The Geological Society of America
Field Guide 69

*Geologic and anthropologic history of Riverfront Park, Spokane, Washington, USA**

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ABSTRACT

Riverfront Park in Spokane, Washington, USA, hosts a wide range of sites that highlight the interplay between prominent geologic features and the cultural development of Spokane. Stops in this field guide illustrate such topics as the impacts of historic Silver Valley mining, extraordinary fluvial incisions in Miocene Columbia River Basalt Group flows, cataclysmic alterations to the Spokane River valley from Pleistocene megafloods, earthquake hazards, hydroelectric generation, stormwater management solutions, and fascinating historical tidbits. Human interactions with the land began with the Interior Salish-speaking tribes, who have inhabited this region for thousands of years and historically gathered at the falls to fish. After European American influx, the Spokane River has been harnessed for many uses, including mills, water supply, irrigation, flood control, and hydropower. Today, Riverfront Park is the core of downtown Spokane, providing community access to the river and the largest urban waterfall in the United States.

INTRODUCTION

The City of Spokane was originally an area in which the Spokane Tribe resided. After the initial influx of European Americans in the early nineteenth century, regional mining discoveries and the arrival of railways contributed to a boom in population growth. On 29 November 1881, Spokane became an incorporated city. In 1889, the Great Spokane Fire destroyed the downtown area and helped shape much of the city development as will be discussed later. The 1974 World's Fair, known as the International Exposition of the Environment (EXPO), was hosted by Spokane 50 years ago in 1974 from 4 May to 3 November.

*Please see the associated story map for this field trip at https://storymaps.arcgis.com/stories/ac6eaa8743ed47949be3226bbf0e4027 or scan the QR code.

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The EXPO, held in Riverfront Park, was the first environmentally themed EXPO and converted a highly industrialized downtown and river corridor to a beautiful park. The centerpiece of Riverfront Park is the Spokane River and Spokane Falls, so this field guide will focus on the Spokane River, generally going from east to west (Fig. 1). Important geologic features include the Miocene Columbia River Basalt Group and Pleistocene megaflood features, so there will be a brief introduction to these topics before the field-trip stop discussion.

Columbia River Basalt Group

Between ~17 and 5 million years ago, a series of flood-basalt lavas (collectively known as the Columbia River Basalt Group) inundated 210,000 km^2 of the Columbia Plateau of eastern Washington and portions of Oregon and Idaho, USA (Reidel et al., 2013; Cahoon et al., 2020; Kasbohm et al., 2023; Fig. 2). Spokane is located along the northeastern margin of the Columbia River Basalt Group flows and is underlain by the Grande Ronde Basalt (older) and Wanapum Basalt (younger) flows that were emplaced between 16.5 and 16.3 million years ago (Kasbohm et al., 2023; Fig. 3). In the Spokane area, the contact between the Wanapum and Grande Ronde Basalts is at elevations of 670–640 m (2200–2100 ft). Riverfront Park sits on top of and is immediately surrounded by the lowest and thickest basalt in our region, the Wapshilla Ridge Member of the Grande Ronde Basalt (Derkey et al., 2004; Pritchard et al., 2020; Fig. 3). Basalt is used extensively for building materials and landscaping, but, more importantly, in western Spokane County, the basalt makes up aquifers with local groundwater flow following a gentle (<3°) gradient to the north and northeast toward the Spokane River (Pritchard et al., 2020). This

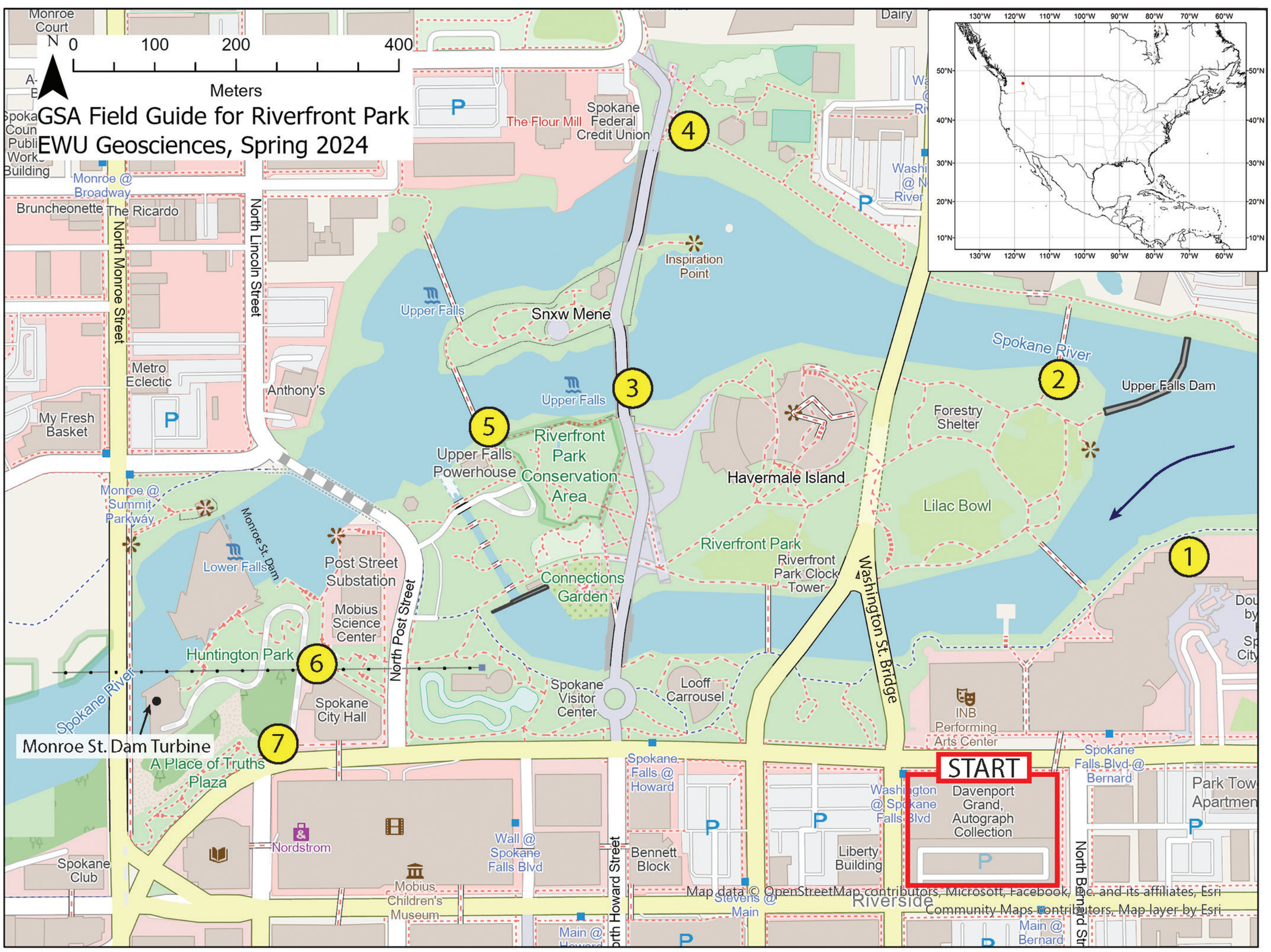

Figure 1. Map of field-trip stops (recommended order is 1–7) in Riverfront Park, Spokane, Washington. The arrow on the east side of the map shows where water is diverted by Upper Falls Dam (Stop 2) into the south channel and the Upper Falls Powerhouse (Stop 5). Basemap from Esri. EWU—Eastern Washington University.

