General Investigation Report
Skagit River Basin Levees
Skagit County, Washington

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SKAGIT COUNTY, WASHINGTON

1.0 INTRODUCTION

This report presents the results of our investigation into the existing information available from the Seattle District of the United States Army Corps of Engineers (USACE) for the Skagit River Basin levee system in Skagit County, Washington. Notice to proceed with this work was provide by the USACE under Task Order No. 002. Our work was performed in general accordance with Contract No. W912DW-09-D-1005 and the corresponding Statement of Work for Task Order No. 002.

2.0 SITE AND PROJECT DESCRIPTION

The Skagit River is located in southwest British Columbia, Canada, and in northwestern Washington State. The river originates in the Cascade Mountains of British Columbia, flowing southward into Washington and then west, discharging into the Skagit Bay of Puget Sound. The river flows approximately 100 miles through Skagit County, splitting into two distributaries, the North Fork and South Fork, before discharging into Skagit Bay (Figure 1, Vicinity Map). Cities and farmland currently line the river within Skagit County. Major cities along the river include Sedro-Woolley, Burlington, and Mount Vernon. The community of Fir Island is located between the two distributaries. Most of the levees along the river are located downstream of Sedro-Woolley, occupying the lower 30 miles of river. Isolated sections of levee are also located near the towns of Lyman and Hamilton, upstream of Sedro-Woolley.

Our scope of services was to identify subsurface geotechnical, geologic, and hydrogeologic conditions for the existing levee and underlying foundation soil along the Skagit River. This information would be used as a first step in procuring subsurface information for levee failure analyses and in identifying opportunities for the development of a flood reduction project. Our research was limited to the information collected by the USACE Seattle District from Skagit County, the City of Burlington, and other USACE projects. Identified historical explorations and project features, including past failure locations, repairs, gravity drains, and pump stations are shown on Figure 3. Historical explorations and interpreted geology along the Skagit River Basin are shown in Figure 4.

3.0 RETRIEVED INFORMATION

Most of the retrieved levee and foundation soil information along the Skagit River is located downstream of Sedro-Woolley. Very limited information was available from the USACE upstream of Sedro-Woolley. The collected information was reviewed and divided into four sections. The information in each section was used to give a better understanding of site geology (Section 3.1), levee history and flood protection (Section 3.2), levee geometry and erosion control implementations (Section 3.3), and river history (Section 3.4). The following summarizes our findings.

3.1 Reports

3.1.1 General Design Memorandum, 1979

In July 1979, a two-volume General Design Memorandum was issued by the Seattle District USACE recommending levee system upgrades from Sedro-Woolley to Skagit Bay. The upgrades propose providing flood protection in urban areas for a 100-year flood event, and in rural areas for a 50-year flood event. The proposed project was later de-authorized due to a lack of local support. However, as part of this study, 181 borehole explorations were conducted between January 23, 1978, and March 7, 1979. The boreholes were located approximately 2,000 feet apart along the proposed levee improvement alignments and 1,000 feet apart in areas of proposed channel widening and deepening. The report also included information for 33 hand-auger explorations completed along the study area in November 1964.

The borehole explorations extended between 7.0 and 71.5 feet below ground surface (bgs) and the hand augers explorations extended between 0.5 and 10.0 feet bgs. Two deeper boreholes, extending 100 and 145 feet, were completed for a proposed gate structure along the alignment. Depth to groundwater was noted during drilling. Standard Penetration Tests (SPTs) were conducted every 5 feet in the boreholes to estimate soil density. Disturbed soil samples were recovered and select samples tested using Atterberg limits to confirm visual classification. The liquid limit, plasticity index, and SPT N-values are incorporated into the logs.

3.1.2 Flood Damage Reduction Study, 1993

In May 1993, the Seattle District USACE produced a Flood Damage Reduction Study report to identify problems, opportunities, and potential solutions for the recurring flooding along the Skagit River from Sedro-Woolley to Skagit Bay. The report, which relied upon existing information, evaluated past flood damages and the feasibility of alternative solutions. The

USACE recommended increasing the level of flood protection in Burlington, Mount Vernon, and West Mount Vernon to accommodate a 100-year flood event, and select rural areas between Sedro-Woolley and Skagit Bay to a 25-year flood event. The USACE concluded that increasing the flood protection in these areas was economically feasible and recommended conducting further geotechnical, hydraulic, and hydrogeologic studies in the area.

3.1.3 Preliminary Geotechnical Evaluation, 2009

In March 2009, Golder Associates (Golder) completed a preliminary geotechnical evaluation of the levee system in the City of Burlington and Skagit County Dike District 12 (Dike District 12). The report was part of a project for the City of Burlington and Dike District 12 to evaluate and improve the existing levees and construct new levees to accommodate a 100-year flood event. Golder's report is based on existing information and a site reconnaissance conducted on February 2, 2009. Golder identified areas of under-seepage, sand boils, and former repairs; identified geologic hazards; and interpreted subsurface information in the report. The report recommends a subsurface exploration and laboratory testing program to characterize levee and foundation material for stability and seepage analyses.

3.1.4 Geotechnical Investigation and Levee Analysis, 2009

In November 2009, Golder completed a geotechnical investigation and analysis of the levee system in the City of Burlington and Dike District 12. The project was a continuation of their preliminary work completed in March 2009. Approximately 4.6 miles of levee was evaluated, from north of the intersection of Lafayette Road and Peter Anderson Road to west of the intersection of Bouslog Road and Bennett Road. Golder drilled 28 borings for the project using hollow-stem auger drilling methods. Piezometers were installed in eight of those borings for groundwater observation. Boring depths ranged from approximately 26.5 to 80.5 feet bgs. SPTs were conducted every 2½ feet in the upper 20 feet and at 5-foot intervals thereafter, to estimate soil density. Both disturbed and relatively undisturbed soil samples were collected from the borings for laboratory testing.

Golder also advanced 11 cone penetration tests (CPTs) as part of the exploration program. The CPTs extended approximately 32.3 to 81.0 feet bgs. Tip resistance, friction ratio, and pore pressure were continuously measured and recorded. Pore pressure dissipation tests were conducted at select locations to estimate static ground water levels.

Golder and Soil Technology, Inc. conducted laboratory tests on select soil samples to characterize engineering and index properties. Laboratory testing included natural moisture content, Atterberg limits, grain size distributions, percent passing the No. 200 sieve, and one-dimensional consolidation tests.

For the project, Golder analyzed liquefaction potential, slope stability, seepage, and settlement along the existing levee and the proposed levee improvements. The proposed improvements included raising the existing levee, building a new levee adjacent to the existing one, and constructing a setback levee. In the report, Golder recommended that the new levee slopes, and the fill sections placed on the existing levee, were to be constructed at 3 Horizontal to 1 Vertical (3H:1V). A survey of the report findings is as follows:

- The depth of potential liquefaction based on an earthquake recurrence interval of 10 percent probability of exceedence in 50 years (475-year return period) varies along the levee alignment. Approximately 1- to 10-foot-thick zones liquefy between 23 and 56 feet bgs along the upper 3.1 miles of levee. Zones of approximately 2 to 11 feet thick liquefy between 4 and 69 feet bgs along the lower 1.5 miles of levee.
- The long-term static stability of the existing and proposed levee improvement slopes were analyzed. Golder concluded that the existing riverward and landward slopes meet the USACE design minimum factor of safety of 1.4, with the exception of two existing levee sections as shown in Figure 3, Sheets 5 and 6. Golder further concluded that the recommended proposed levee improvement slopes meet the USACE design minimum factor of safety. Groundwater and river levels were modeled below the levee elevations, and slip surface failure slopes were restricted from the levee crest to the levee toe. Shallow surface sloughing, erosion, and scour were not considered as part of this analysis.
- The proposed levee improvement slopes were analyzed for seismic stability using the developed long-term static stability model, but with residual strengths applied to those sections of liquefied soil occurring during an earthquake with a 475-year return period. The analyses did not include application of a pseudo-static force on the levee. Golder concluded that the riverward slopes meet the USACE design minimum factor of safety of 1.2, with the exception of one section located west of Interstate-5 (I-5). Shallow liquefiable soil is present at this location underlying the proposed levee.
- The proposed levee improvement slopes were analyzed for steady state seepage stability during a maximum considered flood event. Three sections were analyzed based on three different anticipated conditions along the levee alignment.
    1. The first section was based on the northern levee alignment, where the overbank foundation soil deposit thins to about 5 feet.
    2. The second section was based on the calculated levee section having the lowest riverside factor of safety close to the river.

3. The third section was based on a setback levee.

Golder concluded that landward slopes modeled with slip surface failures from crest to toe meet the USACE design minimum factor of safety of 1.4. Localized, shallow failures less than the recommended design factor of safety were identified along the landward slope for the first section. Transient flow analyses performed by Golder concluded that a flood stage will not remain at its maximum level long enough for steady state seepage to develop, reducing the risk of localized shallow failures. Exit gradients were also low, indicating piping of the embankment soil will not likely occur during flooding.

- The proposed levee improvement slopes were analyzed for stability during rapid drawdown using the steady state seepage model conditions. Flood conditions were simulated based on data collected from flood events between 1989 and 2006. A maximum rapid drawdown rate of 7 feet per day was used in the analysis. Golder concluded that riverward slopes meet the USACE design minimum factor of safety of 1.0 during rapid drawdown conditions.
- Golder analyzed foundation settlements for two different proposed levee improvements. The first improvement section was raising the existing levee in place, or constructing a new levee section adjacent to the existing levee, using the existing levee as part of the construction. The first improvement would occur along the northern 3.3 miles of the project site. Height increases ranged from 3.3 to 16.6 feet above the existing levee crest and slopes. The second improvement section was for constructing a new setback levee of 13.7 to 26.6 feet height along the southern 1.3 miles of the project site. Golder's analyses determined that settlements of approximately 0 to 4 inches could be expected from raising the existing levee or constructing an adjacent levee, and ½ to 6 inches of settlement could be expected from constructing a new setback levee. They also concluded that seismically induced foundation settlements along the alignment could reach up to 6 inches during a 475-year return period earthquake.

The report concluded that construction of a 100-year flood level levee protection at this site is feasible. Levee design recommendations were provided for crest widths, side slope geometry, and levee material. Construction recommendations were provided for clearing, grubbing, stripping of the foundation area, and for levee fill placement and compaction.

3.2 Flood Damage Reports/Repair Letters

Following several flood events, the Skagit County Diking Districts submitted damage reports and levee restoration proposals to the USACE under public law 84-99. The following list summarizes each proposed job and includes location, estimated damages, proposed repairs, and the estimated level of protection at the time each report was prepared. Where noted, the general levee composition prior to flooding is included.

- Job SKA 79-1 (Reference Figure 3, Sheet 2):
  - *Location*: Right bank of Hill Ditch at river mile 4.8, approximately 1 mile upstream from Freshwater Slough and 1 mile southeast of Conway.
  - *Damage*: Area overtopped and 90 feet of levee destroyed; temporary plug of 4-inch minus rock placed in break.
  - *Proposed Repairs*: Excavate riverward half of levee and replace with semi-impervious fill to previous levee crown elevation; 4-inch minus rock to be removed and spread evenly at 1.5H:1V slope on levee landward side.
  - *Protection*: Prior studies estimate levee to provide three-year flood event protection.

- Job SKA 79-2 (Reference Figure 3, Sheet 2):
  - *Location:* Right bank at river mile 5.7, approximately 1 mile downstream from point where Freshwater Slough diverges from the South Fork and 1 mile southwest of Conway.
  - *Damage:* Erosion along 300-foot section on outside river bend, stripping most of the riprap on the riverside.
  - *Proposed Repairs*: Excavate and place 3-foot layer of Class III riprap at 1.5H:1V slope on riverside for 300 feet.
  - *Protection:* Prior studies estimate levee to provide five-year flood event protection.

- Job SKA-79-3 (Reference Figure 3, Sheet 8):
  - *Location:* Near town of Hamilton at river mile 39.
  - *Damage:* Erosion and overtopping at four sections of a 4,000 foot-long levee.
    - Site A: 450 feet of levee overtopped, eroding levee top and backslope to depths of 4 feet.
    - Site B: 70 feet of levee eroded to below adjacent ground surface with an additional 80 feet sustaining erosion up to 2 feet deep.
    - Site C: 200 feet of riprapped levee eroded to adjacent ground elevation and 260 feet of rock slope protection on adjacent riverbank sloughed into river.
    - Site D: 830 feet of rock slope protection sloughed into river and center of levee eroded landward up to 7 feet from the toe.
  - Proposed Repairs:
    - Site A: Replace 450 feet of levee backslope with semi-impervious fill and the 100 cubic yards of levee embankment salvaged from adjacent fields.
    - Site B: Replace 80 feet of eroded levee backslope and 70 feet on riverward side with semi-impervious fill at 2H:1V slope.

        - Site C: Construct top width to 12 feet and side slopes at 2H:1V, place 30 inches of Class IV riprap on riverside, install berm on landward side with construction excavation material, and repair adjacent riverbank with Class IV riprap at 2H:1V slope and with a 50 foot transition of 1.5H:1V slope.
        - Site D: Construct 10-foot by 4-foot rock toe at levee base; contour riverbank with quarry spalls below the water surface and pit-run gravel above the water surface, place 30 inches of Class IV rock protection on top of quarry spalls and pit-run gravel, and construct road on top of levee.
    - *Protection:* Prior studies estimate levee to provide nine-year flood event protection.

- Job SKA-79-4 (Reference Figure 3, Sheet 8):
    - *Location:* Right bank near town of Lyman at river mile 35.5.
    - *Damage:* Erosion of 125 feet of riprap slope and the creation of a scour hole on the riverward side of the levee to a maximum depth of 10 feet.
    - *Proposed Repairs:* Construct a 3-foot layer of Class V riprap on riverward side at 1.5H:1V slope, install a 12-foot-wide by 5-foot-deep weighted toe, and place quarry spalls below the water surface and pit-run gravel above the water surface beneath the riprap.
    - *Protection:* No prior study estimate for levee flood event protection.

- Job SKA-79-5 (Reference Figure 3, Sheets 5):
    - *Location:* On right bank below Sedro-Woolley, adjacent to the City of Anacortes water pumping station, about ¼ mile south of Avon at river mile 14.
    - *Damage:* Erosion of riprap toe and 70 feet of riprap slope.
    - *Proposed Repairs:* Temporarily remove log boom to place 10-foot-wide and 4-foot-deep toe, place 12-inch-thick quarry spalls below the water surface and 12-inch-thick pit run gravel above the water surface, and install 3 feet of Class V riprap on top of quarry spalls and gravel at a 1.5H:1V slope.
    - *Protection:* Prior studies estimate levee to provide 25-year flood event protection.

- Job SKA-79-6:
    - *Location:* Right bank below Sedro-Woolley about 4 miles south of La Conner.
    - *Damage:* 300 feet of levee, overtopping inundated 1,000 feet of farmland and overtopped Landing Road-Dodge Valley Dike and fine-grained soils forced out on landward side caused 20 percent of shoulder and roadway to subside.
    - *Proposed Repair:* Excavate then install semi-impervious fill to previous levee elevation.
    - *Protection:* Prior studies estimate levee to provide 10-year flood event protection.

