COLORADO GEOLOGICAL SURVEY
COLORADO SCHOOL OF MINES
GOLDEN, COLORADO

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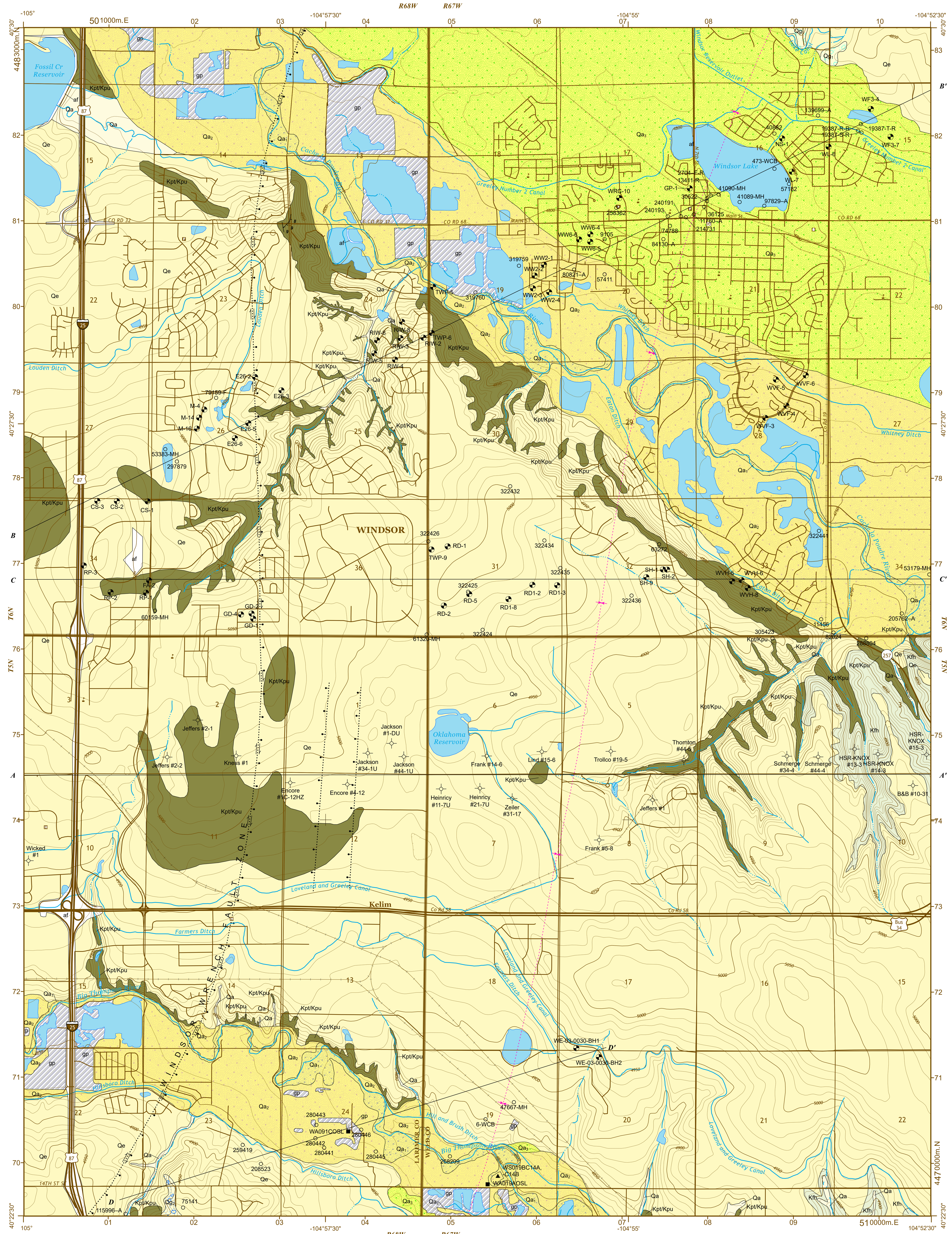

Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983

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Roads....U.S. Census Bureau, 2016
Names....GNIS, 1978-2019
Hydrography....National Hydrography Dataset, 2004-2019
Contours....National Elevation Dataset, 1998-2015
Boundaries....Multiple sources; see metadata file, 2017-2018
Public Land Survey System....BLM, 2018

SCALE 1:24,000

KILOMETERS 1 0.5 0 1 2
METERS 1000 500 0 1000 2000
MILES 1 0.5 0 1
FEET 1000 500 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL 10 FEET

COLORADO
QUADRANGLE LOCATION

Geology mapped in 2021
GIS and cartography by Pangaea Geospatial

Fort Collins	Timnath	Severance
Loveland	Windsor	Bracewell
Berthoud	Johnstown	Milliken

ADJOINING QUADRANGLES

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GEOLOGIC MAP OF THE WINDSOR QUADRANGLE, LARIMER AND WELD COUNTIES, COLORADO

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2024

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DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

For more detail on grain size, sorting, color, secondary calcium carbonate, and other characteristics of surficial map units see Table 1; general characteristics are presented below in the text describing the map units. For details on geologic hazards (e.g., flood potential) of map units, see the Plate 2 section on Mineral Resources, Groundwater Resources, and Geologic Hazards. For radiocarbon and optically stimulated luminescence (OSL) ages of select map units see Table 2 and for results of grain-size analyses of Quaternary units see Table 3. Subdivision of the Quaternary follows the International Chronostratigraphic Chart, v 2020/01 (International Commission on Stratigraphy, International Union of Geological Sciences, 2020). Particle-size designation is according to the Udden-Wentworth grain-size scale (see Nichols, 2009), but (in Table 1) modified such that each sand-size category is divided into a coarser (U) and a finer (L) sub-category with the aid of a sand grain-size card (US GeoSupply, Incorporated, 2020). For example, very coarse (vc) sand is divided into the categories vcU (very coarse – coarser) and vcL (very coarse – finer).

In Table 1 the colors are designated with the aid of Munsell soil color charts (Munsell Color, 1991). Description of soil-carbonate morphology is after Machette (1985), and the type of effervescence of sediment or soil observed when treated with dilute hydrochloric acid is according to U.S. Department of Agriculture (2018).

HUMAN-MADE DEPOSITS

af **Artificial fill (Upper Holocene)** — Mostly riprap, fill material, and, locally, refuse placed during construction of roads, railroads, buildings, dams, and landfills. The fill deposits generally consist of unsorted clay, silt, sand, and rock fragments. Typically, the unit is less than 6 m thick. Some deposits of artificial fill are not mapped because they are too small to show at map scale. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted and (or) if placed on unstable slopes.

ALLUVIAL DEPOSITS

Qa_1 **Alluvium one (Upper Holocene)** — Unit Qa_1 occupies active and historically active channels of the Cache la Poudre River and Big Thompson River. In these channels the coarse-grained sediment of the unit typically forms point bars of gravelly sand or sand, with the bars being up to several meters wide, up to 20 m long, and as high as 0.6 m above stream level. Sand content increases with depth in some point bars. Sand in point bars ranges from medium to very coarse and is light gray and gray (hue 10YR), angular to subrounded, moderately sorted, loose, and without secondary carbonate. Sand composition is 85 percent quartz, 10 percent feldspar and other nonopaque minerals (including mica), and 5 percent opaques. Gravel ranges from granules up to cobbles 17 cm in diameter (or largest dimension) and the clasts are subrounded to rounded. Gravel consists of granitics, granitic gneiss, dark fine-grained metamorphics, quartzite, vein quartz, and rare sandstone and volcanics. Fine-grained sediment is locally present in channel bottoms and banks. It is mostly a dark-brown mixture of clay, silt, and very fine to fine sand, and can form a veneer 6 to 8 cm thick overlying coarser sediment. Thickness of unit Qa_1 is not known but may be 2 m or less. Within the Windsor quadrangle unit Qa_1 is not likely to be a potential source of sand and gravel because of the paucity and relatively small size of point bars. Areas mapped as unit Qa_1 are prone to flooding.

