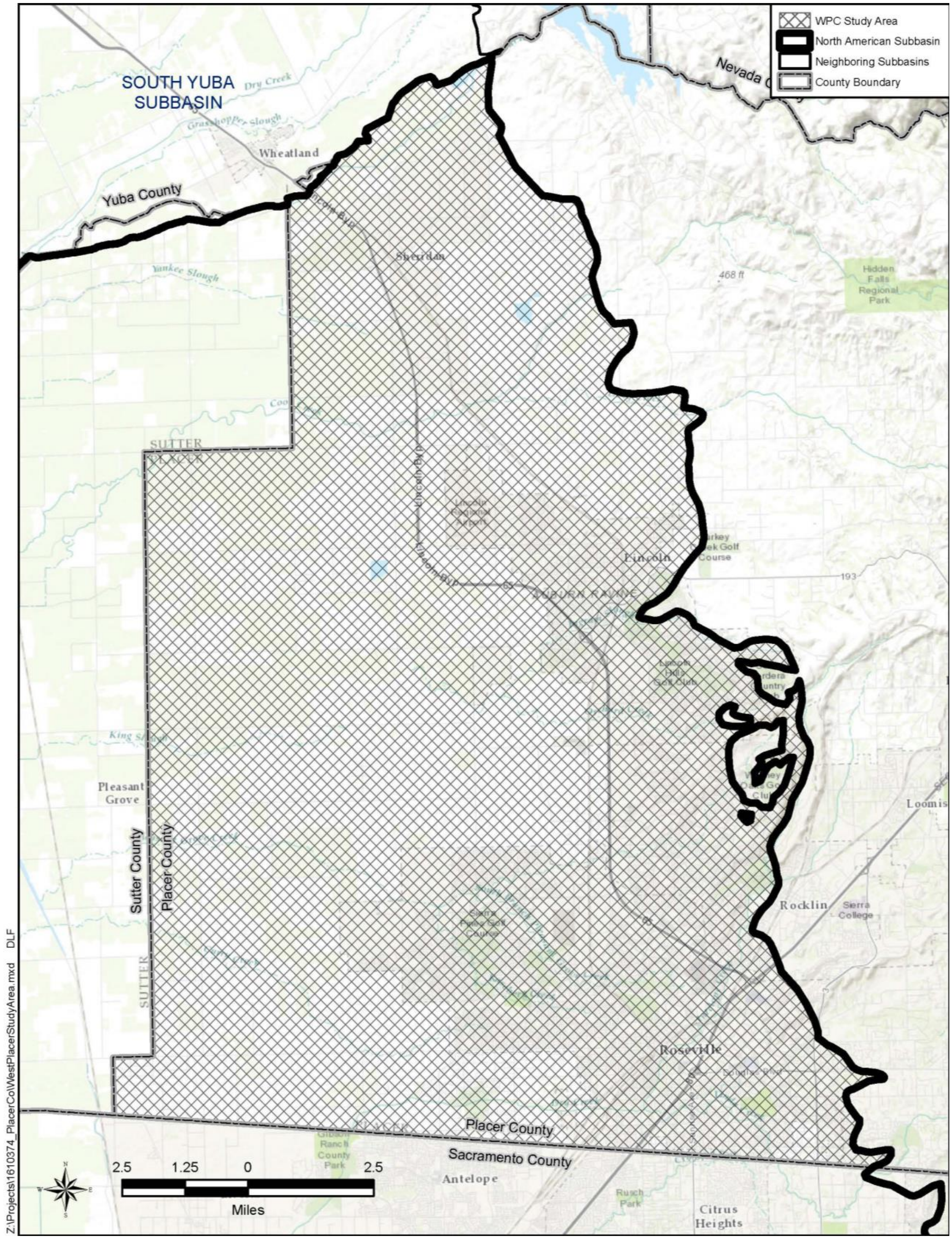

Figure 1. Study Area

2 Recharge Methods

There are two general approaches to artificial groundwater recharge; direct recharge and indirect recharge. Direct recharge includes physically delivering water to the aquifer system, whereas indirect (or in-lieu) recharge increases groundwater storage by reducing the groundwater removed from the basin. Direct recharge approaches are split into two types, recharge by flooding or ponding water on the ground surface or injection directly into the aquifers. There are advantages to each approach, and local conditions will suggest which method is more appropriate for a specific location. In all cases a successful recharge program requires unsaturated permeable areas both locally near the recharge areas and within the Subbasin.

2.1 Direct Recharge – Surface Water Spreading

The use of surface spreading basins is the most common method of direct groundwater recharge in California. More recently, flooding of agricultural fields during the winter is being tested and is proving to have significant potential.

2.1.1 Spreading Basins

The use of surface spreading basins or spreading ponds is the most common type of artificial groundwater recharge. Typically, recharge facilities consist of a series of connected surface basins that may range in size, depending on the available space and slope of the land. Recharged water moves away laterally and vertically from the recharge ponds, initially through the unsaturated zone to the unconfined aquifer system. The existence of low permeability layers in the near surface may affect the performance of the spreading basins. If low permeability layers are encountered near the ground surface, they may be deep ripped or excavated and removed during basin construction, with the excavated material used to construct the dikes or berms that create the individual basins.

The type and location of the spreading basins may dictate the level of engineering and construction needed for their development and operation. Spreading basins utilizing existing excavations, such as sand and gravel mines, borrow pits, golf course water features, or natural depressions may require few improvements. Where such features do not exist, recharge basins may require more extensive planning, engineering, and construction.

Some of the features of spreading basins/ponds include:

- Recharge of an unconfined aquifer system
- Relatively low cost to design and construct
- No seasonal constraint on their use
- Regulatory constraints associated with water quality are likely to be less burdensome

- Existing features such as natural depressions or drainage detention facilities may be utilized

Factors affecting successful implementation include:

- Requires large areas of relatively flat land
- Requires permeable soils with no or few impermeable layers near the surface
- Requires the presence of a significant unsaturated depth below the basins
- Requires surficial recharge areas are hydraulically connected with aquifers that can be utilized for water supply
- Requires routine maintenance (e.g., scraping of pond sediments) to maintain adequate recharge rates
- Requires considerable unrestricted unsaturated permeable margin areas beyond the boundaries of the proposed pond area

2.1.2 Flooding Agricultural Lands

A direct recharge approach that has recently received considerable attention is the use of storm water to flood crop lands to increase groundwater recharge. This practice is being tested at locations throughout California to determine the types of soils and crops best suited to groundwater recharge, the effect on crop yield and health at various stages of crop development and the extent to which flooding exacerbates leaching of salts, nitrates and pesticides. One product of this research is the Soil Agricultural Groundwater Banking Index (SAGBI) (UC. Davis, 2015). This index uses the following five factors to determine the suitability of agricultural lands for groundwater recharge:

- Deep percolation: ability of soils to transmit water beyond the root zone
- Root zone residence time: duration of saturated/near saturated conditions after water application must not be damaging to crops
- Topography: slopes conducive to field flooding
- Chemical limitations: high soil salinity may result in large volumes of saline leachate
- Soil surface conditions: soil susceptibility to compaction or erosion if inundated.

The SAGBI is available as an on-line screening tool for use in identifying farmlands that may be suitable for flooding. Screening using SAGBI must be supplemented by an understanding of the local geology and by knowledge of crops and farming practices to determine 1) whether fields can be flooded without harming agricultural production, 2) timing of flooding should not interfere with farming operations or spring preparation soil preparation for planting, and 3) whether flooding in areas and on crops suited to the practice will accomplish the goal of aquifer recharge.

2.1.3 Instream and Canal Replenishment

Canals and stream channels are also used as a method for applying water to the land surface to increase recharge (DWR, 2017). Diverting water outside of the irrigation season into unlined canals can supplement groundwater recharge if canal seepage reaches the underlying aquifers. In some areas of California, water management agencies release water from reservoirs into stream channels to enhance recharge while also providing or improving aquatic habitat. Some streams and rivers in California have been modified through the construction of levees, berms, and inflatable rubber dams to divert water from the stream channel into off-stream spreading basins and detention ponds, and to extend retention times within the stream channel to improve infiltration.

2.1.4 Mines

The use of depleted gravel pits has been used for surface spreading basins in many Southern California groundwater basins. A study recently conducted by the Sacramento County Water Agency to evaluate the potential for use of gravel pits in the Sacramento Valley indicated that the recharge potential is very site specific and varies greatly.

2.2 Direct Recharge – ASR Injection Method

Aquifer Storage and Recovery (ASR) recharge involves using wells to inject treated surface water into target aquifers. Stored water can be later recovered, often through the same wells. Because the recharge well can penetrate confining layers, confined aquifers (those overlain by relatively impermeable sediments or aquitards) can be recharged.

Although the basic concept of ASR is straightforward, proper implementation of a full-scale facility requires careful planning and design. ASR projects require expertise in geology, engineering, water quality, instrumentation and control technology, and permitting to comprehensively address the needs of each project. The State Water Resources Control Board passed a general order in 2012 to help standardize and streamline the permitting and CEQA evaluation.

ASR wells require controlled operation and regular maintenance to sustain adequate recharge rates. Several factors that may affect the long-term viability of recharge wells include:

- Chemical reactions in the aquifer
- The formation of biosolids on well screens
- Entraining air in the aquifer system
- Deflocculation caused by the reaction of high-sodium water with soil particles

The ASR recharge method requires the source water to be treated, sediment-free and of suitable quality for operation and preservation of beneficial uses. ASR projects generally have higher capital, operation, and maintenance costs than other recharge methods.

Some of the benefits of ASR recharge include:

- Does not require large areas of land
- More cost-effective when located near existing local infrastructure
- Effectiveness is not dependent upon near-surface local hydrogeologic conditions
- No seasonal constraints on operation

Factors affecting successful implementation include:

- Access to reliable water supply of suitable quality
- The ability to utilize existing wells and infrastructure
- Capacity of distribution system to deliver and distribute water to and from the ASR well
- Implementation of an operation and maintenance plan

The City of Roseville's ASR program has confirmed the feasibility of this technology for use in the West Placer area through extensive technical studies including exploration to define the suitability of the aquifers, groundwater flow modeling, geochemical modeling, construction of ASR wells and pilot testing. The pilot testing included multiple injections and extractions on different time scales. The City has an approved and permitted ASR program.

