3.0 Watershed Conditions

This section contains a detailed description of historical and existing conditions, data gaps, and identified problems and potential solutions within the five subbasins of the Murray/Sequalitchew watershed.

3.1 Topography, Geology, and Soils within the Watershed

Topography, regional and surface geology, and local soils have a profound influence on the manner in which the ground surface intercepts precipitation, allows it to infiltrate to support ground water recharge and vegetative growth, and promotes surface water runoff to nearby water bodies.

3.1.1 Topography

The landscape within the Murray/Sequalitchew watershed is characterized by western-sloping plains with several kettles, or depressions that were created by glacial processes. Some of these kettles have formed lakes, while others have become marshes or wetlands. The elevation above mean sea level (MSL) ranges between 400 feet near the headwater hills, to 236 feet around American Lake, 216 feet around Sequalitchew Lake, and down to sea level where the mouth of Sequalitchew Creek meets Puget Sound (Pierce County 2004).

Upper, Middle, and Lower Murray Subbasins, and American Lake Subbasin

Most of the area comprising the Upper, Middle, and Lower Murray subbasins, as well as the American Lake subbasin, lies within the boundaries of Fort Lewis. The topography within Fort Lewis is dominated by nearly level prairies. Low-lying hills are more common in the western portion of the installation, while low-lying hummocky topography, characteristic of glacial moraines, is present in the southern portion (ENSR 1992). Very little natural erosion occurs at Fort Lewis because of the relatively level topography and permeable, coarse-textured soils.

Sequalitchew Subbasin

The topography of the Sequalitchew subbasin (including the lake and much of the drainage) is relatively flat with the greatest topographic relief occurring at the east end of the lake, where the banks rise as much as 50 feet above the water surface (Shapiro 1997a). Beginning at Sequalitchew Lake, Sequalitchew Creek flows through Hamer Marsh and Edmond Marsh before traveling through a steep canyon to Puget Sound, dropping 220 feet in elevation over a horizontal distance of 7,750 feet (2.8% average slope).

3.1.2 Regional Geology

Regional and local geologic conditions influence watershed size, hydrology, and channel geomorphology. These landscape features provide a framework within which watershed processes are able to respond to both natural and human-induced changes.

Fort Lewis is situated within the southern portion of the Puget Sound lowland region. The region is underlain by several thousand feet of glacial and interglacial sediments overlying bedrock. The glacial sedimentary deposits include a complex and discontinuous mix of lake deposits, advance outwash, till, and recessional outwash deposits that were deposited from about 16,000 to 2 million years ago during each of at least five major and several minor glacial advances. Typical nonglacial deposits were low-energy stream and lake deposits. The uppermost geologic units in the lowland region reflect the final deposits of the last glacial advance, known as the Vashon Stade of the Fraser Glaciation (Booth et al. 2003), which culminated approximately 16,000 years ago.

The following geologic layers, listed in descending order from the surface are the Steilacoom gravels, Vashon recessional outwash, Discovery nonglacial unit, and the Narrows glacial drift. It is this most recent ice sheet advance, combined with other local postglacial landscape modifications, that largely dictates the channel and watershed processes in the Murray/Sequalitchew watershed.

Upper, Middle, and Lower Murray Subbasins

Vashon till was deposited at the base of the Vashon glacier and is found in the upper hills of the Murray Creek watershed. These hills include Stover, Harper, Kemp, and Miller's Hill to the south of Murray Creek, and McCall Hill to the north. The deposits are between 5 and 30 feet thick and appear to be discontinuous as a result of erosion (Zulaf 1979). These till deposits are composed of a very dense, consolidated mixture of silt, sand, and gravel, compacted by the weight of the glacier into a hardpan with the appearance and characteristics of concrete. Because of their impermeable nature, the till layers control whether ground water will infiltrate to recharge deeper aquifers (Booth et al. 2003).

The Murray Creek stream channel is characterized by outwash gravel known as Steilacoom gravel, which was deposited as the Vashon glaciers receded. The Steilacoom gravels were originally deposited by the large rivers that drained a glacial lake in the Puyallup River Valley and which flowed west and southwest to Puget Sound. These rivers eroded the Vashon till into numerous large channels surrounding elongated till- and outwash-cored hills. The Steilacoom gravel deposit is generally about 20 feet thick but ranges in thickness up to about 60 feet. The coarse gravel typically has diameters greater than 1 inch, with occasional cobbles and boulders up to 1 foot in diameter.

The Steilacoom gravels are well-sorted and are particularly important because they permit rapid infiltration and ground water movement. Because they lack cohesion, the Steilacoom gravels are prone to fluvial erosion and therefore become a principal component of the stream and river bedload (the sediment found in ample quantities along the channel bed that is transported through the stream system). When overlaying less permeable layers, such as the till present in the hills, the gravels yield seeps and springs (Booth et al. 2003).

American Lake Subbasin

The surface geology around American Lake is dominated by the Steilacoom gravel. In this subbasin, the Steilacoom gravel supports the upper portion of the surface aquifer which maintains ground water discharge to the lake (Brown and Caldwell et al. 1985).

Vashon till provides the lower boundary of the lake. This dense mixture of sand and gravel within a larger matrix of silt and clay provides an aquitard (i.e., a layer of low permeability impeding vertical ground water flow), which allows very limited water movement. However, a report dating from 1993 (Kramer, Chin, & Mayo, Inc.; KCM), suggests that lake water penetrates the till and is in hydraulic contact with a deeper portion of the aquifer dominated by sand and gravel known as the Vashon advance outwash formation (see the Ground Water section of this document).