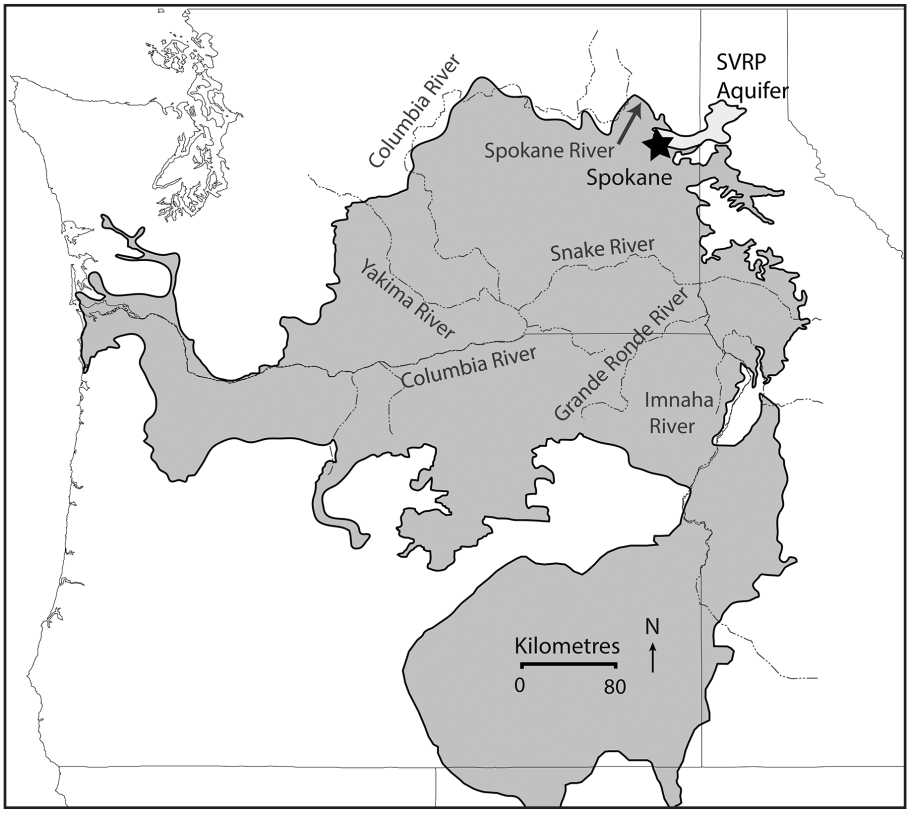

Figure 2. Map of the extent of the Columbia River Flood Group flows (gray). Spokane is located at the star. Modified from Reidel et al. (2013). SVRP—Spokane Valley–Rathdrum Prairie (presented in light gray).

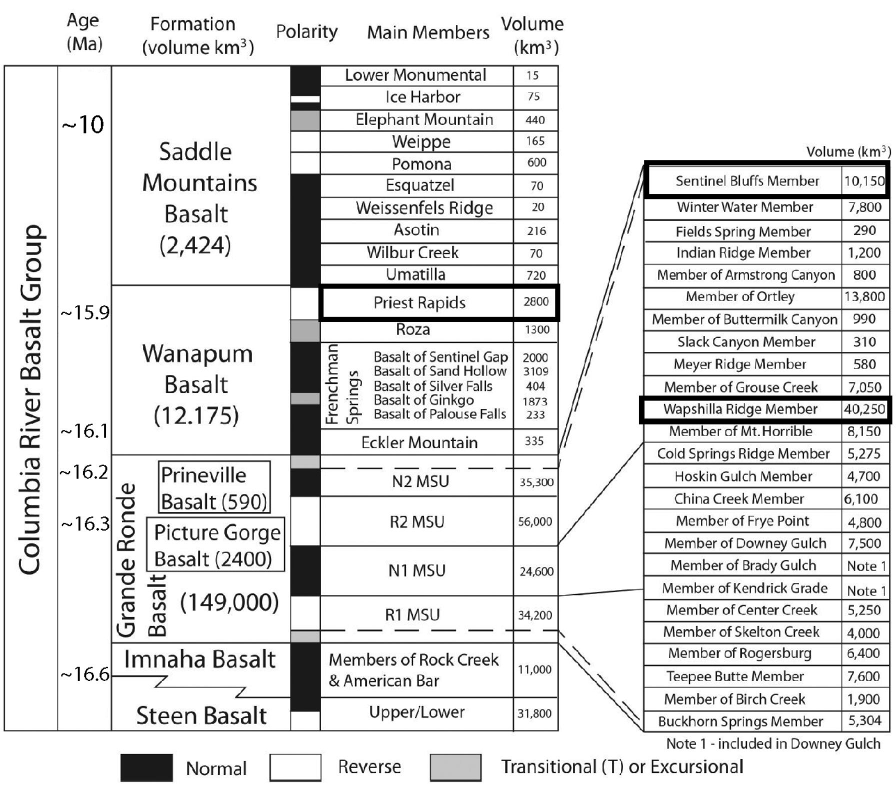

Figure 3. Generalized stratigraphy for the Columbia River Basalt Group from Reidel et al. (2013) and ages from Barry et al. (2013), Kasbohm et al. (2023), and Cahoon et al. (2020). Units present in the Spokane area have thick boxes; the Sentinel Bluffs and Wapshilla Ridge Members of the Grande Ronde Basalt, and at higher elevations in the city, the Priest Rapids Member of the Wanapum Basalt.

flow direction differs from most of the Columbia Basin, where groundwater and surface water generally flow to the central part of the basin and to the Snake and Columbia Rivers (Kahle and Bartolino, 2007; Fig. 2). The Columbia River Basalt Group is also extensively exposed in eastern Washington due to erosion from Pleistocene megafloods.