2.3 Indirect Recharge (In-Lieu Recharge)

Indirect recharge differs from the direct recharge methods because it does not physically place the water into the aquifer system. Rather, surface water is used in-lieu of groundwater, thereby reducing local demand on the groundwater basin to maintain higher groundwater levels. Indirect recharge is often called in-lieu recharge and is commonly used in areas where the historical water demand has relied on the underlying groundwater basin for supply.

In-lieu recharge has been used in both urban and agricultural areas and often utilizes the existing infrastructure to distribute water supply to individual customers. One of the requirements of an in-lieu recharge program is that the replacement supply must be of the appropriate quantity and quality to satisfy the existing supply requirements.

In-lieu recharge programs are often used to improve overall supply reliability by using the surface water supply in wet years or months when it is available, thereby reducing the dependence on the groundwater basin. Then in dry years, when imported supplies may be reduced or not available, groundwater is used to meet demands not met by the surface water supply. For an in-lieu recharge program to be successful, the in-lieu surface water supply to be used should reduce the demand on the local groundwater system and not be used to accommodate additional increases in demand.

Some of the benefits of in-lieu recharge include:

- Relatively cost-effective when able to use existing local infrastructure
- Does not require construction of recharge facilities
- Effectiveness is not dependent upon near-surface local hydrogeologic conditions

Factors affecting successful implementation include:

- Access to imported water supply of suitable quality
- The ability to utilize existing infrastructure or construct new infrastructure
- The ability to incentivize groundwater users to shift to surface water
- Limited to periods of time when both water is needed and surface water is available

In 1997, DWR evaluated the Placer and Sutter county portion of the Subbasin for conjunctive use projects and found that direct recharge by percolation ponds is not generally suitable in the area. Therefore, the approach proposed was to focus on in-lieu recharge. The project was conceptualized to have South Sutter Water District (SSWD), Pleasant Grove, Verona Mutual Water Company, Natomas Central Mutual Water Company and Placer County Water Agency provide surface water during normal and wet years to irrigate lands identified as being solely or partially dependent on groundwater to reduce or eliminate pumping in their wells. During dry or critically dry years owners of wells would pump groundwater and those water districts and companies would restrict their deliveries of surface water for use by the State Water Project or other users. Some new wells were also considered as part of the project. The project was not implemented.

Since that time South Sutter Water District has proposed raising of the Camp Far West Dam and Nevada Irrigation District has proposed construction of Centennial Dam. The projects could greatly expand agricultural conjunctive use projects in both West Placer and Sutter counties and put extra stored water to use locally.

3 Potential Water Sources for Groundwater Recharge

Groundwater recharge facilities all need a source of water. These may be seasonal or relatively constant sources. For the entire Subbasin, which includes portions of West Placer, Sacramento, and Sutter counties, a recent estimate for water available for replenishment of groundwater is 240,000 acre-feet (DWR, 2017). The following sections describe potential water sources, but no attempt was made to quantify the volume available for recharge.

3.1 Stormwater

During the winter months, excess stormwater runoff (floodwater) can be captured for groundwater recharge which would otherwise end up in rivers and the ocean. Diversion of this water during storms reduces flooding potential in creeks and rivers. However, the flood water typically contains sediments which can plug and reduce soil permeability.

3.2 Raw Surface Water

Placer County Water Agency (PCWA), Nevada Irrigation District (NID), and South Sutter Water District (SSWD) own and operate canal systems to convey water from reservoirs and rivers in the Sierra Nevada Mountains into West Placer County. Some of the water is conveyed through natural drainage courses (i.e. creeks) and canals where groundwater recharge can occur. However, some of the canals have been lined, especially over areas of coarse-grained sediment to reduce conveyance losses and thereby reduce groundwater recharge. PCWA, NID, and SSWD canal systems are shown on **Figure 2.**

3.3 Treated Surface Water

The City of Roseville and PCWA operate water treatment plants to treat surface water to drinking water standards before delivering it to residents. The surface water is collected from the North Fork of the American River or Folsom Lake from areas outside of the Subbasin.

3.4 Treated Wastewater

The cities of Auburn, Roseville, and Lincoln all have wastewater treatment plants that provide treated water for irrigation of landscape medians and golf courses. The City of Auburn has one treatment plant that discharges water to Auburn Ravine. The City of Roseville has two treatment plants, the Dry Creek and Pleasant Grove plants. The City of Lincoln has one treatment plant. Most of the treated wastewater originated as surface water imported into the Subbasin from the surrounding watersheds. Some of the excess treated water is being discharged to creeks where groundwater recharge occurs; however, other than for the City of Auburn, most of the discharges to creeks are located where fine-grained sediments underlie the creeks that restrict the amount of water that is recharged.

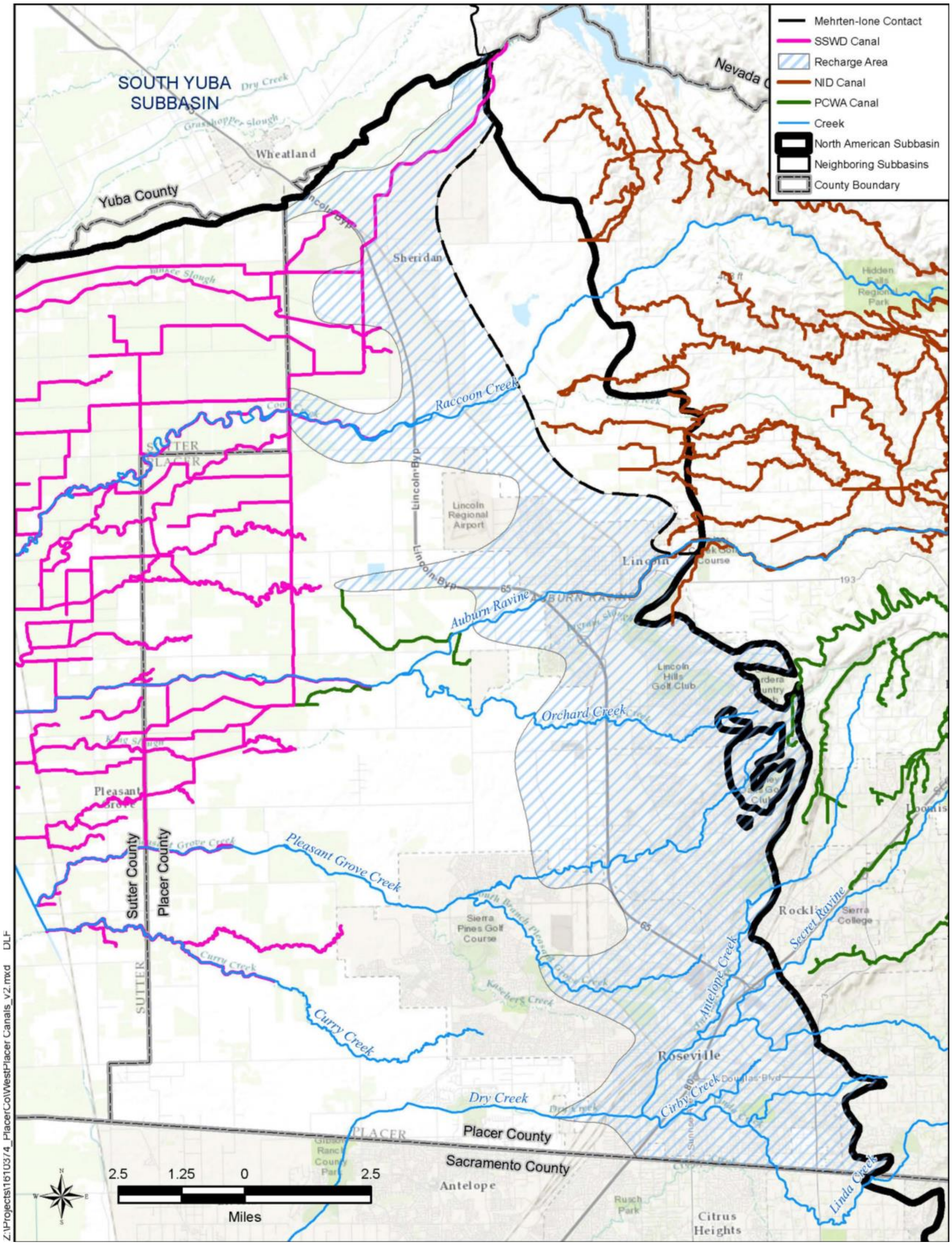

Figure 2. Major Canals and Creeks

4 General Hydrogeologic Conditions

This section provides a brief discussion of how potential groundwater recharge areas and suitable recharge methods were developed based on soils, geology and other indicators.

4.1 Soils

Soil permeability provides an initial indication of where recharge to the underlying aquifers may occur. Soil types have been mapped in WPC by the U.S. Department of the Agriculture's Natural Resources Conservation Service (NRCS). The data is made available to the public in the SSURGO database. One of the soil attributes available in SSURGO is the Hydrologic Soils Group which describes the soil's drainage characteristics. The groups range from Type A soils, which are well drained (highly permeable) to Type D soils that are very poorly drained (low permeability). **Figure 3** shows the soil types mapped within the study area. Most of the coarse-grained, well-drained soils (Types A and B shown in a green and yellow) occur along major stream channels and some along the eastern margins of the subbasin. These areas are given a higher preference for recharge site locations.

Much of WPC is covered with poorly drained soils (Types C and D shown in orange and red on **Figure 3**). While these less permeable soil types often inhibit flow to the subsurface, these soils classifications are generalizations of soil types and localized windows of connection to the underlying aquifers can exist particularly when streams are incised through the soil profile. In particular, ponded water and fields where flood irrigation is used can result in significant amounts of recharge.

Figure 4 shows data from the Soil Agricultural Groundwater Banking Index (SAGBI) developed by researchers at UC Davis (O'Greene, et al., 2015). While the Hydrologic Soils group shown in **Figure 3** only indicates the drainage characteristics of the soils, the SAGBI also considers additional factors that affect the suitability of active agricultural lands for groundwater recharge, including root zone residence time, topography, chemical limitations, and soil surface condition. **Figure 4** shows a similar distribution of suitable lands for groundwater recharge as **Figure 3**, primarily because poor drainage characteristics are captured in both. Note that the white/gray areas did not contain the data necessary to calculate the SAGBI.