Sequalitchew Subbasin

Similar to American Lake, the geology underlying most of Sequalitchew Lake and Sequalitchew Creek is dominated by the Vashon drift formation, with a layer of Vashon recessional outwash closest to the surface, followed by a layer of Vashon till over a layer of Vashon advance outwash.

Sequalitchew Creek flows through the DuPont delta (also called the Steilacoom delta), which is a thick geologic unit (over 200 feet) characterized by coarse sand, gravel, cobbles, and boulders with lesser amounts of silt and clay (CH2M Hill 2003).

3.1.3 Soils

Similar to the geologic characteristics, soil characteristics are consistent throughout the watershed, with significant differences present only near the mouth of Sequalitchew Creek at the Puget Sound shoreline where soil is developing in contemporary sediments in a wetland (Figure 3.1-1).

Overall Murray/Sequalitchew Watershed

Soils within this watershed largely consist of the Spanaway and the Everett series (Zulaf 1979). The Spanaway soil covers extensive areas in all subbasins. The two phases of the Spanaway soils present are the Spanaway gravelly loam found on low-gradient slopes (1 to 6 percent slope) and the Spanaway gravelly sandy loam, which occurs as a deep, nearly level (1 to 3 percent) soil that extends deeper than the Spanaway gravelly loam phase.

Shapiro (1996) made correlations between the surface characteristics and the subsurface geologic units. At the regional scale, these comparisons found that the Spanaway soil series correlated to subsurface lithologies described as gravel, sandy gravel, and silty sand and gravel.

The Everett series occurs on smaller land features of glaciated uplands and has developed from loose, poorly sorted glacial drift. The Everett series correlates with the finer deposits of silty sand that were deposited within the Steilacoom gravels (Shapiro 1996).

Other soil series present, to a lesser extent, include the Fitch, Nisqually, DuPont, Greenwood, and McKenna series. The Fitch gravelly sandy loams are found in several locations in the Sequalitchew and Middle Murray subbasins, usually adjacent to Everett soils. The Fitch and Greenwood series are now grouped in the Everett series.

The Nisqually series is a loamy sand found in several locations along Murray Creek. It formed in sandy glacial outwash under grassland in the Fort Lewis area. It is relatively flat (less than 6 percent slope) and has rapid permeability.

The DuPont series is an organic soil developed from plant remains with measurable amounts of volcanic ash. This soil forms in topographic depressions and is poorly drained and saturated for most of the year (Zulaf 1979). The McKenna gravelly loams are found east of McChord Air Force Base. This soil, formed in glacial till, is nearly level and is poorly drained.

Lower Sequalitchew Subbasin

Although lower Sequalitchew Creek is beyond the study area, this downstream reach of the stream is important to salmon migration upstream from Puget Sound. A field reconnaissance of the marsh adjoining the mouth of Sequalitchew Creek indicated that the topsoil layer of the marsh is relatively thin (less than 1 inch) and is composed of silt loam with a high amount of organic matter overlying gravels (Anchor Environmental 2004a).

3.1.4 Key Issues

Topographic, geologic, and soil characteristics should be considered when identifying watershed problems and when proposing particular management solutions. Much of the Upper Murray/Sequalitchew watershed has fairly flat topography and thus low stream gradients. Low stream gradients are associated with low flow velocities and can compound capacity problems such as those experienced in upper Sequalitchew Creek (see Surface Water Resources section).

The flat topography, and its associated lower stream velocities, also reduces the ability of the stream to recruit and transport sediment. As a result, variation in substrate conditions and thus fisheries habitat is reduced (see Aquatic Habitat and Fisheries section). This situation is easily aggravated by human disturbances to the system. Permeable soils and substratum with high infiltration rates closely tie stream and lake flows to ground water movement. Such well-drained materials contribute to losing reaches of Murray Creek when the ground water table is low.

The high infiltration capacity of the soils in the study area allows extensive use of low-impact development techniques. Low-impact development techniques include bioswales, dry wells, permeable pavement, and other facilities that enhance the infiltration of stormwater into the ground.