Glacial-Outburst Megafloods and Deposits

Spokane is located on a geomorphically distinct landscape of basalt sculpted by repeated episodes of cataclysmic Pleistocene glacial-outburst megafloods (Bretz, 1923; Bretz et al., 1956; Baker, 1973, 2009; O'Connor et al., 2020). These megafloods produced spectacular erosional features in the underlying basalt that regionally include >100-m-deep, steep-walled channels termed "coulees," as well as dry falls, cataracts, potholes, and inter-coulee loess-capped islands. The megafloods also generated widespread, >100-m-thick gravel fan and bar accumulations, tens-of-meters-thick gravel-dominated and sand-bearing megaripples, and tens-of-meters-thick successions of sand-, silt-, and clay-rich slackwater deposits (Bretz et al., 1956; Baker, 1973, 2009; Waitt, 1985; Smith, 1993).

Spokane is located ~110 km downstream from where the Purcell lobe of the Cordilleran ice sheet periodically impounded glacial Lake Missoula near the Idaho-Montana border. The late Wisconsin (Fraser age) Purcell lobe ice dam formed, failed, and re-formed between ~17,500 and 14,500 calibrated yr B.P. as constrained by tephrochronologic, stratigraphic, and radiocarbon data (e.g., Waitt, 1985; Atwater, 1987; Hanson and Clague, 2016). Megafloods flowed to the WSW along a topographically constricted Spokane Valley–Rathdrum Prairie, an elongate ~960 km^2 alluvial plain containing up to 75 m of gravel- and sand-rich sediment (Kahle and Bartolino, 2007; Figs. 2 and 4). The famous Spokane Valley–Rathdrum Prairie aquifer now flows westward through the impressive mass of gravel that fills the ancient valley. Immediately downstream from the Spokane Valley–Rathdrum Prairie portion of the megaflood pathways, flood waters spilled out of the Spokane River Valley, scouring broad channels across the loess-covered Columbia Plateau. The main flow continued down the Spokane and Columbia Rivers, leaving the Columbia River valley where it was blocked by the Okanogan lobe below present-day Grand Coulee dam. The main flow turned south down the Grand Coulee, across the Quincy Basin, and then southward to the confluence of the Snake and Columbia Rivers before rejoining megaflood waters from the Cheney-Palouse and other scabland channel tracts (Waitt, 1985; Baker, 2009).

Archaeological evidence indicates that people have been living in the region for the last eight to thirteen thousand years (Ruby and Brown, 2006), and the river below the falls in the

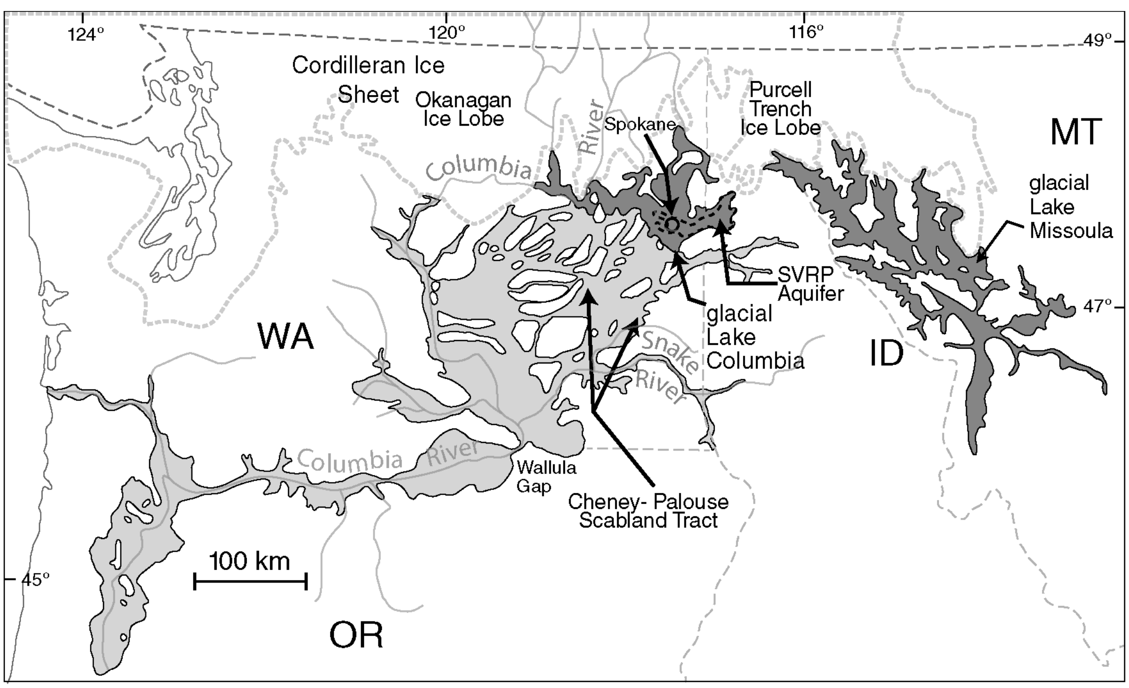

Figure 4. Map of late Pleistocene glacial-outburst megafloods, glacial lakes and current rivers (gray lines), and areas of intense megaflood erosion (gray). The dashed gray line represents the approximate extent of the Cordilleran ice sheet. The Spokane Valley–Rathdrum Prairie (SVRP) aquifer is also represented within black dashed lines. The Spokane River is located along the approximate center of glacial Lake Columbia. Map modified from Kahle and Bartolino (2007). ID—Idaho; MT—Montana; OR—Oregon; WA—Washington.

center of the park has long been a spectacular location for fishing. Modern-day Riverfront Park would have been the termination point for spawning salmon in the Spokane River, as they would not have been able to climb the Lower Falls. Therefore, Inland Salish tribes like the Spokane Tribe gathered here to harvest the salmon. Early European settlers arrived in the mid-1800s with the city of Spokan Falls (the “e” was added later) being incorporated in 1881 with a grand total of 300 citizens (https://www.historicspokane.org/). Growth soon followed with the arrival of the Northern Pacific Railroad and the discovery of gold and later lead-zinc-silver in the Coeur d’Alene mining district to the east.