The UC Davis researchers have also developed an index that ignores restrictive layers in the first six feet. This "modified SAGBI" is shown in **Figure 5** and assumes that tillage practices could break up the shallow restrictive layers. These kinds of tillage or ripping practices may have already been used in certain areas or could be used to greatly enhance the suitability of soils for recharge. **Figure 5** shows a much larger area that could be considered.

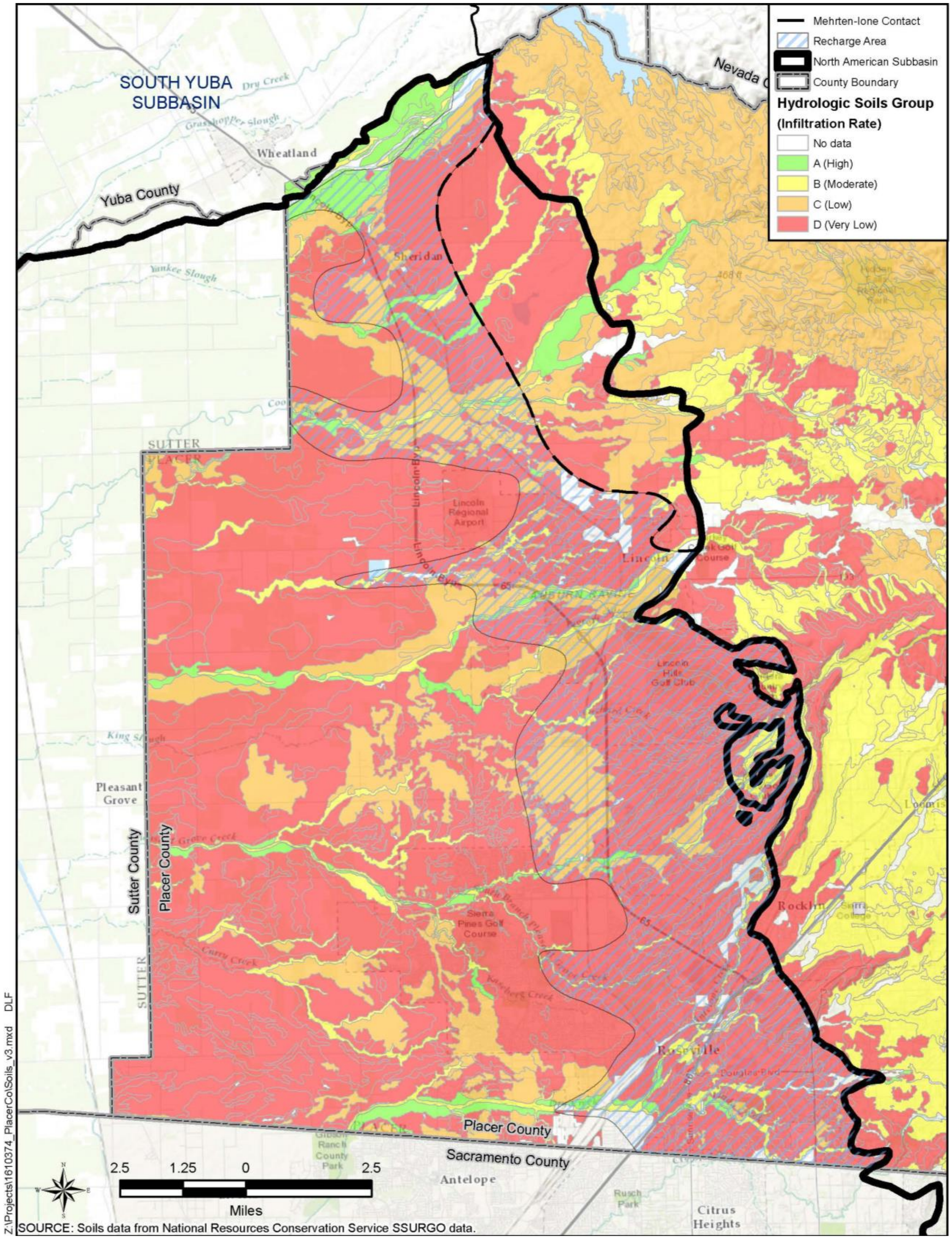

Figure 3. Hydrologic Soil Groups

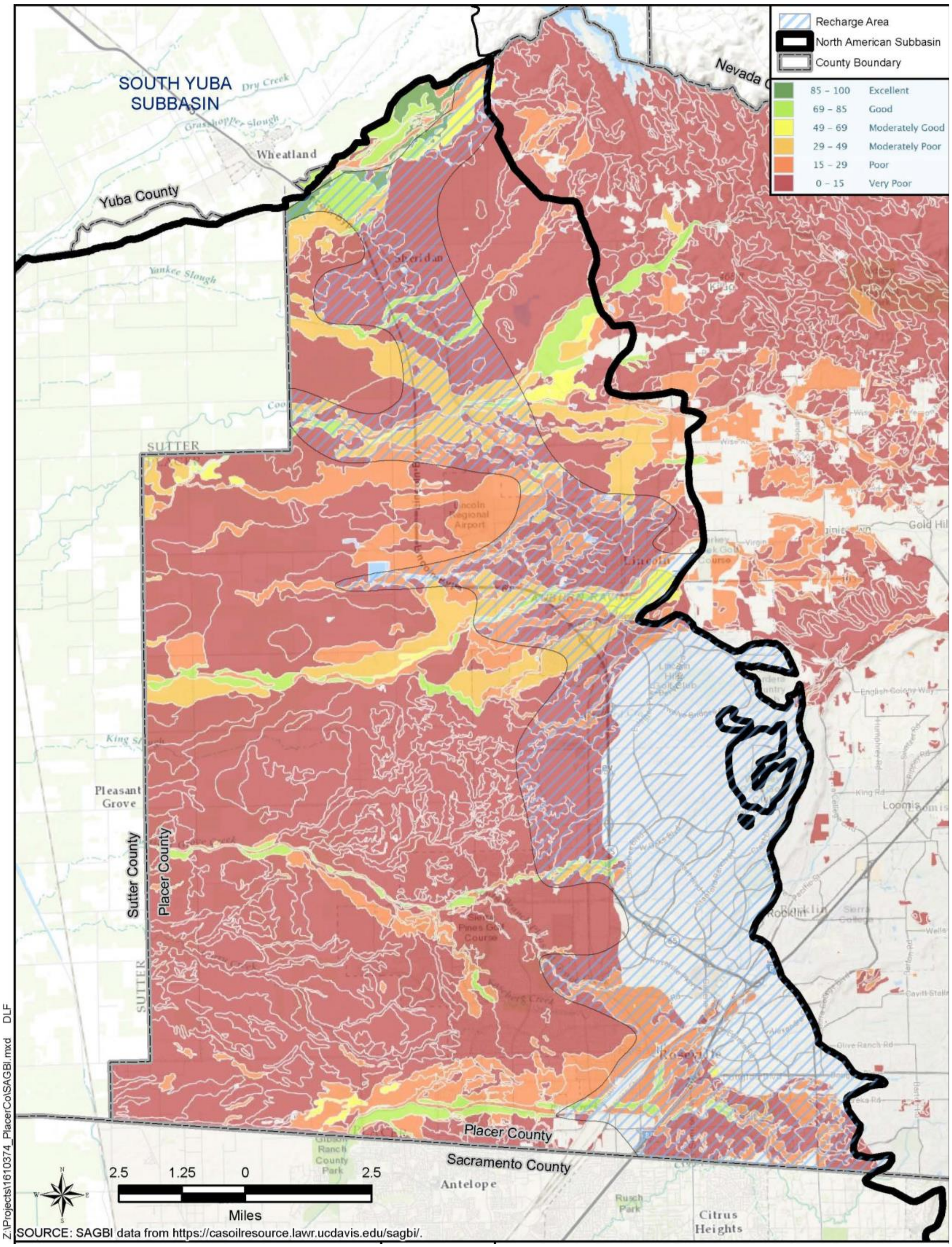

Figure 4. Soil Agricultural Groundwater Banking Index – Unmodified

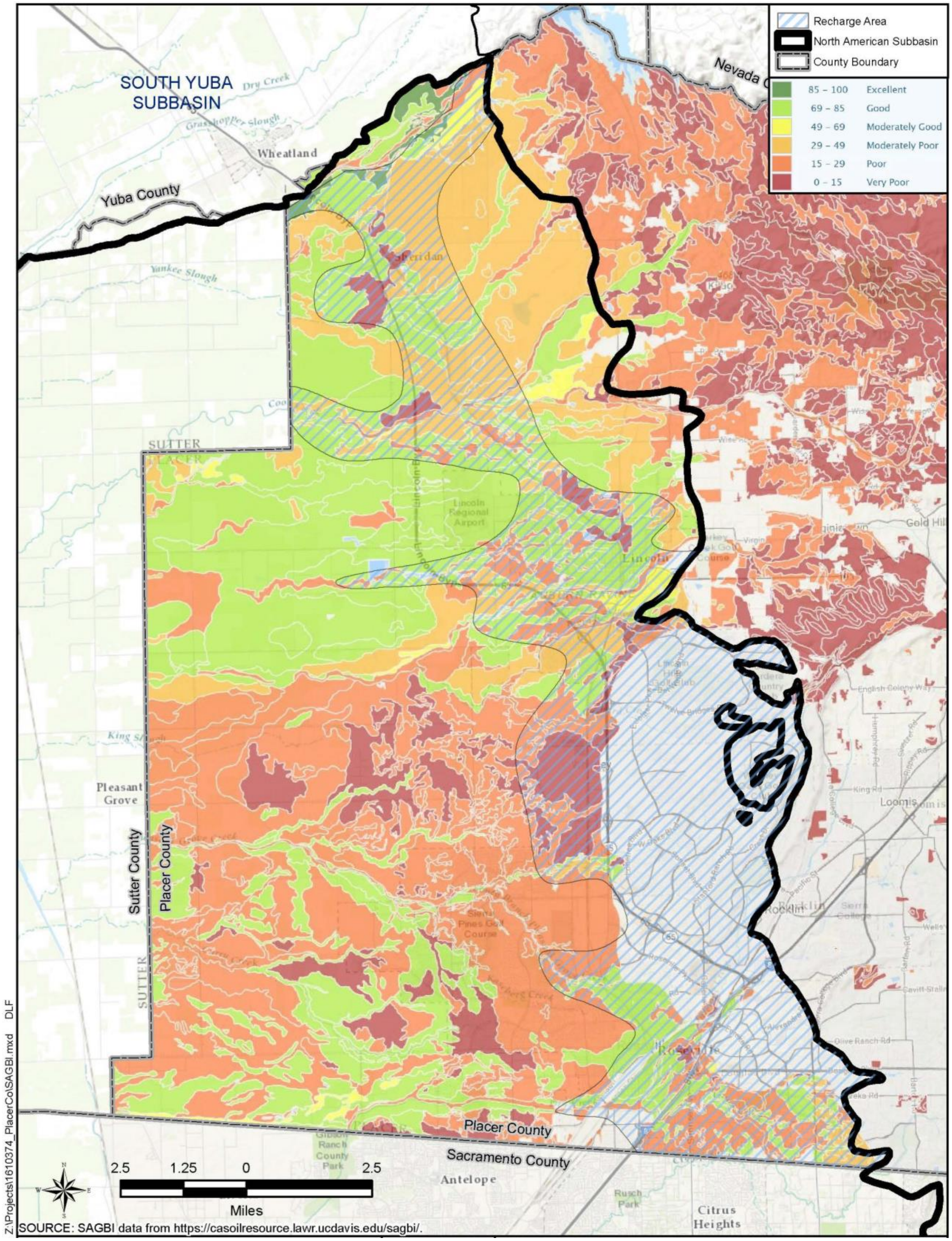

Figure 5. Soil Agricultural Groundwater Banking Index – Modified

4.2 Geology

For recharge methods that rely on water percolating from the surface to reach groundwater aquifers, the soils must be underlain by permeable sediments that are connected to the aquifers. In the WPC area, the aquifers dip from east to west and are exposed on ground surface or beneath thin layers of soils in the eastern portion of the WPC. Aquifers commonly used for agriculture and municipal uses are within the Turlock Lake/Laguna, Riverbank, and Mehrten formations. **Figure 6** shows the surficial exposures of these formations at or near ground surface. **Figure 7** is shows a geologic cross section of the formations through the study area on the top of the figure and shows how water recharged at the eastern edge of the basin would travel through the aquifers on the bottom of the figure shown in a blue color as it flows from northeast to southwest, which is the general direction of flow in the area. It should be noted that the assumption of this geologic depiction is that sediments throughout each aquifer are continuously interconnected. This assumption should generally hold true, but the aquifers are often not continuous and contain many narrow, long-buried stream channel deposits of coarse grained sediments (DWR, 1974). These ancient stream channels meander and overlap, creating conduits (preferential pathways) for recharged water to migrate both horizontally and vertically through aquifers. The blue aquifers shown on **Figure 7** are exposed on the ground surface or inferred to be present beneath the soils based on water well drilling sediment logs. Where these coarse-grained sediments are exposed at the surface, water from potential sources listed above can directly enter the aquifers. Where fine-grained, clayey sediments are present (shaded brown color) the ability to recharge water from ground surface will be small.

4.3 Previous Studies

Investigations have been performed to evaluate potential recharge from creeks in WPC. These studies, discussed below, also provide additional information regarding potential groundwater recharge areas.

The California Department of Water Resources (DWR) performed a groundwater accretion/depletion study on Auburn Ravine and Racoon Creek (DWR, 2010). The study concluded that some groundwater recharge is occurring along Auburn Ravine, but the isotope work could not conclusively confirm the presence of young water in the underlying aquifers, to verify that that recharge is from local sources. The volume of water recharged was not quantified due to complications within the ravine caused by such issues as beaver dams. Recharge along Racoon Creek was not quantified, but further investigation was recommended. Additional gaging of the creek to evaluate recharge is in progress.

Additional surface water/groundwater interaction investigations were performed along Dry Creek and its tributaries to assess where groundwater recharge was occurring (GEI, 2015 and 2017). Monitoring wells were constructed to evaluate the amount of recharge, where it is occurring, and provide measurements of the groundwater responses. Easterly portions of Dry Creek and possibly Miners Ravine were found to be groundwater recharge areas; however, the amount of recharge or discharge of groundwater cannot be fully quantified due to the lack of multiple gaging stations in the potential recharge areas, along some of the creeks and rivers. Potential gaging locations to help quantify the recharge volumes have been selected (GEI, 2017) and will be monitored during 2018.