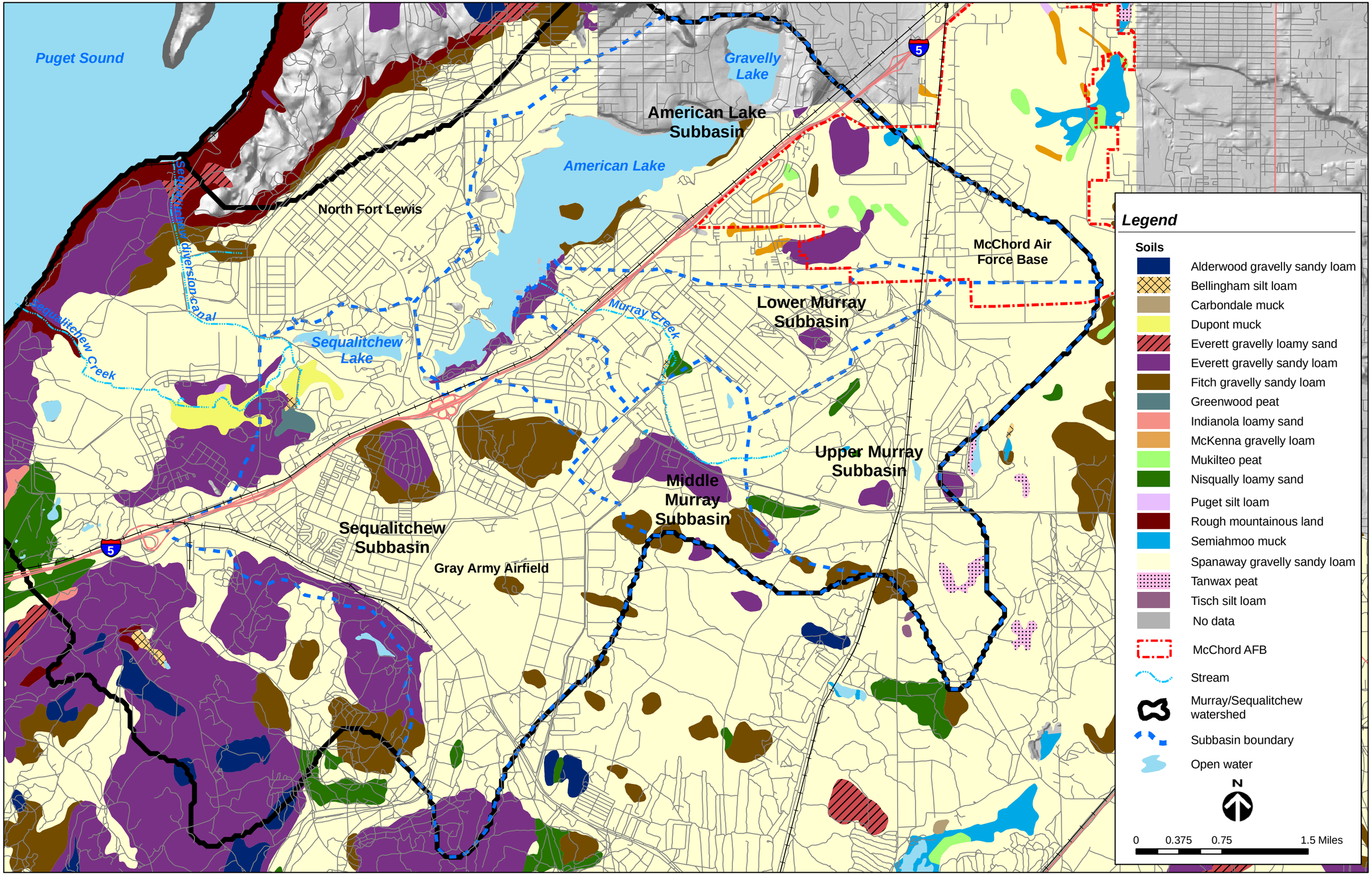

Figure 3.1-1 Soils Within the Murray/Sequalitchew Watershed Sudy Area.

3.2 Climate

The Puget Sound region has a relatively mild climate, characterized by the cool, wet winters and warm, dry summers that are typical along the Pacific Coast. The climate of Pierce County is moderated by Pacific Ocean winds. Numerous weak storm fronts pass through the area during the winter, bringing the majority of the rainfall. Most winters experience only one or two storms with damaging winds and rain. About 80 to 85 percent of the annual precipitation occurs from November through April. The annual precipitation generally increases with elevation from west to east across the county, from 40 inches near Puget Sound to more than 160 inches on Mount Rainier. Periodically, a large inverted air mass will form, causing abnormal temperatures and stagnant air conditions resulting in poor air quality, especially in urban centers at lower elevations.

Puget Sound area streams usually have the highest flows during the rainy season in winter. Much of the streamflow originates from ground water entering the upper reaches of Murray Creek, which derives from rain over the preceding months. In the Murray/Sequalitchew Creek watershed, however, the close interaction between surface water and ground water potentially alters this pattern.

The climate is largely responsible for streamflows in a watershed. Therefore, it is useful to look at long-term weather patterns to determine when significant deviations from the usual climate have occurred and how these deviations may have affected streamflows. In 1994, Murray Creek was reported to run dry during the summer months (Shapiro, 1996).

Available rainfall data were examined to determine whether rainfall patterns were significantly different after 1994 as compared to earlier periods, and whether changes in rainfall might be responsible for alterations in streamflow. Long-term data were available at the Washington state climatology website from three locations: Tacoma (about 11 miles northeast of Fort Lewis), Olympia (17 miles southwest of Fort Lewis at the Olympia Airport), and the McMillin Reservoir (about 12 miles northeast of Fort Lewis). Data from Tacoma and Olympia span the period from 1948 to the present. McMillin Reservoir data date to 1941, but the years prior to 1947 were excluded to create a consistent data set among the three locations. The Tacoma gauging station was moved after 1981. The new station (Tacoma 1) is fairly close to the former station (Tacoma WB) geographically and has yielded a similar mean annual rainfall, so the records from the two Tacoma gauging stations were considered as one for this analysis.

3.2.1 Historical Climate Conditions

Monthly average maximum temperatures usually range between 45 and 50 degrees Fahrenheit (°F) during winter and usually exceed 70°F during the summer (Table 3.2-1).

The average precipitation in the vicinity of Fort Lewis is approximately 42 inches per year. About 85 percent of this precipitation occurs as rainfall from October to April (Table 3.2-2), with

almost half of that falling in just 3 months, November through January. Snowfall seldom occurs in the Murray/Sequalitchew watershed.

Table 3.2-1 Average Maximum Temperatures (°F) in the Fort Lewis Vicinity.

Climatological Station and Years Sampled	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Olympia (1948-2005)	44.5	49.2	53.4	59	65.7	71.0	77.1	77.1	71.6	60.6	50.5	44.8	60.4
McMillin (1941-2005)	44.5	48.6	52.5	57.9	64.3	69.1	75.2	75.3	70.0	60.2	50.4	45.3	59.4
Tacoma WB (1948–1981)	45.0	50.1	52.8	58.7	65.8	70.3	75.5	75.0	69.9	60.9	51.9	47.3	60.3
Tacoma 1 (1982–2005)	48.3	50.8	55.5	60.6	66.2	71.9	76.4	77.1	71.4	61.3	52.4	46.6	61.5

Data from Washington State Climatologist (2005).

