Western Oregon University

Geologic Setting of the Nehalem Watershed:

Framework for Geomorphic Analysis and Habitat Assessment

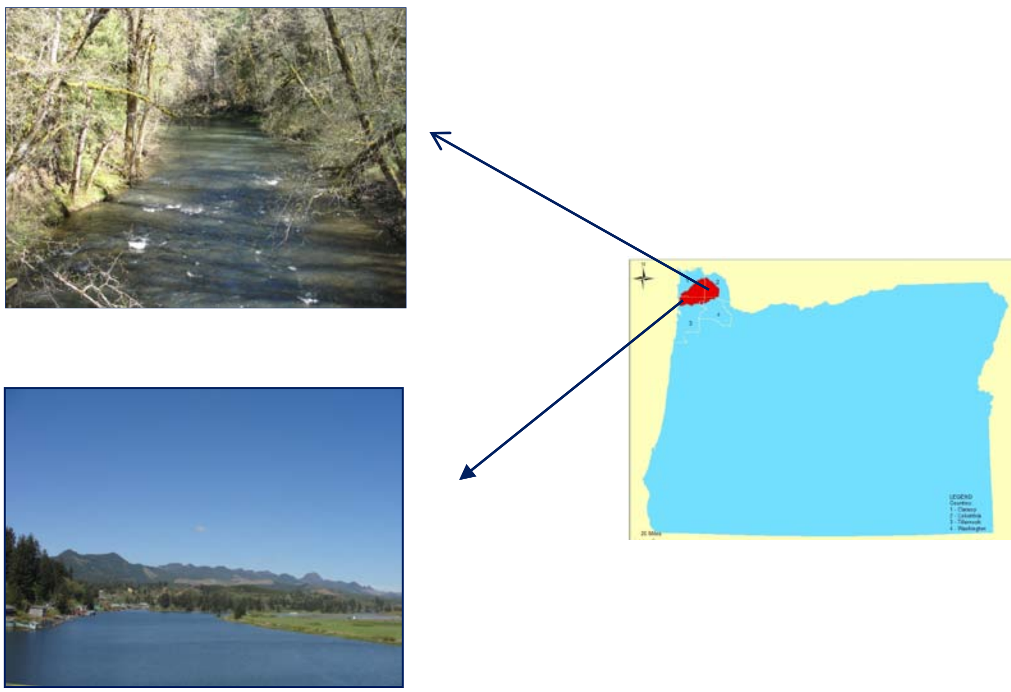

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TABLE OF CONTENT

Figures and Maps

ABSTRACT

The geologic setting of the Nehalem watershed is strongly influenced by active tectonic associated with the Cascadia Subduction Zone and Oregon Coast Range. Surface elevations range the sea level to over 3,000 feet. Bedrock stratigraphy includes several formations ranging in age from Eocene up to middle Miocene, in addition to Quaternary terrace gravel and alluvium. The oldest rock unit from this is represented by Tillamook Volcanics (Eocene age), with the youngest formation is represented by Columbia Basalt Group (Miocene age). Early Tertiary strata were subsequently intruded by gabbroic intrusive. Evidence of tectonic activity shows a major late Eocene extensional event that produced abundant normal faulting that may be attributed to initial forearc extension. Topographic lineaments in the Nehalem basin are associated with known fold structures, faults, formation contacts and/or resistant strata. Surficial geology is characterized by parent rock and soils formed through volcanic and depositional processes. This study forms part of an undergraduate research project at Western Oregon University to characterize the geology and geomorphology of the Nehalem basin as part of broader watershed assessment efforts in the region.

I. INTRODUCTION

Nehalem Watershed has been the subject of various studies over the years, starting with J.D. Dana (1838) and Diller (1896). Researchers have focused on the basin's important resources: hydrological (construction of dams, reservoirs, and hydropower plants), geological (gas prospects), paleontological (rich fossil beds), timber production, fisheries, and recreational activities.

Located in the northwest corner of Oregon, Nehalem basin is west flowing tributary to the Pacific Ocean with adjacent sub-basins including the Columbia, Scappoose, and Tualatin. (Figure 1)

Site topography is diverse, ranging from steep Coast Range slope mountains to gentle hill slopes, terraces, and valley bottoms. Elevation ranges from the sea level at Nehalem Bay to 3,283 feet at Saddle Mountain. (Figure 2)

The climate is moderated by proximity of the Pacific Ocean that induces a maritime climate with rainy winter months and dry summers.