STOPS

Stop 1: Spokane River and the Legacy of the Silver Valley (47.661689, −117.414799; all coordinates in WGS 84)

This tour begins with a short walk from the Davenport Grand Hotel (333 West Spokane Falls Boulevard, Spokane, Washington 99201) along the Centennial Trail to the southern bank of the Spokane River, upstream (NE) from the King Cole Way bridge at a statue dedicated to the miners of the Silver Valley (the Coeur d’Alene district) to the east in Idaho (Fig. 5). The Spokane River is ~180 km long, flowing from its inlet at the northwestern outlet of Coeur d’Alene Lake in Idaho, through eastern Washington, over the Spokane Falls in the heart of downtown Spokane, and ultimately into the Columbia River at Lake Roosevelt (Fig. 6). The Spokane and Columbia valleys were filled deeply with Pleistocene lake and megaflood deposits, outwash and alluvium that buried the former river channel to the north and the basalt ridge where Spokane Upper and Lower Falls are located today. When glacial Lake Columbia drained, the post-Pleistocene river was superimposed across the buried basalt ridge. Today, the resulting recessional cataract of Spokane Falls continues its slow(er) up valley migration. The river now drains a 16,160 km^2 drainage basin, and has likely supported human occupation for more than 11,000 years.

European American settlement of Spokane began in 1807 when Englishman David Thompson arrived and built a trading post to the north along the Little Spokane River. By the late 1800s, industry flourished, drawn by the river and the reliable power it provided. The area that is now Riverfront Park underwent a process of rapid industrialization, seeing the construction of lumberyards, saw mills, and later extensive rail yards when the Northern Pacific Railroad made Spokane Falls the center of its operation in the late 1800s (https://www.historicspokane.org/).

Regional mining history began in 1860 with the discovery of gold in Orofino Creek, a tributary to the Clearwater River in northern Idaho. Word spread quickly, resulting in a gold rush that continued through 1875 before petering out as the gold ran dry. Prospectors mining gold in the Prichard area, however, soon discovered a new source of mineral wealth, this time in the form of zinc, lead, and silver. In the Coeur d’Alene district, now also known as the Silver Valley (Fig. 5), hundreds of mining claims were developed; the largest was the Bunker Hill mine in Kellogg, Idaho, which opened in 1886. This area quickly became so productive that by the 1970s, half of the U.S. silver production came from the Silver Valley alone. The resources and wealth of the Silver Valley traveled downstream to Spokane, both figuratively and literally, spurring on further economic growth and development of the largest metropolitan center in the region in the early 1900s. Over the course of the Bunker Hill mine’s operation from 1885 to 1991, over a 165 million ounces of silver, 3 million tons of zinc, and 8 million tons of lead were produced, with a combined worth of over 6 billion U.S. dollars in today’s dollars (https://bunkerhillmining.com/). A bronze statue and plaque at Stop 1 commemorates

Figure 5. Bronze statue along Riverfront Park at Stop 1 commemorating the contributions of the Silver Valley to Spokane’s economic growth and development.

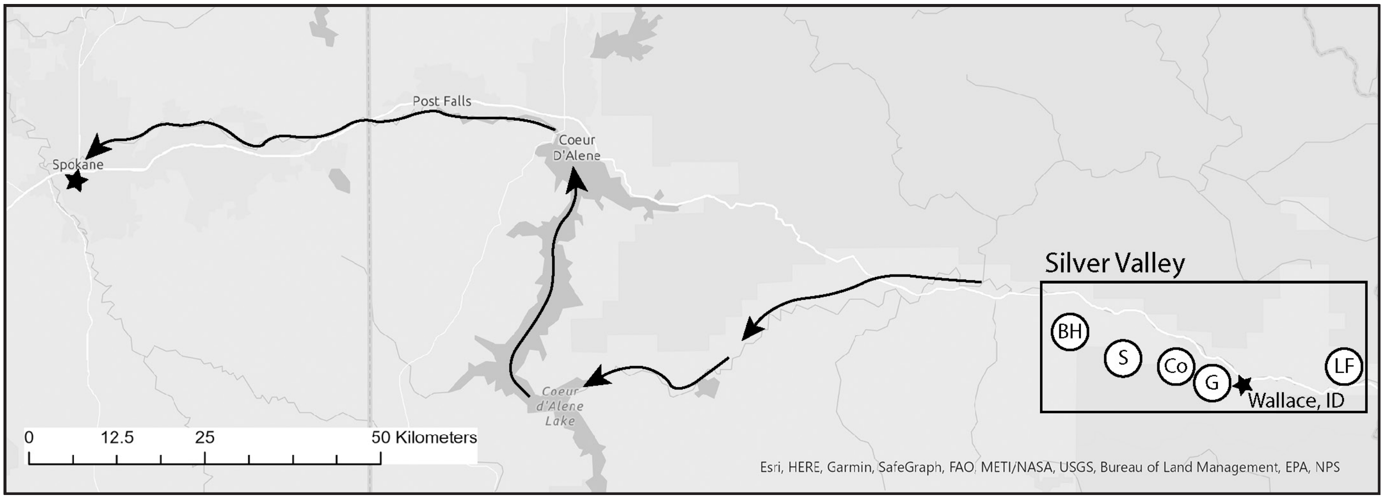

Figure 6. Map showing the location of Silver Valley, Idaho, to the east of Spokane. Contamination from early mining practices flowed downstream (arrows) and has impacted Coeur d'Alene Lake, which sources the Spokane River. Locations of mines are approximate; Bunker Hill (BH), Sunshine (S), Coeur (Co), Galena (G), and Lucky Friday (LF). Basemap from Esri.

the integral role that the development of earth materials and resources played in the growth of Spokane.

Mining in the Silver Valley, however, brought more than just money downstream along the rivers. Decades of ore mining and processing resulted in extensive heavy metal contamination in the Silver Valley. Enriched ore bodies along a series of faults in the Belt Supergroup rocks were mined for galena (lead sulfide), sphalerite (zinc sulfide), and tetrahedrite (copper antimony sulfosalt). These sulfide minerals were commonly accompanied by other accessory heavy metals such as arsenic, cadmium, mercury, and antimony. Mine tailings were frequently dumped next to or directly into the Coeur d'Alene River and its tributaries, which subsequently carried contaminants into Coeur d'Alene Lake and, ultimately, the Spokane River. To this day, surface sediments in the Spokane River are enriched in lead, zinc, arsenic, cadmium, antimony, and mercury as compared to background levels (Grosbois et al., 2001). In 1983, the Bunker Hill mine and surrounding area was designated as an EPA Superfund site by the U.S. government. Today, cleanup efforts remain active in the Silver Valley, Coeur d'Alene Lake, and along the Spokane River as productive modern mining works to mitigate and prevent contamination issues.

Stop 2: Upper Falls Diversion Dam (47.663186, –117.416204)

From Stop 1, proceed downstream (west) and cross King Cole Way bridge northward to Stop 2.