Table 3.2-2 Average Monthly Precipitation (inches) in the Fort Lewis Vicinity.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave. Annual
Olympia (1948–2005)	7.95	5.82	5.12	3.35	1.98	1.57	0.72	1.20	2.04	4.74	8.10	8.18	50.76
McMillin (1941–2005)	5.54	4.29	3.98	3.19	2.40	2.10	0.96	1.26	1.93	3.70	6.04	5.77	41.17
Tacoma WB (1948–1981)	5.46	4.02	3.43	2.40	1.46	1.35	0.82	1.21	2.02	3.32	5.34	6.09	36.92
Tacoma 1 (1982–2005)	5.71	3.78	4.07	3.02	1.98	1.59	0.74	0.88	1.16	3.70	6.50	5.46	38.59

Note: The averages are continually revised as new information becomes available. Therefore, some data from the first part of 2005, but not the entire year, are reflected.
Data from Washington State Climatologist (2005).

3.2.2 Existing Climate Conditions

Precipitation was above average for two stations from 1994 through at least 1999 (Table 3.2-3). From 2000 to the present, moderately dry and wet years have alternated. Substantial amounts of data are missing from the Tacoma records for 1998, 2000, and 2002. However, the Olympia and McMillin Reservoir gauges indicate that precipitation was substantially below average during 2000 and 2002; therefore, it is likely that precipitation in Tacoma was well below average during these years. In 2004, Tacoma was about 17 percent below average for annual precipitation, McMillin Reservoir was 12 percent below average, and Olympia was 22 percent below average. The year 2004 was the fourth driest year during the period of record at the Olympia gauge (Table 3.2-4). Precipitation at all three climate stations was near or above average in 2001 and 2003.

Examining older climate data, 1993 was the fourth driest year during the period from 1948 through 2004 (see shaded cells in Table 3.2-4) for Tacoma. Olympia and McMillin Reservoir data generally agree, showing 1993 as the third driest year. The previous two years (1991 and 1992) were below average in precipitation at all three sites. Furthermore, the monthly Tacoma data show that precipitation was below average during every single month from June 1993 through January 1994, totaling 14.57 inches compared to the normal 25.74 inches. The Olympia and McMillin gauges have similar records, showing precipitation below average from August 1993 through January 1994 (indicated by shaded cells in Table 3.2-4). The decreased flows in Murray Creek in 1994 were likely influenced by this drought.

Table 3.2-3 Total Precipitation (inches) by Year at Climatological Stations in the Fort Lewis Vicinity from 1991 through 2004.

	Tacoma 1 [a]	Olympia	McMillin Reservoir
1991	34.71	42.43	40.00
1992	31.88	40.15	35.24
1993	29.29	35.55	33.13
1994	38.12	49.67	43.33
1995	43.86	54.90	44.52
1996	53.27	59.28	62.88
1997	39.59	64.83	47.34
1998	data missing	57.96	48.08
1999	47.46	66.64	48.90
2000	data missing	40.86	38.98
2001	40.71	50.07	42.27
2002	data missing	41.48	36.07
2003	40.29	52.56	41.11
2004	32.04	39.42	36.18
Average [a]	38.59	50.76	41.17

[a] Period of record: Tacoma 1 = 1982–2004, Olympia = 1948–2004, and McMillin = 1941–2004. Data from Washington State Climatologist (2005).

Table 3.2-4 Driest Years Recorded at Rain Gauges in the Fort Lewis Vicinity.

	Tacoma WB	Tacoma 1	Olympia	McMillin Reservoir
Period of record	1948–1981	1982–2005	1948–2005	1941–2005
Driest year	1952: 16.96 inches	–	1952: 29.92 inches	1952: 22.07 inches
2nd driest year	–	1985: 24.94 inches	1985: 35.07 inches	1985: 27.83 inches
3rd driest year	1976: 27.7 inches	–	1993: 35.55 inches	1993: 33.13 inches
4th driest year	–	1993: 29.29 inches	2004: 39.42 inches	1976: 33.42 inches
5th driest year	1949: 29.56 inches	–	1976: 39.61 inches	1987: 33.67 inches

Shapiro (1996) ran an analysis of cumulative precipitation departure from normal at Tacoma during the period from 1948 to 1995, which showed that the 1993 to 1994 drought was similar to

a 1977 to 1982 episode, but less severe than the 1952 to 1954 episode. Unfortunately, flow records from these other drought periods are not available for Murray Creek.

A more revealing statistic for correlating low streamflow with weather patterns is rainfall during the hydrologic water year (October through September). Table 3.2-5 shows that although the 2004 to 2005 water year was dry, the 1993 to 1994 water year was considerably drier. This may explain why staff from Camp Murray reported that Murray Creek flowed throughout the summer of 2005 (Clouse 2005) but dried up in 1994.

Table 3.2-5 Comparison of Total to Average Annual Rainfall During Dry Hydrologic Years (% change from normal).

	Tacoma (October–June)	Olympia (October–August)	McMillin Reservoir (October–May)
1993 to 1994 Water Year	–24	–33	–24
2004 to 2005 Water Year	–19	–22	–9

3.2.3 Data Gaps

Although climate information has been collected at several locations closer to Fort Lewis than Tacoma, Olympia, or McMillin Reservoir, the information is not readily available, and does not appear to be complete. For instance, weather information from McChord Air Force Base is listed as being available only prior to 1999. Recording rainfall data at McChord would be helpful for better understanding rainfall patterns at Fort Lewis.