II. PHYSIOGRAPHIC SETTING

A. Location

The Nehalem watershed is located on the northwestern corner of Oregon, within the Coastal Range. It is spread across four counties including: Clatsop, Columbia, Tillamook and Washington. (Figure1).

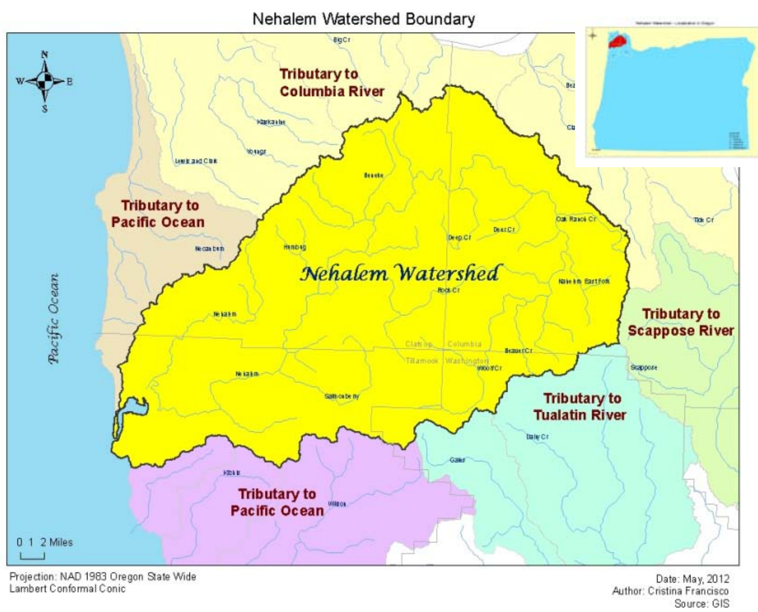

Fig. 1 - Watershed Boundaries

The watershed is surrounded by the rivers tributary to Columbia, Scappoose, Tualatin, and drains directly to the Pacific Ocean. Nehalem basin is bounded to the north-northeast by major rivers that flow into Columbia River including: Lewis and Clark, Youngs, Klaskanine, Big Creek, and Clatskanie. To the east-southeast the basin is bounded by rivers tributary to Scappoose and Tualatin. The Pacific Ocean forms the western limit of the watershed. (Figure 1)

B. Topography

The Nehalem River has its headwaters in the northern Oregon Coast Range near Cochram and drains 118.5 miles from its longest length into Pacific Ocean at Nehalem Bay. (Figure 2)

Flowing direction is generally northeast to southwest, with a total drainage area of 855 square miles.(ODF, 2005)

Watershed elevations increase from the sea level (0 feet) at Nehalem Bay to 3,200 feet in the Costal Range near Salmonberry River. The average altitude of the drainage divide is 1,600 feet reaching a maximum value of 3,283 feet at Saddle Mountain. Several high points inside the basin reach 2,000 feet. (Figure2)

In general, the topography reflects the underlying geology such that areas predominantly underlain by the sedimentary lithologies have moderate relief (10 to 50 percent slope) while areas composed of erosion resistant volcanic rock exhibit much more extreme relief with many vertical cliffs.