- Job SKA-1-90 (Reference Figure 3, Sheets 2, 3, and 4):
  - *Location:* Dike District No. 22 – Area A encompasses 6,170 feet of levee downstream of North Fork Skagit River Bridge, Area B encompasses 3,685 feet of levee on both North and South Fork, Area C encompasses 260 feet downstream of North Fork Skagit River Bridge, and Area D encompasses 750 feet downstream of North Fork Skagit River Bridge.
  - *Levee Composition:* Areas A through D silty sand.
  - *Damage:*
    - Area A: Five locations of landward levee embankment sloughing caused by erosion of post-breach flood waters.
    - Area B: Nineteen locations of landward levee embankment sloughing caused by levee seepage when high water subsided.
    - Area C: Six locations of localized scour on riverside embankment protection.
    - Area D: Two locations with erosion on the riverside embankment and a loss of overlapping riprap due to localized scour at the levee toe.
  - Proposed Repairs:
    - Area A: Excavate landward side at 1.75H:1V slope from levee centerline and re-use suitable material to backfill and compact to the original top width at a 1.75-2H:1V slope.
    - Area B: Excavate landward side at 1H:1V slope from levee centerline and import granular material to be placed and compacted at 2H:1V slope from the shoulder of the roadway; suitable excavated material to be placed on riverside slope at 2H:1V to re-establish minimum 12-foot top width.
    - Area C: Place 12-inch-thick rock spall blanket, install a 5-foot by 10-foot weighted toe, and place 24-inch-thick Class II riprap on top.
    - Area D: Excavate as necessary to re-establish a 2H:1V riverside slope, place a 12-inch-thick layer of gravel bedding above waterline and a 12-inch-thick layer of rock spalls below the waterline, construct a 5-foot by 10-foot weighted toe, and install a 24-inch-thick Class II riprap cover over the bedding material.
  - *Protection:* No prior study estimate for levee flood event protection.

- Job SKA-4-90 (Reference Figure 3, Sheets 5 and 6):
  - *Location:* Left bank of Diking District No. 17 – Area A near river mile 15.0, approximately 1.75 miles upstream of Anacortes Water Treatment Plant, and Area B near river mile 12.5, approximately 0.75 mile downstream of Anacortes Water Treatment Plant.
  - *Levee Composition:* Areas A and B silty sand.
  - *Damage:* Areas A and B were reduced to a two-year level of protection after the flooding.
  - *Proposed Repairs:*

    - Area A: 450-foot cutoff trench on riverside toe.
    - Area B: Remove unstable side slopes and re-slope to 1.5H:1V, install 1-foot-thick gravel filter blanket above water line and a blanket of rock spalls below the water line, place 4-foot-thick layer of Class II riprap over filter blanket; construct 6-foot by 20-foot weighted toe, re-establish interior gravity drain by installing 276 feet of 18-inch-diameter pipe from new manhole placed on existing line to new outlet about 75 feet downstream of existing outlet, 260 feet of existing line to be grouted and abandoned, and install flexible check valve at outlet end of pipe and manual slide gate within manhole for back flood protection.
  - *Protection:* Prior studies estimate levee to provide 15-year flood event protection.

- Job SKA-95-1 (Reference Figure 3, Sheets 5 and 6):
  - *Location:* Diking District No. 17 – Area 2 from BNSF Railway Company (BNSF) Bridge down river to center of I-5 Bridge; Area 3 from center of I-5 Bridge to center entrance of Anacortes Water Treatment Facility; and Area 4 from center entrance of Anacortes Water Treatment Facility to intersection of Freeway Drive and Riverbend Road.
  - *Damage:* Two flood events: dike slides and sinkholes and BNSF Bridge blocked.
    - Event 1, Area 2: Undercutting resulted in major slide failure into river; temporary repair included benching into existing dike and placing riprap.
    - Event 2, Area 2: Cracking and apparent failures east of 1990 repairs, extent of toe damage unknown at time of report but estimated from BNSF Bridge downstream approximately 1,500 feet.
    - Event 2, Area 3: Sloughs and slides appearing at time of report, slippage 6 to 12 inches along 100 feet of dike.
    - Event 2, Area 4: Slippage on riverward side of dike.
  - *Proposed Repairs:* Backfill riverward side to 1.5H:1V slope with 12-inch-thick gravel filter blanket above the water line and 12-inch-thick rock spalls below the water line and cover gravel and spalls with Class III or Class IV riprap at 2H:1V slope.
  - *Protection:* No prior study estimate for levee flood event protection.

- Job SKA-95-2 (Reference Figure 3, Sheets 3 and 4):
  - *Location:* Right bank of Dike District No. 1 at river mile 5 to 8.6 of Skagit River and river mile 10 to 6 of North Fork.
  - *Levee Composition:* Levee surface changes from sand and gravel to silty sand with small gravel to paved road with sand and small-sized crushed rock along the Skagit River and levee surface silty sand along the North Fork.

  - *Damage:* Prior riverside sloughing at river mile 6.4 of North Fork, seepage from animal burrows and sand boils during flood, and minor depressions on levee crown at river mile 12 on Skagit River.
  - *Proposed Repairs:* Clear brush and trees; excavate riverward side bench and deposit at toe of slope, backfill riverward side to 1.5H:1V slope with 12-inch-thick gravel filter blanket above the water line and 12-inch-thick rock spalls below the water line, cover gravel and spalls with Class III riprap at 2H:1V slope, seed slopes with grass except where riprap present, and remove pump house at river mile 8.9.
  - *Protection:* No prior study estimate for levee flood event protection.

- Job SKA-95-3 (Reference Figure 3, Sheet 5):
  - *Location:* Left bank of Dike District No. 3 at river mile 13 of Skagit River in the town of Mount Vernon, Division Street Bridge crossing to approximately 1,000 feet upstream.
  - *Levee Composition:* Silty sand with gravel.
  - *Damage:* Loss of slope protection and a portion of the levee fill and settlement along 100 feet of levee evident by surface fracture extending along access road.
  - *Proposed Repairs:* Excavate and re-compact embankment material to 1.5H:1V slope with 1-foot gravel filter and Class IV riprap on top.
  - *Protection:* Prior studies estimate levee to provide 15-year flood event protection, but flood damage report estimates 10½-year flood event protection.

- Job SKA-95-5 (Reference Figure 3, Sheets 2, 3, and 4):
  - *Location:* Dike District No. 22 at Fir Island in lower Skagit River Basin – Area A on left bank of North Fork at most upstream reach extending 3,000 feet, Area B on left bank of North Fork at approximate river mile 5.5 extending several hundred feet, and Area C on left bank of North Fork from river mile 4.7 to 5.5 and right bank of South Fork from river mile 5.5 to 7.0.
  - *Levee Composition:* Silty sand overlain by topsoil.
  - *Damage:* Areas A, B, and C reduced to 10-year flood level protection after flooding.
    - Area A: Numerous sand boils 0 to 30 feet landward of landward levee toe.
    - Area B: 380 feet of discontinuous toe scour and loss of riprap from toe to about 32 feet up the levee slope.
    - Area C: 2,300 feet of significant seepage and loss of levee material on landward slope and sand bags and gravel blanket built as temporary fix during flooding.
  - Proposed Repairs:
    - Area A: Construct 3,000-foot-long, 4-foot-deep, and 10- to 30-foot-wide gravel seepage berm along landward slope.

    - Area B: Add 30-inch-thick Class III riprap blanket to riverside slope and 5-foot-thick, 10-foot-wide Class III riprap toe at base of riverside slope repair areas.
    - Area C: Excavate 2,300 feet of backslope and place and compact new imported material.
  - *Protection:* Prior studies estimate levee to provide 17- to 25-year flood event protection; proposed repairs to provide 17-year flood event protection.

- Job 96-Skagit River at Cockerham Island (Reference Figure 3, Sheet 8):
  - *Location:* Cockerham Island.
  - *Damage:* Approximately 200 feet of riverward slope rock lost, minor overbank flooding observed, and levee reduced to a two-year flood level of protection after flooding.
  - *Proposed Repairs:* Project to return levee to a 10-year flood level of protection rejected due to economic benefits.
  - *Protection:* Levee remains at two-year flood level protection.

3.3 Plans, Cross Sections, and Profiles

Several levee plans, cross sections, and profiles from 1951 to 2008 were available for review in the USACE files. In general, the retrieved information identifies levee geometries, gravel filter blankets, riprap, and river flood levels. No levee soil, foundation soil, or groundwater information was included in the drawings. Temporal variations documented in these plans, cross sections, and profiles illustrate the dynamic state of the levee geometries and corresponding erosion protection measures implemented over the years. Changes in the levee geometry and erosion protection are both flood and design induced.

A plan sheet completed in 1956 for a bridge near Rexville includes generic subsurface soil descriptions and bedrock contact elevations based on test hole data. No relative soil consistency, laboratory test information, or groundwater identification is noted for these test holes. However, the distribution of shallow bedrock shown on the plan sheet is consistent with recent geologic maps of the area.

3.4 Aerial and Ground Photographs

The USACE records include aerial and ground photographs taken between 1971 and 1995. Aerial and ground photographs were taken along the levee alignments after the December 1979, November 1995, and December 1995 flood events in support of the Flood Damage Reports/ Repair Letters identified in Section 3.2. Aerial photographs of the river basin were taken in 1977 and annotated with sketches to illustrate the extent of levees/dikes, drainage ditches, gravity drains, pumping plants, drainage gates, riprap, and sandbags in place at that time. Additional aerial photographs were taken along the river basin in 1971, 1972, 1974, 1978, and 1986, and may prove useful in identifying old river channels beneath the current levee system. The aerial photographs are included in a DVD with this report.

4.0 GEOLOGY AND SUBSURFACE CONDITIONS

4.1 General Geologic Conditions

The Skagit River flows from the Cascade Mountains to a broad lowland delta along the eastern margin of the Puget Sound Basin. Pleistocene (approximately 2 million to 10,000 years ago) glacial and Holocene (past 10,000 years) fluvial processes have largely shaped topography and surface geology along the Skagit River (Figure 4).

During the Pleistocene, continental ice sheets advanced from Canada at least six times (Clague and James, 2002). Thick deposits of glacial and non-glacial sediments were deposited during and between the repeated glacial advances across the Puget Sound basin. During the last glaciation (Vashon Stade), continental ice moved eastward, up the Skagit Valley, damming the Skagit River. Lake, outwash, and till deposits form a thick fill in the vicinity of the Lower Baker Valley (Heller, 1978). As the Vashon ice sheet thinned and retreated, marine water flooded the lowland, floating the remaining ice. The retreating glacier carried sand and gravel that intermixed with marine silt and clay.

Since deglaciation, the Skagit River has built a broad, deltaic alluvial plain from Blanchard Mountain on the north, Fidalgo Island on the west, and Camano Island on the south. Holocene alluvium primarily consists of interbedded channel, overbank, and lake deposits. Skagit River channel deposits consist primarily of sand and gravel that were deposited in a relatively high-energy environment. Overbank sediment is deposited when the Skagit River floods beyond its bank, spreading sediment-laden water over the delta and depositing silt, fine sand, and organics in a low-energy environment. Sediment deposited in quiet-water environments such as lakes, estuaries, and marshes primarily consist of silt, clay, fine sand, and organic material. Fill may overlie native sediment, and is commonly encountered near developed areas. Holocene deposits can be in excess of 100 feet thick in the Skagit Valley.

Isolated bedrock outcrops are present locally within the valley, including on the right bank of the North Fork Skagit River near Rexville. Bedrock constrains channel migration east of Hamilton.

4.2 Foundation Conditions

The USACE provided Shannon & Wilson, Inc. with subsurface information to assist in our evaluation of the Skagit River foundation conditions. These borings are located along the North and South Forks of the Skagit River and upstream along the main stem Skagit River to northeast Burlington, Washington. Approximate boring locations are shown in Figures 3 and 4. These explorations include:

- Two hundred fourteen (214) explorations by the USACE drilled between 1964 and 1979.
- Twelve (12) borings drilled by Harry R. Powell and Associates in 1956 for the North Fork of Skagit River Bridge near Rexville, Washington.
- Twenty-eight (28) borings and eleven (11) CPTs by Golder in April and May 2009, near the right bank of the Skagit River in Burlington, Washington.

The following provides a synopsis of subsurface conditions encountered in the borings and CPTs. The descriptions are divided into three subsections: South Fork Skagit River, North Fork Skagit River, and Main Stem Skagit River.

South Fork Skagit River from Skagit Bay to the divergence from the main stem Skagit River. Based on the borehole logs reviewed along the South Fork Skagit River, the sediments underlying the levee system generally consist of trace of fine sand to fine sandy silt and trace of silt to silty, fine sand with clay interbeds. Scattered peat deposits and wood fragments, along with shell fragments, were found near the river mouth. Gravel layers with scattered cobbles were encountered in isolated borings. The soil conditions are consistent with sediment deposited in a fluvial delta environment.

North Fork Skagit River from Skagit Bay to the divergence from the main stem Skagit River. Boreholes along the North Fork Skagit River were advanced both on land and over water. On land, foundation soils are similar to the South Fork. These deposits are generally characterized as interbedded trace of silt to silty sand and trace of sand to sandy silt with scattered clay layers. Scattered shells and wood fragments were encountered in isolated borings. Borings advanced in the river channel encountered interbedded silt and sand, and at the downstream levee extent they encountered thick deposits of trace of silt to silty gravel. The soil conditions are consistent with sediment deposited in a fluvial delta environment.

On the right bank, borings completed in 1956 for the North Fork of Skagit River Bridge near Rexville, Washington, and borings 78-WB-59, 78-WB-61, and 78-WB-62 encountered bedrock.

Explorations show that depth to bedrock increases to the southeast along the bridge alignment. Bedrock outcrops near the northwest abutment but was not encountered in borings drilled to 115 feet bgs at the southeast abutment. In the North Fork Skagit River Bridge borings and boring 78-RD-121, the bedrock was found to be overlain by gravelly clay. This gravelly clay unit represents glacial marine sediment, deposited during the retreat of the Vashon glacier.

Main Stem Skagit River from the North and South Fork divergence to the intersection of State Route 20 and Lafayette Road. We reviewed borehole logs along the main stem Skagit River that were drilled both on land and within the river. On land, borings encountered fill, quiet water deposits, overbank deposits and channel deposits. Near Burlington, fill ranged from about 2 to 5 feet thick and up to 25 feet thick near levees and roads. Fill generally consists of a mixture of sand, silt, and gravel. Channel and overbank deposits dominated the foundation soils. Explorations typically encountered overbank deposits overlying, and interbedded with channel deposits. Overbank deposits ranged from silt to fine sandy silt. Channel deposits typically included trace of silt to silty sand with slightly silty gravel layers. Clay and silt quiet-water layers were commonly interbedded with channel and overbank deposits. Scattered wood fragments and organics were found in sand, silt, clay and gravel. No bedrock was encountered along this reach.