The period in 1994 when Murray Creek dried up appears to follow the third driest year on record, 1993. It would be informative to compare the effects of the two driest years, 1952 and 1985, on Murray Creek flows. Unfortunately, no flow data, even anecdotal, are available for 1952 or 1985, so the effects on streamflow cannot be determined.

The lack of stream monitoring data also makes it impossible to compare periods of below-average rainfall since 1993 directly with streamflows. However, anecdotal reports of flow continuing throughout the summer of 2005 indicate that creek flows may not be affected until extremely dry weather occurs for an extended period of time. Precipitation at all three nearby rain gauges was 7 to 8 percent less in 1993 than in the 2004 to 2005 water year.

Although historical streamflow data for Murray Creek are unavailable, it would be useful to compare rainfall-runoff relationships between historical periods (early 1940s) and under current land cover conditions to examine what impact the increasing imperviousness within the Murray Creek watershed may have. An updated model of flow in Murray Creek could be compared with earlier model results presented in Shapiro (1996).

3.2.4 Key Issues

One of the key issues identified is the reported lack of base flow in Murray Creek during the summer. It was reported that certain reaches of Murray Creek dried up in 1994, when they had not done so historically. Shapiro's subsequent 1996 studies of Murray Creek determined that streamflow was lost to seepage through the bottom of the stream.

During the June 16, 2005, deconfliction meeting conducted for this watershed plan, Fort Lewis personnel reported that Murray Creek continues to dry up during the summer in the lower reaches, although it apparently flowed throughout the summer of 2005, a very dry year, as noted above. (See the Surface Water Resources section for additional information on flows in Murray Creek.)

A primary climatological question is whether the years since 1994 have experienced significantly lower than average amounts of rainfall to cause the channel-drying effect. It may be that land and water use changes within the watershed have compounded the effects of lower than normal annual rainfall, causing Murray Creek to run dry. It is possible that certain reaches of Murray Creek dried up historically, but these occurrences went undocumented. A key issue, therefore, is determination of the point at which decreased rainfall noticeably affects flows.

3.2.5 Potential Solutions

A potential solution for proactively maintaining streamflow in drought years is to establish guidelines for instituting additional water conservation measures at Fort Lewis if precipitation falls below a certain measure, such as more than 20 percent below normal during the hydrologic water year. This threshold can be set based on further evaluation of precipitation records and the occurrence of dry streambed conditions. Establishment of a rain gauge within the Murray Creek watershed or working with McChord Air Force Base to receive precipitation data are recommended.

3.3 Land Use and Land Cover in the Watershed

Many previous studies have shown that the composition of land use and land cover within a watershed can account for much of the variability in water quality (Hunsaker et al. 1992; Charbonneau and Kondolf 1993) and stream ecology (Whiting & Clifford 1983; Hachmoller et al. 1991; Thorne et al. 2000). Land cover is defined as the observed physical and biological cover of the land as vegetation or manmade features. Land use is the range of uses of Earth's surface made by humans. Land use and land cover patterns have major influences on how and where precipitation is intercepted by vegetation, infiltrated, or transferred to runoff. The land use and land cover patterns within the Murray/Sequalitchew watershed are directly related to the jurisdiction responsible for that area.

The majority of the Murray/Sequalitchew watershed lies within three military installations: Fort Lewis, McChord Air Force Base, and Camp Murray. Other portions of the watershed are within the cities of Lakewood and DuPont (as shown in Figure 1-1). These jurisdictions create zoning

designations that focus urban land uses in particular areas while preserving parks and open space elsewhere. In addition, military areas allocate particular areas for field training. In this way, biophysical characteristics (i.e., forest, grass, or impervious surface) that compose the landscape surface are strongly correlated to the zoning or land use designations. Urban land uses are likely to be characterized by greater amounts of impervious surface, while parks and other undeveloped areas and some types of training areas are likely characterized by greater amounts of grass and trees. Where infiltration and other low-impact development practices are incorporated, the adverse impacts of development are minimized, and the natural hydrology and water quality are preserved. Therefore, the differing jurisdictions and their land use designations will continue to have a significant influence on the quality and quantity of environmental resources in the watershed.

This section of the watershed management plan describes the historical and existing conditions of the land use and land cover characteristics within the Murray/Sequalitchew watershed. Although the discussion focuses on the subbasins within Fort Lewis jurisdiction, land use and land cover characteristics are described throughout the Murray/Sequalitchew watershed in order to understand the potential landscape scale interactions with watershed resources. In particular, both McChord Air Force Base and the City of Lakewood are located upstream of portions of Murray Creek, American Lake, and Sequalitchew Creek that lie within Fort Lewis property. Therefore, land use and land cover patterns within these upstream jurisdictions can affect water resources within Fort Lewis. Similarly, although the downstream portion of Sequalitchew Creek is beyond the Fort Lewis jurisdictional boundary, the extent to which downstream land uses affect aquatic habitat and vegetation can have profound implications for the ability of aquatic species to access habitat and resources within Fort Lewis.

3.3.1 Historical Land Use and Land Cover in the Vicinity of Fort Lewis

The landscapes within the Murray/Sequalitchew watershed were first mapped by European land surveyors in the mid-1800s. Approximately 43 percent of the area was covered by forest, while about 48 percent of the area was covered by grasslands or mixed grassland/oak woodlands. The forested areas were most common along the Nisqually River, including the western portions of the present-day installation area. Other patches of coniferous forest and conifer/hardwood forest were located throughout and adjacent to the grassland areas (U.S. Army 2005b).