Qa **Alluvium, undivided (Upper Holocene)** — Unit Qa covers the flat valley floor of Fossil Creek, a tributary to the Cache la Poudre River, and occurs in small tributary drainages to that river and to the Big Thompson River. In its physical properties and position in the landscape unit Qa correlates with unit Qa of Sheep Draw, also tributary to the Cache la Poudre River, in the Bracewell quadrangle adjacent to the east (Palkovic, 2020), and to unit Qa in tributaries to St. Vrain Creek in the Johnstown quadrangle adjacent to the south (Palkovic and Morgan, 2017). Based upon radiocarbon ages in Box Elder Creek (in the Hardin quadrangle, ~45 km to the southeast; Palkovic and Morgan, 2021), unit Qa sediments appear to coeval with unit Qa_2 sediments in the South Platte River valley (Keller and Morgan, 2022). By analogy, the unit Qa sediments of the Windsor quadrangle may be coeval with unit Qa_2 in the valleys of the Cache la Poudre River and Big Thompson River. Generally, in the Colorado Piedmont quadrangles mapped by the Colorado Geological Survey (CGS), unit Qa sediments are finer-grained than unit Qa_2 sediments, probably because of the smaller stream discharges and velocities in unit Qa tributary streams compared to those of the unit Qa_2 streams receiving the tributaries. Unit Qa is poorly exposed in the Windsor quadrangle. Based upon data from one field station (a trench to which access was not possible), three geotechnical boreholes, and one water well, unit Qa consists of brown (hue 10YR) clay, silty to sandy clay, and clayey sand. Thicknesses from water well drillers' logs (Colorado Division of Water Resources [DWR]), 2021; and geotechnical boreholes (Colorado Geological Survey [CGS], 2021; Town of Windsor, 2021) boreholes are 2.1 m, 4.3 m, and 4.9 m deep.

The chart for correlation of map units for the Windsor quadrangle is presented in Plate 2. Contacts between unit Qa and older units Qe and Qa_3 are not exposed in the quadrangle. Based upon relative ages of the geologic units, however, units Qa and Qa_2 possibly are locally incised into unit Qe (eolian sediment). On the basis of one geotechnical borehole, unit Qa in the valley of Fossil Creek may overlie unit Qa_3. This is analogous to unit Qa demonstrably overlying unit Qa_3 in the Box Elder Creek valley in the Hardin quadrangle. Areas mapped as Qa may be prone to flooding (see Mineral Resources, Groundwater Resources, and Geologic Hazards in Plate 2).

Qa_2 **Alluvium two (Upper Holocene)** — Unit Qa_2 (mapped as post-Piney Creek alluvium by some researchers in the region) occupies the flood plains of the Cache la Poudre River and Big Thompson River (see Quaternary cross sections B-B', C-C', and D-D'). The unit is locally exposed in cut banks along both rivers and in some gravel pits. Unit Qa_2 underlies the lower (younger) terrace in both river valleys; the higher (older) terrace overlies alluvium three, unit Qa_3. The unit Qa_2 fill-cut terrace is ~1.6 m above active streams, and unit Qa_2 overlies an eroded surface on the valley-fill sediments of unit Qa_3. As indicated from water well drillers' logs (Colorado DWR, 2021) and geotechnical boreholes (CGS, 2021; Town of Windsor, 2021), where cross section B-B' crosses the Cache la Poudre River valley, unit Qa_2 thickness ranges from 2 to 5 m; where cross section C-C' crosses the valley the thickness ranges from 2 to 4 m. Where cross section D-D' crosses the Big Thompson River valley, unit Qa_2 thickness ranges from 2 to 4 m. Bedding in cut banks was observed at only one location and was indistinct. Fresh unit Qa_2 exposures at two gravel pits in the Big Thompson River valley were unbedded. At one of these gravel pits a unit Qa_2 channel, with ~ 1 m of relief, is incised in gravel of underlying unit Qa_3. In the Windsor quadrangle and elsewhere in the Colorado Piedmont, unit Qa_2 can be readily distinguished from unit Qa_3. Unit Qa_2 consists mostly of dark-colored sand whereas unit Qa_3 consists mostly of light-colored sandy gravel and gravelly sand (see Table 1 for unit colors). Unit Qa_2 is moderately to strongly cohesive whereas unit Qa_3 is weakly cohesive. The stratigraphic relationship of unit Qa_2 overlying unit Qa_3 is supported by radiocarbon ages of both units sampled at the same location in the St. Vrain Creek valley ~40 km to the southwest near Longmont, Colorado (Madole, 2016). Elsewhere in the piedmont the sequence is confirmed by visual observation, radiocarbon and optically stimulated luminescence (OSL) ages, and water well data. On the basis of deposit type and position in the landscape, unit Qa_2 likely correlates with unit Qa_2 of the adjacent Bracewell, Johnstown, and Greeley quadrangles (Palkovic, 2020; Palkovic and Morgan, 2017; and Keller and Morgan, 2020).