As the Spokane River flows into downtown Spokane it splits into two channels. This stop highlights the north channel of the river, where the Upper Falls Control Works Diversion Dam is located. This dam provides water level and spill control and can be viewed by walking across the wooden pedestrian bridge, which connects Riverfront Park to the Centennial Trail by the Centennial Hotel (Fig. 7). Operational by 1922, the Upper Falls hydroelectric facility includes two dams. One dam includes the head gates on the north channel, and the intake structure is located downstream in the south channel.

On your way west across the park you will walk over (or under) the Washington Street bridge. Of interest to the authors is a story by Lee Nelson on the reputable app Spokane Historical (https://spokanehistorical.org/items/show/266) that describes a winter 1910 "jump" off the newly completed bridge by classic magician, Harry Houdini, with cuffed hands and locked chains around his legs. The frigid and magical jump was to celebrate

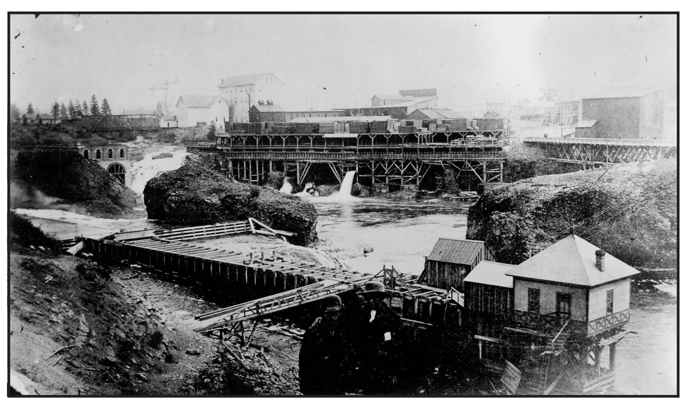

Figure 7. Looking southeast to sawmill in ~1900 along the Upper Falls on Spokane River; early wooden dams were used to power equipment (https://lange.spokanelibrary.org/items/show/1238). Some of these structures may still be present as bricks mounted on basalt visible from the walking bridge at Upper Falls, and the main structure appears to be located at the site of the current powerhouse for Upper Falls.

the new bridge, and, luckily, the wily Harry Houdini pulled off the trick successfully and lived on to continue his astounding theatric displays.

Stop 3: Columbia River Basalt and the Spokane Fault (47.662754, −117.421047)

The south end of the Howard Street middle channel bridge has impressive downstream views of incised basaltic rock. The downtown area of Spokane is built on the lower Wapshilla Ridge Member of the Grande Ronde Basalt, the lowest and thickest Columbia River Basalt Group member in the area (Fig. 3). Figure 8 shows results of portable X-ray fluorescence (pXRF) analyses from samples at Huntington Park (down the hill from Stop 6), Ice Age Floods Playground (sampled during construction, Stop 4), lower level of Clinkerdagger Restaurant (just downstream from Fig. 4), and the Lincoln combined sewer overflow (CSO) tank (located north of Lower Falls). Stop 7 is another CSO tank located south of the falls and was excavated into anthropogenic material used to fill what was once Cowley Creek (see Stop 5). Geochemistry of the basalts confirms that the basalt in this area is the Wapshilla Ridge Member of the Grande Ronde Basalt: regionally overlying Sentinel Bluffs and Priest Rapids Members of the Columbia River Basalt Group have been locally eroded.

Spokane is a relatively quiescent tectonic setting compared to the western/Cascadia subduction zone side of the state, but there are still a number of significant local geologic structures. Stop 3 is situated along the approximate location of the northeast-trending Spokane fault (Wicks et al., 2013; Stephenson et al., 2016) as generally shown in Figure 9. The unexposed Spokane fault was inferred to explain 15 mm of offset observed in an InSAR (interferometric synthetic aperture radar) uplift anomaly based on multiple satellite passes of the area by multiple countries and removing any northern shifts (Wicks et al., 2013). This geophysical-inferred fault was also presented in seismic reflection survey (Stephenson et al., 2016). The 2013 and 2016 geophysical work was conducted to help explain the 2001 swarm of small magnitude earthquakes in Spokane. Initially, the 2001 earthquake swarm had been attributed to splays or stepover faults associated with the Latah fault (Derkey and Hamilton, 2001; Fig. 9). Epicenters of this swarm are presented on Figure 9, but at the time of detection in 2001 there were few seismometers in the area. Field mapping does not reveal structures that match the Spokane fault, aside from secondary Riedel shears associated with the Cheney fracture zone (Fig. 9; Pritchard and Cebula, 2016), the Spokane fault matches a NW to SE compression shown in the general strain ellipsoids of the region (Fig. 10). However, the inconsistency between field observations and geophysical data will persist and will be a pleasure for geologists to unravel for years to come.

Stop 4 (Optional): Ice Age Floods Playground—Public Geology (47.665100, −117.420432)

For an optional stop from the main field-rip guide, cross the footbridge linking Snxw Meneʹ (formerly Canada) Island to the north bank of the Spokane River. Here is the northernmost portion of Riverfront Park, a smaller feature known as the Ice Age Floods Playground (Fig. 11). This playground park is dedicated to the Ice Age floods, including the Missoula Floods that ran