Before the area that is now Fort Lewis was developed into a military reservation, it was used for homesteads, ranchland, agriculture, and later for timber harvest. Agriculture developed most intensively near the rich soils within the Muck Creek watershed to the south of the Murray/Sequalitchew watershed, whereas the native grassland areas were settled by sheep-herding enterprises (Nature Conservancy and WDNR 1994). The agricultural and timber harvest land uses of the late 19th century caused a change in the land cover. Douglas-fir began to encroach upon the drier grasslands and mixed-oak woodlands that had previously been maintained by grazing and frequent fires. Forestland increased by about 39 percent, while grassland decreased by about 58 percent between 1870 and 1990 (ENSR 2000).

The period of peak timber harvest occurred around 1870, before military acquisition. By 1910, most forested areas within the present-day Fort Lewis had been harvested. When the U.S. Army began acquiring the land within the Murray/Sequalitchew watershed area in the early 1940s, it began to complete selective clear-cuts to make room for development. Since 1962, logging within Fort Lewis has continued at a moderate pace, with an estimated 8 to 12 million board feet of timber harvested annually (U.S. Army 2005b).

The Murray/Sequalitchew watershed area first became used for military activities during the years leading up to World War I, in the early 1900s. At that time, Army National Guard units began using the area surrounding American Lake as a training site (Washington Army National Guard 2005). A few years later, in 1917, the Fort Lewis Military Reservation was first established on land donated by Pierce County residents. In 1924, 423 acres of Fort Lewis property located west of American Lake were dedicated to the Veterans Affairs Medical Center, also known as the Veterans Hospital (KCM 1993). In 1926, the National Guard unit, formerly known as the State Military Reservation at American Lake, was designated as Camp Murray and located just east of American Lake (Washington Army National Guard 2005).

McChord Air Force Base was first established in 1938. Since that time it has been used for military training, as well as for aircraft service, repair, and maintenance (KCM 1993). The majority of McChord Air Force Base is located within the American Lake subbasin, just east of the lake and Interstate 5.

In 1941, the Logistics Center was developed in the portion of Fort Lewis located north of Madigan Hospital in the Lower Murray subbasin. The Logistics Center was originally operated as an ordnance depot from 1942 until 1963, and since 1963 it has served as a non-aircraft maintenance facility for Fort Lewis (KCM 1993).

The nearby cities of DuPont and Lakewood were established in 1970 and 1996, respectively (Lakewood 2005; Andrews and Swint 1994). The City of DuPont is located on Puget Sound in the western portion of the Murray/Sequalitchew watershed. The City of Lakewood is located within the northwestern portion of the Murray/Sequalitchew watershed between south Tacoma, McChord Air Force Base, and north Fort Lewis.

Upper, Middle, and Lower Murray Subbasins

The Upper, Middle, and Lower Murray subbasins have undergone several surges of land use and land cover change since the military first began clearing the land for development in the 1940s. The development has led to an increasing amount of impervious surface cover (roads, parking lots, rooftops, sidewalks, and other hard surfaces that restrict infiltration of precipitation and runoff into the soil). A few of the existing buildings on Fort Lewis have been present for at least 60 years, including the old Madigan hospital complex, numerous barracks in the vicinity of the hospital complex, and the Logistics Center. Highway Interstate 5 and a number of residential areas, including Phase 1 of the Evergreen housing development, were constructed in the 1960s.

Much of the lower watershed was developed in the 1980s, including the construction of the Special Forces compound, the new Madigan Army Medical Center, Phase 2 of the Evergreen housing development, and Berkeley-Jackson Avenue adjacent to and across Murray Creek, as well as the expansion of existing parking lots in the area (Shapiro 1996).

American Lake Subbasin

Similar to the Murray subbasins, the American Lake subbasin first became developed by European settlers during the mid-1800s, when a community known as Ponders Corner was established just north of the American Lake watershed (Pierce County 1991; KCM 1993). Residential development ensued through the turn of the century, with the construction of small summer houses and estates along the lake shoreline. In the years preceding World War I, the American Lake area in the vicinity of the present-day Camp Murray began to be used as a training site by Army National Guard units. In 1926, the state military reservation at American Lake was designated as Camp Murray (Washington Army National Guard 2005).

During the 1930s and 1940s, the scattered homes located along the American lake shoreline developed into a full-time residential community (KCM 1993). The American Lake subbasin was influenced by development in the watershed with the establishment of Fort Lewis and McChord Air Force Base in 1917 and 1938, respectively. Development in the watershed increased the amount of impervious area resulting in more runoff and higher pollutant loads entering the lake.

The American Lake subbasin has a long history of recreational land use. The Tacoma Country and Golf Club has been located along the northeastern shoreline of American Lake since 1917. American Lake has been a popular place for fishing. Beginning in 1957, the WDFW supported the establishment of a trout-only fishery. To date, rainbow trout and kokanee are being stocked annually in American Lake.

Sequalitchew Subbasin

The Sequalitchew subbasin has experienced significant land use and land cover changes during the last 150 to 200 years. Before settlement, the landscape surrounding Sequalitchew Lake and the upper reaches of Sequalitchew Creek was dominated by wetlands, while the lower reach of Sequalitchew Creek passed through a canyon before entering an estuary at its mouth in Puget Sound (Wolcott 1973; Andrews and Swint 1994; DuPont 1994; Anchor 2004a, 2004b). Sequalitchew Creek historically provided a rich fishing and recreational resource (Andrews and Swint 1994).