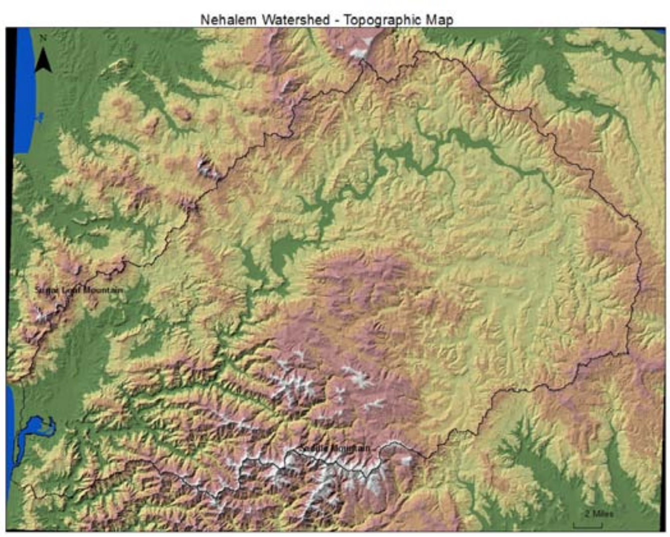

Fig. 2 – Nehalem Watershed Atlas Relief Model

C. Climate

Nehalem watershed is under two major climatic influences: the maritime effects of the Pacific Ocean and orographic effect of the costal mountains. Westerly winds blow inland from the Pacific Ocean and result in a warm wet winters and cool summers. Annual precipitation is abundant, with a high intensity in the winter months ranging from approximately 80 inches in lower elevations to more than 150 inches near the higher elevation divide to the east. (Figure 3)

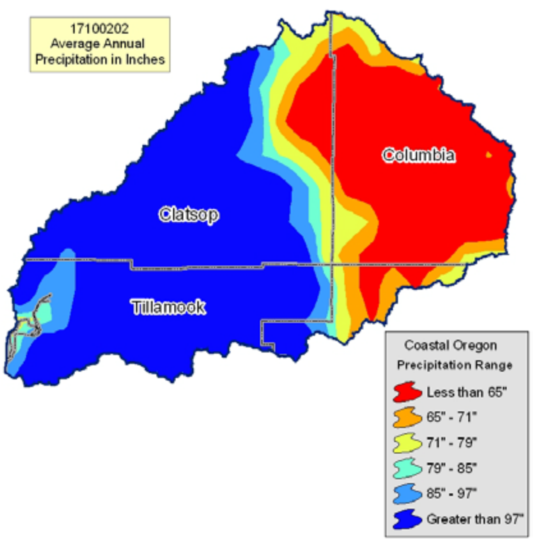

Fig. 3 – Average Annual Precipitation in inches
Source: USDA NRCS Nehalem

Periodic snowfall is possible at upper elevations, with rain-on-snow flood events possible. Cool marine air in summer results in frequent fog along the coast and the northern part of the watershed. The east side of the Costal Range is often associated with dry summer weather. (ODF, 2005)

D. Soils

Nehalem watershed soils are spatially correlated with geologic and climatic factors. The flood plains and the terraces consist of deep well drained soils that have formed in alluvium. **Nehalem Series** soils are characterized by average annual temperatures 48-50 °F and average annual precipitations 70- 100 in. The slopes associated with this type of soil are between 0 and 3 percent. (USDA, Soil Survey of Clatsop County, 1982)

Nehalem silt loam is associated with 3 to 7 percent slopes and formed in more recent alluvium. This soil has a weak structure and generally occurs in sharp bends of streams that are flooded during times of high water. (USDA, Soil Survey of Tillamook County, 1964)

Other soils types in this class are moderately deep and deep gently sloping to moderately steep. They are also moderately well drained and somewhat poorly drained silt loams that formed in colluvium derived from sedimentary rocks. Hill slope soils are found on gradients between 60 and 90 percent.

Muren soils are deep, gently sloping to very steep, well drained silt loams that formed in colluvium derived from igneous rocks and mixed with volcanic ash. (USDA, Soil Survey of Columbia County, 1986)

The **Hembre silt loam**, 30 to 60 percent slopes is found on steep terrain associated with rugged mountain areas in the Coastal Range. Runoff is rapid and erosion potential is severe in this portion of the landscape. (USDA, Soil Survey of Washington County, 1982)

III. GEOLOGIC SETTING

A. Tectonic Setting and Geologic History

The Nehalem River Basin and the Coast Range formation are the result of two historic upheavals, partial submergence, and subsequent erosion over time (ODF, 2005). The Oregon Coast Range is comprised of sedimentary and volcanic rocks deposited on oceanic crust (Oblinski,1983). These rocks reflect several periods of tension, related to seafloor spreading, and subsequent periods of compression related to subduction events during the middle Eocene time (Munford, 1988).

According to Newton and Van Atta, there are two hypotheses involving the western edge of the North American continent. The first hypothesis states that the volcanic islands in the Pacific Ocean were rafted by Eocene crustal spreading to the margin of the continent and that intervening material was subducted beneath the North American plate in Oligocene time. The second hypothesis does not involve crustal drifting but posits that extrusion of tremendous volume of volcanic material in Eocene time resulted in subsidence of the adjoining continental shelf and slope (Newton and Atta, 1976).