In the Windsor quadrangle unit Qa_2 is fine-grained and generally unbedded. It consists of silty clay or clayey silt with very fine to medium sand, very fine to medium sand, and coarse to very coarse sand, with the sand containing subordinate fines (clay and silt). Gravel content is minor at locations where it is found. Unit Qa_2 grain size analyses in geotechnical reports indicate that in 22 analyses among six project sites (Table 3), unit Qa_2 consists on average of 41 percent fines (clay and silt), 57 percent sand, and 2 percent gravel (Colorado Geological Survey, 2021; Town of Windsor, 2021). The finer-grained, lower-energy Qa_2 sediments are interpreted to be lower-energy beds, probably overbank deposits, and these are preponderant in exposures. The coarse-grained sediments are interpreted to be higher-energy beds, probably former active channels, and these are subordinate in exposures. No visible secondary carbonate was observed, but locally the unit ranges from no effervescence to weak to violent effervescence.

At a unit Qa_2 exposure in the Coulson Excavating gravel pit in the Big Thompson River valley, radiocarbon analyses of were performed for material immediately overlying unit Qa_3 (sample location WA019BC14B, 2.4 m below ground surface), and for material at the top of the exposure (sample location WA019BC14A, 0.3 m below ground surface). The lower sample yielded an age of 4,360 +/- 30 yr B.P. (calibrated), and the upper sample yielded an age of 3,590 +/- 30 B.P. (calibrated). Both ages are Late Holocene and are comparable to unit Qa_2 radiocarbon ages in other Colorado Piedmont quadrangles mapped by the CGS. Unit Qa_2 in the Windsor quadrangle is unlikely to be a potential source of sand and gravel because most of the deposit is dominantly fines or contains significant fines. Areas mapped as Qa_2 are prone to flooding, as during the September 2013 flood events along the Front Range (see Mineral Resources, Groundwater Resources, and Geologic Hazards in Plate 2).

Qa_3 **Alluvium three (Upper Pleistocene)** — Unit Qa_3 (mapped as Broadway Alluvium by some researchers in the region) is volumetrically the largest alluvial unit in the Cache la Poudre River valley and the Big Thompson River valley. Locally it is overlain by either unit Qa_2 (alluvium two) or unit Qe (eolian sediment). A small area of unit Qa_3 is exposed on the south side of the Big Thompson River valley, where a terrace of composed of this deposit extends northwest into the Windsor quadrangle from the Johnstown quadrangle; part of the terrace has been removed by a gravel pit. On the north side of the Cache la Poudre River valley, in the northeast quarter of the quadrangle, unit Qa_3 forms a terrace several kilometers wide and extending across the quadrangle from northwest to southeast. This terrace is 4 to 5 m higher than the unit Qa_2 terrace adjacent to the southwest; it is mapped by Colton (1976) in the geologic map of the Boulder-Fort Collins-Greeley area and by Palkovic (2020) in the geologic map of the Bracewell quadrangle (adjacent to the east). In the Fossil Creek valley east of Fossil Creek Reservoir, in the northwest corner of the quadrangle, unit Qa_3 may underlie unit Qa, although there are no local water well data to support this possibility. In nearby quadrangles (e.g., Greeley and Valley View School) in the Colorado Piedmont, tributary valleys like that of Fossil Creek are buried valleys filled with unit Qa_3 overlain by unit Qe or unit Qa (Keller and Morgan, 2020, 2022).