The landscape surrounding Sequalitchew Creek began to be altered from its natural state in the mid-1850s. At that time, the Puget Sound Agricultural Company began to drain the swampy areas between the Sequalitchew Lake outlet and the downstream canyon to make the land more suitable for farming. In the early 1900s, Sequalitchew Creek was dammed at the head of the canyon by the E.I. DuPont de Nemours Company (DuPont) in order to supply hydroelectric power for their explosives manufacturing facility (Aspect 2004). In the 1950s, the Sequalitchew subbasin landscape and drainage was altered again when Fort Lewis constructed a separate

stormwater drainage canal to convey overflow from Sequalitchew Lake to Puget Sound (Runge et al. 2003; Andrews and Swint 1994). Channelized drainage from Hamer Marsh now enters the diversion canal; however, historically, Hamer Marsh was likely a bog with no surface water connection to the Sequalitchew subbasin (Gilbert 2005).

In 1906, the village of DuPont was established south of Sequalitchew Creek to provide employee housing for DuPont. DuPont manufactured large quantities of unstable explosives (nitroglycerin dynamite) for more than 75 years. The village of DuPont was chartered as a city in 1951, when residents were allowed to purchase their houses (DuPont Historical Museum 2006). The DuPont manufacturing plant continued its operations adjacent to the city until 1976, when it sold its 3,200 acres to the Weyerhaeuser Company (Quadrant 2005). The manufacturing area is now a toxic cleanup site, and Weyerhaeuser is currently constructing a large residential development, called Northwest Landing, adjacent to the historical DuPont village center. Sequalitchew Creek flows through the middle of the Northwest Landing development. Upon completion, this development is expected to bring 15,000 additional residents to the Sequalitchew Creek area (Andrews and Swint 1994; DuPont 2005).

When Weyerhaeuser purchased the DuPont land in 1976, it also purchased an additional parcel on the north bluff of Sequalitchew Creek. This parcel (among other parcels) is slated for the proposed expansion of the Glacier Northwest Pioneer Aggregates Mining Facility (Glacier Northwest facility; Anchor 2004b; Anchor et al. 2004). The Glacier Northwest facility was given a permit to build in 1993, but has been in the process of negotiating with environmental advocacy groups.

3.3.2 Existing Land Use and Land Cover in the Vicinity of Fort Lewis

Fort Lewis is an Army installation of approximately 86,176 acres that is used for military training. Although Fort Lewis's training and support role has not changed significantly in recent years, the installation has continued to develop new facilities, and has modified older facilities, to continue to meet the needs of the increasing number of personnel stationed there. Because Fort Lewis is federally owned military land, it is subject to federal regulations, including those administered by the State of Washington, but is legally exempt from state regulations and local ordinances. However, in many cases Fort Lewis has chosen to exceed the minimum-required federal standards by officially adopting local regulations or by establishing programs and policies that meet the intent of many state and local regulations.

Primary Land Use Zones

Fort Lewis currently operates under two primary land management schemes, one based on military needs and another based on ecosystems (e.g., the characteristics of soil, vegetation, and water). These schemes have developed over time to benefit the military and environmental programs that use them (ENSR 2000). Overall, land use at Fort Lewis is governed by the *Fort Lewis Real Property Master Plan, Volume I* (U.S. Army 1997a), which allocates certain Fort Lewis activities to specific zones. Most Fort Lewis activities fall within one of two identified land use zones (ENSR 2000):

- The cantonment area (10,603 acres throughout Fort Lewis, primarily developed area), which includes Gray Army Airfield and residential, administrative, commercial, industrial, and open space uses; or

- The training areas (75,573 acres throughout the entire Fort Lewis property, primarily undeveloped area), which include maneuver, impact, range, and special-use areas.

The Fort Lewis cantonment area includes the North Fort area, the Garrison area, a community center, Gray Army Airfield, Madigan Hospital, Old Madigan Hospital Historic District, the Logistics Center, Miller Hill, and Rainier Park. Family housing and recreational facilities are located throughout the cantonment area. The cantonment area includes plots of land reserved for future development (ENSR 2000). A recent nationwide military base reorganization plan will bring an additional brigade and other units to Fort Lewis and a number of construction projects have been started throughout the base to accommodate the extra personnel (ENSR 2004). Much of this construction is occurring in the North Fort Lewis area.

The training areas on Fort Lewis are divided into maneuver, impact, range, and other training areas, which include airborne training sites and urban combat areas. These areas are comprised of forestland, wetlands, grasslands, brush, and marine environments. Specific training activities that are performed on these areas include off-road vehicle maneuvers, gunnery practice, digging activities (tank ditches, vehicle positions, and foxholes), unit assembly areas, and unit field training exercises (ENSR 2000). Many portions of training areas are used for recreation, such as hunting, and many areas have active timber management.

Because the activities occurring within the two land use zones at Fort Lewis (the cantonment area and the training areas) are so different, they have unique influences on water resources. The cantonment area produces a significant portion of the stormwater runoff in the subbasins, due to its association with roads, buildings, and storm drain networks. In contrast to the developed areas, the vegetated nature and permeability of soils in the training areas causes most precipitation to infiltrate either into the soil, or to evapotranspirate back into the atmosphere following uptake by vegetation.

The portions of the watershed subbasins that are dedicated as either cantonment or training areas were identified. Most of the Lower Murray, American Lake, and Sequalitchew subbasins are within the cantonment area, the Middle Murray subbasin is equally divided between the cantonment and training land uses, and most of the Upper Murray subbasin falls within the training area. Figure 3.3-1 illustrates the locations of the cantonment areas and training areas relevant to the study subbasins (see the methods discussion for a detailed description of the subbasin delineation). Table 3.3-1 summarizes the portions of the subbasins within the cantonment and training area zones, as well as the subbasin area beyond the Fort Lewis installation.