In the early Eocene, the subduction zone formed by the Farallon oceanic plate (the remnant fragment is now named Juan de Fuca Plate) was underthrusted beneath the North American continental plate (Eriksson A, 2002). (Figure 4)

During the middle of Eocene, the subduction activity was obstructed by seamounts and trench deposits, resulting in accretion and westward shift of the subduction zone with attendant volcanic arc development (Munford, 1988). During subduction, the basaltic crust of the Oregon

Coast Range, also interpreted as a micro-plate, rotated clockwise and formed a linear forearc basin, where sedimentary strata were subsequently deposited (Oblinski, 1983).

The late middle Eocene time was marked by volcanism that produced a large volcanic island complex and rejuvenated the older Eocene eruptive centers (subaerial seamounts). These eruptions resulted in the Tillamook Volcanics on the southern margin of the present-day Nehalem basin (Munford, 1988). Later, volcanic activity was reduced, and regional uplift associated with convergence produced an angular unconformity cut to the base of Eocene strata. (Oblinski, 1983).

Oligocene time had no major volcanic activity but was marked by marine sedimentation associated with the Cowlitz Formation (Newton and Atta, 1976).

The late middle Miocene time is associated with Oregon Coast Range uplifting and deformation associated with long-term underthrusting of Juan De Fuca plate beneath the North American (Oblinski, 1983).

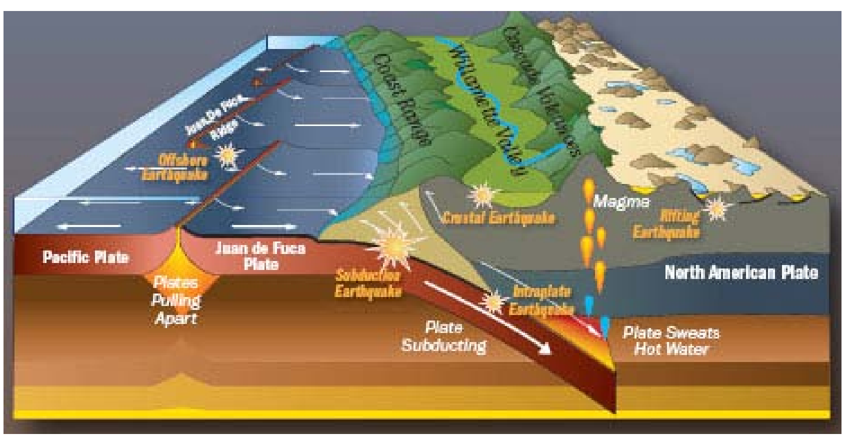

Fig 4 – Cascadia Subduction Zone
Source: Robert J. Lillie - The Oregon Historical Society

Close to Pliocene time, more tectonic activity produced north-south structures. The Coast Range anticline formed at this time and the ancestral Cascade Range volcanoes began erupting from a north-south chain of vents (Newton and Atta, 1976).

Pleistocene glaciation did not affect the northern Oregon Coast Range; however, there are significant amounts of glacial outwash carried by Columbia River System (Newton and Atta, 1976). The Cascadia subduction zone is still active today (Figure 4) with potential for large megathrust earthquakes and tsunamis. New research shows that in the last couple of thousand years, earthquakes have had recurrence interval of one in 500 to 300 years (Goldfinger et al., 2008)

Following these events, Nehalem River and its tributaries have initially formed terraces then eroded this area into remarkably deep and broad canyons. Studies suggest that the Nehalem River had a temporary base level about 400 feet higher than the present elevation of 800 feet (Van Atta, 1971).

B. Stratigraphy

The Coastal Range in northwestern Oregon is comprised of three distinct groups of rocks. The oldest group is the Eocene submarine basaltic lava associated with the Tillamook Volcanics Formation (Figure 5). Subjacent to the Tillamook is an intermediate group of marine sedimentary beds of upper Eocene to Miocene age, with Oligocene gabbroic intrusive cross-cutting the older strata. Resting uncomfortably on the lower Tertiary package are basaltic lava flow associated with Columbia River Basalt (Warren and Norbisrath, 1946).