Borings advanced in the river channel primarily encountered sand and gravel with a trace of silt to approximately 19 to 20 feet bgs. Below 19 to 20 feet, deposits transition to organic silt, clayey silt, and sandy silt. The shift from fine-grained material at the bottom of the borings to coarse material at the top represents a transition from overbank- and flood-dominated sedimentation to high-energy channel deposition. All borings drilled in the channel were located on the riverbend between the intersection of Riverbend Road and Freeway Drive, and near the intersection of West Hazel Street and South 1st Street.

In March 2009, Golder compiled existing data for a preliminary geotechnical report along an approximate 5-mile-long levee section on the right bank of the Skagit River, adjacent to the city of Burlington. Included in the report were borings from the USACE 1979 General Design Memorandum. Golder described the sediments underlying the levee as discontinuous layers of sand and sandy silt, with zones of silt, clay, and peat. Gravel layers were encountered in deeper borings. Scattered wood and organics were common in the explorations. The explorations they reviewed preceded recent levee construction by Dike District 12. Therefore, Golder did not consider the explorations to be a reliable source of information for levee soils and completed a new set of explorations during April and May 2009. The soil layers encountered in the more recent explorations are generally consistent with other nearby explorations.

4.3 Levee Material

Early settlers in the area individually constructed dikes to protect their holdings. During the late 1890's Dike Districts were formed and by 1963, levees had been constructed from the cities of Burlington and Mount Vernon to Skagit Bay. In general, the existing levee material consists of very loose to medium dense, clean to silty, fine to medium sand and slightly sandy to sandy silt. Occasional to numerous organics were locally identified. Coarser grained material consisting of silty sandy gravel, rock spalls, and cobbles were used at select locations for levee repairs. County and maintenance roads were constructed on portions of the levee crest and were about ½ to 2½ feet thick at the time of exploration. The roadway material consists of loose to medium dense, silty sandy gravel and 2-inch minus crushed rock.

The 1979 General Design Memorandum identifies levees at the time of exploration as ranging from 4 to 27 feet in height. Explorations for the memorandum were conducted along both river banks from Burlington and Mount Vernon to Skagit Bay. The average levee height for this region at that time was about 10 feet.

The 2009 Golder Geotechnical Investigation and Levee Analysis report identifies levees along the right bank of the Skagit River, adjacent to the city of Burlington, to range from 2 to 24 feet in height. Explorations in the same area completed for the 1979 General Design Memorandum revealed the levee to range from 5 to 16 feet in height. Based on these reports, the average levee height along the right bank of the Skagit River, adjacent to the city of Burlington, was about 8 feet in 1979 and about 11 feet in 2009.

The majority of boring logs reviewed for this study are from explorations conducted prior to levee improvements performed along the levee system. Therefore, much of the information provided from these borings may not be representative of the present-day levee soil conditions.

4.4 Groundwater Conditions

Groundwater was encountered in many of the boring logs reviewed for this study. Based on these records, the depth to groundwater was inferred from (a) the soil moisture classification descriptions, (b) the depth to groundwater indicated during drilling, and (c) the groundwater levels measured in observation wells. During subsurface explorations conducted between 1965 to 2009, groundwater was observed from 0 to 22 feet below the native ground surface.

Golder installed piezometers in eight of borings completed in April 2009. Between mid-April and mid-May 2009, the groundwater levels were observed to fluctuate up and down within a range of about 1.3 to 3.2 feet. Sand is a dominant foundation soil between northeast Burlington and Skagit Bay, and can be expected to have high permeability. Groundwater levels likely fluctuate with daily and seasonal variations of the Skagit River stages.

The United States Geological Survey maintains and operates a water level gauge along the right bank of the Skagit River at River Mile 15.7, approximately 220 feet downstream of the bridge at U.S. Highway 99. The gauge is designated 12200500, and located at latitude 48°26’42” and longitude 122°20’03” (NAD27). The gauge datum is based on NGVD29. Water levels and discharge rates have been recorded and published since October 1940. Based on these records, the maximum discharge rate and river elevation were observed on November 25, 1990, at 152,000 cubic feet per second and 37.37 feet, respectively. The minimum discharge rate and river elevation were observed on October 26, 1942, at 2,740 cubic feet per second and 7.37 feet, respectively.

5.0 DISCUSSION

The majority of the information collected identifies levee geometries and proposed erosion protection measures for the lower 30 miles of the Skagit River, downstream from the city of Sedro-Woolley. The information documented in Sections 3.2 through 3.4 provides historical information on past flood damages, proposed repairs, changes in levee and river geometry, and the anticipated level of flood protection along discrete levee sections. Much of the information gathered may have been superseded by subsequent flood events and temporary or permanent repairs. In some cases, repairs could have been made during or after the floods by local communities or jurisdictions with no record of the work. Additionally, for those areas identified in Section 3.2, no construction information was available to confirm the repairs or that the work was completed in accordance with the presented plans. However, this information is useful for identifying high risk areas and prioritizing future work.

The information documented in Section 3.1 provides a general understanding of the site geology along the lower 30 miles of river. The subsurface information reviewed provides a basis for future studies, but with the exception of the 4.6 miles adjacent to the city of Burlington, does not provide the level of detail required to meet USACE standards for geotechnical and hydrogeologic stability assessments. The explorations performed for the 1979 General Design Memorandum were spaced at approximately 2,000-foot intervals along the proposed alignment. According to the April 2000, U.S. Army Corps of Engineers Design and Construction of Levees Engineer Manual, subsurface explorations should be spaced every 200 to 1,000 feet along the alignment. Laboratory testing was minimal and used primarily to confirm visual soil classifications. Hydrogeologic and geotechnical stability analyses would require additional laboratory testing, including soil index tests, strength tests, and hydraulic conductivity tests, as well as groundwater level monitoring from observation wells. The 1979 Design Memorandum indicates difficulty during power auger and hollow-stem power auger drilling below the water table. Caving and water pressure led to sloughing and loose soil at the bottom of the boreholes. Soil samples and SPT results from such borings would not be representative of in situ soil conditions given these circumstances.

6.0 CONCLUSIONS

Except for the recent work along 4.6 miles of levee adjacent to the city of Burlington, the available foundation and levee composition information along the Skagit River is not adequate to prioritize where levee improvements are most needed. The subsurface information collected by the USACE provides background information that will assist in the development of an exploration program for levee characterization, but it is our opinion that the provided information is outdated and could prove misleading. Flooding and repair along the levees since the explorations likely have resulted in changed ground conditions by loosening the soil, altering the levee geometries, and changing the levee composition.

Additionally, no comprehensive assessment of the levee and its protective measures was available for review. Updated information such as the current levee geometry, levee and foundation composition and consistency, erosion protection, and seepage control measures are necessary to perform geotechnical and hydrogeologic seepage and stability assessment of the levee system. Observations of sloughing, cracking, undermining, piping, sand boils, depressions, sinkholes, settlement, vegetation, animal burrows, and buried objects (i.e., logs and stumps) help to identify critical areas along the levee and prioritize those areas for repair and flood reduction construction.

7.0 LIMITATIONS

This report was prepared for the exclusive use of the USACE. It should be considered factual data only and not as a warranty of surficial or subsurface conditions. The interpretations and conclusions contained in this report are based on the referenced site information as they existed during the preparation of each identified document. Changed conditions may exist at or near the site due to natural forces or construction since each documents inception.

Within the limitations of the scope, schedule, and budget, the interpretations and conclusions presented in this report were prepared in accordance with generally accepted professional geotechnical engineering principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied.

The scope of our services did not include any environmental assessment or evaluation of hazardous or toxic materials in the soil, surface water, groundwater, or air at the subject site. Shannon & Wilson, Inc. has qualified personnel to assist you with these services should they be necessary.

Shannon & Wilson, Inc. has prepared an Appendix, "Important Information About Your Geotechnical Report," to assist you and others in understanding the use and limitations of our report.

SHANNON & WILSON, INC.

Jennifer Parker

Jennifer K. Parker
Geologist

Brian S. Reznick

Brian S. Reznick, P.E.
Principal Engineer

JKP:BSR:DNC/bsr

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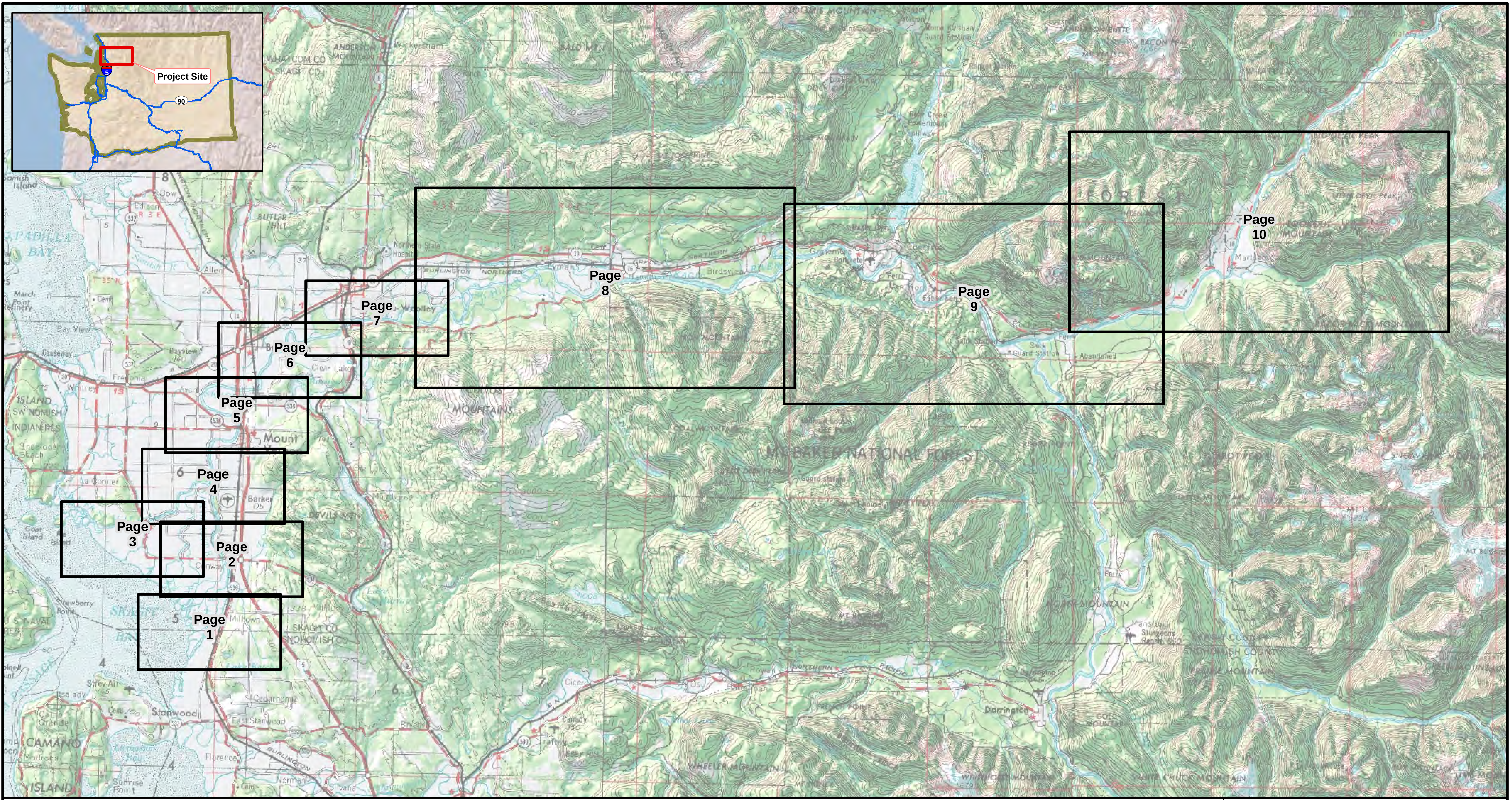

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Skagit River Levee General Investigation
Skagit County, Washington

VICINITY MAP

January 2011 21-1-21199-001

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FIG. 1

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HISTORICAL EXPLORATIONS & PROJECT FEATURES

(Figures 3 and 4)

◐	USACE (1979)	●	Pump Station	═	Gravity Drain
⌖	Landau Associates (2003)	★	Piezometer/Monitoring Well	—	Historical Dike Failures
◐	Golder Associates (2009)	△	Levee Relief Well	═	Levee
🟦	Golder Associates (CPT, 2009)	◆	Repairs	-·-	City Boundary
🔴	Shannon and Wilson (2000)	🔵	Factor of Safety is less than 1.4 for existing levee static slope stability (Golder Associates, 2009)	-··-	County Boundary
				▬	Repair Zones

GEOLOGIC UNITS

(Figure 4)

🟩	wtr - water
🟧	Qf - artificial fill, including modified land
🟧	Qa - alluvium
🟧	Qa(c) - alluvium, clay and silt
🟫	Qa(s) - alluvium, sand
🟫	Qta - talus deposits
🟧	Qp - peat deposits
🟨	Qls - mass-wasting deposits, mostly landslides
🟫	Qaf - alluvial fan deposits
⬜	Qvl(k) - lahars, Kennedy Creek assemblage
🟫	Qoa(s) - alluvium, older, sand facies
🟨	Qoa - alluvium, older
🟫	Qgo - continental glacial outwash, Fraser-age mostly Vashon Stade in western WA; unnamed in eastern WA
🟫	Qgo(e) - continental glacial outwash, Fraser-age Everson Interstade, outwash deposits of
🟫	Qgdm(e) - glaciomarine drift, Fraser-age Everson Glaciomarine Drift
🟧	Qgom(e) - continental glacial outwash, marine, Fraser-age Everson Glaciomarine Drift, outwash, marine
🟫	Qgt - continental glacial till, Fraser-age mostly Vashon Stade in western WA; unnamed in eastern WA
🟫	Qad - alpine glacial drift, Fraser-age
🟫	Qgd - continental glacial drift, Fraser-age
⬜	Qga - advance continental glacial outwash, Fraser-age mostly Vashon Stade in western WA; unnamed in eastern WA
🟨	Qgas - advance continental glacial outwash, sand, Fraser-age mostly Vashon Stade in western WA; unnamed in eastern WA
🟧	Qc(o) - continental sedimentary deposits or rocks Olympia-age nonglacial sediments
🟫	Qgpc - continental glacial drift, pre-Fraser, and nonglacial deposits
⬜	OEc(b) - continental sedimentary deposits or rocks
🟪	Ec(b) - continental sedimentary deposits or rocks, Barlow Pass Volcanics
🟪	Ec(cb) - continental sedimentary deposits or rocks, Bellingham Bay Member
🟪	Ec(c) - continental sedimentary deposits or rocks, Chuckanut Formation
⬛	OEn(b) - nearshore sedimentary rocks
🟪	Evr - rhyolite flows
🟩	Oigd(md) - granodiorite
🟦	Kog(c - orthogneiss
🟪	TKog(s) - orthogneiss, Skagit Gneiss
🟦	Jph(d) - phyllite, low grade,Darrington Phyllite
🟦	Jsh(s) - schist, low grade, Shuksan Greenschist
🟪	TRPMhmc(n) - heterogeneous metamorphic rocks, chert bearing Napeequa unit, Chelan Mtns. terr., Napeequa Schist
🟪	TRPMu(n) - ultrabasic rocks Napeequa unit, Chelan Mountains terrane
🟪	TRhm(cc) - heterogeneous metamorphic rocks Cas. Riv. unit, Chelan Mtns. terr., Cas. Riv. Schist
🟪	TRiq(m) - quartz diorite Marblemount Meta-Quartz Diorite, Chelan Mts. terrane
🟫	MZPZigb - gabbro
🟧	MZPZms(r) - metasedimentary rocks
🟨	MZu(h) - ultrabasic rocks
🟫	PMDmb(c) - marble
🟩	PMDms(c) - metasedimentary rocks
🟩	PMDmv(c) - metavolcanic rocks
🟩	pDi(y) - intrusive rocks, undivided Yellow Aster Complex of Misch (1966)

NOTES

1. Historical explorations provided by General Design Memorandum Levee Improvements Vol. 2 of 2 July 1979; Preliminary Geotechnical Evaluation City of Burlington and Dike District 12 Levee Certification; and Geotechnical Investigation and Levee Analysis City of Burlington and Dike District 12 Levee Certification.
2. Pump station, levee relief well, levee centerline and gravity drain features provided by GIS from the USACE Seattle District.
3. Geology from the Washington State Department of Natural Resources, GIS data Surface Geology, available: http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/gis_data.aspx, accessed 2009.
4. In Figure 4, geologic units are displayed within a 3,500 ft buffer of the Skagit River and the surrounding levees.