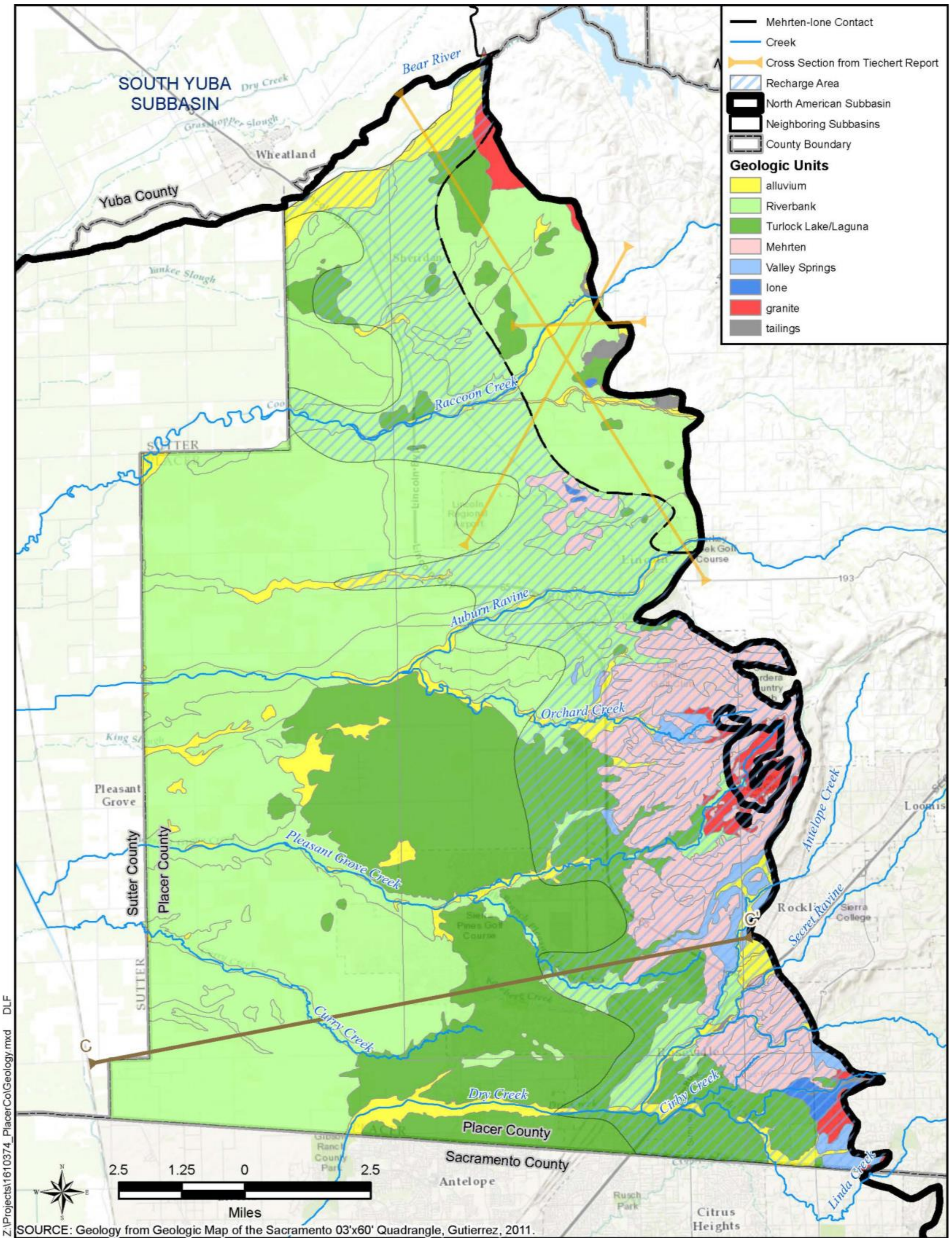

Figure 6. Surficial Geology

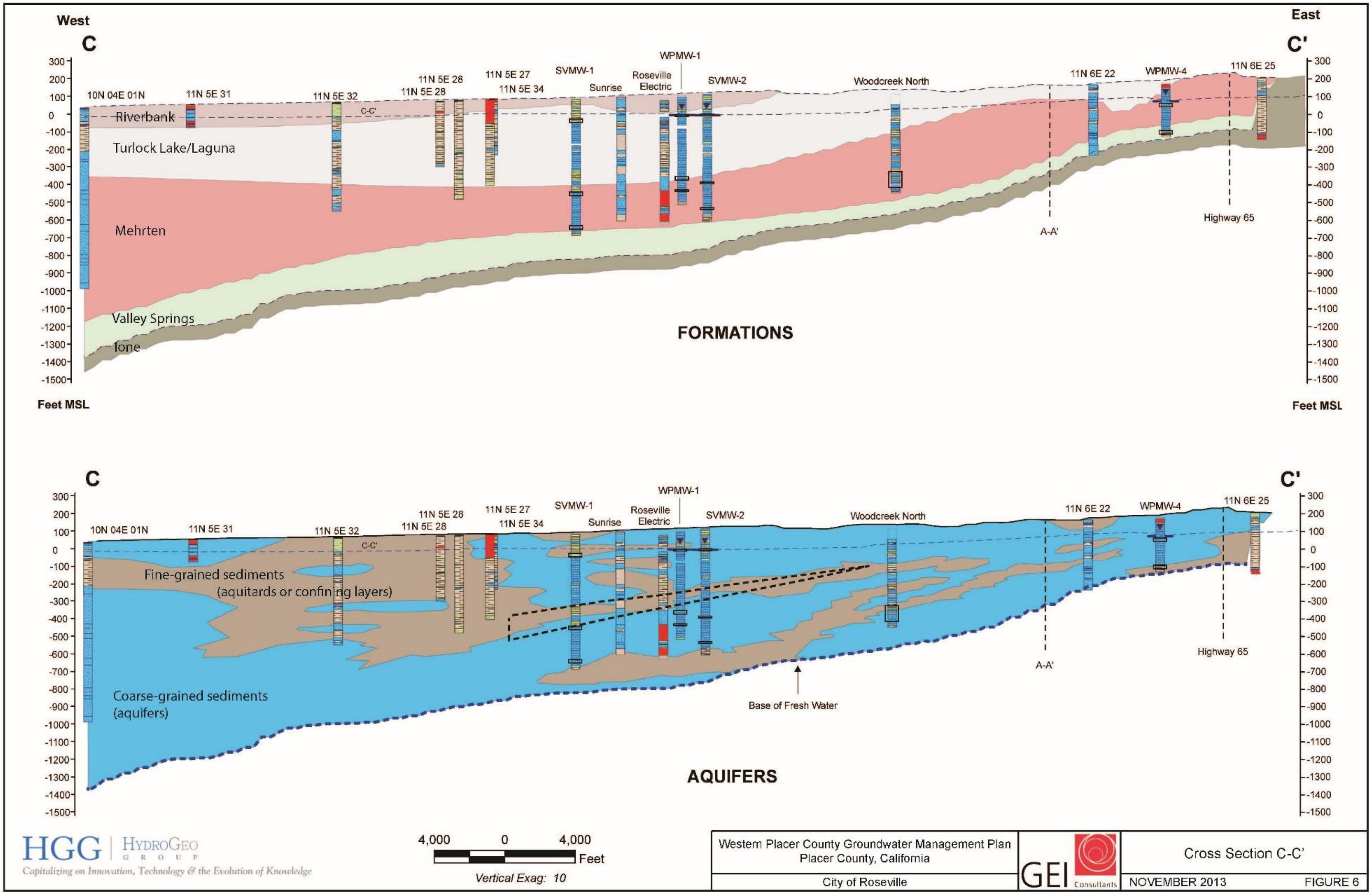

Figure 7. Geologic Section Showing Aquifers Extending to Ground Surface

4.4 Indirect Indications of Soil Characteristics

Land use studies, especially agricultural crop studies, can provide indications of the soil types and potential groundwater recharge areas. Typically, areas used to grow rice are located over areas where the soils are clayey and limit groundwater recharge. Orchards, on the other hand, are grown in well-drained soils, which can be groundwater recharge areas. GEI reviewed aerial imagery for orchard and rice field locations to further refine the potential groundwater recharge areas shown on **Figure 6**. The orchards were found to be present over the mapped coarse grained soils as shown on **Figures 3 and 4.** Some adjustments to the recharge area were made based on the the rice fields locations.

4.5 Potential Direct Recharge Areas

The potential direct recharge area where surface water spreading would be viable were developed based on hydrologic soil groupings (generally based on soil permeability ranges), well logs, geologic cross sections, and crop types. **Figure 8** shows the potential recharge areas, between the eastern edge of the Subbasin and a dashed line approximating the western edge where water could infiltrate from ground surface through coarse-grained soils and sediments into the underlying aquifers. As shown this is a broad band parallel to the eastern side of the groundwater Subbasin. Site specific investigations will need to be performed to assess the actual potential for recharge.