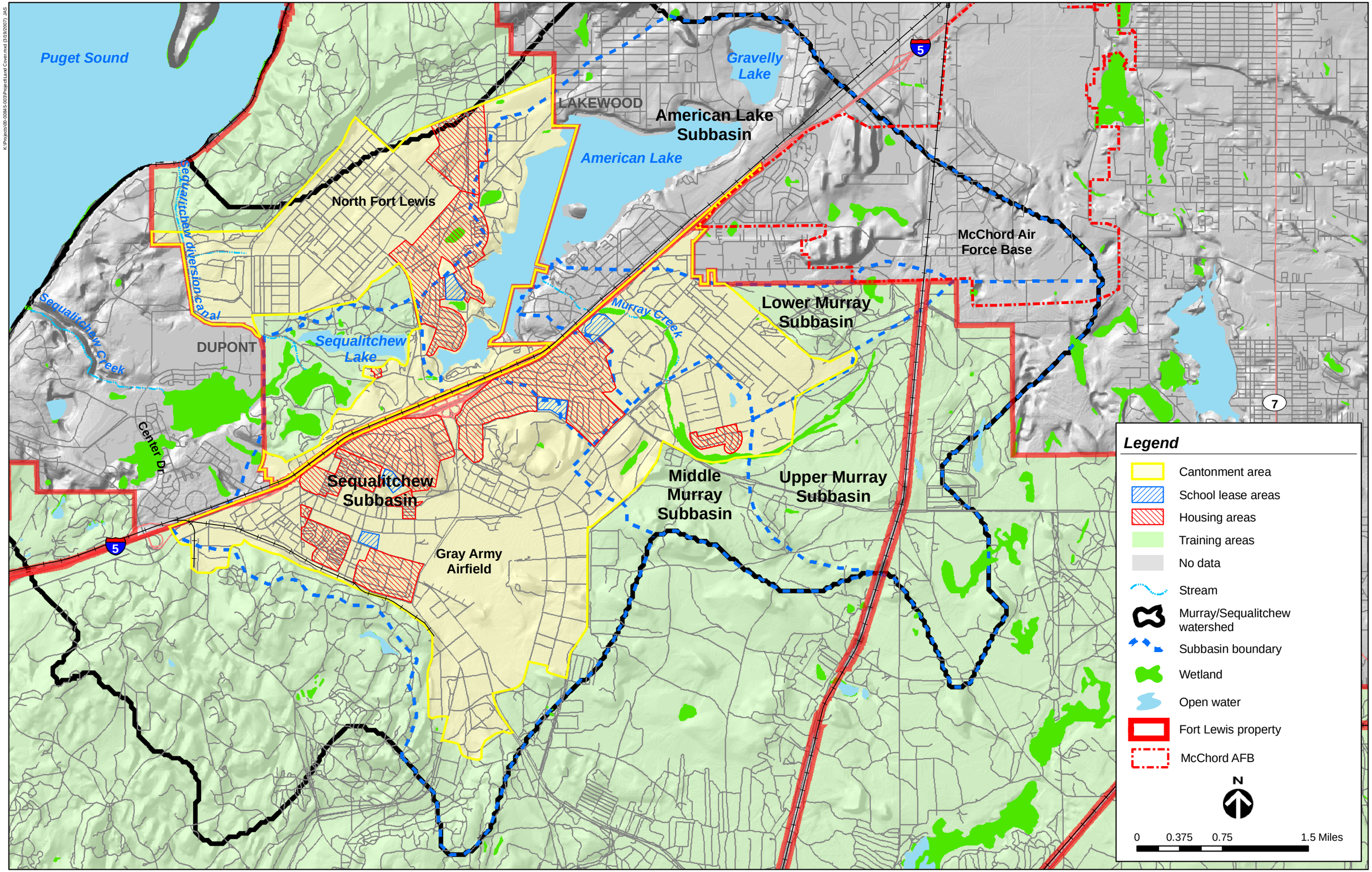

Figure 3.3-1 Existing Land Use Within the Fort Lewis Jurisdictional Area of the Murray/Sequalitchew Watershed.

Table 3.3-1 Portions of Subbasins Within the Fort Lewis Boundaries.

Subbasin	Subbasin Area (acres)	% Cantonment Area	% Training Area	Total % Fort Lewis Area	% Non-Fort Lewis Area
Upper Murray	3,239	3	79	82	18
Middle Murray	1,304	49	51	100	0
Lower Murray	1,737	56	27	83	17
American Lake	6,166	24	12	36	64
Sequalitchew	5,970	66	32	98	2

Ecosystem Management Units

Fort Lewis is divided into three ecosystem management units in order to view complex patterns and processes at different landscape scales and ecological levels of organization (U.S. Army 2005b). Ecosystem management units are designed for control of landscape-level attributes and patterns such as forest stand age and class diversity, vegetation patch size, vegetation community type composition, landscape stability, spatial patterns of connectivity, and functional interaction among vegetation community types. Vegetation community types provide the primary level for characterization of disturbance regimes, species composition, stand structure, successional stages, and local ecological stability.

The three ecosystem management units delineated at Fort Lewis are the North-Central Fort (approximately 45,000 acres), the East Fort (approximately 23,000 acres), and the Rainier Training Area (approximately 18,000 acres), which are described in further detail in the upland habitat section of this report.

Fort Lewis leases part of its cantonment area to private developers and the school district for residential areas and schools. These areas are managed separately from the rest of the property within the cantonment area. The division of these areas by subbasin is shown in Table 3.3-2 and Figure 3.3-2.

Table 3.3-2 Portions of Subbasin Cantonment Area Leased for School and Housing Purposes.

Subbasin	Subbasin Area (acres)	Total Leased School Area (acres)	Total Leased Housing Area (acres)
Upper Murray	3,239	0	0
Middle Murray	1,304	0	49
Lower Murray	1,737	21	2
American Lake	6,166	27	481
Sequalitchew	5,970	36	728