Where cross section B-B' crosses the Cache la Poudre River valley, unit Qa_3 thickness from water well drillers' logs (Colorado DWR, 2021) ranges from 3 to 8 m and depth to bedrock (Pierre Shale) ranges from 7 to 10 m; where cross section C-C' crosses the valley the thickness ranges from 2 to 4 m and bedrock depth ranges from 4 to 9 m. Cross section B-B' shows that the greatest thickness is in the center of the valley, and that the unit tapers to the southwest and northeast. Where cross section D-D' crosses the Big Thompson River valley, unit Qa_3 thickness ranges from 2 to 4 m and depth to bedrock ranges from 5 to 6 m. The Windsor region bedrock surface topography map of Shelton and Rogers (1975) shows that in the Windsor quadrangle the thalweg gradients of the Cache la Poudre River and Big Thompson River both are ~ 2 m per km to the southeast. In the part of the Colorado Piedmont north and northwest of Denver, unit Qa_3 is areally and volumetrically the largest alluvium in the South Platte River valley and its major tributary valleys. This is evidenced by cross sections in Lindsey and others (2005); by CGS mapping in the Johnstown quadrangle adjoining the Windsor quadrangle to the south (Palkovic and Morgan, 2017), Bracewell quadrangle adjacent to the east (Palkovic, 2020), and Greeley quadrangle 20 km to the east (Keller and Morgan, 2020); and by U.S. Geological Survey geologic maps of the Masters quadrangle (Berry and others, 2015a) and Orchard quadrangle (Berry and others, 2015b), ~70 km to the southeast.

According to Madole (2016), unit Qa_3 alluvium consists of vertical sequences of superposed, longitudinal bars of sand and gravel deposited by braided streams. These sequences locally contain finer-grained layers that probably are overbank deposits. In the water-well driller's logs used to assemble cross sections B-B', C-C', and D-D', unit Qa_3 consists of sandy gravel and gravelly sand (lower portion of unit), sand (lower or middle portions of unit), and clayey sand and sandy clay (upper portion of unit, and local interbeds in sandy gravel and gravelly sand). Unit Qa_3 grain size analyses in geotechnical reports indicate that in 28 analyses among eight project sites (Table 3), unit Qa_3 consists on average of 9 percent fines (clay and silt), 51 percent sand, and 40 percent gravel (Colorado Geological Survey, 2021; Town of Windsor, 2021).

In gravel pit faces in the Big Thompson River valley, layers constituting unit Qa_3 are ~20 cm to ~1 m thick, with sandy gravel and gravelly sand layers being interbedded with medium to coarse sand layers having low to moderate gravel content. Fines content in the sandy gravel and gravelly sand locally is sufficient to cause the material to be stiff and cohesive, but usually the gravel is only moderately cohesive. Fines content in the sand layers is low. Bedding at a scale of 10 to 20 cm is discernable but indistinct in the sandy gravel and gravelly sand layers; the sand layers locally have planar bedding at a scale of several millimeters and high-angle cross bedding at a scale of 1 to 2 cm. At the Coulson Excavating pit in the Big Thompson River valley, the uppermost unit Qa_3 gravel is incised by a unit Qa_2 channel having ~ 1 m of relief.

Two samples were collected from unit Qa_3 for optically stimulated luminescence (OSL) dating. Sample WA019AOSL, from the Coulson Excavating Co. gravel pit near the center of the Big Thompson River valley, was at the top of a gravel layer and near the contact with overlying unit Qa_2. The sample yielded an age estimate of 1,035 +/- 50 yr (~0.1 ky). This age is in error because unit Qa_3 here is overlain by unit Qa_2 having radiocarbon ages of ~4.4 ky (bottom of unit Qa_2) and ~3.6 ky (top of unit Qa_2). The error may be due to exposure to light during sampling. Sample WA091COSL, from the Loveland Ready Mix Concrete, Inc. gravel pit, also near the center of the Big Thompson River valley, was in a laminated sand layer lying between two gravel layers. The sample yielded an age estimate of 16,285 +/- 9.8 yr (~16 ky), which is Late Holocene in age. In the Cache la Poudre River valley, in the terrace adjoining that valley on the northeast, and in the Big Thompson River valley, unit Qa_3 is an important shallow alluvial aquifer. In both river valleys the deposit is historically and presently an important aggregate resource.