Injection wells can be used in any portion of the WPC area as this method is not constrained by land or surficial soils.

4.6 Groundwater Storage

The ability to recharge groundwater requires that there be room in the aquifers to store the water. **Figure 9** shows the depth to groundwater in WPC. Near the eastern portion of the basin groundwater levels are relatively shallow but toward the western portion of the county the depth to groundwater is up to 120 feet below ground surface (bgs). Assuming a specific yield of 7% and that groundwater levels could be raised to 80 feet bgs in this area, the aquifers could store 110,000 AF within this portion of the basin. However, the to ability raise groundwater levels is constrained by remedial activities using soil vapor extraction at former McClellan Air Force Base, which is located in Sacramento County. This type of remediation requires the soils remain dry to be effective.

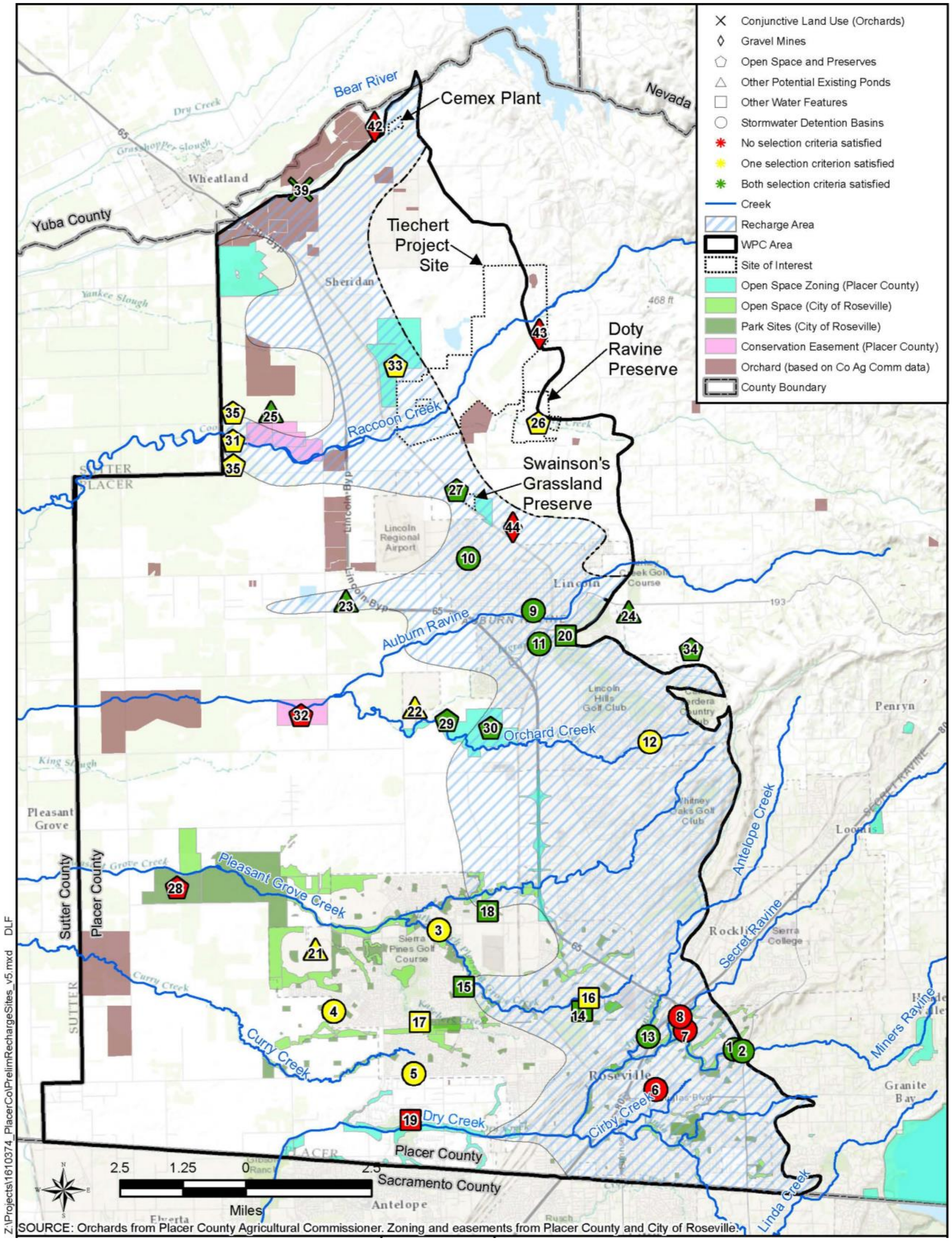

Figure 8. Potential Recharge Sites

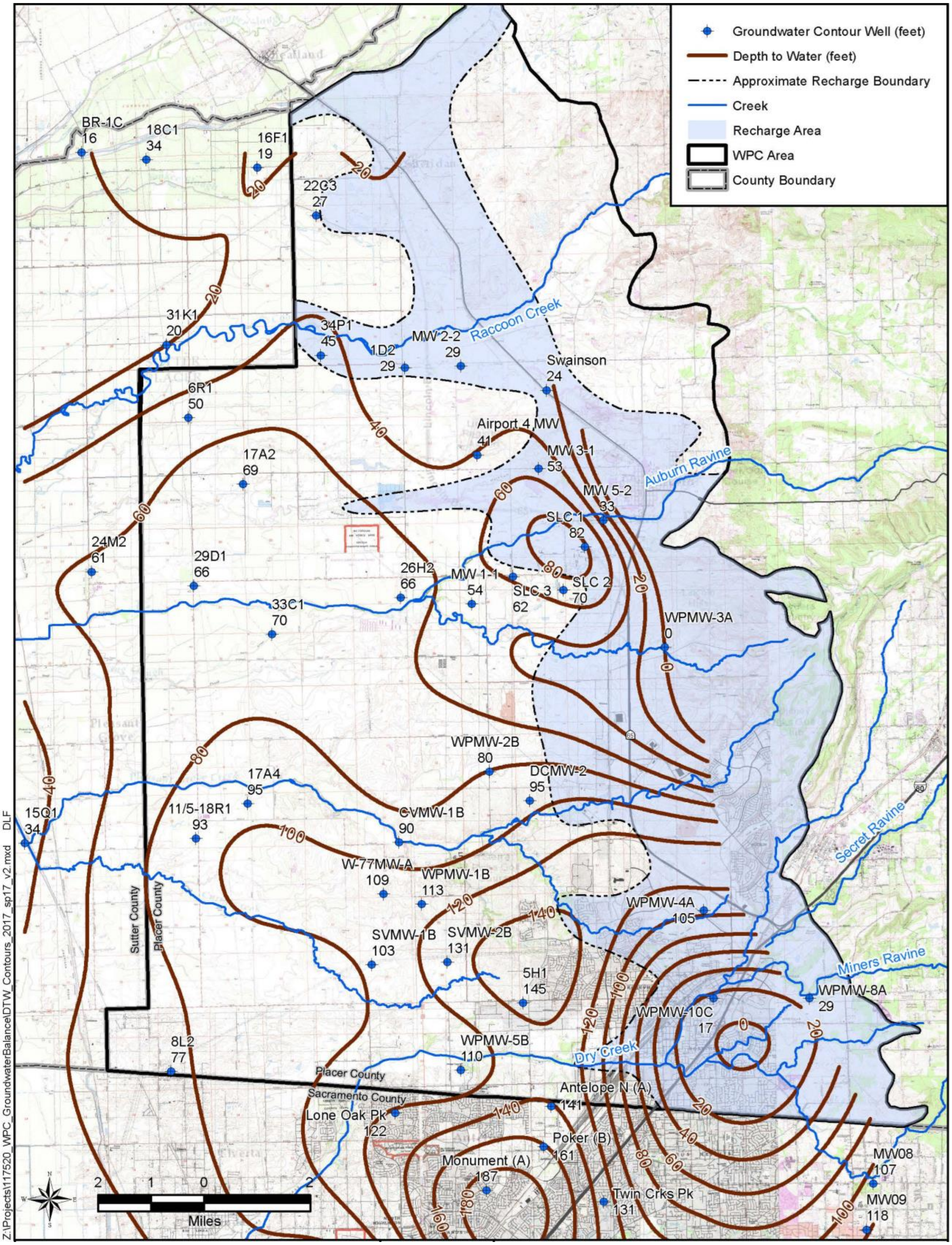

Figure 9. Depth to Groundwater

4.7 Groundwater Flow Direction

Groundwater recharge does not have to occur directly over an area where recharge is needed. **Figure 10** displays the groundwater elevations in the area and the groundwater flow directions. Groundwater flows from higher elevations to lower elevations, generally from the east toward the southwestern corner of the county. Therefore, groundwater recharge facilities in the east, between Racoon and Pleasant Grove Creeks, can raise levels and be transported to and stored in the aquifers to the west within WPC.