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LEGEND

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FIG. 2

NOTE

See Figure 2 for legend and references.

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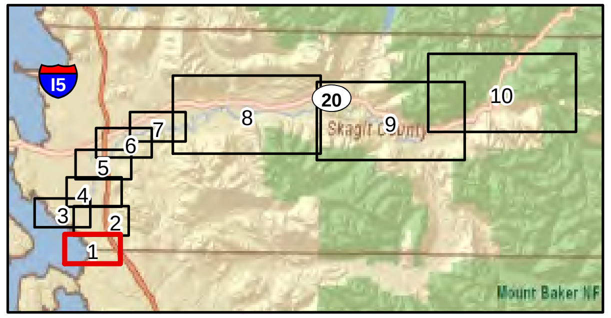

Skagit River Levee General Investigation
Skagit County, Washington

PROJECT FEATURES AND HISTORICAL EXPLORATIONS

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FIG. 3
Sheet 1 of 10

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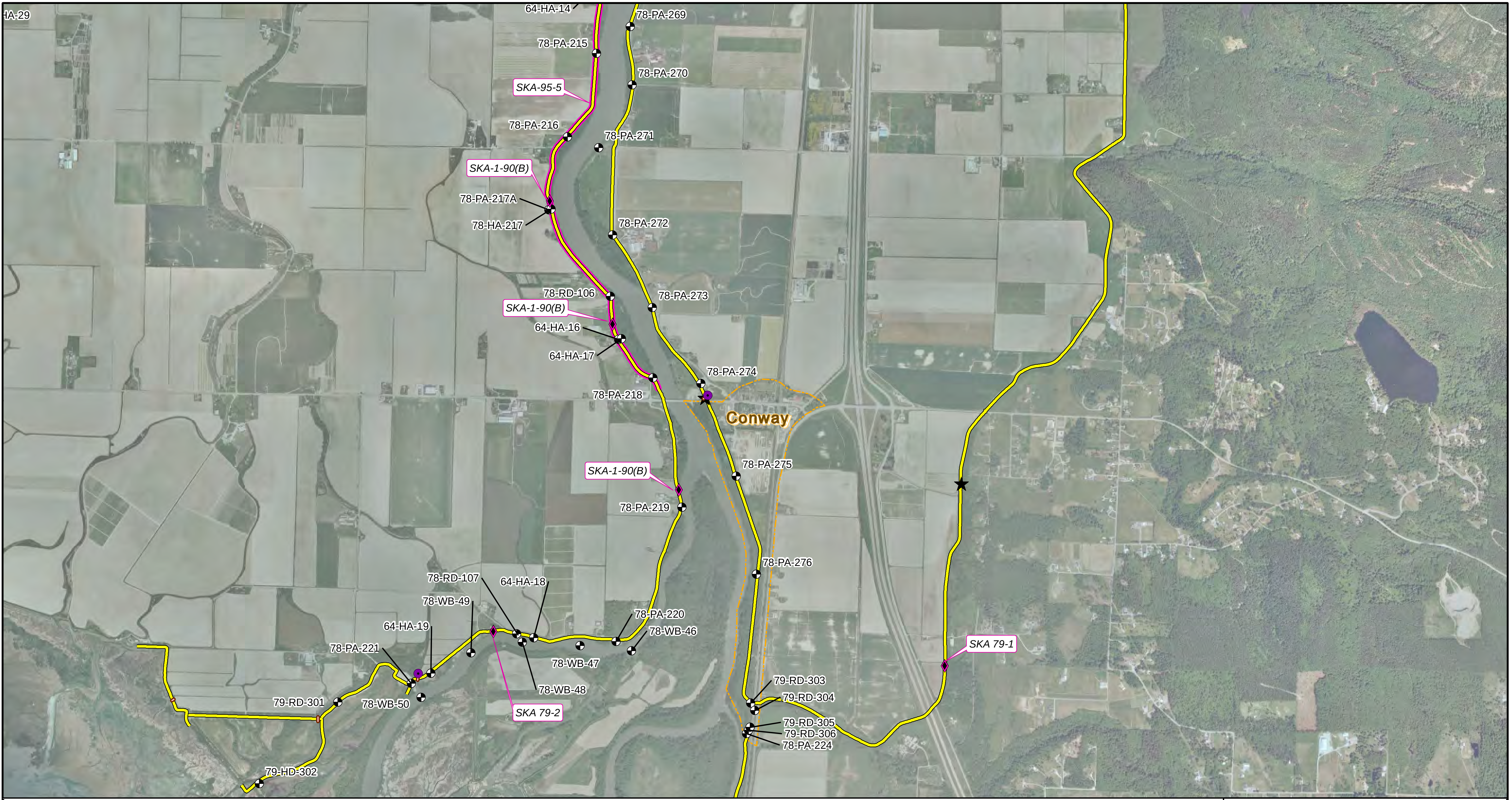

NOTE

See Figure 2 for legend and references.

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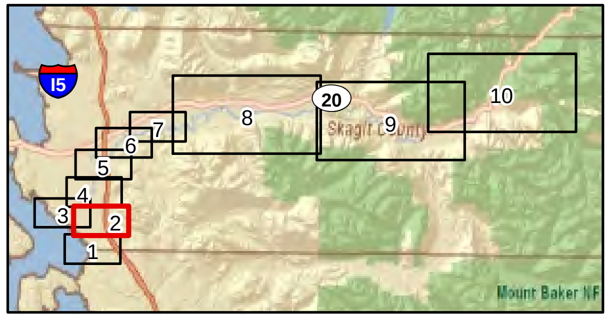

Skagit River Levee General Investigation
Skagit County, Washington

PROJECT FEATURES
AND HISTORICAL EXPLORATIONS

January 2011 21-1-21199-001

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FIG. 3
Sheet 2 of 10

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NOTE

See Figure 2 for legend and references.

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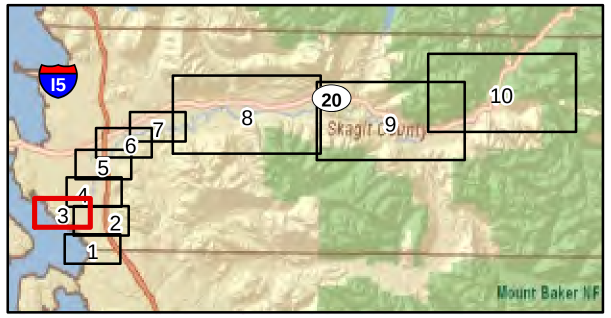

Skagit River Levee General Investigation
Skagit County, Washington

PROJECT FEATURES AND HISTORICAL EXPLORATIONS

January 2011
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FIG. 3
Sheet 3 of 10

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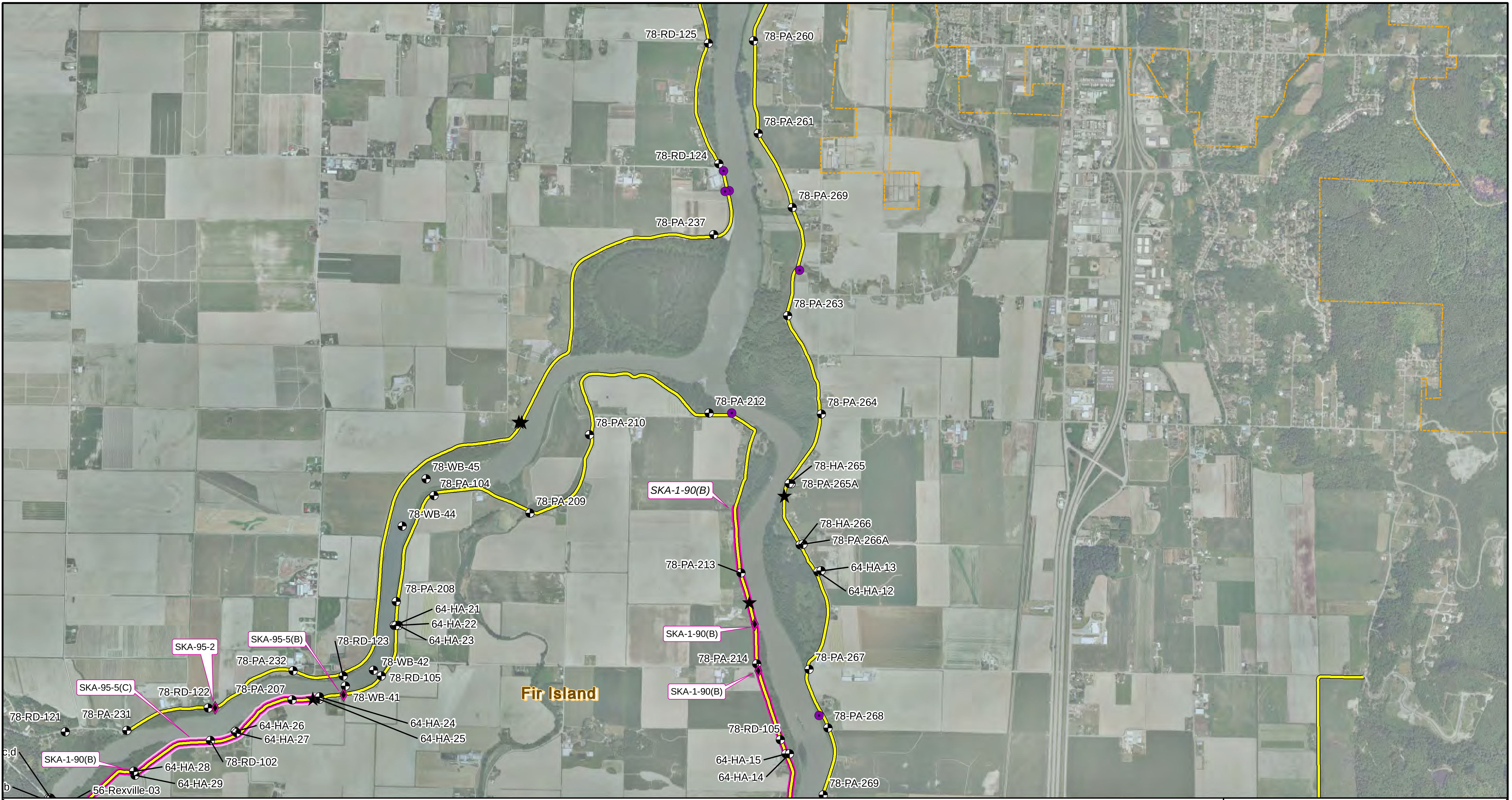

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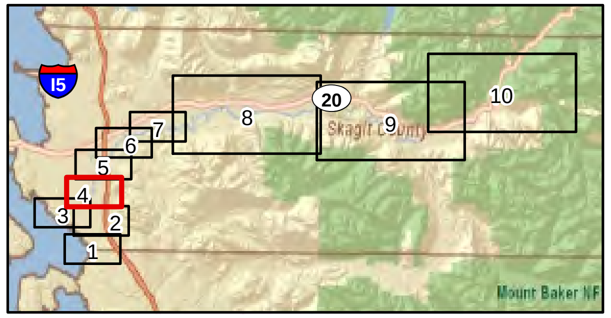
NOTE

See Figure 2 for legend and references.



Skagit River Levee General Investigation
Skagit County, Washington

PROJECT FEATURES AND HISTORICAL EXPLORATIONS

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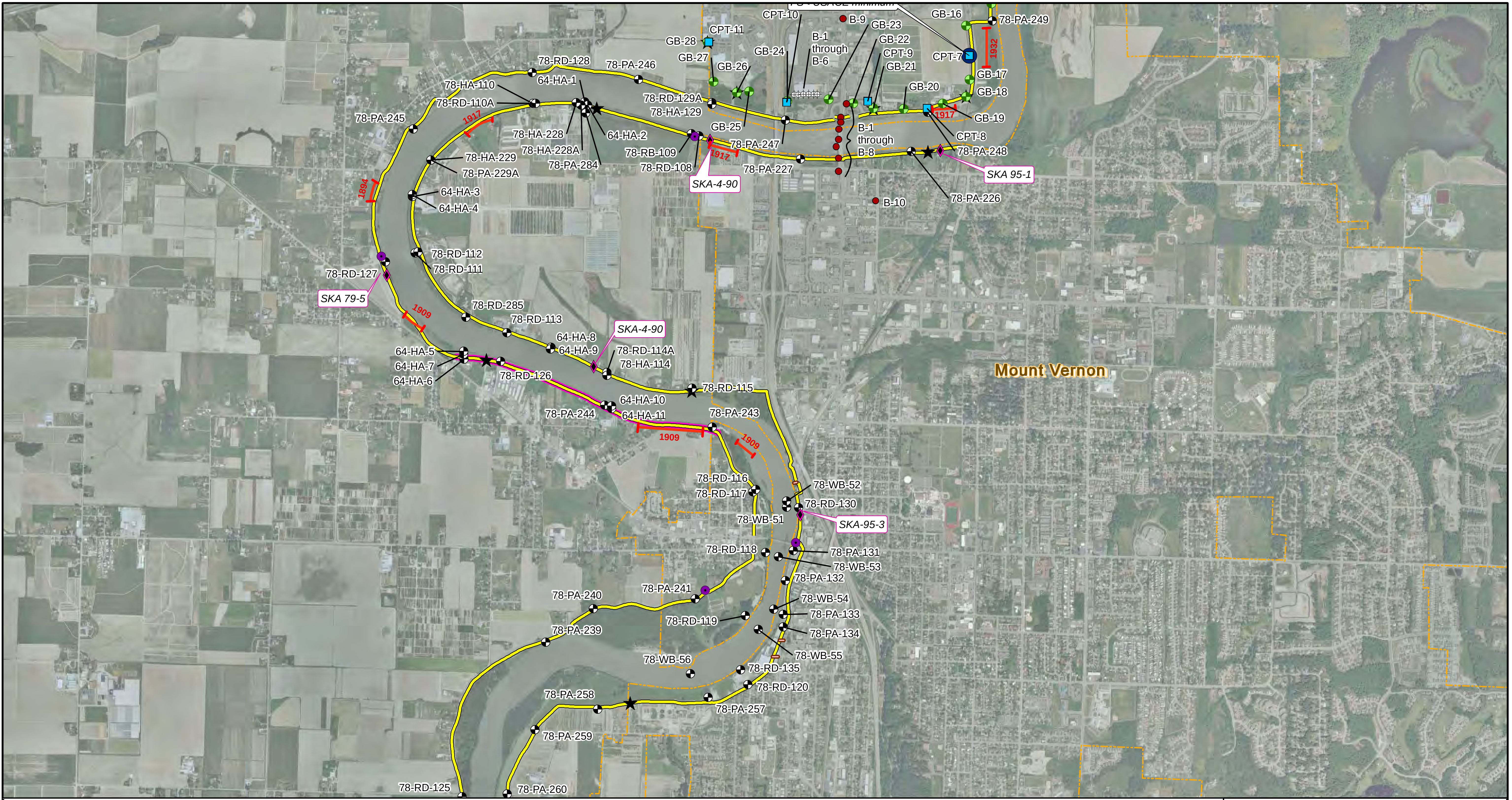
SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3
Sheet 4 of 10