Qg_1 **Gravel deposit one (Middle Pleistocene)** — Two areas of unit Qg_1 lie along the edge of the upland adjacent to and northeast of the Cache la Poudre River valley, in the northeast corner of the quadrangle. In the Timnath quadrangle, ~5 km northwest of the above areas, ~2 m of the gravel is exposed in the face of a small gravel pit. All the locations are at an elevation of ~6 m above the valley floor. Here the unit is mapped as Slocum Alluvium by Colton (1976). Access was denied to an excavated exposure (~2 m high) on the east side of Hollister Lake Drive, but from the road this exposure could be seen to be poorly sorted, moderately to well-rounded sandy gravel or gravelly sand, with clasts as large as small cobbles. The material is stiff and cohesive, many pebbles and cobbles have carbonate rinds, and there is a Bk secondary carbonate horizon (possibly Stage II) ~1 m thick. At this site the mapped extent of the unit is based upon the National Resource Conservation Service (NRCS) soils map of the quadrangle (Crabb, 1980), which shows the location to be underlain by Cascajo gravelly silt loam. Also on the edge of the upland, in the Timnath quadrangle and ~ 5 km to the northwest of the above locations, there is a fresh excavation face of ~3 m of unit Qg_1. Here the unit is a very poorly sorted, rounded to well-rounded, very cohesive, granule to cobble gravel with a sand fraction. There are abundant carbonate rinds on the gravel clasts and the mass has pervasive Stage III to IV secondary carbonate development.

Qg_2 **Gravel deposit two (Middle Pleistocene)** — Unit Qg_2 is poorly exposed in a road cut along Colorado Highway 54 in the southwest corner of the quadrangle, where ~0.6 m of the deposit overlies weathered Pierre Shale. The location is in the upland adjacent to and southwest of the Big Thompson River valley, ~1 km to the northeast, and is at an elevation of ~37 m above the valley floor. At this exposure the unit is mapped as Verdos Alluvium by Colton (1976). From 1.5 to 7 km southeast of this exposure there is a line of several unit Qg_2 areas, trending parallel to the river valley, mapped both by Colton (1976) and Palkovic and Morgan (2017). In the Windsor quadrangle the deposit is mostly clay and silt with a subordinate gravel fraction ranging from pebbles to cobbles. Carbonate rinds are abundant on the clasts, and the mass has pervasive stage IV secondary carbonate development. The mapped extent of the unit is based upon the NRCS soils map of the quadrangle (Crabb, 1980), which shows the location to be underlain by Larim gravelly sandy loam.

EOLIAN DEPOSITS

Qe **Eolian sediment (Lower Holocene and Upper Pleistocene)** — Eolian sediment of unit Qe covers approximately three-quarters of the quadrangle, occupying the large upland area between the valleys of the Cache la Poudre River and Big Thompson River, and the smaller upland areas respectively northeast of and southwest of these valleys. It overlies the Pierre Shale in most of the upland between the river valleys, overlies the same unit along much of the swath of dissected slope on the southwest side of the Cache la Poudre River valley, overlies the unit Qa_3 terrace adjacent to and northeast of the Cache la Poudre valley (cross section B-B'), and overlies the Fox Hills Sandstone in the area along the east quadrangle boundary and south of the Cache la Poudre River valley. Mapping of unit Qe in the Windsor quadrangle is supported by observations in construction excavations and road cuts, and by sample holes made during field work, grain size analyses from geotechnical reports (CGS, 2021; Town of Windsor, 2021), water-well drillers' logs (Colorado DWR, 2021), and the NRCS soils map for the quadrangle (Crabb, 1980). As in other Colorado Piedmont quadrangles mapped by the CGS, unit Qe mostly occupies uplands, but per Madole (2016) is not associated with particular landforms and can be present over a broad range of elevations. On the basis of its position in the landscape, lithologic characteristics, and secondary calcium carbonate development, unit Qe in the Windsor quadrangle is similar to that in the Longmont (Madole, 2016), Milliken (Palkovic and others, 2018), Greeley (Keller and Morgan, 2020), Valley View School (Keller and Morgan, 2022) quadrangles and in other Colorado Piedmont quadrangles mapped by the CGS. In cross sections B-B', C-C', and D-D', water-well drillers' logs (Colorado DWR, 2021) and geotechnical boreholes (CGS, 2021; Town of Windsor, 2021) indicate that unit Qe thickness values range from 1 to 11 m. Most thickness values are in the range of 2 to 7 m and a small number of values fall between 1 and 2 m and between 7 and 11 m.