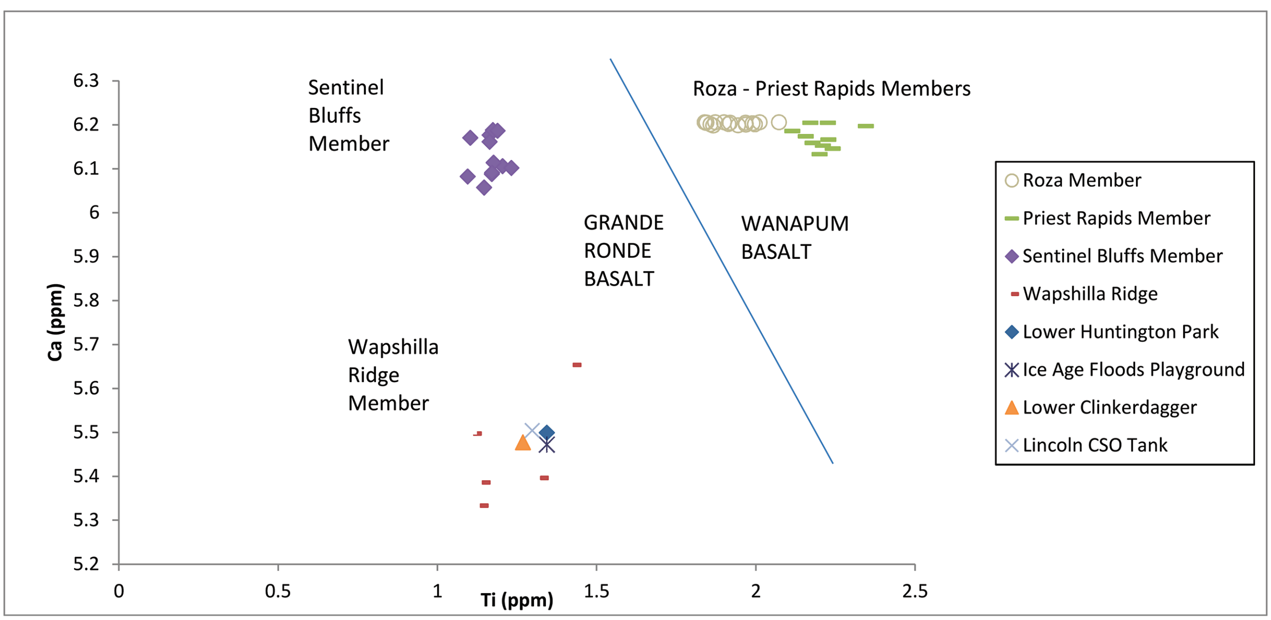

Figure 8. Columbia River Basalt Group geochemistry from a portable X-ray fluorescence at Eastern Washington University showing that basalt in the downtown area is likely Wapshilla Ridge Member of the Grande Ronde Basalt, based on Hooper (2000) and Reidel (2005). CSO—combined sewer overflow.

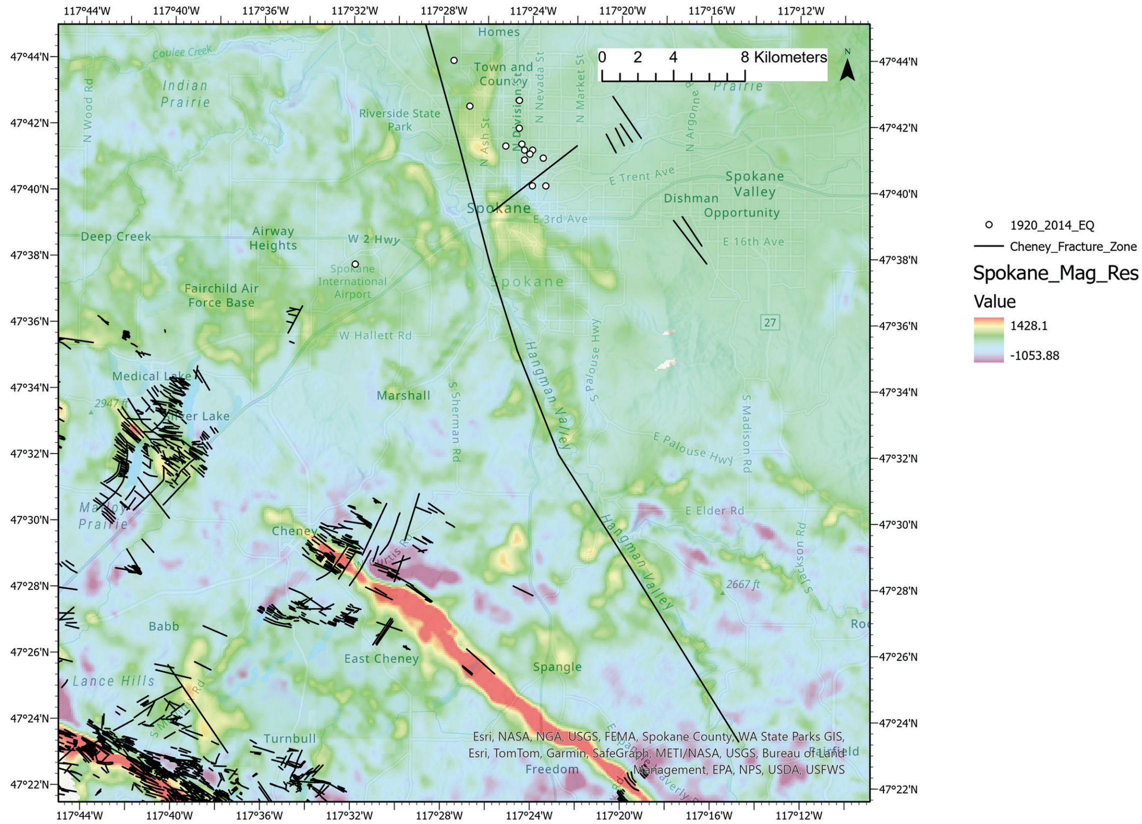

Figure 9. Map of Spokane area showing approximate locations of northwest faults in Eocene and older faults (modified from Derkey et al., 1999), the Spokane fault (modified from Wicks et al., 2013), the Latah fault (modified from Derkey et al., 2004), and the Cheney fracture zone cutting Miocene Columbia River Basalt (Pritchard and Lloyd, 2016). The coloration is from a USGS aeromagnetic survey with red as high and purple as low (Blakely et al., 2020). The northwest-trending aeromagnetic anomalies coincide with the Cheney fracture zone and are likely normal-magnetic polarity dikes associated with the Columbia River Basalt. Epicenters from the Pacific Northwest Seismic network highlight the 2001 earthquake swarm in Spokane with sizes relative to moment magnitude, the greatest being 3.7 Mw.

through and carved a large network of valleys into the majority of eastern Washington. These channels and valleys are known as the Channeled Scablands and allow us to view the rock that underlies the Columbia River basalts. Glacial outwash floods deposited a large amount of gravel that is quarried for building materials and also hosts important aquifer systems in arid eastern Washington.

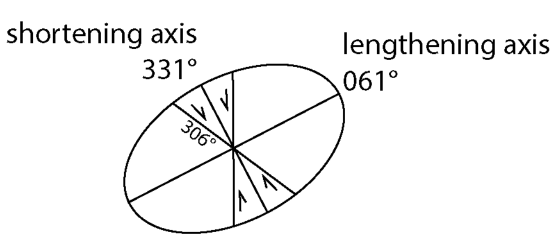

Figure 10. Strain ellipsoid for post–Columbia River Basalt fractures in eastern block of Washington; modified from Hammond (2013) by Pritchard and Cebula (2016).

The Ice Age Floods Playground is a valued educational and recreational site and gives homage to the legacy of ice age floods in eastern Washington. It was established with the help of the Ice Age Floods Institute and is a location along the National Trail of the Ice Age Floods supported by the National Parks Service.

Stop 5: Megafloods and Upper Falls Dam Powerhouse (47.665100, –117.420432)

As the Spokane River flows into downtown Spokane it splits into two river channels. Operational by 1922, the Upper Falls hydroelectric development includes two dams. One dam includes the head gate structure and is located on the south channel. As you follow the south channel through Riverfront Park, situated adjacent to the City of Spokane's first all-inclusive playground and the Theme Stream (ice skating rink), you reach the intake for water that flows in a penstock, below the park, into the Upper Falls Powerhouse, where it spins a turbine and can generate up to 10 MW of power.