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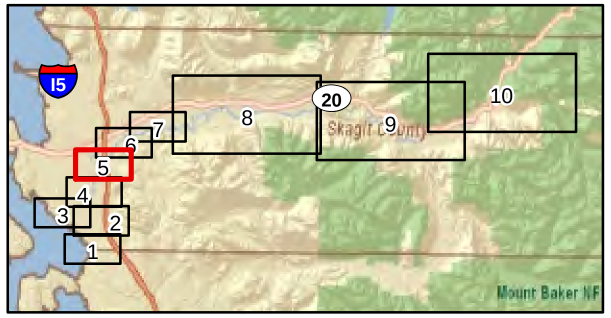

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FIG. 3
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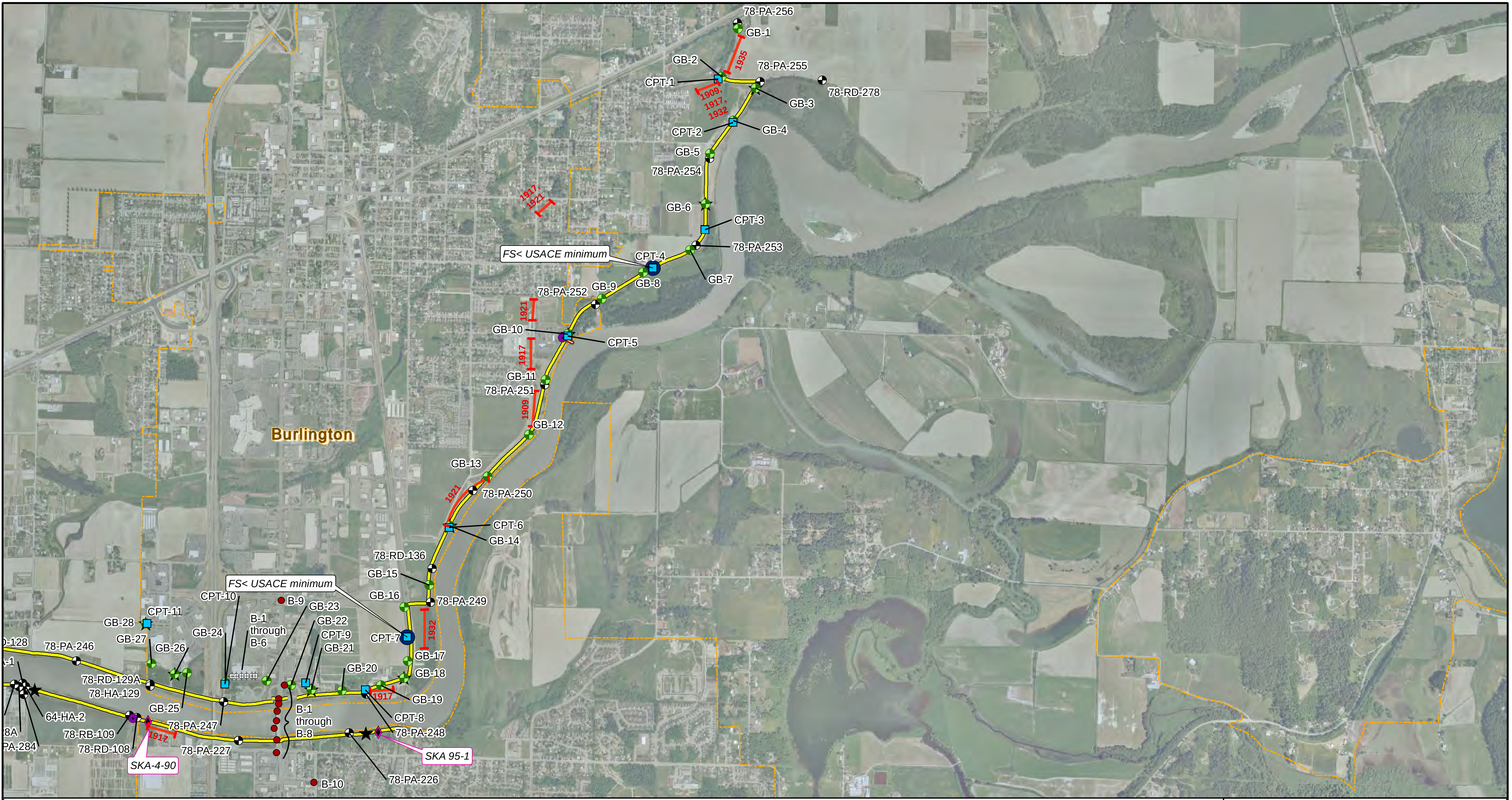

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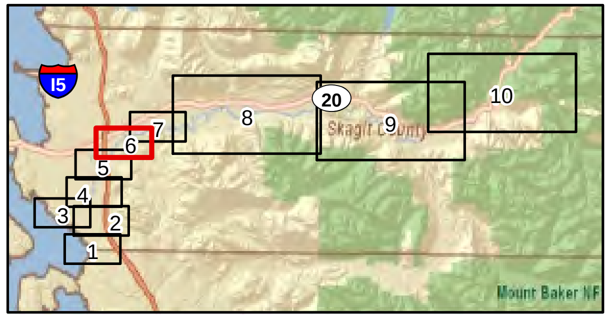

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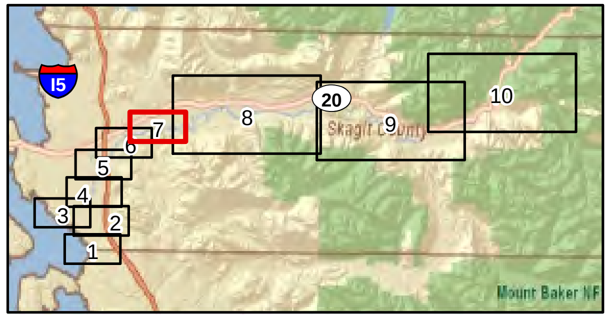

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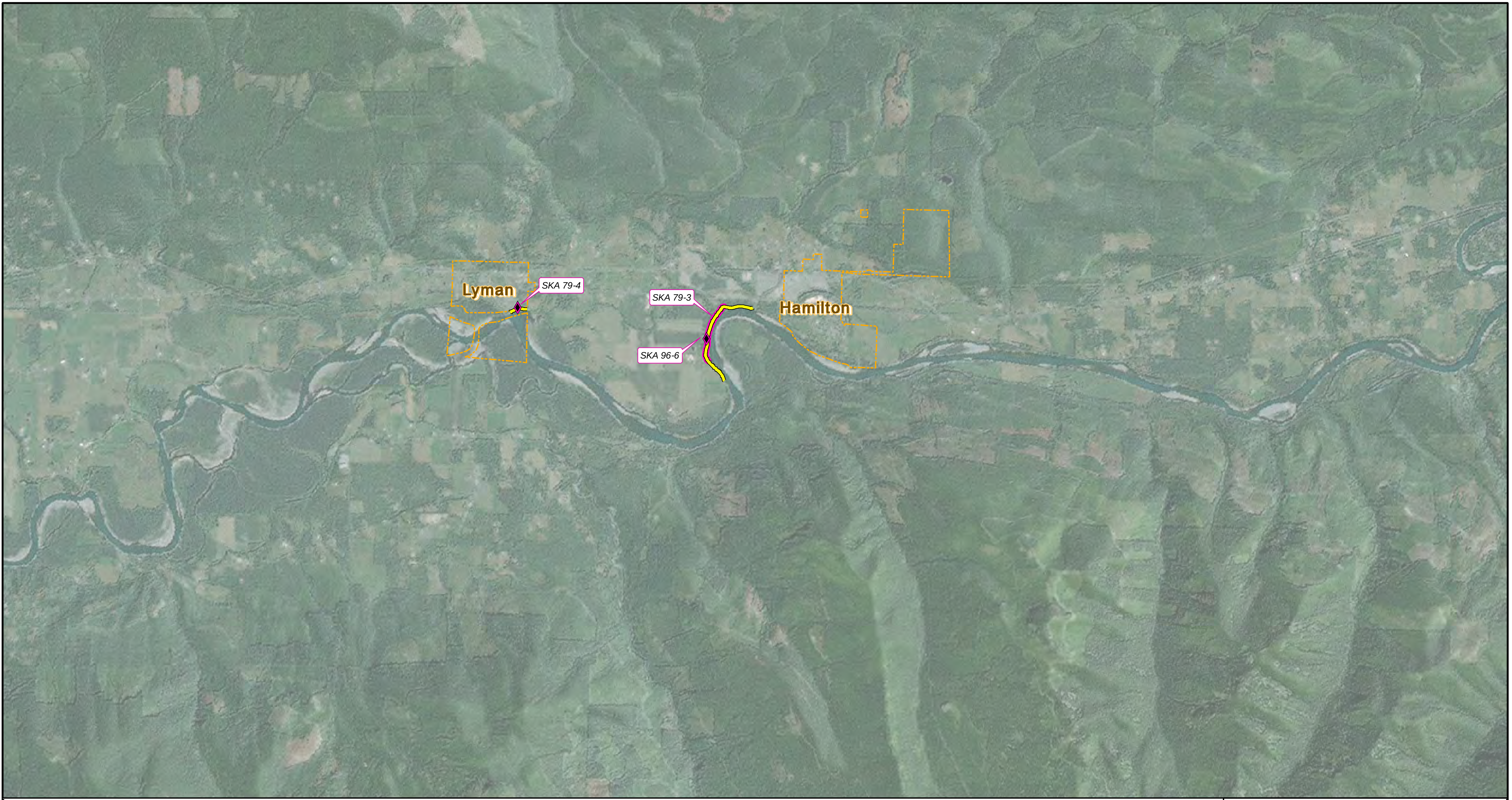

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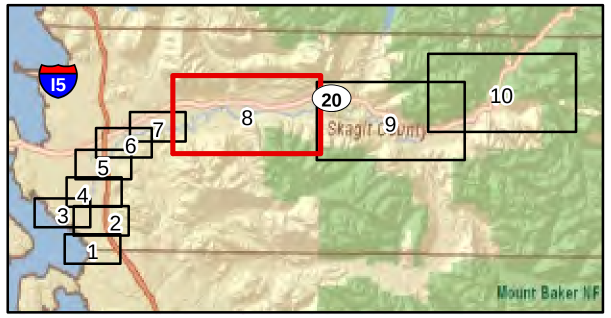

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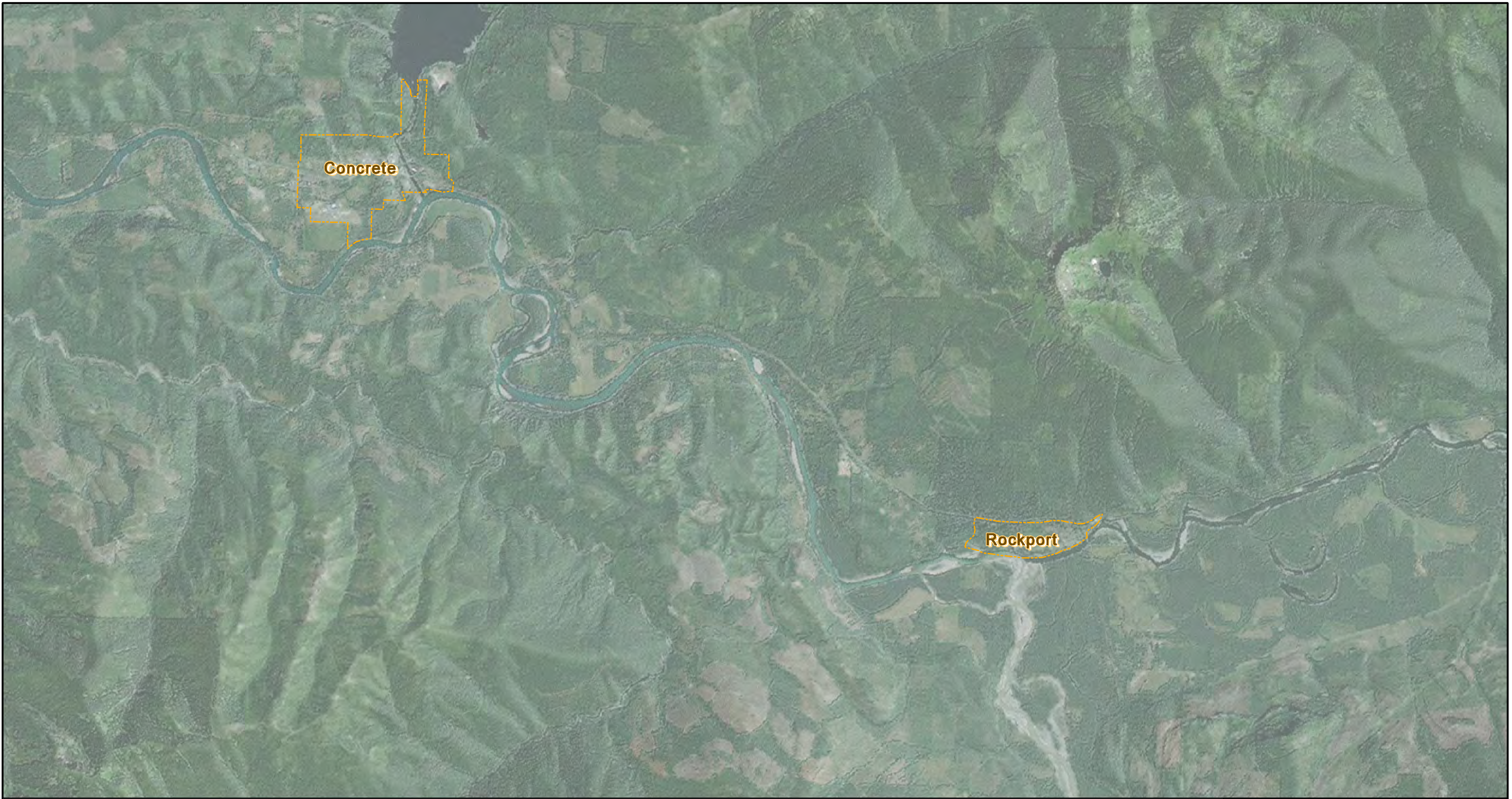