In the western portion of the county where low permeability soils limit surface water infiltration into the aquifers and therefore ASR wells is the preferred recharge approach. However, using the groundwater flow directions it can be seen how surface water recharge in the east can migrate the recharge the aquifers to the west. As previously mentioned ASR has rather high initial and operating costs and requires a source of treated water for injection. Spreading basins or other natural or artificial features can recharge excess storm water or delivered raw water from the NID or PCWA canal systems, reducing operating costs.

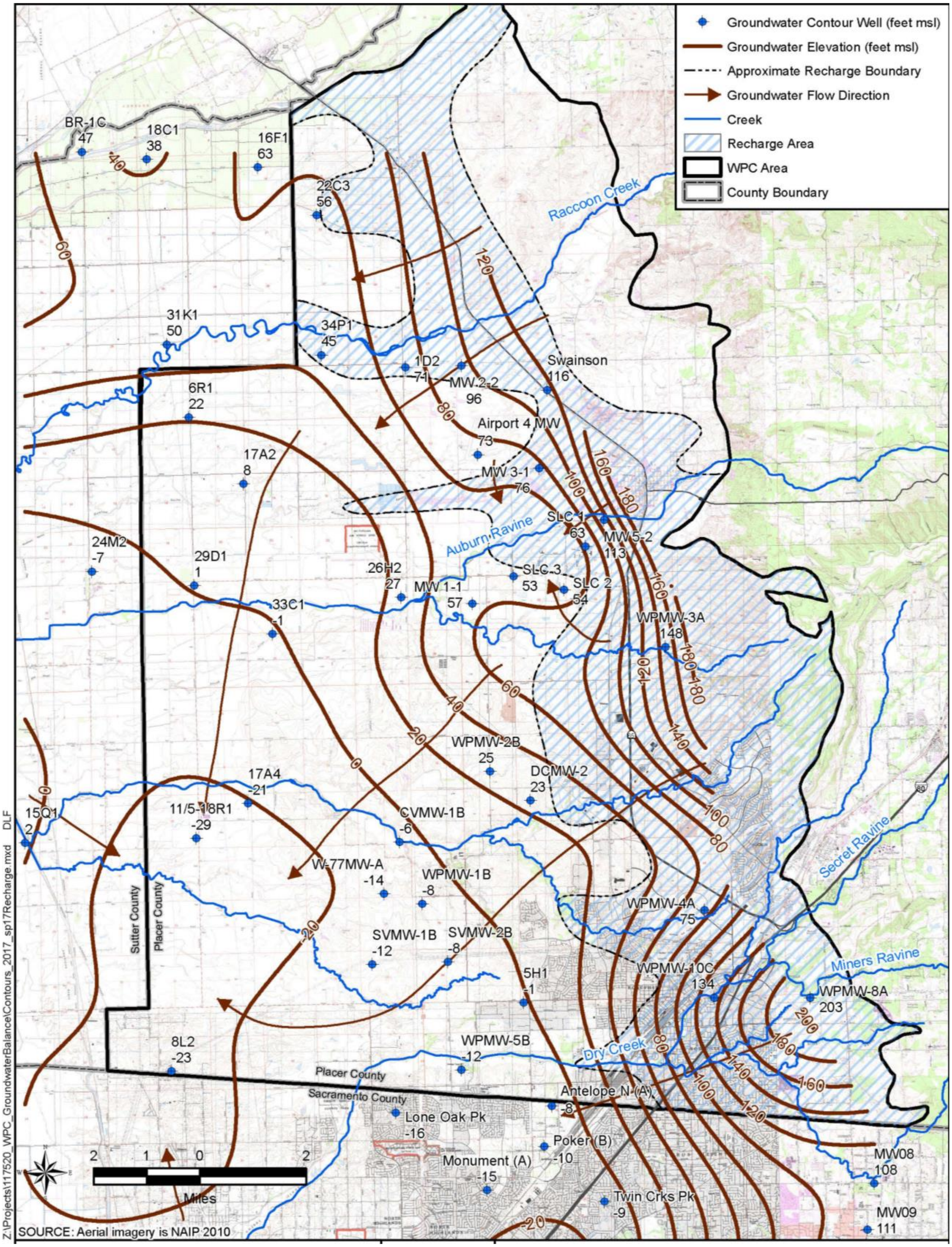

Figure 10. Groundwater Elevations and Flow Directions

5 Potential Recharge Sites

Potential direct groundwater recharge sites suitable for spreading surface water would ideally be compatible with or enhance existing land uses. Therefore, this assessment did not attempt to identify where new facilities could be constructed rather where existing land uses could be conjunctively used to increase groundwater recharge. **Figure 8** shows the potential recharge sites evaluated. **Table 1** lists the sites by recharge category and provides a preliminary indication of whether the site should be evaluated further. The sites selection criteria were based on large acreage (greater than 1 acre) and whether they were located within the area identified where direct recharge to the aquifers may occur. For ease of identification the sites were color coded in **Table 1** with "green" as meeting both criteria, "yellow" has having one, but not both criteria and "red" for those sites that did not meet either selection criteria. The following sections provide a summary of the most favorable sites.

If a large-scale groundwater spreading basin approach is desired, then as tracts of land become available, special studies should be performed to evaluate their potential.

5.1 Stormwater Detention Basins

Existing or planned stormwater detention basins were considered because they are existing depressions where storm water runoff could be detained to enhance groundwater recharge. The Cities of Roseville and Lincoln provided GEI with coordinates of existing and proposed detention basins. GEI performed a review of aerial imagery of each of the sites along with the information described above and developed a preliminary assessment to assist in refining the scope of this investigation. **Table 1** provides a summary of the conditions for each site and a preliminary ranking (color coded), whether it should be included in this assessment. Sites 1 through 13 are the stormwater detention basins.

Stormwater detention basins are typically present with the City of Roseville and the City of Lincoln, but are typically small, less than one acre. Of the City of Roseville's eight stormwater detention basins only two (color coded green) are within the potential direct recharge area and are greater than one acre and should be evaluated further. In the City of Lincoln three of their stormwater detention basins are within the potential direct recharge area and are greater than 1 acre and should be evaluated further.

A proposed five-acre stormwater detention basin (Antelope Creek Flood Control Project)in the potential recharge area, is proposed near Roseville Parkway and Highway 80 and should be evaluated further.

Table 1. Potential Groundwater Recharge Sites or Approaches

Site Number	Owner	Nearest Major Road Crossing or Pertinent Feature	Acres	Type of Use	Conservation Easement Existing	Within or Outside of Potential Direct Recharge Area	Source of Water	Potential Contaminants	Potential for Recharge Water to Daylight	Geologic	Warrants Further Investigation
Stormwater Detention Basins											
1	Roseville	Sierra College and Miners Ravine	2.1	Detention or Habitat	Possible	Within	Suburban area runoff and PCWA tailwater	None	No	Mehrten	Yes
2	Roseville	Sierra College and Miners Ravine	10.7	Detention or Habitat	Possible	Within	Suburban area runoff and PCWA tailwater	None	No	Mehrten	Yes
3	Roseville	Blue Oaks Blvd at School (adjacent to ASR well)	0.8	Stormwater detention		Outside	Runoff from school turf area	Nitrates, fertilizers, THMs, pesticides	Yes	Laguna	Yes
4	Roseville	Market Street	1.6	Stormwater detention		Outside	Urban stormwater runoff	Oils, copper, nitrate	No	Laguna	Yes
5	Roseville	Baseline and Junction Blvd	2.1	Stormwater detention		Outside	Urban stormwater runoff	Oils, copper, nitrate	No	Laguna	Yes
6	Roseville	Sierra Gardens Drive Dog Park	1.7	Stormwater detention		Within	Urban stormwater runoff	Oils, copper, nitrate, bacteria, viruses	No	Laguna	No
7	Roseville	Sutter Memorial Hospital	0.1	Stormwater detention		Within	Parking lot runoff	Oils, copper	No	Underlain by Ione	No
8	Roseville	Sutter Memorial Hospital	0.1	Stormwater detention		Within	Parking lot runoff	Oils, copper	Yes	Mehrten Lahars	No
9	Lincoln	Ravine Meadows bounded by Auburn Ravine (S), 1st St (N), Old 65, and Joiner Pkwy (W).	1.3	Stormwater detention		Within	Urban stormwater runoff/Auburn Ravine	Oils, copper, nitrate	No	Laguna/Mehrten	Yes
10	Lincoln	Markham Ravine Park. City Park located between Lakeside Dr and Toyon Cir.	1.6	Stormwater detention		Within	Urban and natural stormwater runoff/ Markham Ravine	Nitrates, fertilizers, THMs, pesticides	No	Laguna/Mehrten	Yes
11	Lincoln	Pond at Lincoln Crossing (Ingram Slough). Corner of Old 65 and Joiner Pkwy	1.3	Stormwater detention		Within	Urban stormwater runoff/Ingram Slough	Nitrates, fertilizers, THMs, pesticides	No	Laguna/Mehrten	Yes
12	Lincoln	Coyote Pond (Orchard Creek)	0.3	Stormwater detention		Within	Urban stormwater runoff/Orchard Creek	Oils, copper, nitrate	No	Laguna/Mehrten	Yes
13	County	Near Roseville Pkwy and Hwy 80 at Antelope Creek Trail. Part of Antelope Creek Flood Control Project	5	Proposed Stormwater detention		Within	Antelope Creek	Oils, copper, nitrate	No	Laguna/Mehrten	Yes