Figure 11. Ice Age Floods Playground, located at the northern end of Riverfront Park, is a popular venue for recreation and educational opportunities focused on geological history of the area. Courtesy of Visit Spokane.

From the vantage point of the Upper Falls Powerhouse you can see Anthony's Restaurant to the west and north across the river. In the 1960s, this was the location of The Polynesia restaurant. The restaurant was built directly on top of a cataract/dry waterfall and small drainage system that continues north, which was filled with anthropogenic waste from the Great Fire of 1889 that destroyed most of Spokane.

A 1997 report by CH2M hill and a subsequent ArcGIS study by Cleveland et al. (2017) show the distribution of anthropogenic fill around the Lincoln Street bridge and the filling of Cowley Creek on the south side of Spokane River. The source of the creek is a spring at Cowley Park located near the upper contact of the Grande Ronde Basalt, and continues northwest, forming a valley ~152 m wide and 61 m deep (Fig. 12).

Across the river from this vantage point, a small unnamed channel flowed from the north to the river and a large circular cataract, and/or eddy, that was ~122 m in diameter and 61 m tall. Figure 13A shows the pre-1889 fire topography as an artistic representation, view to the south. This late 1880s image is aligned with the age of the wooden dam from Stop 2; a rendition of the old dam can be seen to the left (east) and upriver of Spokane Falls. Figure 13B is a plat map that also shows the circular cataract or rock-cut eddy.

Stop 6: Lower Falls, Huntington Park, and Monroe Street Dam (47.660867, –117.424279)

The Monroe Street Dam is a dramatic point with the Washington Water Power building sitting on top of the ridge with an amazing view of the Monroe Street bridge and Peaceful Valley. Spokane Falls is the largest urban waterfall in the United States, after all (https://www.pcma.org/5-things-you-didnt-know-spokane/). The Washington Water Power building is an iconic structure and reminder of Spokane's living history and a shining example of early industrial architecture. The building acts as a substation that supplies downtown Spokane with underground power generated from the Upper Falls and Monroe Street Dams.

At this stop, you can take a stroll through Huntington Park, which is located at the site of Avista's Monroe Street Dam, which features numerous works of art from local artists (Fig. 14). Monroe Street Dam has been generating electricity since 1890. Its current configuration allows for 15 MW of electricity. On an average day, 142–170 m^3 per second (cms) or ~5000–6000 cubic feet per second (cfs) of water flows over the falls. However, during runoff or other high flow events, there could be as much as 1133 cms or 40,000 cfs of flowing water, which provides a spectacular display of hydraulic energy.

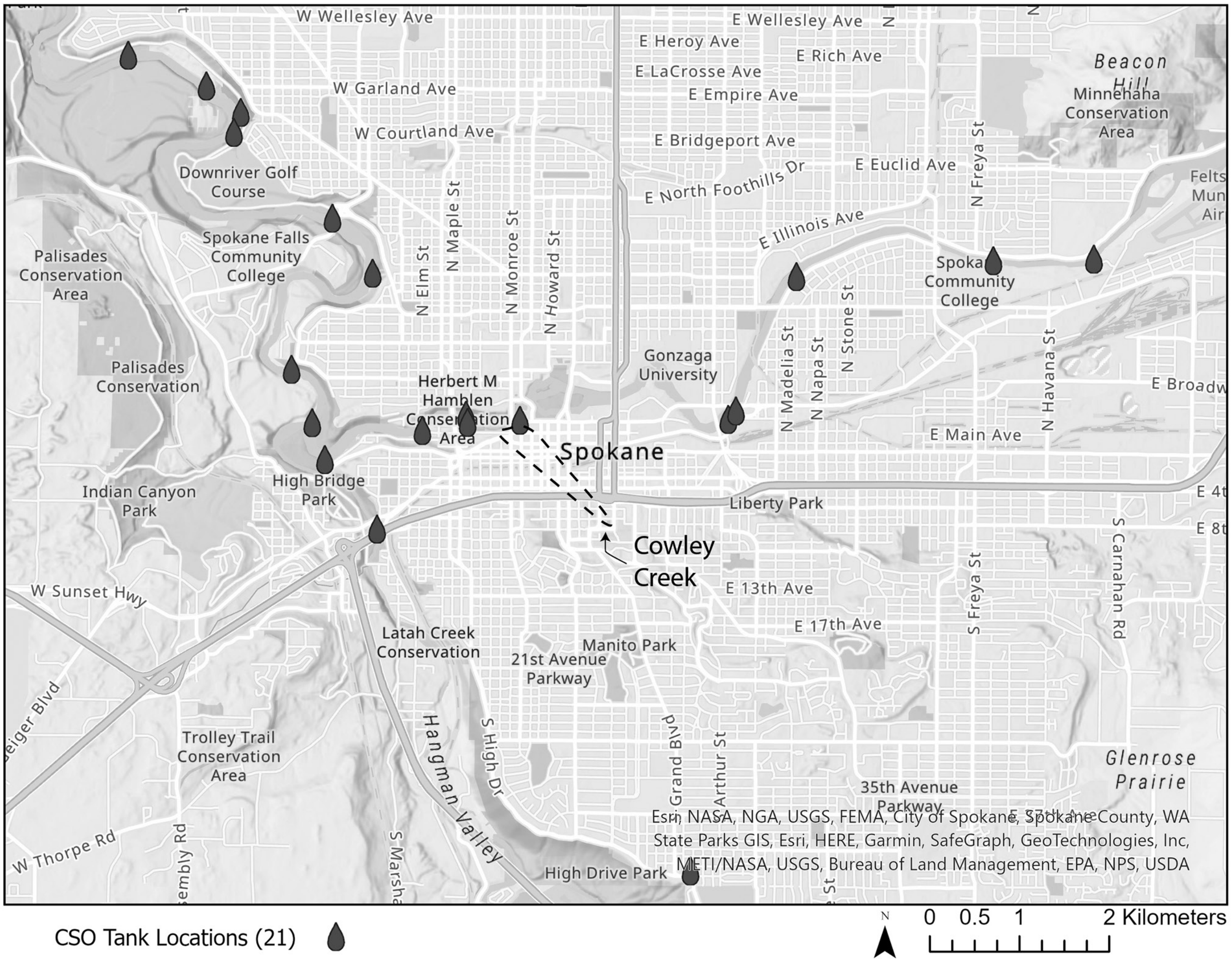

Figure 12. Map of Spokane showing locations of the 21 CSO (combined sewer overflow) tanks that store combined sewer and stormwater runoff during peak storm events to minimize discharge to Spokane River. Pre-1900s Cowley Creek that starts midway up the south hill at today's "Cowley Creek Park" is located at the contact between the Grande Ronde Basalt of the Columbia River Basalt Group and a sedimentary interbed (Latah formation).