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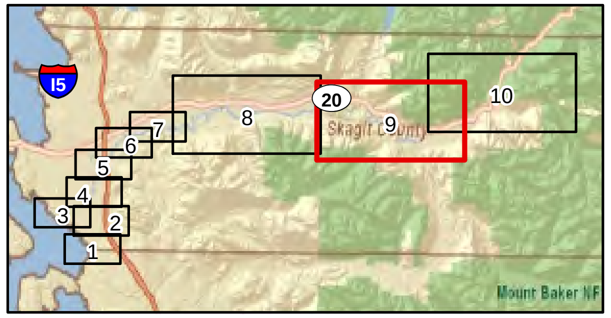

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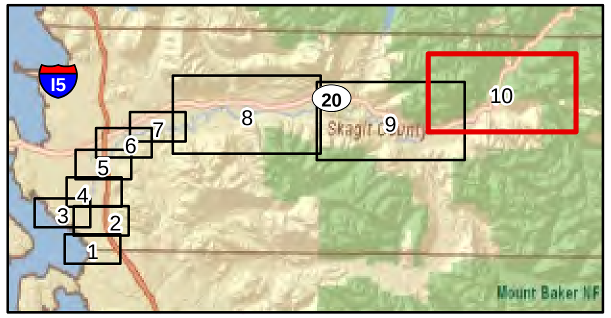

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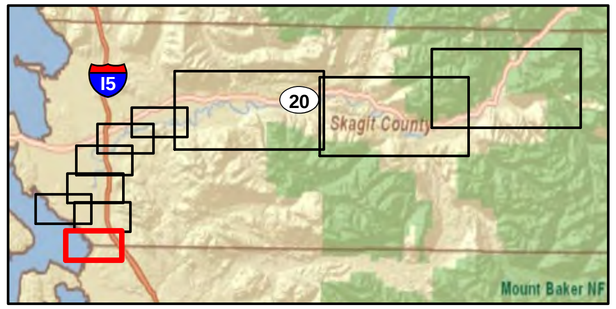

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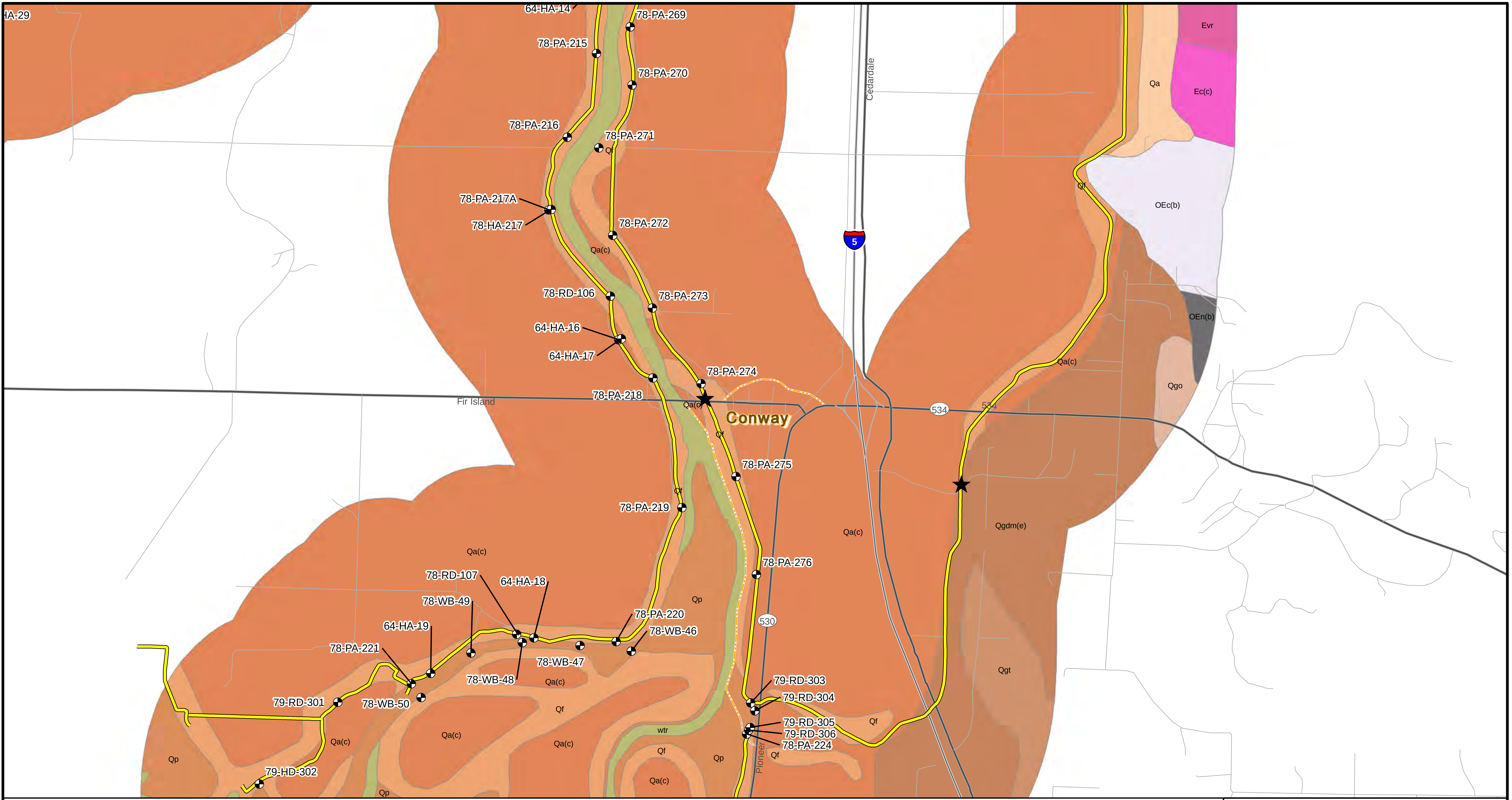

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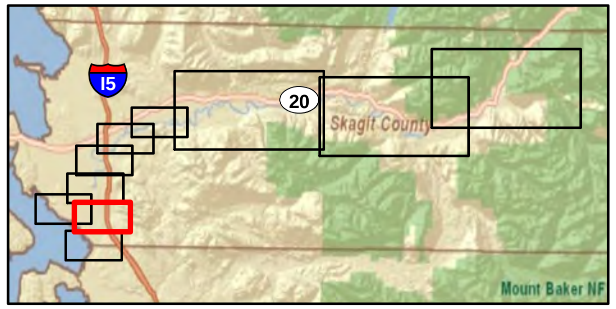

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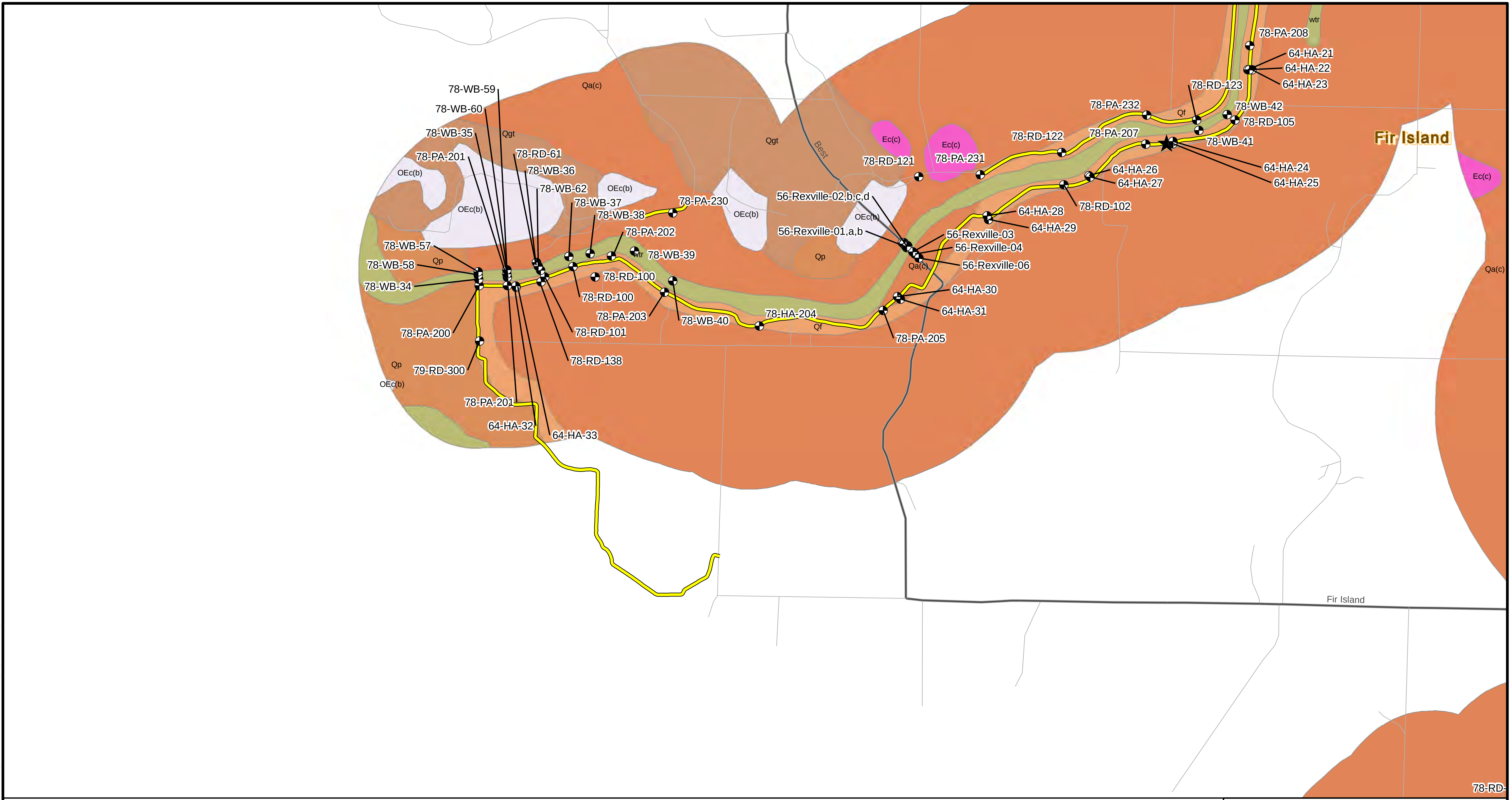

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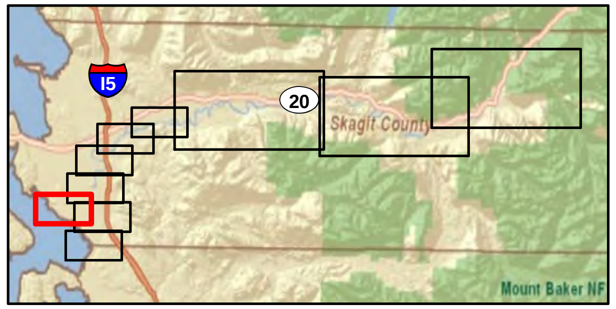

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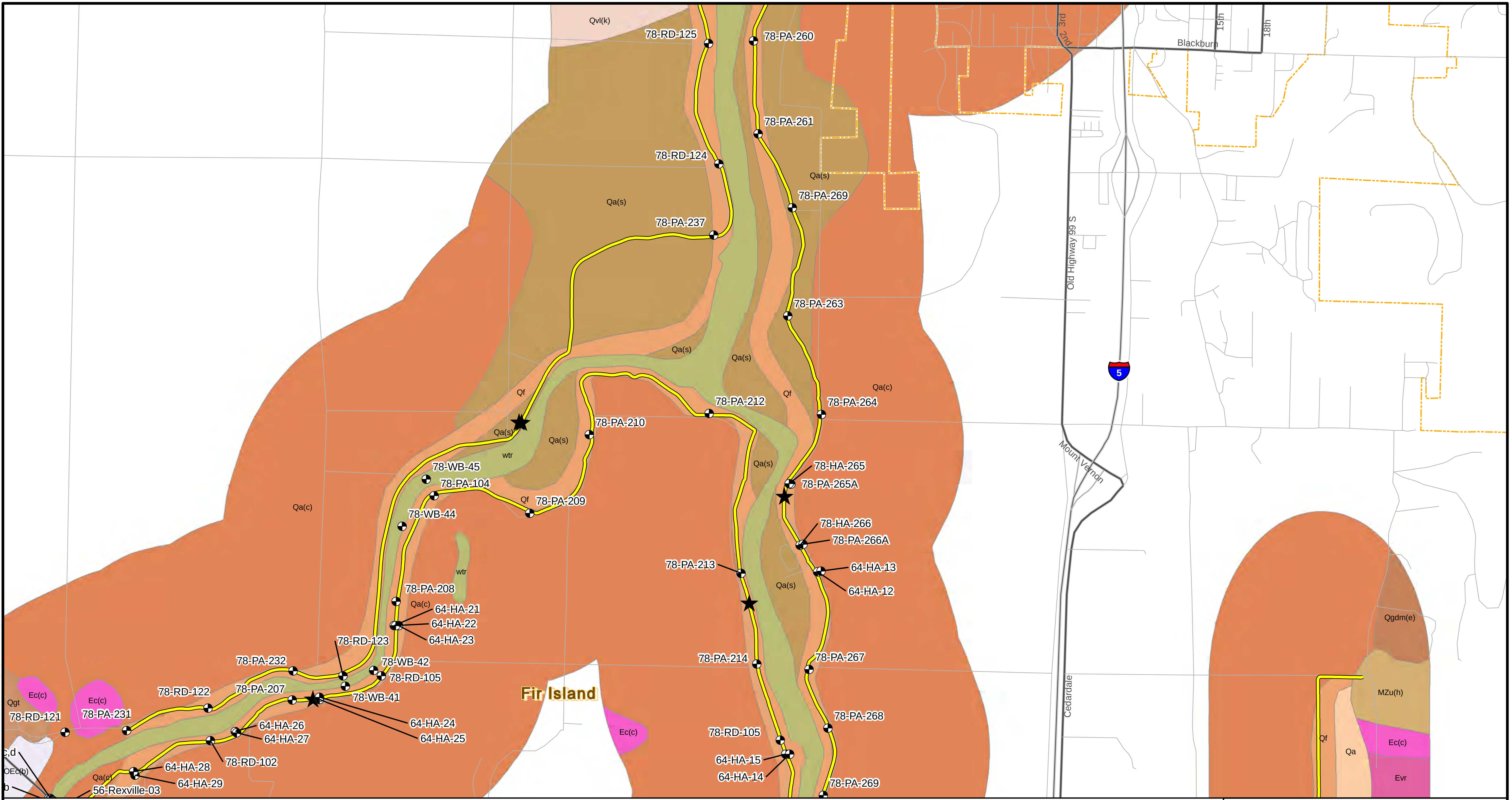