Site Number	Owner	Nearest Major Road Crossing or Pertinent Feature	Acres	Type of Use	Conservation Easement Existing	Within or Outside of Potential Direct Recharge Area	Source of Water	Potential Contaminants	Potential for Recharge Water to Daylight	Geologic	Warrants Further Investigation
Other Water Features											
14	Roseville	Diamond Oaks Golf Course	2.3	Decorative Ponds		Within	Runoff from golf course and possible recycled water	Nitrates, fertilizers, THMs, pesticides	No	Laguna	Yes
15	Roseville	Woodcreek Golf Club	4.1	Decorative Ponds		Just outside	Runoff from golf course and possible recycled water	Nitrates, fertilizers, THMs, pesticides	No	Laguna	Yes
16	Roseville	North of Diamond Oaks Golf Course	0.6	Decorative Ponds		Within	Urban stormwater runoff	Oils, copper, nitrate, bacteria, viruses	No	Laguna	Yes
17	Roseville	Timber Creek Golf Course	0.3	Decorative Ponds		Outside	Runoff from golf course and possible recycled water	Oils, copper, nitrate, THMs	No	Laguna	Yes
18	Roseville	Mallard Creek Drive	2.0	Decorative Ponds		Just outside	Runoff from golf course and possible recycled water	Nitrates, fertilizers, THMs, pesticides	No	Laguna	Yes
19	Roseville	Morgan Creek Golf Course	1.3	Decorative Ponds		Outside	Runoff from golf course and possible recycled water	Nitrates, fertilizers, THMs, pesticides	No	Laguna	No
20	Sun City	Ingram Parkway Lincoln Golf club ponds	11	Decorative Ponds		Within	Runoff from Golf Course and Ingram Slough	Nitrates, fertilizers, pesticides	No	Laguna/Mehrten	Yes

Site Number	Owner	Nearest Major Road Crossing or Pertinent Feature	Acres	Type of Use	Conservation Easement Existing	Within or Outside of Potential Direct Recharge Area	Source of Water	Potential Contaminants	Potential for Recharge Water to Daylight	Geologic	Warrants Further Investigation
Other Potential Existing Ponds											
21	Roseville	Westpark Wastewater Treatment Plant	0.9	Wastewater Treatment		Outside	Recycled water	THMs, nitrate	No	Laguna	Yes
22	Lincoln	Wastewater Treatment Facility on Fiddyment Road just south of Moore Rd.	72	Wastewater Treatment		Outside	Recycled Water	THMs, nitrate	No	Riverbank	Yes
23	Lincoln	Labeled as 2008 Dam, East of Hwy 65	Unknown	Unknown		Within	Urban stormwater runoff	Oils, copper, nitrate	No	Laguna/Mehrten	Yes
24	Placer Co.	Heritage Church, Oak Tree Lane	8	Recreational		Just outside	Ingram Slough	None	No	Alluvium	Yes
25	Unknown	Lakeview Farms	Unknown	Unknown		Within	Unknown	None	No	Laguna/Mehrten	Yes
Open Space and Preserves											
26	Placer Land Trust	Doty Ravine Preserve	427	Open Space		Within	NID	None	Yes	Laguna/Mehrten	Yes
27	Placer Land Trust	Swainson's Grassland Preserve	469	Open Space	No - in Progress	Within	NID	None	No	Laguna/Mehrten	Yes
28	Roseville	Reason Farms Environmental Preserve	227	Wildlife		Outside	Pleasant Grove Creek, recycled water	THMs, nitrate, ammonia	No	Laguna/Mehrten	No
29	Signature Properties - Placer Land Trust Easement	Toad Hill Ranch Preserve 1	500	Preserve	Yes	Within	Orchard Creek	None	No	Fiddyment/Kaseburg Fiddyment?	Yes
30	Farm Credit West - Placer Land Trust Easement	Toad Hill Ranch Preserve 2	500	Preserve	Yes	Within	Orchard Creek	None	No	Fiddyment/Kaseburg Fiddyment?	Yes
31	Placer Legacy	Sundance Lakeview Farms Conservation Easement (Scilacci Farms)	137	Open Space	Yes	Outside	Coon Creek	None	No	Laguna	Yes
32	Private	Aitken Ranch Conservation Easement	320	Open Space	Yes	Outside	Recycled water, raw water, Coon Creek	None	No	Laguna	No
33	Unknown	Unnamed Open Space, SE Sheridan	Unknown	Open Space	Yes	Within	Yankee Slough	Nitrate, perchlorate	No	Laguna	Yes
34	County	Ingram Slough - entire length	26	Riparian habitat		Within and Outside	Ingram Slough	Nitrates, fertilizers, pesticides	No	Laguna/Mehrten	Yes
35	County	Scilacci Farms Flood Easements	340	Ag	Flood Easement	Within	Coon Creek	Nitrates, fertilizers, pesticides	No	Laguna	Yes

Site Number	Owner	Nearest Major Road Crossing or Pertinent Feature	Acres	Type of Use	Conservation Easement Existing	Within or Outside of Potential Direct Recharge Area	Source of Water	Potential Contaminants	Potential for Recharge Water to Daylight	Geologic	Warrants Further Investigation
ASR Wells											
36	Roseville	10 new well locations	NA	Water Supply Wells		Unknown	Folsom Lake	THMs	No	Mehrten	Yes
37	Lincoln	11 existing wells	NA	Water Supply Wells		Unknown	PCWA, NID	THMs	No	Mehrten	Yes
38	PCWA	2 existing wells	NA	Water Supply Wells		Unknown	PCWA	THMs	No	Mehrten	Yes
Agricultural Lands											
39	Private	Various	+4000	Orchards		Unknown	SSWD, NID	Fertilizers, nitrate	No	Alluvium	Yes
Instream and Canals											
40	PCWA	Various	Unknown	Canals		Outside	Auburn Ravine	None	No	Laguna/Mehrten	Yes
41	SSWD	Various	Unknown	Canals		Unknown	SSWD, NID	None	No	Laguna/Mehrten	Yes
Gravel Mines											
42	CEMEX	Bear River	97	Mining		Within	Camp Far West	None	No	Alluvium	No
43	Tiechert	Coon Creek	35	Mining		Outside	Coon Creek	None	No	Ione/Laguna	No
44	Glady- McBean	East of Hwy 65	200	Mining		Outside	Markham Ravine	None	No	Ione	No

5.2 Other Water Features

Sites 14 through 20 are features such as golf course ponds that could be used for recharge due to there being a topographic depression and an existing water source. However, the ponds may be lined to limit infiltration to the underlying sediments which would have to be destroyed or removed to serve as spreading basins. Within the City of Roseville there are two large ponds that receive both stormwater runoff and store treated wastewater and are greater than two acres. At least one of the basins is lined to prevent the treated recycled water from recharging the groundwater. The basins were constructed over 10 years ago when restrictions on the reuse of treated wastewater were greater. These basins should be considered for potential recharge basins, consistent with current regulations. In the City of Lincoln, the Ingram Parkway Lincoln Golf Course has multiple ponds (about 11 acres) that could potentially be used for groundwater recharge. Water is conveyed to the ponds through the Ingram Slough. These ponds should be evaluated further.

There are three additional existing ponds that might be considered for recharge:

- Site 23, near the southwest corner of the City of Lincoln, as noted on one map, is a dam that might be used for a recharge basin. If present it could be a favorable feature for groundwater recharge.
- Site 24, just east of the City of Lincoln the County owns a property near Heritage Church with an 8-acre pond that is underlain by coarse sands favorable for groundwater recharge. However, adjacent to the property is a 28-acre former Titan missile site that has undergone remediation for groundwater contamination with trichloroethene (TCE) and its daughter products. The TCE contamination is limited to about 2.8 acres of the property. Its status is unknown, but if it has been resolved then this site may be favorable.
- Site 25, Lakeview Farms is located north of Lincoln and was a former pheasant hunting club. Its property status is unknown.

5.3 Open Space and Preserves

Open space land is any parcel or area of land or water essentially unimproved and designated for any of the open space uses defined in Section 65560 of the Government Code of California. These open space uses include space for health and safety, natural resources preservation, outdoor recreation, and managed production of natural resources. The following open space land preserves which overlie the potential area of direct recharge include:

- Site 27, Swainson's Grassland Preserve
- Sites 29 and 30, Toad Hill Ranch Preserves which are adjacent to Orchard Creek

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5.4 ASR Wells

The City of Roseville has shown that the ASR approach to groundwater recharge to be a viable technique for groundwater recharge and has permitted and operates six groundwater wells that are equipped for ASR. They plan to construct 10 more wells, all being equipped for ASR purposes.

The City of Lincoln owns and operates five groundwater wells that supplement PCWA and NID surface supplies. The surface water is treated prior to use and could be used as the source water for injection purposes. None of the wells are equipped for ASR. After further evaluation of the well construction details, some of the wells could be used for ASR purposes.

PCWA has the Sunset and Tinker wells for emergency supply and redundant water supply sources. The wells are in Rocklin. PCWA provides treated surface water to the City of Rocklin which could be used as the source water for injection purposes. Neither well is equipped for ASR. There is a potential after further evaluation of the well construction details that the wells could be used for ASR purposes.

Although the town of Sheridan has groundwater wells, they do not have surface water available that could be used for injection. Therefore, at this time there does not appear to be an opportunity for ASR in this area.

Opportunities exist to expand ASR groundwater recharge and should receive further consideration and evaluation. An initial screening of wells should be performed to evaluate whether they are constructed in a fashion that they could be used for ASR purposes. If constructed acceptably then a technical report would need to be prepared. This technical report would provide the geologic and geochemical suitability for ASR andalso any the potential impacts. It is part of the requirements to obtain a permit for injection from the State Water Resources Control Board.

5.5 Agricultural Lands

There are over 4,000 acres of orchards within West Placer portion of the Subbasin. Most of the orchards are adjacent to the Bear River and could be suitable for recharge. Willing land owners could participate in seasonal and periodic flooding of the orchards to enhance groundwater recharge. It is likely some of the orchards have existing infrastructure to deliver surface water to their fields.

Additional orchards are present northeast of Lincoln, but these reside in areas that could result in perched water and are outside of the potential area for direct recharge.

5.6 Stream and Canals

Open space areas are present in both the cities of Lincoln and Roseville, typically narrow bands along creeks. Although each was not specifically evaluated, any of the creeks shown on **Figure 8** that cross the potential area of direct recharge could be used. Ingram Slough in Lincoln has multiple ponds along its course, including some of Ingram Parkway Lincoln Golf Course ponds, and should be further evaluated.

PCWA and SSWD have canals that convey water across the County (generally east-west); however, almost all the canals are not over the potential direct recharge area. SSWD has a few canals that do cross the potential direct recharge areas. Some water is lost from the canals due to this seepage. Although the canals are not wide, they typically are long and are full during the spring and summer months. During the fall and winter months the canals may have available capacity. Due to the seepage from the canals some agencies have lined portions of the canals where other canals are not lined and allow fine sediments carried in by the water to accumulate to reduce seepage.

Enhanced groundwater recharge could be created by selectively cleaning the unlined canals to promote seepage over the potential direct recharge areas and by maintaining water in the canals during the fall and winter months.

5.7 Mines

Although there are three active or proposed mines within WPC, the most favorable location is the CEMEX pits adjacent to the Bear River (Site 42). Its soils and size are favorable and it is an active mine. The proposed Tiechert gravel pit and quarry (Site 43) will be located outside of the potential area of recharge and is underlain by marine sediments (Ione Formation), which would limit its potential future use for groundwater recharge. The Gladding McBean clay mine (Site 44) is excavated into the Ione Formation and again would not be considered a viable area to recharge water.

6 Conclusion and Summary

Groundwater recharge can be accomplished through various techniques and methods. The type of recharge method is dependent on the geologic conditions. Direct recharge by applying water onto land surface is possible in WPC, but typically only along the eastern portion of the groundwater subbasin where coarse grained soils are underlain by coarse-grained sediments that are connected to the aquifers. The groundwater will migrate from these eastern areas towards the southwestern corner of WPC. Potential sites in these areas include stormwater detention basins, lakes, golf course ponds, in-stream and canals, preserves and open space areas, and other water features. Another option is to inject water directly into the aquifers using new or existing wells. The water must first be treated to drinking water standards. Forty-four sites were evaluated and twenty-one sites are recommended for further consideration and investigation as summarized in **Table 2**. A checklist of activities to further evaluate each type of project is provided in **Table 3**.

To further refine the selection of the sites listed in **Table 2** the County should engage in discussions with the landowners to assess if they would be willing to participate. Site-specific investigations should then be performed to assess the geologic conditions, a source of water, leading to the development of an annual recharge estimate to more thoroughly evaluate cost for implementation.

For those open space areas contained in **Table 2**, a review of the conservation easements should be performed to assess any limitations and areas where flooding could enhance habitat. For the Placer County Conservation Plan and State/Federal wildlife regulatory agencies, flooding of certain habitat types would not be permissible (i.e., vernal pool grasslands would not be permitted due to endangered species but there may be others). Habitat types that would benefit from flooding with raw water would include perennial emergent marsh (some standing water throughout the year), seasonal emergent marsh (seasonally flooded), and riparian wetland vegetation (typically associated with riverine, ponds, lakes, etc.) that can be supported both by surface and sub-surface hydrology.

If a large-scale groundwater spreading basin approach is desired, then as large tracts of land become available special studies should be performed to evaluate their potential and how water could be delivered to the property.

Table 2. Selected Groundwater Recharge Sites for Further Evaluation

Site Number	Owner	Nearest Major Road Crossing or Pertinent Feature	Acres	Type of Use	Conservation Easement Existing	Within or Outside of Potential Direct Recharge Area	Source of Water	Potential Contaminants	Potential for Recharge Water to Daylight	Geologic	Warrants Further Investigation
Stormwater Detention Basins											
1	Roseville	Sierra College and Miners Ravine	2.1	Detention or Habitat	Possible	Within	Suburban area runoff and PCWA tailwater	None	No	Mehrten	Yes
2	Roseville	Sierra College and Miners Ravine	10.7	Detention or Habitat	Possible	Within	Suburban area runoff and PCWA tailwater	None	No	Mehrten	Yes
9	Lincoln	Ravine Meadows bounded by Auburn Ravine (S), 1st St (N), Old 65, and Joiner Pkwy (W).	1.3	Stormwater detention		Within	Urban stormwater runoff/Auburn Ravine	Oils, copper, nitrate	No	Laguna/Mehrten	Yes
10	Lincoln	Markham Ravine Park. City Park located between Lakeside Dr and Toyon Cir.	1.6	Stormwater detention		Within	Urban and natural stormwater runoff/ Markham Ravine	Nitrates, fertilizers, THMs, pesticides	No	Laguna/Mehrten	Yes
11	Lincoln	Pond at Lincoln Crossing (Ingram Slough). Corner of Old 65 and Joiner Pkwy	1.3	Stormwater detention		Within	Urban stormwater runoff/Ingram Slough	Nitrates, fertilizers, THMs, pesticides	No	Laguna/Mehrten	Yes
13	County	Near Roseville Pkwy and Hwy 80 at Antelope Creek Trail. Part of Antelope Creek Flood Control Project	5	Proposed Stormwater detention		Within	Antelope Creek	Oils, copper, nitrate	No	Laguna/Mehrten	Yes
Other Water Features											
14	Roseville	Diamond Oaks Golf Course	2.3	Decorative Ponds		Within	Runoff from golf course and possible recycled water	Nitrates, fertilizers, THMs, pesticides	No	Laguna	Yes
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18	Roseville	Mallard Creek Drive	2.0	Decorative Ponds		Just outside	Runoff from golf course and possible recycled water	Nitrates, fertilizers, THMs, pesticides	No	Laguna	Yes
20	Sun City	Ingram Parkway Lincoln Golf club ponds	11	Decorative Ponds		Within	Runoff from Golf Course and Ingram Slough	Nitrates, fertilizers, pesticides	No	Laguna/Mehrten	Yes
Other Potential Existing Ponds											
23	Lincoln	Labeled as 2008 Dam, East of Hwy 65	Unknown	Unknown		Within	Urban stormwater runoff	Oils, copper, nitrate	No	Laguna/Mehrten	Yes
24	Placer Co.	Heritage Church, Oak Tree Lane	8	Recreational		Just outside	Ingram Slough	None	No	Alluvium	Yes
25	Unknown	Lakeview Farms	Unknown	Unknown		Within	Unknown	None	No	Laguna/Mehrten	Yes
Open Space and Preserves											
27	Placer Land Trust	Swainson's Grassland Preserve	469	Open Space	No - in Progress	Within	NID	None	No	Laguna/Mehrten	Yes
29	Signature Properties - Placer Land Trust Easement	Toad Hill Ranch Preserve 1	500	Preserve	Yes	Within	Orchard Creek	None	No	Fiddyment/Kaseburg Fiddyment?	Yes
30	Farm Credit West - Placer Land Trust Easement	Toad Hill Ranch Preserve 2	500	Preserve	Yes	Within	Orchard Creek	None	No	Fiddyment/Kaseburg Fiddyment?	Yes
34	County	Ingram Slough - entire length	26	Riparian habitat		Within and Outside	Ingram Slough	Nitrates, fertilizers, pesticides	No	Laguna/Mehrten	Yes

Site Number	Owner	Nearest Major Road Crossing or Pertinent Feature	Acres	Type of Use	Conservation Easement Existing	Within or Outside of Potential Direct Recharge Area	Source of Water	Potential Contaminants	Potential for Recharge Water to Daylight	Geologic	Warrants Further Investigation
ASR Wells											
36	Roseville	10 new well locations	NA	Water Supply Wells		Unknown	Folsom Lake	THMs	No	Mehrten	Yes
37	Lincoln	11 existing wells	NA	Water Supply Wells		Unknown	PCWA, NID	THMs	No	Mehrten	Yes
38	PCWA	2 existing wells	NA	Water Supply Wells		Unknown	PCWA	THMs	No	Mehrten	Yes
Conjunctive Land Use (Orchards											
39	Private	Various	+4000	Orchards		Unknown	SSWD, NID	Fertilizers, nitrate	No	Alluvium	Yes

Table 3. Investigative Checklist for Selected Recharge Types

Assessment Activities	Stormwater Detention Basins	Other Water Features	Other Potential Existing Ponds	Open Space and Preserves	ASR Wells	Conjunctive Use (Orchards)
Contact Land Owner						
Willingness to participate	X	X	X	X	X	X
Projects in planning process				X		
Long-term plans				X		
Available information	X	X	X	X	X	X
Data Collection						
Water well logs				X	X	
Geotechnical borings	X	X				
Monitoring wells		X			X	
Depth to groundwater	X	X	X	X	X	
Estimate soils permeability	X	X	X	X		
Groundwater quality	X	X	X	X		
Interconnectedness to aquifers	X	X	X	X		
Source of water		X	X	X	X	X
Source water quality	X	X	X	X	X	
Conveyance mechanisms			X	X		X
Soils characterization, hand auger 4 foot holes				X		
Prepare Draft Project Description						
Water Supply Source	X	X	X	X	X	X
Estimated groundwater recharge	X	X	X	X	X	X
Conceptual design	X	X		X	X	
Permits and Approvals	X	X	X	X	X	
Potential Environmental Impacts	X	X			X	
Cost Estimate	X	X	X	X	X	X
Rank and Select most Feasible Projects						
Develop ranking criteria	X	X	X	X	X	X
Rank	X	X	X	X	X	X
Select suitable projects	X	X	X	X	X	X
Regulatory Agency Notice of Intent						
Present potential projects	X	X	X	X	X	X
Discuss regulatory constraints	X	X	X	X	X	X
Winter Water Rights			X	X		X
Recycled Water Reuse Requirements		X				
ASR Permit Requirements					X	
Monitoring requirements		X			X	
Identify Potential Project Funding						
Local	X	X	X	X	X	X
Grant	X	X	X	X	X	X
Design and Construct						
Design Selected Project	X	X		X	X	
Prepare permits	X	X	X	X	X	
Prepare CEQA	X	X	X	X	X	
Prepare Plans and Specifications	X	X			X	
Construct project	X	X			X	
Prepare operations manual	X	X			X	

7 Reference List

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