Stop 7: Stormwater and Combined Sewer Overflow Protection (47.660186, −117.425278)

There are a series of 21 combined sewer overflow (CSO) tanks located along the Spokane River (Fig. 12). The tanks are designed as overflow storage space for a combination of stormwater and sewage because heavy rainstorms and/or rapid snow melt could overwhelm the city sewer system. The tanks operate as a backup catchment system for untreated wastewater and stormwater to prevent it from being washed into the river when the wastewater system becomes overwhelmed with incoming flow. The sewage comes from the residents of Spokane and the stormwater runoff comes from streets, parking lots, and roofs in some of the older parts of the city. These two sources of flow empty into the CSO tank system, which can be pumped (Fig. 15) to the Riverside Park Water Reclamation Facility, ~7 km downstream of the downtown area, when flows return to lower levels and the facility can handle processing the wastewater. The City of Spokane has spent roughly US$450 million improving its wastewater infrastructure in recent years. This includes upgrades to the Water Reclamation Facility and CSO system. Stop 7 highlights one of the larger CSO storage tanks (designated CSO 26) built beneath the plaza along Spokane Falls Boulevard. The goal for the CSO system is to reduce overflow events to a maximum of one per year to ensure good water quality and river health downstream.

From Stop 7, please walk back to the Davenport Grand Hotel for further meeting events. We hope that you have enjoyed a little geology and history of the city hosting this meeting and continue to enjoy the park during your visit to Spokane.

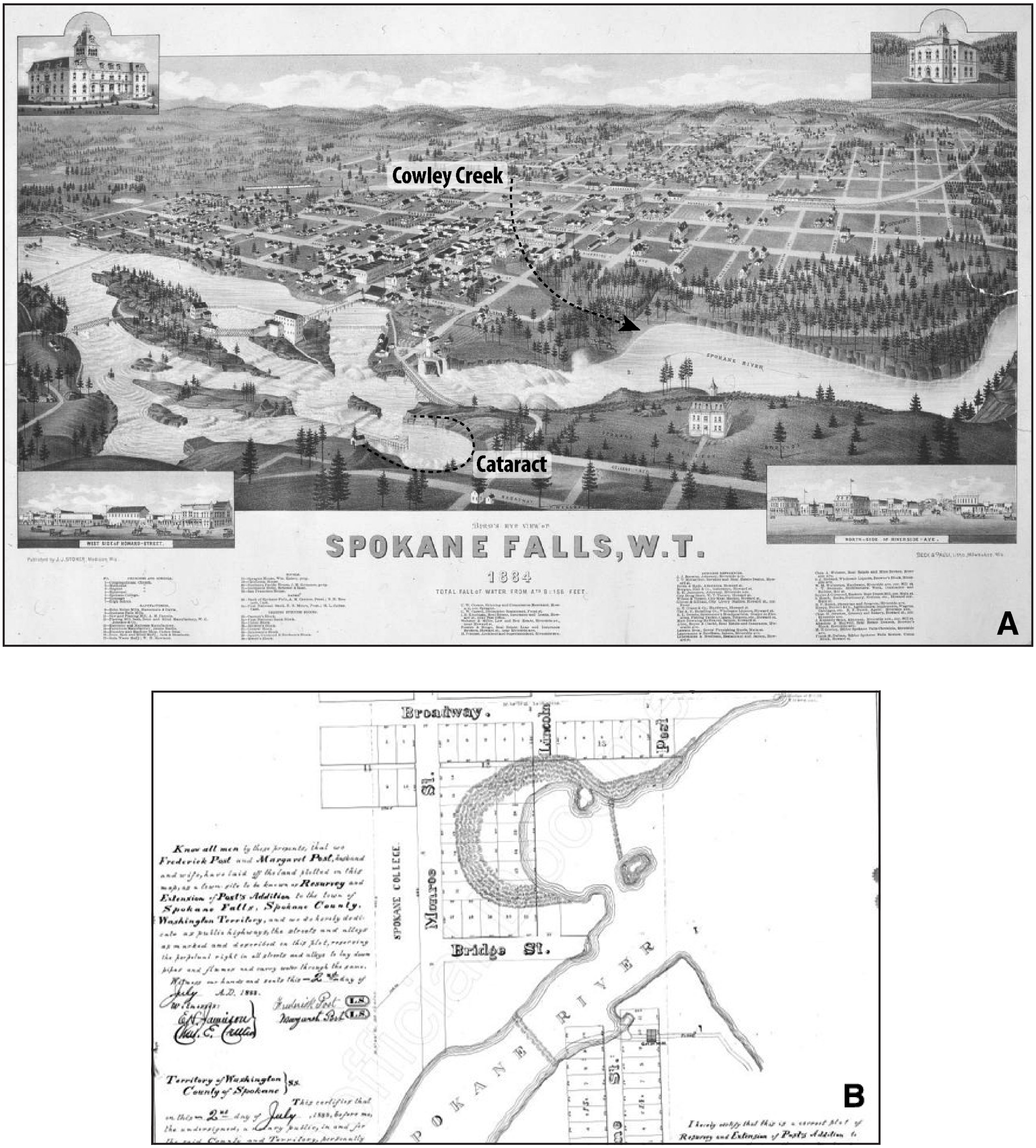

Figure 13. (A) Map image of Spokane in 1884 by Henry Wellge (https://content.libraries.wsu.edu/digital/collection/maps/id/527/; courtesy of Washington State University Libraries' Manuscripts, Archives, and Special Collections). Notice that above the map title is a circular feature that was a cataract from the Pleistocene megafloods that carved the Channeled Scablands and was later filled by anthropogenic fill. The image is looking to the south, so on the south side of the falls, there is a prominent bay with a drainage that matches the projected location of Cowley Creek entering the Spokane River. This drainage has been filled and is not recognizable without subsurface data today. W.T.—Washington Territory. (B) Plat map from Spokane County Assessor's office, with the circular feature; older photos show a drainage coming from the north and entering the coulee just southeast of the intersection of Broadway and Monroe Street.

Figure 14. *The Salmon Chief*, sculpture by Virgil "Smoker" Marchand, portrays a chief giving thanks at the Lower Falls.

Figure 15. Pumping station for CSO 26 (combined sewer overflow tank 26), which gradually pumps the stored sewer-stormwater to the sewage treatment plant after the storm event passes.

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