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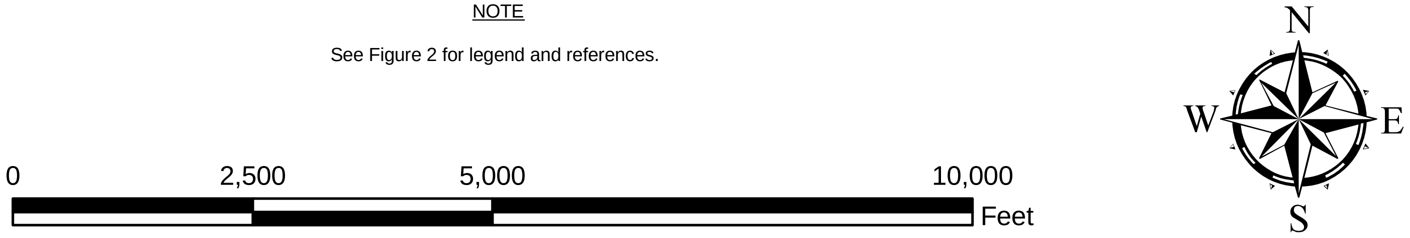

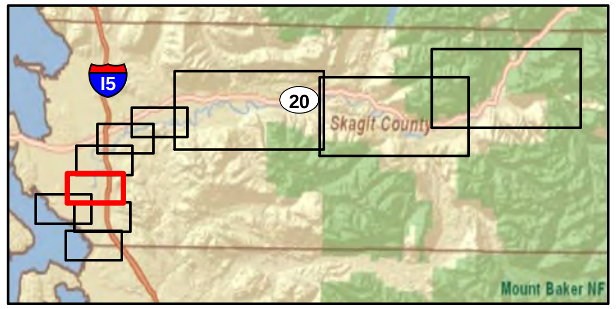

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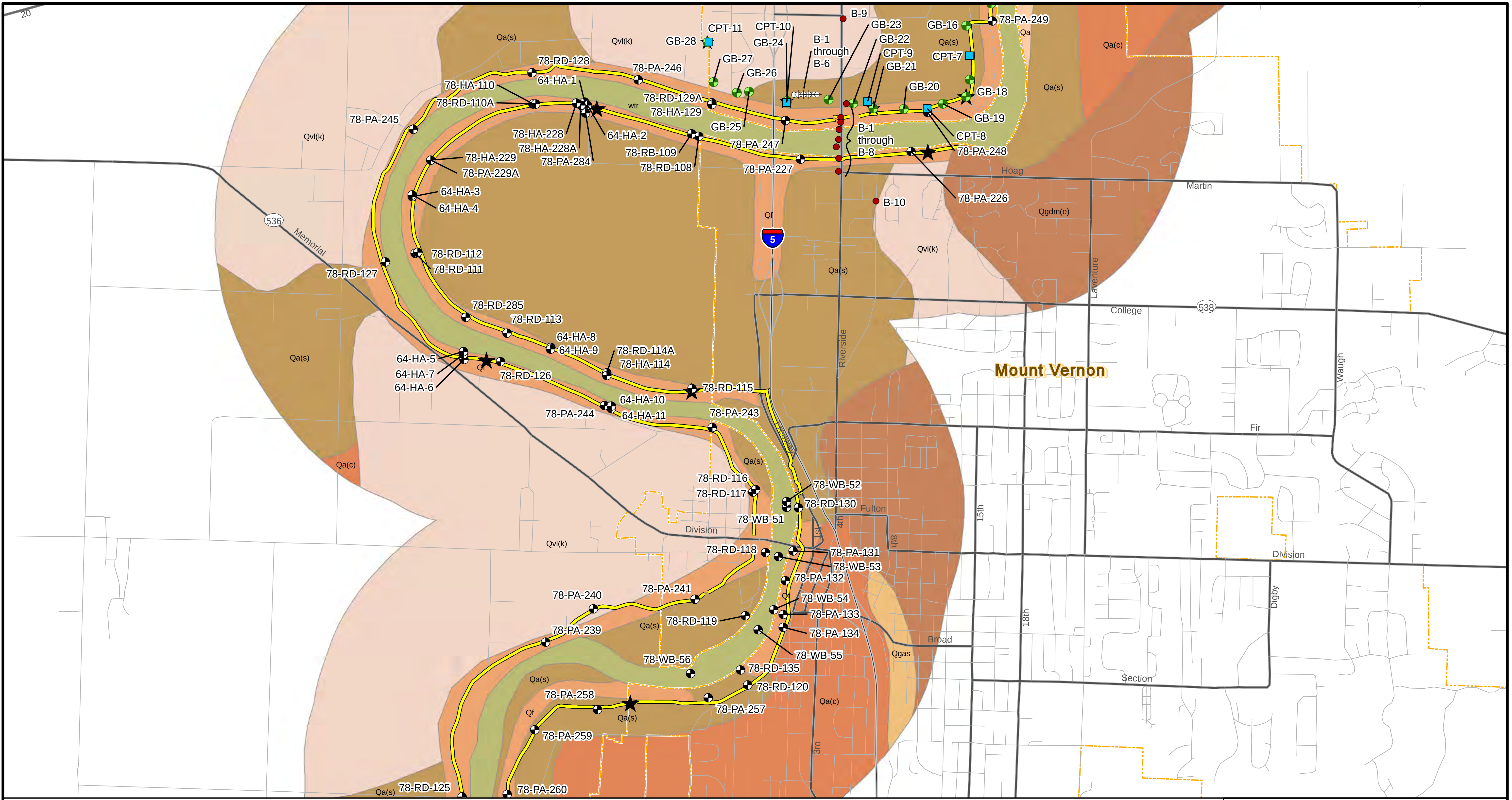

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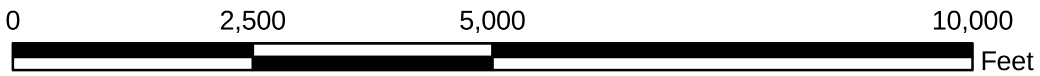

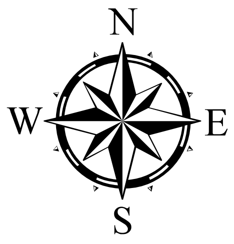

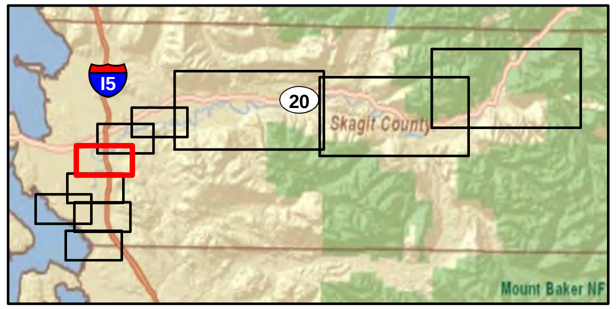

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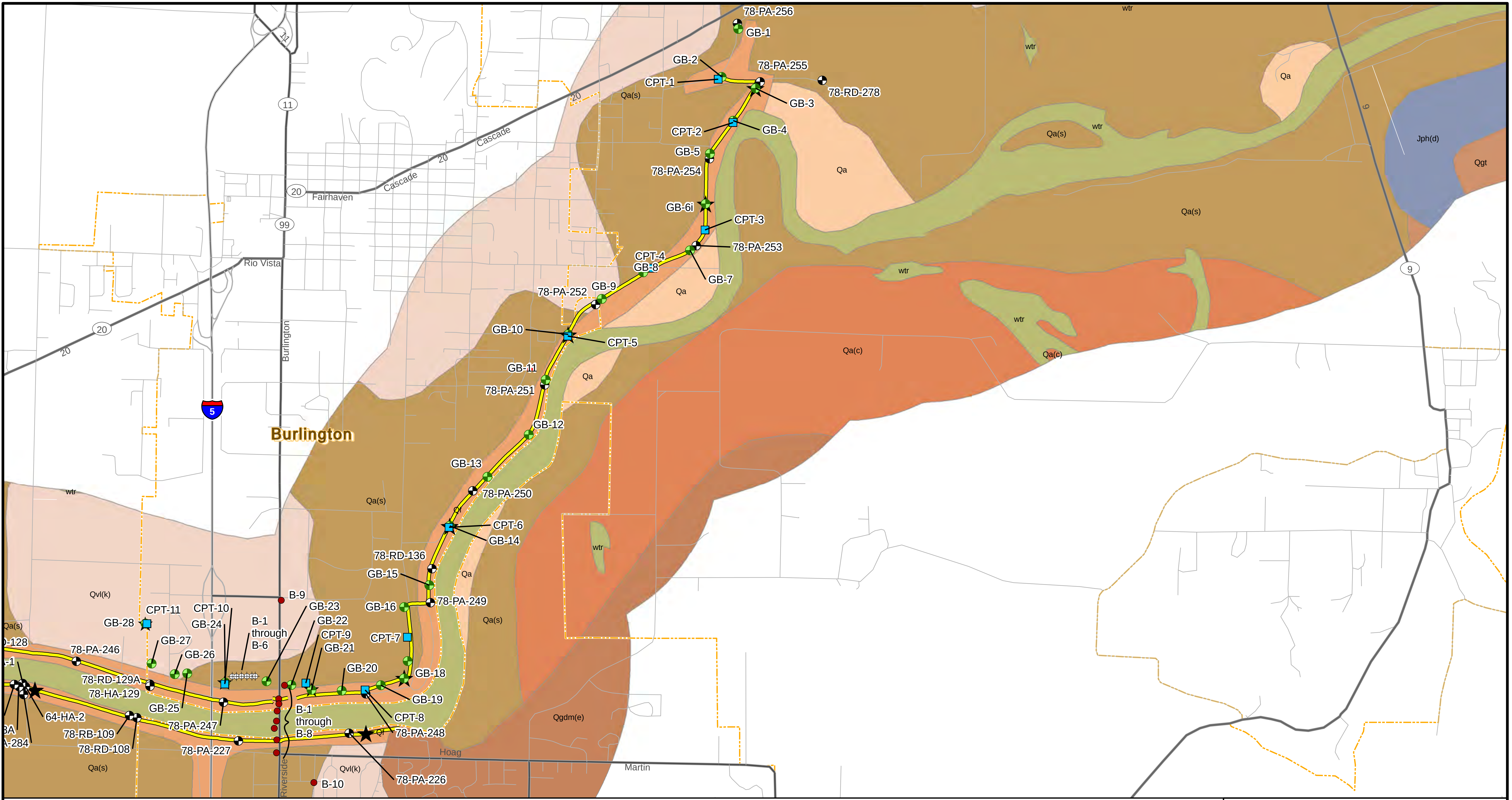

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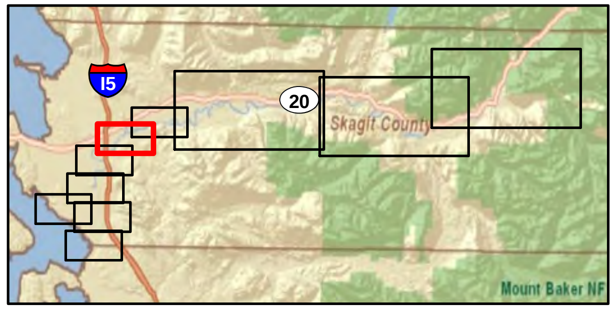

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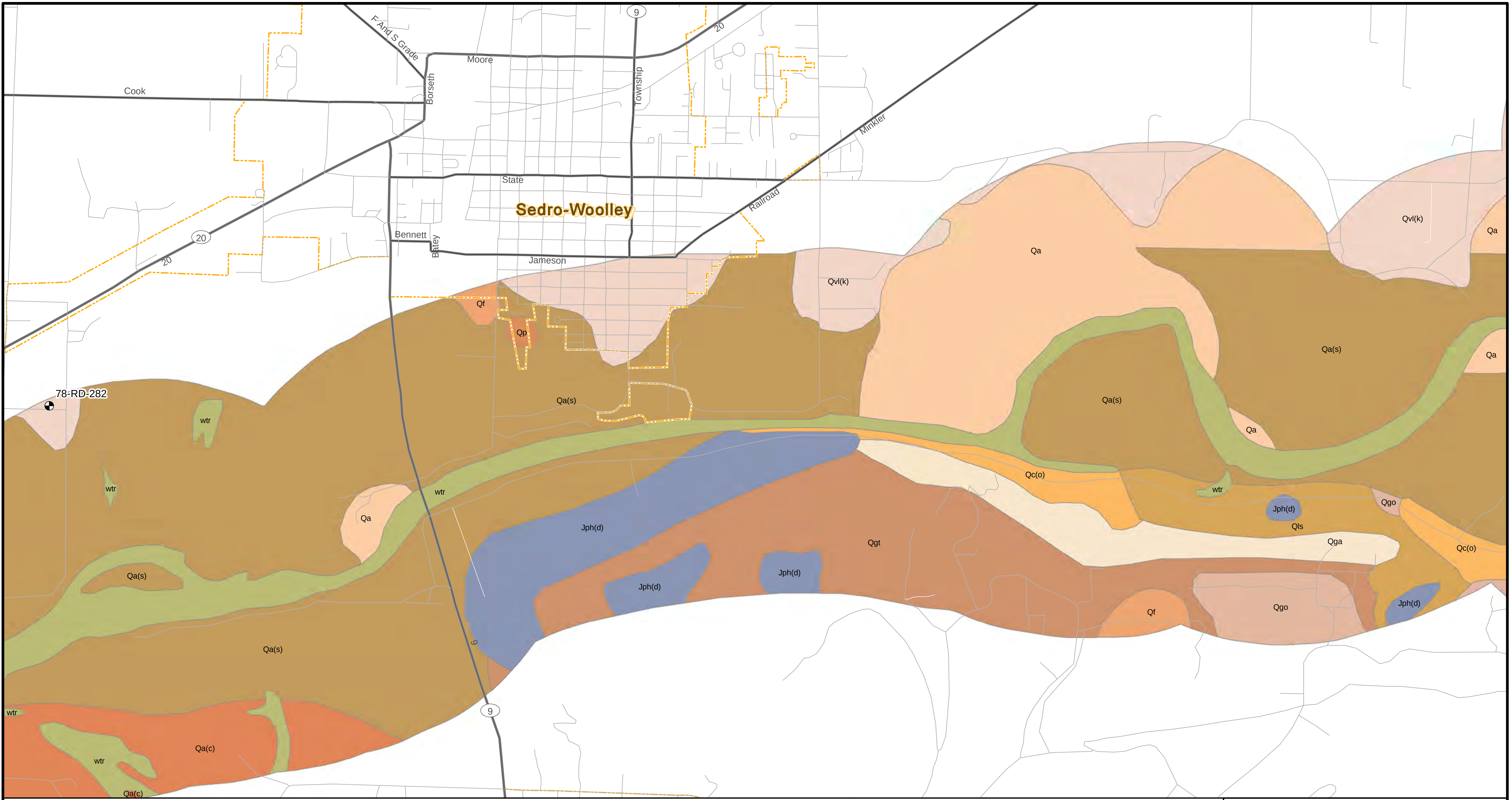