In the Windsor quadrangle most unit Qe exposures are composed of silty clay or clayey silt, with a minor fraction of very fine to medium sand (estimated in the field to be from <1 percent to 5 percent), and very rare granules and small pebbles. A minority of exposures consist of fines and very fine sand, or very fine to very coarse sand with a subordinate fines fraction. Unit Qe grain size analyses in geotechnical reports show that in 73 analyses among seven project sites (Table 3), unit Qe consists on average of 81 percent fines (clay and silt), 19 percent sand, and no gravel (Town of Windsor, 2021). The fines fraction is usually sufficient to impart moderate cohesion although cohesion locally can be either weak or strong. Unit Qe is massive in the excavations where it is exposed (as is the case in excavations in other piedmont quadrangles mapped by the CGS). Colors are dark grayish brown, dark yellowish brown, brown, pale and very pale brown, and light yellowish brown. Most unit Qe exposures do not have visible secondary carbonate, but some have carbonate filaments and nodules 1 to 2 mm in thickness or diameter, respectively, and a few locations have scattered carbonate nodules from 3 to 9 cm in diameter. Only two locations have a continuous Bk horizon and Stage III secondary carbonate development. Most unit Qe exposures have strong to violent effervescence with dilute hydrochloric acid, a a few have only weak to moderate effervescence. In the Timnath quadrangle adjacent to the north, in a foundation excavation 0.6 km north of Kerns and 1.6 km north of the Windsor quadrangle, radiocarbon samples were taken from the top of the unit Qe exposure and the lowest exposed unit Qe. Sample WS028C14A (upper sample) yielded an age of 2,320 +/- 30 yr and sample WS028C14B (lower sample) yielded an age of 6,580 +/- 30 yr, both of which ages are Holocene. Within the Windsor quadrangle unit Qe is not a likely potential source of clean sand because of its relatively high content of fines. The area mapped as unit Qe locally may contain collapsible (hydrocompactive) soils or swelling soils.

BEDROCK GEOLOGY

Within the Windsor quadrangle, the only bedrock units mapped at the ground surface are the Fox Hills Sandstone and underlying Pierre Shale. Bedrock units are shown in cross section A-A' (Plate 2). The description of the Fox Hills Sandstone is from Spencer (1986), who investigated this unit in detail in the Frederick and Erie quadrangles ~43 km south of the Windsor quadrangle. Descriptions of Pierre Shale members are adapted from Scott and Cobban (1965), supplemented by descriptions by Braddock and others (1988) in the geologic map of the Carter Lake Reservoir quadrangle, 26 km to the southwest, where these units are described in outcrop. Descriptions of older units are adapted from Braddock and others (1988). Thickness values for the Fox Hills Sandstone are from Spencer (1986) and cross section A-A'. Thickness values for older bedrock units are from cross section A-A', which was prepared with the aid of oil and gas well logs from the Energy and Carbon Management Commission (ECMC) (2021).

Kfh **Fox Hills Sandstone (Upper Cretaceous)** — Greenish-buff, fine- to coarse-grained quartzose sandstone; cross bedded in the lower part, grading upward to a light-yellow and white, massive, fine- to medium-grained sandstone. Total thickness is 46 to 91 m, of which the basal 12 to 27 m is exposed in the Windsor quadrangle. The contact of the Fox Hills Sandstone with the underlying Pierre Shale is from field mapping. Data for this contact are not included in the oil and gas well logs used for the cross section.

Pierre Shale (Upper Cretaceous) — Marine strata composed of dark-gray shale, siltstone, and fine-grained sandstone. Bentonite beds, rich in weathered volcanic ash, are common in its lower part and calcareous concretions are common throughout. The various members of the Pierre Shale contain index fossil ammonite species (Scott and Cobban, 1965).

Kpt/Kpu **Uppermost transition member and upper shale member, undivided** — These two members are combined in cross section A-A' because they are not distinguished in the oil and gas well data used to prepare the cross section. Both members are observed in outcrop ~28 km southwest of the Windsor quadrangle (Scott and Cobban, 1965). In general, the members consist of friable sandstone and soft shaly sandstone containing thin-bedded sandy shale and calcareous sandstone concretions. Combined thickness of the two members is ~1,060 m per Scott and Cobban (1965), but COGCC data indicate a thickness of 945 to 1189 m in cross section A-A'.

Kplr **Larimer and Rocky Ridge Sandstone Members and intervening shale, undivided** — The Larimer and Rocky Ridge Sandstone Members are well-indurated, light gray to light brown, medium-grained sandstones, composed mostly of quartz with minor feldspar and biotite. Combined thickness is 34 to 43 m in cross section A-A'.

Kpm **Middle shale member** — This unit consists of highly friable, greenish-gray claystone and sandy siltstone, and contains bentonite beds. Thickness is 116 to 213 m in cross section A-A'.

Kph **Hygiene Sandstone member** — The upper part of the unit is well-indurated, light-gray, fine- to medium-grained sandstone composed mostly of quartz, minor feldspar, and minor opaque minerals. The middle part of the unit is medium-gray siltstone; the lower part is a friable, gray concretionary sandstone. Thickness is 98 to 152 m in cross section A-A'.

Kpl **Lower shale member** — Dark olive-gray shale and sandy shale containing limestone and ironstone concretions; bentonite beds are common in the lower part of the unit. Thickness is 671 to 762 m in cross section A-A'.

Kn **Niobrara Formation, undivided (Upper Cretaceous)** — Very fissile, dark-gray shale containing thin (5 m) micritic limestone layers. Unit is an important oil and gas source in the quadrangle and in much of the Denver Basin (see Plate 2 and section on Mineral Resources, Groundwater Resources, and Geologic Hazards). Thickness is 88 to 125 m in cross section A-A'

Kcgg **Colorado Group - Carlile Shale, Greenhorn Limestone, Graneros Shale, and Mowry Shale, undivided (Upper Cretaceous)** — Olive-gray silty claystone and sandy claystone; dark-gray limestone and olive-gray, calcareous, silty claystone and siltstone; dark-gray to grayish-black siltstone and claystone and siliceous shale. Combined thickness is 98 to 137 m in cross section A-A'.

Kd **Dakota Group - South Platte Formation and Lytle Formation, undivided (Upper Cretaceous)** — Unit consists of gray to light-brown, well-sorted, fine- to medium-grained sandstone; dark-gray carbonaceous shale; gray to light-brown, fine-grained sandstone; and gray to light-brown, coarse-grained, conglomeratic sandstone. Combined thickness is 107 m in the one well completely penetrating this unit in cross section A-A'.

MAP SYMBOLS

Contact — Approximately located

High-angle vertical displacement fault — Existence certain (per cross section A-A'), location concealed, ball and bar on downthrown side; insufficient data to tell if fault is normal or reversed

Windsor wrench fault zone — Existence certain, location concealed; ball and bar on downthrown side

Syncline of Weimer (1996)

A|T **Strike-slip fault (in cross section)** — A, away from observer; T, toward observer

Oil and gas well

Water well

Soil boring for geotechnical investigation

Radiocarbon (C14) sample site

Optically stimulated luminescence (OSL) sample site

gp **Gravel pit** — Sand or gravel pit - exposed sand or gravel faces

A — A' **Alignment of cross section**

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