Tertiary sedimentary units extended to a depth of at least 10,000 feet. Below a depth of 5,000 feet, volcanic rocks are interbedded with sediments and comprise the basement rock at greater depths (Newton and Atta, 1976).

Mappable formations in the Nehalem basin include the following (Walker and Norman, US Geological Survey, 1991) (Figure 5).

Tillamook Volcanics (Ttv), are the thickest (about 1,000 feet) and the oldest rocks of the area (upper and middle Miocene). They consist of subaerial basaltic flows and breccias, submarine basaltic breccia, pillow lavas, lapilli and augite-rich tuffs with interbeds of basaltic sandstone, siltstone, and conglomerate**.**

Keasey Formation (Tss) - Tuffaceous siltstone and sandstone (upper and middle Miocene) – Thick- to thin-bedded marine tuffaceous mudstone, siltstone, and sandstone; fine to coarse grained. Contains calcareous concretions and, in places is carbonaceous and micaceous.

Scappoose Formation and Pittsburg Bluff Formation (Tmst) – Marine sedimentary and tuffaceous rocks (middle Miocene to upper Eocene). Tuffaceous and arkosic sandstone, locally fossiliferous, tuffaceous siltstone, tuff, glauconitic sandstone, minor conglomerate layers and lenses, and a few thin coal beds.

Marine sedimentary rocks undifferentiated (Tms) - middle and lower Miocene, fine to medium grained marine siltstone and sandstone that commonly contains tuff beds.

Mafic and intermediate intrusive rocks (Tim) – Miocene age with dikes, plugs, and sills of basalt, diabase, gabbro, and lesser andesite.

Mafic intrusions (Ti) – Oligocene, characterized by sheets, sills, and dikes of massive granophyric-ferrogabbro.

Wanapum Basalt (Tcw) – middle Miocene Columbia River Basalt Group, flows of gray to dark-gray, medium-grained, commonly plagioclase porphyritic basalt.

Cowlitz Formation (Tco) - dated as old as upper Eocene, 950 feet thick, consisting of sedimentary beds of basal conglomerate, shale, and sandstones (Warren and Norbisrath, 1946). Cowlitz Formation was also dated upper and middle Eocene and consists of micaceous, arkosic to basaltic marine sandstone, siltstone, and mudstone. The Cowlitz sediments are also interbedded with *Goble Volcanics* that represents episodes of volcanism during the late Eocene (Newton and Atta, 1976).

Pittsburg Bluff Formation is also mapped as an individual formation, 700 to 850 feet thick, middle Oligocene, represented by fossiliferous tuffaceous sandstone and shale with white tuff of calcareous beds (Warren and Norbisrath, 1946).

Grande Ronde Basalt (Tcg) - middle and lower Miocene this formation is characterized by flow of dark-gray to black aphyric tholeiitic basalt.

Columbia River Basalt (Tc) - Miocene age, consists of subaerial basaltic and minor andesite lava flow and flow breccias. It unconformably overlies rocks aging from late Eocene to early Miocene (Newton and Atta, 1976).

Landslide and debris-flow deposits (Qls) - Holocene and Pleistocene deposits of unstratified mixtures of rock fragments. Map unit locally includes slope wash and colluviums; perhaps extending to late Pliocene in age.

Quaternary Alluvial Deposits (Qal) – late Pleistocene to Holocene, alluvial deposits associated with deposition by the Nehalem river and its tributaries (Newton and Atta, 1976).

Unit consists of sand, gravel, and silt forming flood plains and filling channels of the present streams. In some places includes talus and slope wash. Locally includes soils containing abundant organic material, and thin peat beds.

Nehalem Watershed - Geologic Map

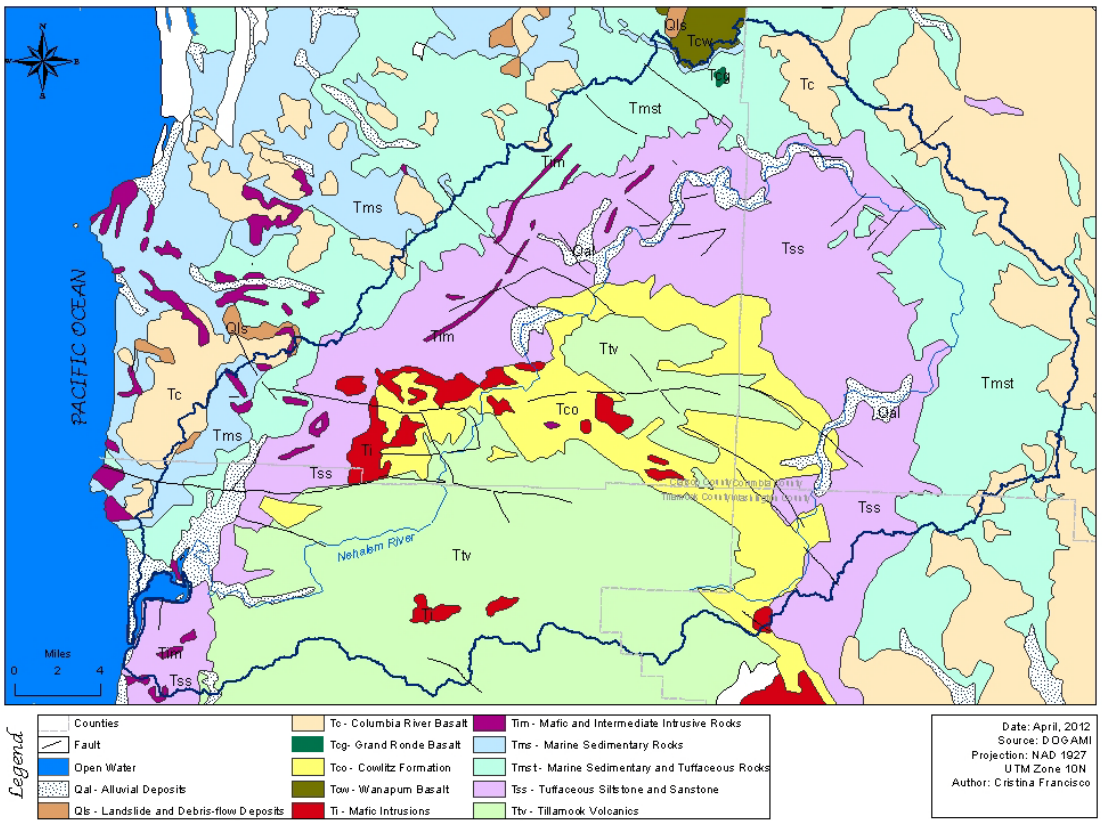

Fig. 5 Geologic Map

C. Structural Geology

During the Tertiary, the western margin of Oregon and Washington was subjected to a large scale reorganization of the Cascadia subduction zone (Figure 4) that resulted in regional rotation and deformation. Since the middle Eocene, the Juan de Fuca slab (a remnant of the Farallon Plate) has been subducting obliquely in a northeasterly direction creating northward migration of the forearc and causing clockwise rotation of coastal blocks of western Oregon and Washington. This rotation has been in part accommodated by complex faulting dominated by dextral slip along northwest trending faults (Figure 5) (Eriksson A, 2002)

The structural geology of the Nehalem basin is aligned with structural trends in the Oregon Coastal Range, a regional anticlinorium that plunges north cross-cut by an interconnected network of northwest, northeast and east trending faults. Munford D, 1988). In addition, the upper Nehalem basin forms part of the lower Columbia River downwarp, in which Miocene lavas accumulated. Uplifting and arching of the northern Coast Range formed a northward plunging anticline which projects into this downwarp (Newton and Van Atta, 1976)

The tectonic history includes a major late Eocene extensional event that produced abundant normal faulting throughout the Nehalem Basin that may be attributed to initial forearc extension. This tectonic episode created the structural traps that later confined the natural gas of the Mist Gas Field. (Eriksson A, 2002).

Surface lineaments correspond to known fold structures and formation contact along mechanically resistant ridges.

IV. CONCLUSIONS

The Nehalem watershed constitutes an important natural resource in the region and is of great scientific, social and economic interest: this study provides an overview of the physiographic and geologic setting of the basin. This work is combined with ongoing watershed assessment activities in the Oregon Coast Range have important implications for wise land-use planning related to hydrology (e.g. construction of dams, reservoirs, and hydropower plants), energy resources (e.g. gas and oil prospects), cultural resources (e.g. paleontology, rich fossil beds), timber production, fisheries, and recreational activities.

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