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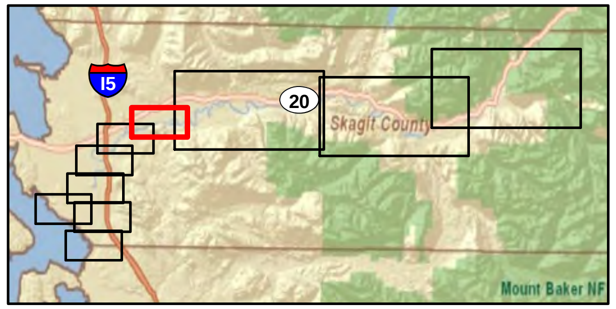

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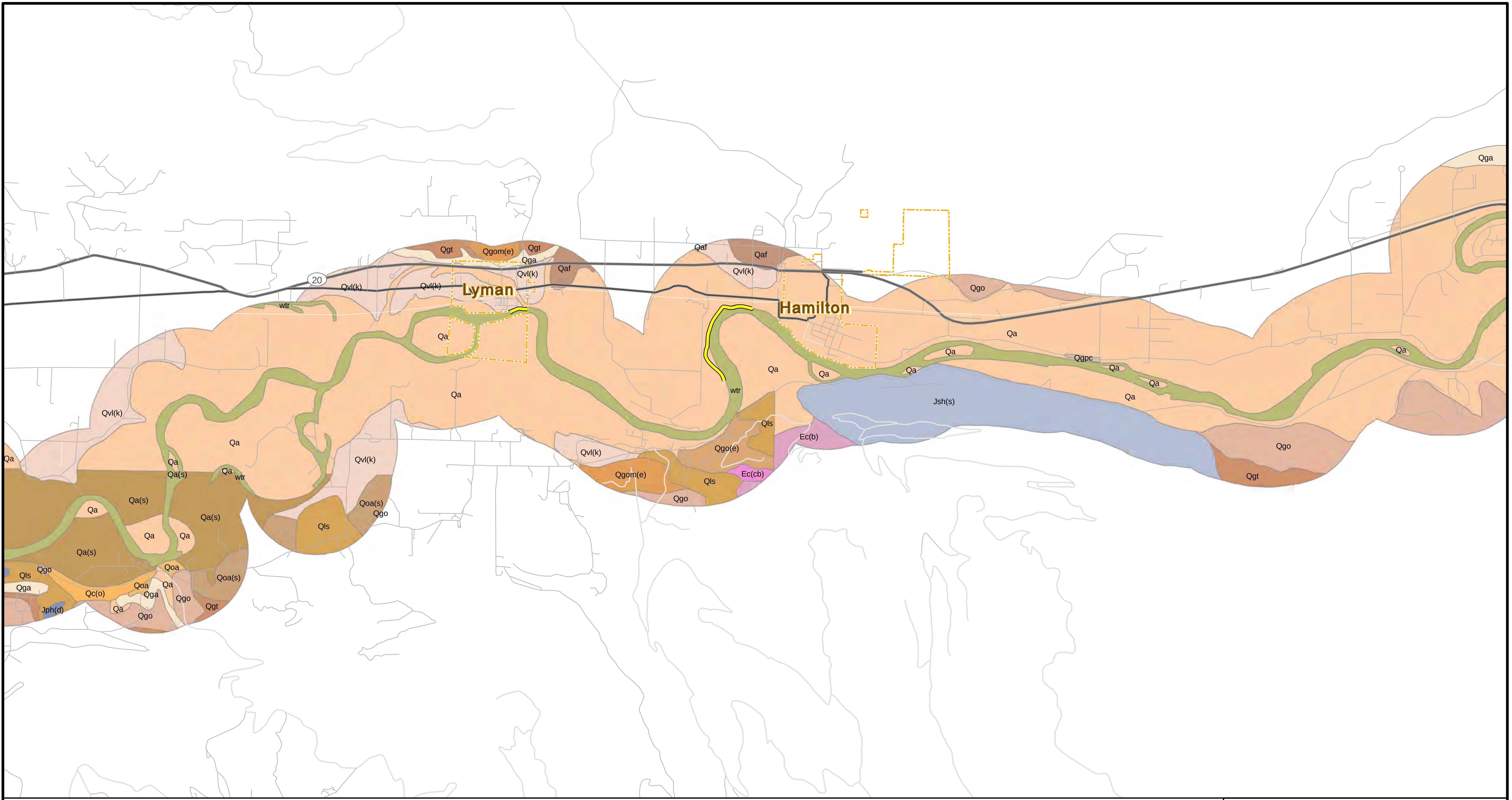

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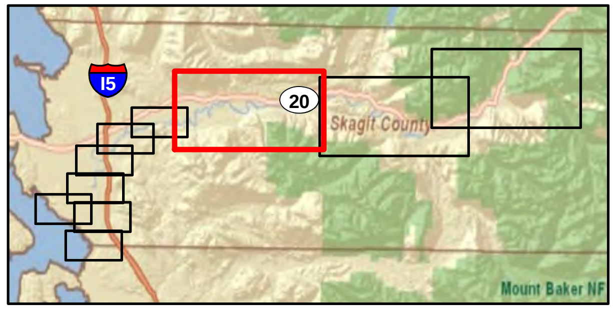

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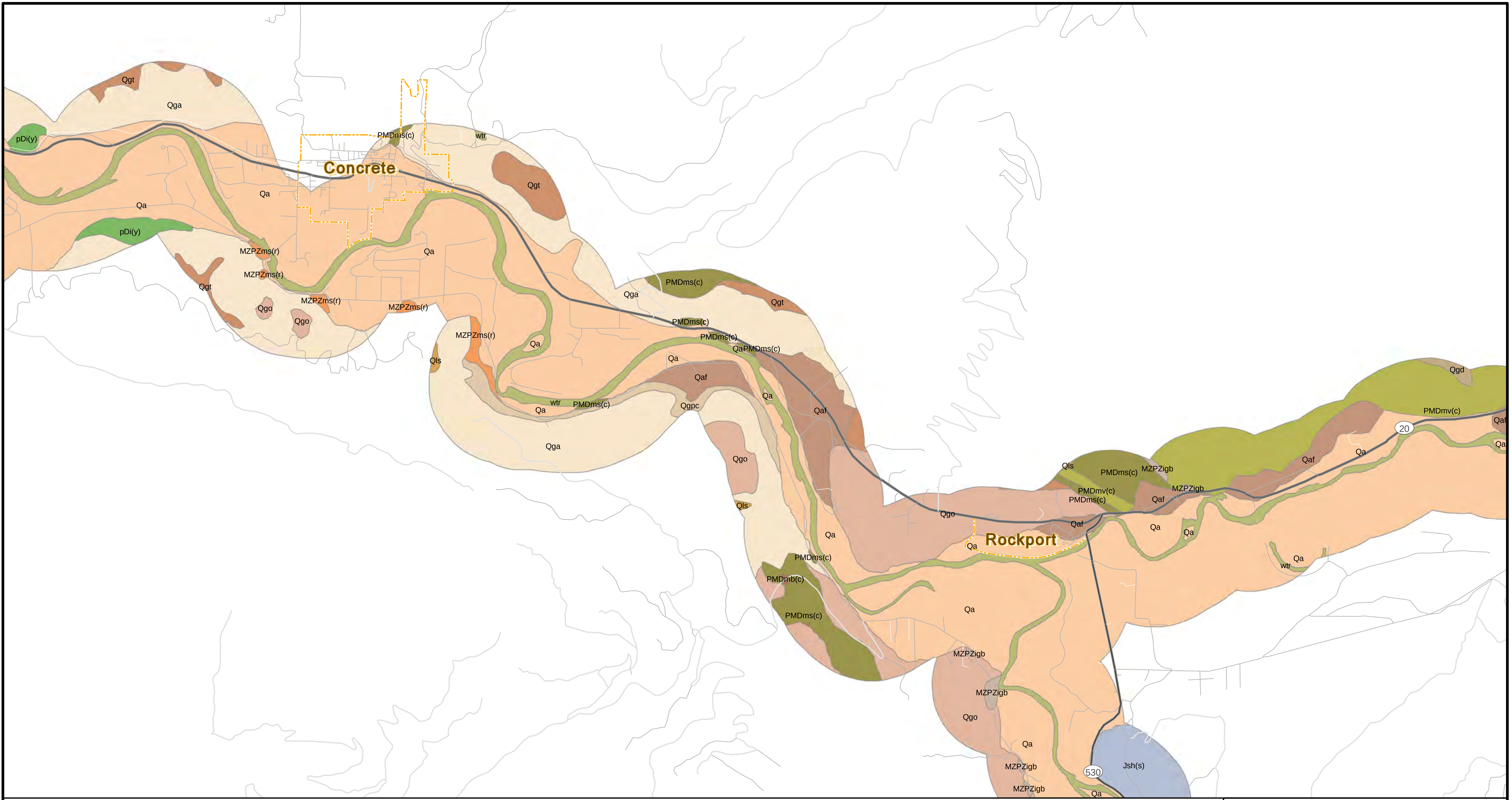

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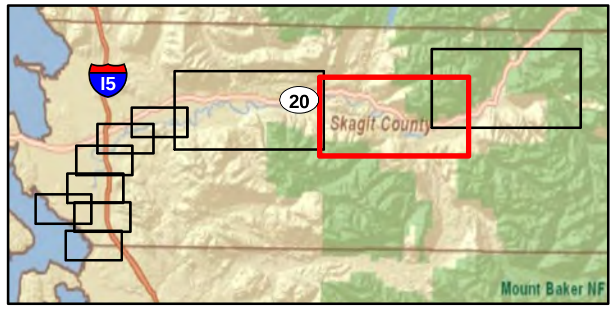

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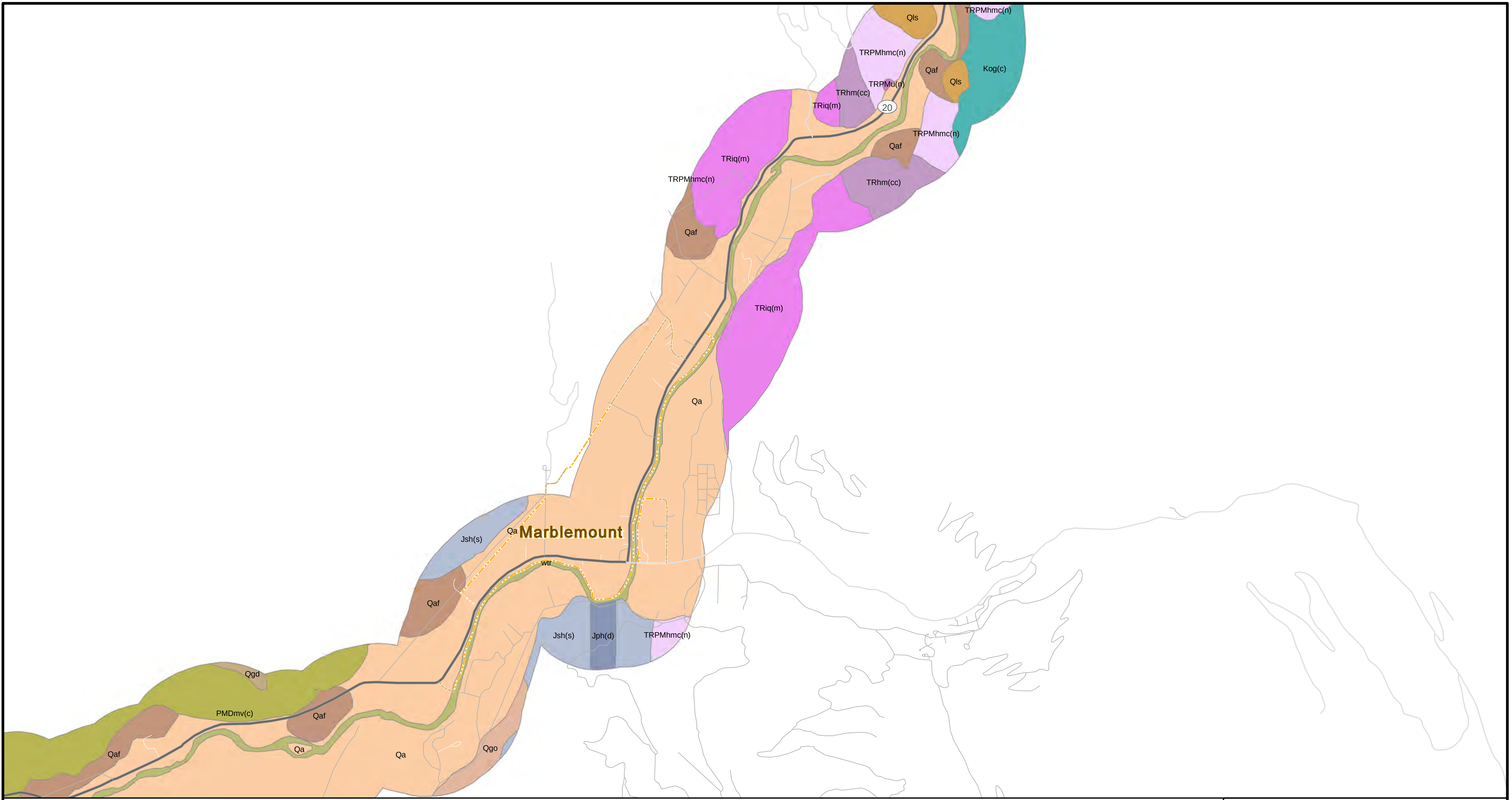

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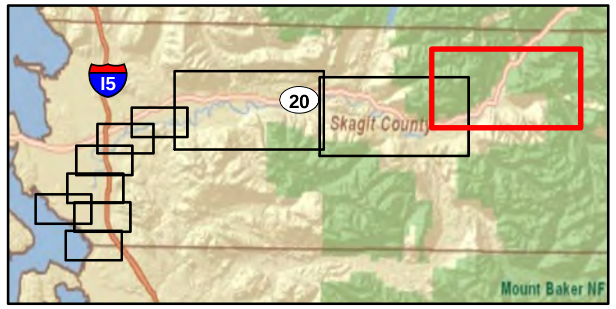

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APPENDIX A

HISTORICAL EXPLORATIONS, AERIAL PHOTOGRAPHS, AND GEOGRAPHIC INFORMATION SYSTEM (GIS) FILES

APPENDIX A

HISTORICAL EXPLORATIONS, AERIAL PHOTOGRAPHS, AND GEOGRAPHIC INFORMATION SYSTEM (GIS) FILES

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APPENDIX B

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Report 21-1-21199-001

Date: January 31, 2011
To: Mr. Daniel E. Johnson
U.S. Army Corps of Engineers, Seattle District

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland