SUB-SECTION 4M.7

PUYALLUP TRIBE ALL HAZARD MITIGATION PLAN
DROUGHT HAZARD

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Identification Description

Definition

A drought is defined as "a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in an affected area."[1]

Unlike most states, Washington has a statutory definition of drought (Revised Code of Washington Chapter 43.83B.400). According to state law, an area is in a drought condition when:

- The water supply for the area is below 75 percent of normal.
- Water uses and users in the area will likely incur undue hardships because of the water shortage.

Drought is a natural part of the climate cycle. However, it can have a widespread impact on the environment and the economy. Both agriculture and certain industries that require a dependable, continuous supply of water can be affected by drought. Since the impacts of drought vary highly depending on the local environment, the type of agriculture and industry, and the type of social systems that have developed in an area, people can have very different ideas about drought. This can lead to a wide range of drought definitions. The two definitions above are both useful in their own way, but are by no means the only possible definitions.

Types[2]

Because of the wide range of drought definitions available, 'drought' has been grouped into four main categories or types. The first three categories measure drought as a physical phenomenon and the last category measures drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socioeconomic systems. This process can be seen in Figure 4.7-1 Sequence of Drought Impacts.

Meteorological Drought

This type of drought is defined as an expression of precipitation's departure from normal over some period of time. These definitions are usually region-specific, and presumably based on a thorough understanding of regional climatology. Meteorological measurements are the first indicators of drought.

Agricultural Drought

This type of drought is defined as an occurrence in which there isn't enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought, but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.

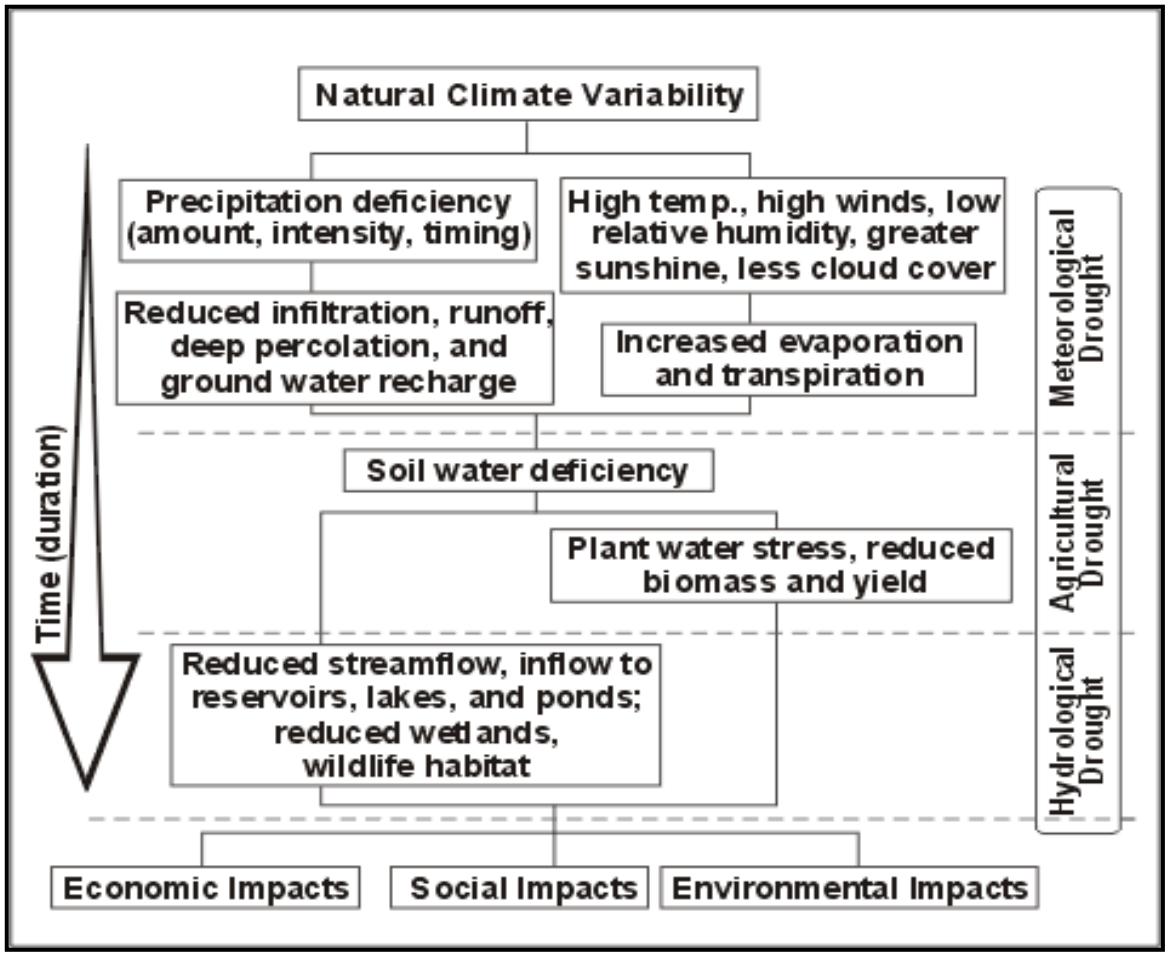
Hydrological Drought

This type of drought is defined by the deficiencies in surface and subsurface water supplies. It is measured as stream flow and as lake, reservoir, and groundwater levels. There is a time lag between the lack of rain and decreasing quantities of water in streams, rivers, lakes, and reservoirs, so hydrological measurements are not the earliest indicators of drought. When precipitation is reduced, or deficient, over an extended period of time, this shortage will be reflected in declining surface and subsurface water levels.

Socioeconomic Drought

This type of drought is defined as the occurrence when physical water shortage starts to affect people, individually and collectively. In more abstract terms, most socioeconomic definitions of drought associate it with the supply and demand of an economic good such as water, food grains, fish, or hydroelectric power.

Figure 4.7-1 Sequence of Drought Impacts



The severity of a drought is measured by the Palmer Drought Severity Index (PDSI) shown in Table 4.7-1. Developed by meteorologist Wayne Palmer for the Office of Climatology of the Weather Bureau, it combines temperature and rainfall in a formula to determine dryness. It is most effective in determining both long term droughts and wet periods. 0 is considered normal and the scale diverges from there[3]. The index determines that an area with a -3.0 to -3.99 rating is in severe drought, while an area with -4.0 is in extreme drought.

Table 4.7-1 Palmer Drought Severity Index

3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.5 to 0.99	Incipient dry spell
-1.0 to -1.99	Mild drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 or less	Extreme drought

Profile

Location and Extent

Drought directly and indirectly affects all of Pierce County and the Planning Area. While the entire region experiences drought, specific natural resources are the most impacted. These resources include, but are not limited to: rivers, streams, ponds, fish habitat, forests, and other natural resources. The impact on resources will vary depending on how each watershed is affected. A watershed that contains a lot of snow late into the summer, will not be affected the same as one that has no snow at all. In Pierce County, the distribution of resources can be tracked by watershed and these are found on Map 4.7-1.

The first noticeable indications of drought, besides lack of rain, are the decrease in soil moisture affecting the County's agricultural base. As time progresses, the effects begin to be felt across the community. Normally available sources of water, like reservoirs and lakes will begin to dry up. Their ability to cover the precipitation deficit can only do so for a limited time. The other option, wells, relies on the amount of ground water and is dependent on the long term maintenance of the aquifer. Short term drought, from three to six months, usually does not affect these. However, long term drought conditions can affect them, drying up lakes and depressing the water table.

With the ending of drought conditions, the recovery will follow the same pattern. First to recover will be the soil water reserves and increases in stream flows. Reservoirs and lakes are next to refill, and finally, as water works its way down, the groundwater can be replenished. While the soil moisture content may rise rapidly following rain, the

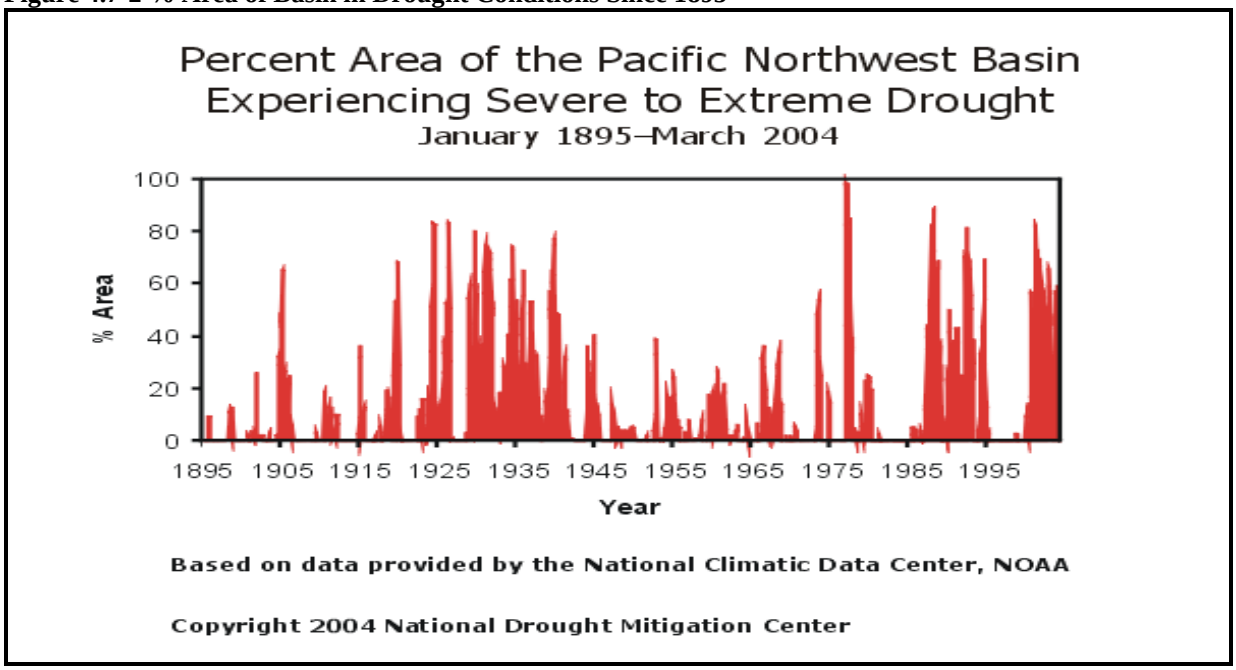
replenishment of groundwater may take many months or even years depending on the drought's duration, its intensity, and the quantity of new precipitation over time.[4]

Occurrences

On average, the nationwide annual impact of drought is greater than the impacts of any other natural hazard. They are estimated to be between $6 billion and $8 billion annually in the United States and occur primarily in the agriculture, transportation, recreation and tourism, forestry, and energy sectors. Social and environmental impacts are also significant, although it is difficult to put a precise cost on these impacts.

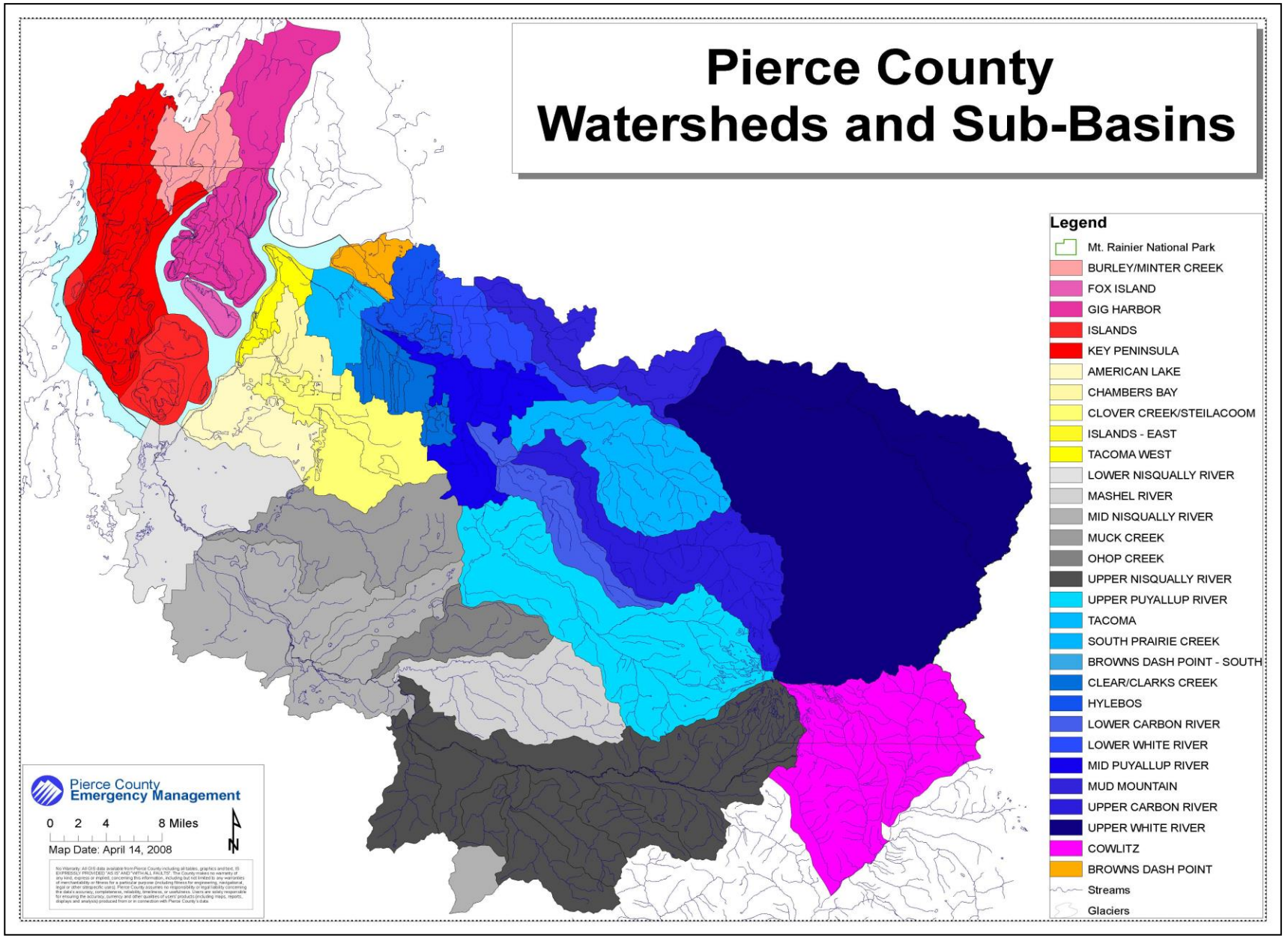
The National Drought Mitigation Center has compiled drought data for the period from 1895 to 1995 using the Palmer Drought Severity Index (PDSI). According to the data, the Pacific Northwest Basin, an area comprised of the states of Idaho and Washington, most of Oregon, and parts of Montana and Wyoming, has experienced severe to extreme drought multiple times in the last hundred years over a large area, see Figure 4.7-2.

Figure 4.7-2 % Area of Basin in Drought Conditions Since 1895[5]

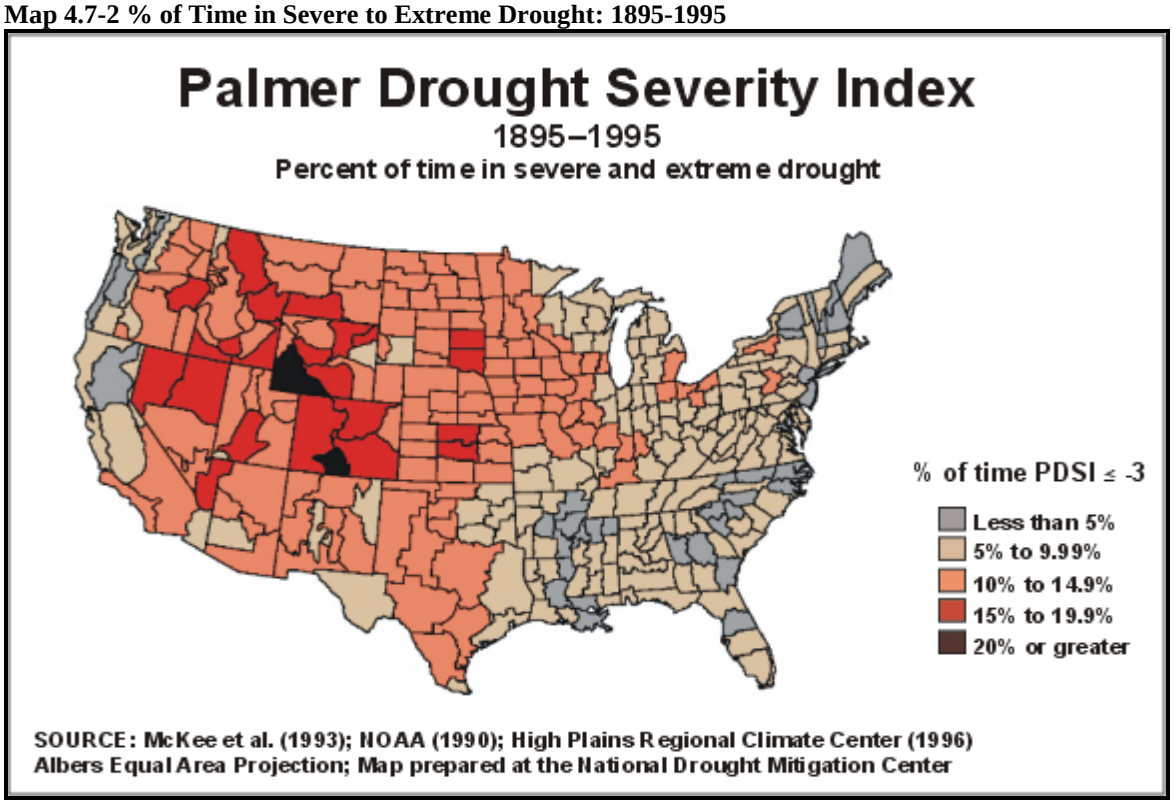


Portions of the County, including the Planning Area have experienced severe drought from five to ten percent of the time during the period from 1895 to 1995, see Map 4.7-2. For the decade from 1985 to 1995, the rate appears to have increased. During this period portions of the Planning Area and County had severe drought conditions between 10 and 20 percent of the time, see Map 4.7-3.[6]

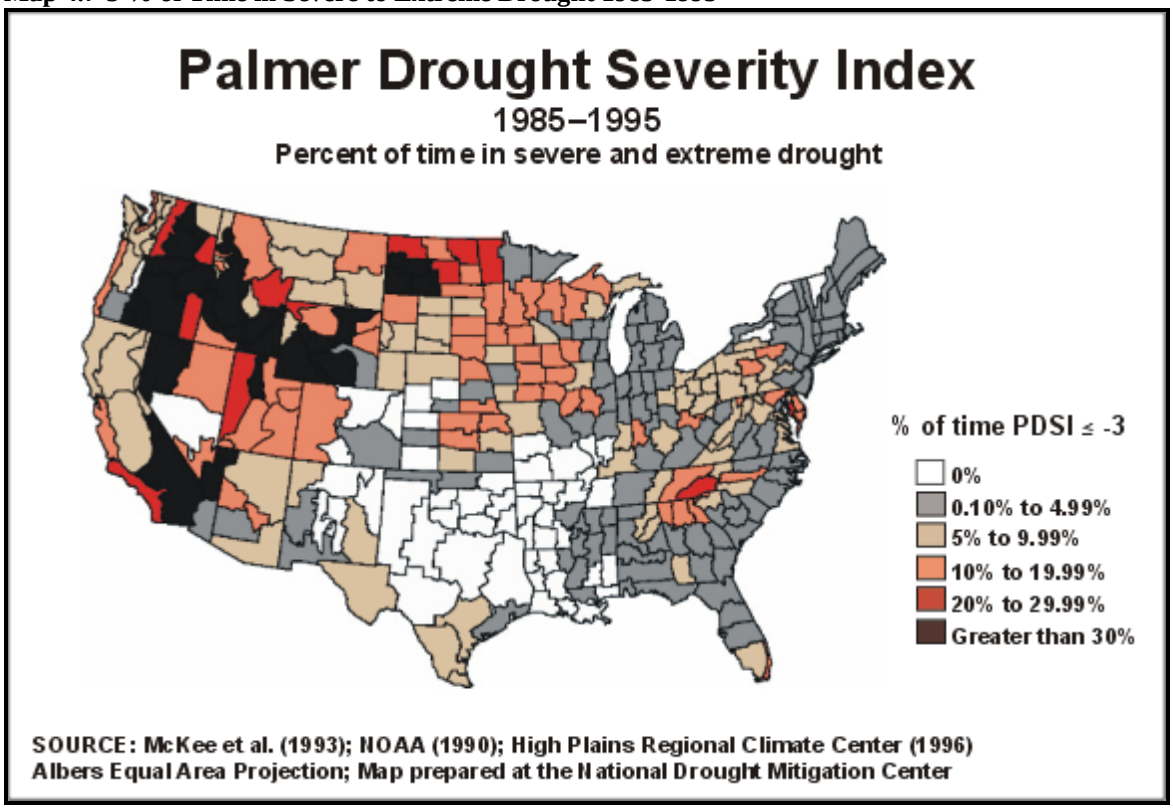
Map 4.7-1 Pierce County Watersheds



Map 4.7-2 % of Time in Severe to Extreme Drought: 1895-1995



Map 4.7-3 % of Time in Severe to Extreme Drought 1985-1995



Historically, droughts have not usually been considered a problem in the area west of the Cascade Mountain Range. However, Pierce County, the Planning Area and other west side communities have felt the effects of drought many times in the past and will continue to do so in the future. Table 4.7-2 catalogues a number of drought periods that have affected the County over the years. Note that several lasted for more than a single season and a few for more than a year.

Table 4.7-2 Notable Droughts Affecting Pierce County[7]

DATE	DESCRIPTION
November 2004 – Summer 2005	The winter of 2004-2005 was the driest winter in recorded history with record low snow packs of only 26% of average and stream flows as low as 22% of average. The drought conditions culminated in a February with no measurable precipitation in many parts of the state. Washington State declared a Drought Emergency on March 10, 2005.[8]
January – March 2001	The second driest winter on record in 106 years and second worst drought in State History. Stream flows approached the low levels of the 1976-1977 drought
October 1976 – September 1977	The worst drought on record. Stream flows averaged between 30% and 70% of normal. Temperatures higher than normal resulted in algae growth and fish kills. Pierce County experienced severe-extreme drought conditions from 10-20 percent of the time.
April 1934 – March 1937	The longest drought in the region's history with PDSI maintaining values less than -1.[9] The driest periods were April-August 1934, September–December 1935, and July-January 1936-37.
July – August 1930	Drought affected the entire state. Most weather stations averaged 10% or less of normal precipitation.
June 1928 – March 1929	Most stations averaged less than 20% of normal rainfall for August and September and less than 60% for 9 months
July 1925	Drought occurred in Washington State.
July - August 1921	Drought in all agricultural sections of Washington State.
August 1919	Drought and hot weather occurred in Western Washington.
July – August 1902	No measurable rainfall in Western Washington.

Unlike most disasters, droughts normally occur slowly but last a long time. Drought conditions occur every few years in Washington. The droughts of 1977 and 2001, the worst and second worst in state history, provide good examples of how drought can affect the state (see details below).

In temperate regions, including Washington, current long -range forecasts of drought have limited reliability. In the tropics, empirical relationships have been demonstrated between precipitation and El Niño events, but few such relationships have been demonstrated above the 30º north latitude are yet understood; Washington sits between

45.30º and 49º north latitude. Meteorologists do not believe that reliable forecasts are attainable at this time a season or more in advance for temperate regions.

Comparing the droughts of 1977 and 2001[8, 9]

The 1977 drought was the worst on record, but the 2001 drought came close to surpassing it in some respects. The following table has data on how the two droughts affected Washington by late September of their respective years.

As the state began water year 2001 (October 1, 2000 – September 30, 2001), there was little reason to expect anything out of the ordinary. Climatologists had predicted cooler, wetter-than-normal weather for the Pacific Northwest. While November and December 2000 were unusually dry, most experts assumed the typical heavy snow and rainfall levels would begin again in January 2001. However, the dry weather pattern continued through January and February, not returning to normal until March.
By mid-March, nearly every corner of the state was suffering from a water supply deficit. Between November 2000 and March 2001, the state received just 60 percent of normal rain and snowfall. The outlook for summer water supplies looked bleak. Federal, state and local officials worried low river flows would disrupt state hydroelectric power production and that dwindling water supplies would put various threatened and endangered fish species at risk.

On March 14, 2001, Gov. Gary Locke authorized the Department of Ecology to declare a statewide drought emergency; Washington was the first Northwest state to make such a declaration, which remained in effect until December 31, 2001.

The central part of the state, from the crest of the Cascade Mountains to the east banks of the Okanogan and Columbia Rivers, suffered the most from water shortages. The Palmer Drought Index for March 2001, left top, graphically displays the height of drought conditions in Western Washington; the August 2001 index, left below, shows the height of drought conditions in Eastern Washington. These maps provide a comparison of drought conditions in Washington with those in the rest of the lower 48 states at the time. The scale used for the Palmer Drought Index characterizes severe drought as having likely crop or pasture losses, very high fire risk, water shortages common with water restrictions imposed. An extreme drought has major crop and pasture losses, extreme fire danger, and widespread water shortages or restrictions.

Among the impacts of the 2001 drought:

- Energy: The drought decreased river flows, resulting in less electrical generation and tighter power supplies. Available out-of-state power was extremely expensive, causing higher rates and financial emergencies at many of the state's utilities. Bonneville Power Administration paid to keep electricity-intensive industries including aluminum smelters to shut down. Many small-scale power generators were placed into emergency service throughout the state.

- Agriculture: With stream flows below half of normal and groundwater levels threatened, there was significantly less water available for irrigation; irrigated land produces about 70 percent of the state's crops. The Governor's drought order authorized the Department of Ecology to exercise emergency powers to: To issue temporary emergency water-rights permits and change existing water rights for farmers in 13 counties.

- Fish: As the drought progressed, reduced stream flows caused numerous fish passage problems on the American River, Rattlesnake Creek, and other Yakima River tributaries. Some fish stocks were lost. To help Columbia River fish populations, the Bonneville Power Administration paid growers in the basin to remove 75,000 acres from agricultural production; this kept additional water in the river during the most critical drought months. Improvements were made at a number of hatcheries, and salmon and steelhead were moved out of two hatcheries that experienced water problems.

Historically, drought has not commonly been considered a problem in the area west of the Cascade Mountain Range. In spite of this, the Planning Area has felt the effects of drought many times in the past and will continue to do so in the future. Multiple measurable and documented droughts have hit the region in the past 100 years but the following three are the most notable:

April 1934—March 1937: The longest drought in the region's history with the PDSI maintaining values less than 1.

October 1976 – September 1977: The worst drought on record. Stream flows averaged between 30% and 70% of normal. Temperatures were higher than normal, which resulted in algae growth and fish kills.

January – March 2001: The second driest winter on record in 106 years. Stream flows approached the low levels of the 1976 – 1977 drought.

Vulnerability

Recurrence Rate

Scientists at this time do not know how to predict drought more than a month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. How long they last is dependent on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale.

Based on the State's history with drought from 1895 to 1995, as shown in Map 4.7-2, the state as a whole can expect severe or extreme drought at least five percent of the time in

the future. Table 4.7-2 shows that since the beginning of the 20th Century, there have been ten droughts with major effects on the Planning Area and Pierce County. However, only four of those have happened in the past 71 years with gaps of 39 and 24 years. This implies that Western Washington, including the Planning Area, can expect severe or extreme drought from five to ten percent of the time. This is too short a period to make a definitive statement as to whether this is a change in frequency or not. So, to conservatively cover the variance, this chapter is defining the drought recurrence rate for Pierce County as being 50 years or less.

The future intensity and patterns of drought in the Planning Area could be altered due to the expected changes in the global climate. Warming trends that will deliver less snow to the mountainous areas, and threaten the possibility of drier summers could have a dramatic impact on the frequency and intensity of drought in the Planning Area. The dwindling of the average annual snowpack will mean there is less available water for agriculture, the environment, citizens, businesses and industry, all leading to more frequent drought conditions. For a further discussion of this, see the Climate Change section.

Planning Area

Dissimilar to other hazards a drought is not an instantaneous threat requiring an immediate reaction but allows for time to prepare and react on all levels within the Planning Area. There would be enough time to strategize and plan the best course of action. Conserving public consumption would reduce some of the demands. The fisheries would augment their pumps due to an insufficient supply of water if need be.

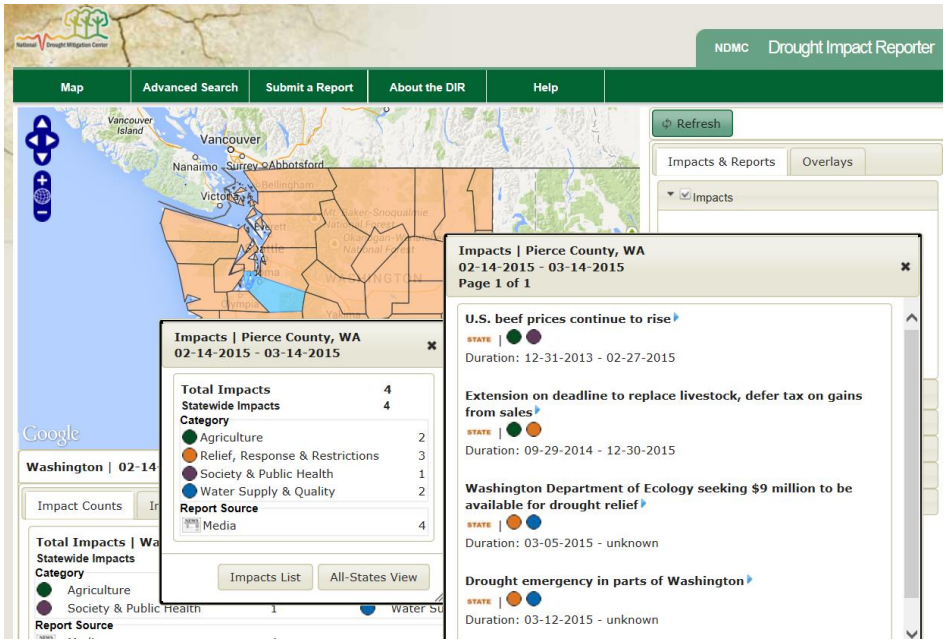
The Planning Team determined that the Planning Area has a low vulnerability to the drought hazard because of the following factors: the impacted area, impacted natural resources, and probability of occurrence. In the entire Planning Area, approximately 16,000 acres (100%) are vulnerable to the drought hazard identified by the Planning Team. The total damage to the Planning Area could equal approximately $8 billion (the assessed value of 19.048 parcels in the Planning Area).

For Tribal Trust parcels located in the Planning Area, approximately 485 parcels are vulnerable to drought hazard. The total estimated losses to these parcels would equal $300 million.

Impacts[10]

Depending upon its severity in Pierce County, drought typically does not result in loss of life or damage to property, as do other natural disasters. On the other hand drought can lead to impacts on agriculture, water supply availability, the public's health and economic condition. (See figure 4.7-3). However, it can be a contributor to the development of other natural disasters like forest fires or crop diseases.

Figure 4.7--3 National Drought Mitigation Center Drought Impact Reporter Feb. 14-Mar 14. 2015[11]



Health and Safety of Persons in the Affected Area at the Time of the Incident

In the Planning Area, based on historical precedent, drought will not by itself cause a decrease in the health and safety of its citizens. Rather damage will be done to the environment, business, agriculture, etc. However, problems frequently associated with drought can influence the health and/or safety of local citizens. These would include:

- High temperatures leading to heat related injuries including some deaths;
- Mental and physical stress which can lead to a susceptibility to other diseases such as heart disease;
- Low moisture content in the forest leading to an increase in the number of forest fires threatening homes, citizens and firefighters;
- Conflicts between citizens and government over water usage; and
- Conflicts between citizens over water usage.

Health and Safety of Personnel Responding to the Incident

There should be no extra health or safety impacts from drought beyond those for the general public. Individual hazards exacerbated by the drought, such as an increase in wildfires, by themselves threaten the health and safety of responders; however they are not a direct result of the drought.

Continuity of Operations and Delivery of Services

Drought, on the scale experienced in Pierce County, should not affect the ability of most agencies to continue operations. While services to the public for some operations may have to be cut back, the actual ability of agencies to continue operations in some form should not be compromised.

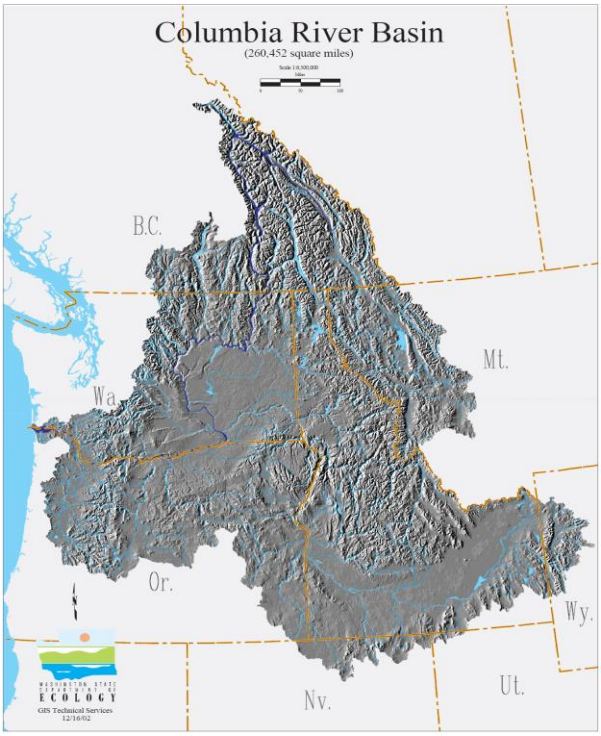
Delivery of services to the public will probably not be considered a problem for most local law enforcement agencies. Any increase in public tension regarding limiting the use of water or caused by layoffs from industry dependent on water should be within the ability of departments to handle.

For fire operations, however, impacts would be dependent on two factors, the actual quantity of water available and the dryness of the environment. If the drought is extreme enough and long lasting to the point that fire flow[12] is affected then fire departments and districts will not be able to fulfill their mission in relation to fire suppression. Related is the dryness of the environment in general. As the water supply decreases the probability of large scale fires, wildland, urban, or on the wildland/urban interface become more probable. An increase in the number of fires as well as their size could tax the ability of departments to respond, causing them to rely on mutual aid or going to state mobilization. In either case, their operations will continue, albeit with support from outside agencies and possibly at a reduced level.

The ability to maintain service at a level required by the public can be threatened during drought for many utilities. Both electric and water utilities rely on a steady supply of water throughout the year.

The foundation of northwest electricity is hydroelectric. Without a steady supply of water supplying the dams, utilities will either have to cut back production, possibly causing brownouts, or buy expensive power from other areas that have an excess. Much of this supply originates in the mountain snowpack that normally exists in the Cascades and Olympics, or in the case of the Columbia River, an area incorporating portions of seven states and one Canadian province, see Map 4.7-4.[13]

Map 4.7-4 Columbia River Basin



Pierce County's water purveyors receive their water either from mountain watersheds or wells locally supported by the purveyor. Short term drought has caused limited problems in the past, usually rectified by volunteer water rationing. As the population grows and the demand for water to support that population increases the need for more extreme measures may also increase.

Lack of rain will directly affect the aquifers that many of the water purveyors rely on. Changes in the aquifers may require the drilling of new wells. Small water purveyors with wells that run dry and no intertie with another system may have to temporarily bring in water either by truck or in bottles to supply customers.

Lack of rain will also decrease in the quantity of water flowing in the Green River, located in southern King County. The City of Tacoma relies on that supply for much of its water needs. While Tacoma also has a number of wells on its system, these could be taxed if the aquifer also begins to drop. The longer a drought continues the stronger its effects will be felt, not only from the Green River watershed, but also from the aquifers that could act as a backup. Eventually the point could be reached where in order to get water to the citizens not only would there be voluntary rationing, but also some mandatory controls implemented with fines for violators. Such controls would also affect industry. Many industrial processes require a quantity of water. To distribute enough water to citizens for health reasons, and critical infrastructure like fire hydrants and hospitals, some industry may have to either reduce or suspend operations.

Property, Facilities, and Infrastructure

Drought is a slowly developing problem with little immediate impact on any property, public facilities or the infrastructure. Many built up properties such as buildings, highways, and transmission towers will not be adversely affected by drought in any form. As a drought progresses however, from a short-term inconvenience to a long-term problem, certain portions of the infrastructure will begin to be affected. The lack of water in the reservoirs, streams and rivers will restrict how it can be used. For example, the need to use it for agriculture will conflict with the need to maintain an adequate flow for fish. Confounding the problem will be industries need for a continuous supply and of the public for drinking, cooking and bathing water.

The decreasing water level in reservoirs used for hydroelectric generation creates two obstacles that limit the output of electricity. First, drought limits the amount of water available for generation. Without water behind the dams, they cannot generate power. Second, the amount of electricity generated depends on the pressure of the water on the turbines or how much head there is behind the intakes to the turbines. So, as the water level behind the dams drops the pressure turning the turbines decreases. The result is that the dams are not getting as much electricity generated per cubic foot of water from a low water level as you do from a high water level.

The water distribution system could also be impacted. Water purveyors may find their normal sources drying up. Water from the Green River, currently used by the City of

Tacoma, may no longer be adequate or dependable. As the water table drops, shallow wells distributed throughout the Planning Area used mostly by small water purveyors may begin to dry up. Most of these do not have interties with other purveyors. The result could be that they will have to bring in outside resources to assist with getting an adequate supply to citizens.

The Environment

The environment that makes the Planning Area and Pierce County an enjoyable place to live, work and play has its basis in the rainfall that supports the diverse ecosystems that exist across the County. Based as it is on an abundance of water, the environment could be the most adversely affected portion of the County by a drought, especially long term drought. Impacts on the Pierce County environment include:

- A reduction in viable habitat for fish and wildlife;
- As the environment becomes more stressed, there will be an increase in both plant and animal diseases, and
- An increase in wildfires.

Habitat Reduction

Many of the plants, fish and wildlife native to the Planning Area and Pierce County are used to periods of moderate drought which happens irregularly in Western Washington. However severe drought could stress the various environments or individual species within those environments. A decrease in rain and snow will not be uniform across any individual biotic zone and so the effects from a drought will not be universal throughout Pierce County. In some areas they could be much worse than in others.

Pierce County resides in the following watersheds: Chambers-Clover, Cowlitz, Kitsap, Nisqually, and Puyallup, see Map 4.7-1. The Planning Area resides in the Puyallup watershed consisting of the Tacoma, Clear/Clarks, Hylebos, Mid Puyallup River, and Browns Dash Point Sub-Basins. A watershed is a basin-shaped area that drains into a river, lake, or the ocean. It includes freshwater, both ground and surface waters, as well as the saltwater of Puget Sound.

A Water Resource Inventory Area (WRIA)[14] may include more than one watershed and may overlap into more than one county. All of the WRIAs in Pierce County with the exception of the Chambers Creek have a portion of their watershed located in other counties and homeland security regions. Water Resource Inventory Areas are important for looking at the availability of overall water resources and how a change in precipitation, either as rain or snow, will affect the other resources that depend on it. One of their key areas is looking at the availability of water to maintain fish habitats.

The most obvious immediate impact from drought is on fish populations. Drought can have a variety of negative impacts on salmon and other fish populations at several points of their life cycles. Drought can dramatically affect the ability of fish to thrive and reproduce. Streams that lack a continuous source of water tend to dry up leaving only

pools for the fish to live in until the next rain brings a new flow of water down the channel. Many fish are sensitive to an increase in water temperature and a low stream flow can allow the water temperature to rise well above normal. According to the Washington Department of Fish and Wildlife:

> The downstream migration of juvenile salmon in the spring is linked to the surge in stream flows created by runoff from melting snow in the mountains. With mountain snow packs either well below average or completely gone, there could be some change on out-migration patterns as young fish attempt to reach saltwater to continue their life cycle. Adult salmon can have difficulties reaching upstream spawning grounds if river flows remain below normal.
>
> Some salmon species spawn in channel margins, side channels and smaller tributaries. Spawning would have to occur in mainstream waters if those other areas are unavailable because of low flows. This could make salmon nests, known as redds, and the eggs incubating in them, more susceptible to bed scour during the fall and winter.
>
> In other cases, instream flow can drop after the salmon spawn. Salmon nests are then dewatered and the eggs within them are lost. Impacts of drought can result in depressed salmons runs three to five years later, when those fish would be returning as adults.
>
> Warmer-than-normal stream temperatures and low dissolved-oxygen levels in isolated pools can lead to fish deaths both in wild populations and at fish hatcheries[15]. Just as reduced water levels affect wild spawners, reduced water supply can lead to warmer water temperatures and thus result in increased fish disease, treatment costs and fish mortality. Some of the likely causes of problems are fungal and bacterial diseases, which can kill fish or lead to fewer fish eggs.
>
> Many of our hatcheries depend on a clean and consistent source of water. So, during a drought, hatcheries can be at risk because of lack of water of sufficient quality and quantity to rear fish. The Washington Department of Fish and Wildlife (WDFW) sometimes might be required to pump water from wells, which adds significant costs to operations[16]

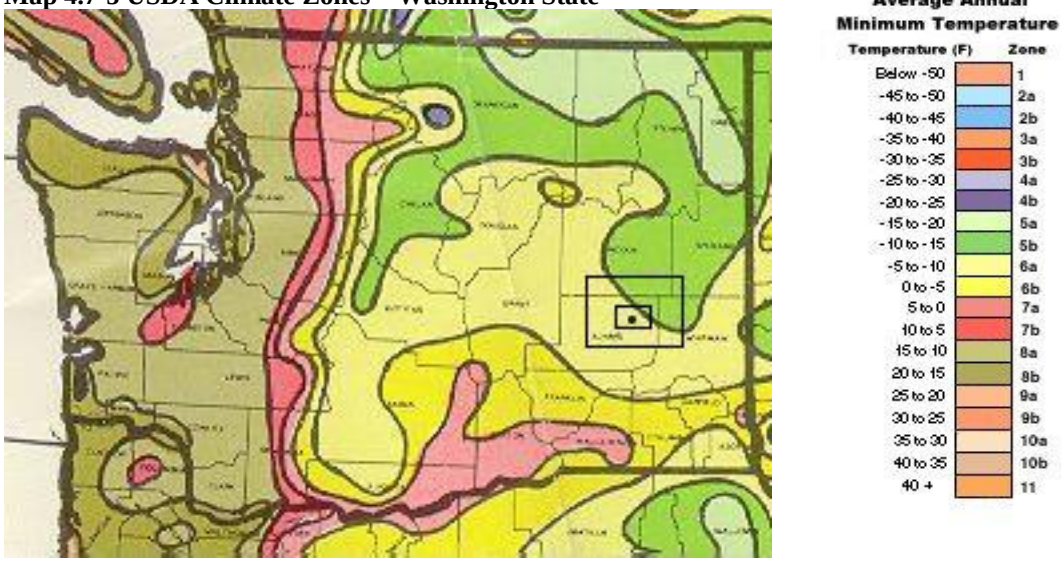
However it must also be pointed out that while drought may be detrimental to some species, it may not be detrimental to all. "During droughts, the in-stream habitat conditions can actually be favorable for some fish species, such as certain minnows and darters, as well as fry and fingerlings of larger species. Drought conditions allow these fish to compete with other fish, such as larger predators, which may be favored at higher flows. The result is a more robust and diverse fish community."[17]

The impact on wildlife can also be dramatic and can vary considerably across the County. With topography ranging from sea level to over 14,000 feet there is a wide range of plants and animals that inhabit different areas.

The United States Department of Agriculture (USDA) has developed climate zones (also called hardiness zones) based on temperature for the entire United States. These zones are based on the mean of the lowest temperature recorded each year. Pierce County is divided into various climate zones; see Map 4.7-5 USDA Climate Zones. Since these zones are based on temperature, other factors need to be taken into account when looking at the effects of drought on the County.

Eastern Pierce County, as can be seen from the USDA Climate Zones map, has a very different range of temperatures from western Pierce County. Temperatures are cooler and because of the rise in elevation precipitation is much higher. This creates a different series of zones called life, or biotic zones. These zones are not just related to temperature, but include precipitation, are very variable, contain different animal and plant species and generally are located at different elevations.

Map 4.7-5 USDA Climate Zones – Washington State[18]



A number of different categorizations of life zones have been utilized or defined over the years. Some more detailed and others simpler. The one shown here has been in use for over 50 years, and is a variation of one first developed in the late 1800s.

Pierce County has four of the seven Washington State biotic zones established within it[19]. These include:

> Coast Forest Zone -This zone encompasses the lowlands of Pierce County up to the foothills of the Cascades and climbing their lower slopes until it meets the
>
> Mountain Forest Zone- This zone is also called the Canadian Zone. It includes the evergreen forests that range up to approximately 5,000 feet where it meets the

Sub-Alpine Zone- This zone includes the species that exist near tree line and ranges from 5,000 to 7,000 feet in elevation. As the trees peter out to tundra and snow the zone is called the

Alpine Zone - This zone includes all terrain above timberline. Most of this is located on Mt. Rainier; however there is a portion of it lying along the highest portions of the Cascade crest.

The marine climate associated with these zones provides the moisture to maintain them. Within the different zones the various species of plants and animals are more or less tolerant of drought conditions.

Animals that have an association with water resources, like amphibians (frogs, salamanders, etc.), ducks, geese, herons, and many others, will find their habitats drying up and will not have their normal food source available. Waterfowl and other birds have the ability to move elsewhere, however many smaller non-flying species do not. They in turn may attempt to migrate. While some may be successful others will not.

Deer and elk will find their normal food sources decreasing and may have to change their normal migration patterns. Voles, mice and others will find their populations decreasing, a situation that can put stress on the predators that rely on them. As water sources dry up animals will tend to congregate near water sources that are still viable. This concentration leaves many of them vulnerable to predators also congregating at the water source.

The result of extended drought in particular, is a total change in the distribution of the flora and fauna that currently inhabit Pierce County. This can push many species into conflict with people as they leave their normal habitats and migrate into more populated areas. The change in habitat limiting food and water can push some marginal species into localized decline or even eliminate them from the local environment decreasing the biodiversity.

Plant and Animal Disease

Maritime forests, like we have in Western Washington, in drought conditions tend to become stressed. Initial effects will be to the tree root system. Lack of water in the top 12-18 inches of the soil will begin to dry up and kill the root hairs that normally take up water. This causes a water deficit in the tree. Trees stressed like this are unable to grow properly, begin to lose their resistance to disease and also become susceptible to attacks by insects.[20] This can lead to wide areas having diseased or dead trees all of which can increase the potential for wildfire.

Research into the effects of drought on local environments shows that it can alter the effects of other disasters. A recent example is the loss of wetlands due to drought along the Gulf Coast. The weakening and killing of marsh grass by drought allowed periwinkle snails to further destroy the wetlands. This loss of coastal wetlands exacerbated the destructive tendencies of Hurricane Katrina.

> "It's important to note that drought was the trigger that initiated these events – and because drought stress is becoming more extreme with global warming, events like this could become both more frequent and intense,"[21]

In drought conditions, the lack of water and food supply will put extra stress on wildlife. Because of this stress, the combination of dehydration, hunger and in some cases heat, many animals may become susceptible to disease.[22]

Wildfire

The heavy forest growth, and resulting duff, existing on the west side of the Cascades has the potential during prolonged drought of creating conditions conducive to wildfires. Once started, the steep terrain combined with the heavy load of fuel can make these fires hard to put out. As with a wildfire in any part of the state, a large scale wildfire within Pierce County could leave a lasting impression on the local environment that may not rebound for years if not decades or longer. Animal and fish habitat would be destroyed. The loss of the forest canopy would eliminate the shade needed for many species of both plant and animals. Streams would be polluted with burnt material and there would be an increase in erosion leading to silt deposits that could destroy fish habitat.

In contrast, it must be understood that while fire is destructive, it opens up new environmental opportunities. Forests go through a cycle of growth, decay and destruction. Fire is a natural part of the forest ecology. Previous attempts to eliminate all fires proved counterproductive for a healthy environment. Burning the understory in many cases increases the health of a mature forest. The newly burnt landscape would allow the introduction of other species, tolerant of the open spaces and increased sunshine. Many plants are intolerant of the deep shade that exists in the heavily forested areas. These newly burned areas allow them an opportunity to thrive. With them will come animals that thrive on those particular plants. The result is a new ecological niche will have been created.

Summary

The impact of drought on the environment and the Planning Area will follow a sequence of events. These begin with relatively minor inconveniences and as time progresses can get much worse leading to major environmental degradation. This can eventually lead either directly or as a result of fire to major changes in the local ecosystems that exist within Pierce County.

Economic and Financial Condition

Drought will impact the agricultural and industrial bases as well as the population in Pierce County. Most previous periods of drought have been, at their worst, an inconvenience. However, a prolonged severe drought could impact the agricultural and industrial basis of the local economy.

Economic impacts become apparent as we move from a strictly meteorological drought to an agricultural drought. Crops are damaged due to lack of water. These crops are highly variable in Pierce County, ranging from the rhubarb farms near the City of Sumner to the forests supporting our logging industry. As crops are damaged, farmers lose money, and the citizens who rely on these crops, either for jobs or part of their regular diet begin to feel the effects. Damaged crops and closed national forests mean that processors, including canneries and lumber mills, shippers and their staff who move agricultural products, as well as retailers, begin to lose business. Layoffs can begin leading to financial and mental, stress on individuals and families.

Damaged crops may lead to a decrease in food quality as well quantity causing more food importation. This results in higher costs for the distributors and therefore higher food prices for consumers.

Planning Area industries that rely on a large supply of water for manufacturing goods could have a similar predicament in that as supplies of water dwindle they may have to cut back some processes and also lay off workers with consequences down the chain of distribution.

A lack of water in the rivers and streams will result in lower levels behind dams used for hydroelectric power generation. Power bought from other sources will be more costly than that locally generated. These costs will eventually be passed on to the consumer.

Recreation will also be affected. As a drought intensifies, recreation resources will be closed to the public. Dry conditions creating fire danger will limit the use of National Forest and both State and National Park lands. Communities acting as entry points to the recreation areas would be affected by the National Forest and Park closures. As lakes dry up and the flow in rivers and streams decrease, water recreation will also diminish. Boat ramps and docks may be high and dry. Recreational fishing could be curtailed.

Public Confidence in the Jurisdiction's Governance

Public dissatisfaction with government regarding drought response can erode confidence in local governments. This is especially true if a portion of the public feels that it is being denied a legitimate share of the water available. Required rationing, while necessary, must be scrupulously carried out to ensure that no bias is felt by others, especially the low or middle income portions of the population. If this is not done, it can lead to a lack of confidence in either local utilities or local government or both. Eventually this can lead to unrest.

Resource Directory

Regional

- **Pierce County Department of Emergency Management**
  http://www.co.pierce.wa.us/PC/Abtus/ourorg/dem/abtusdem.htm

- **Seattle Office of the National Weather Service**
  www.wrh.noaa.gov/seattle

- **Western Regional Climate Center**
  http://www.wrcc.dri.edu

- **Washington State Comprehensive Emergency Management Plan, Annex Z2, DROUGHT CONTINGENCY PLAN**
  http://courses.washington.edu/cee576/Drought_Planning/WAplan.pdf

National

- **ASCE Wind Speed Maps**
  http://www.ascepub.infor.com/windload.html

- **Coastal zone management programs by state**
  http://www.ocrm.nos.noaa.gov/czm/czmsitelist.html

- **Extreme Heat Fact Sheet**
  http://www.fema.gov/library/heat.htm

- **National Severe Weather Laboratory estimates the likelihood of severe thunderstorm hazards in the United States.**
  http://www.nssl.noaa.gov/hazard

- **National Weather Service Climate Prediction Center**
  http://www.cpc.ncep.noaa.gov

- **Snow and Ice – National Snow and Ice Data Center, University of Colorado**
  http://www-nsidc.colorado.edu

- **Snow and Ice – National Snow and Ice Data Center, University of Colorado**
  http://www-nsidc.colorado.edu

Endnotes

[1] What is meant by the term drought? Referenced by the National Weather Service, Western Region Headquarters from Glossary of Meteorology , 1959 edition. http://www.wrh.noaa.gov/fgz/science/drought.php The current edition lists it as "A period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance." http://amsglossary.allenpress.com/glossary/search?p=1&query=Drought&submit=Search&def=on

[2] The drought types are taken from the National Drought Mitigation Center (NDMC), School of Natural Resources, University of Nebraska, Lincoln, 2006, http://www.drought.unl.edu/whatis/define.htm

[3] The Palmer Drought Severity Index, NOAA's Drought Information Center, NOAA, http://www.drought.noaa.gov/palmer.html

[4] What is Drought: Understanding and Defining Drought., The National Drought Mitigation Center (NDMC), http://www.drought.unl.edu/whatis/concept.htm

[5] National Drought Mitigation Center, http://www.drought.unl.edu/whatis/palmer/pacnw.gif --05/2005

[6] What is Drought: Historical Maps of the Palmer Drought Index., National Drought Mitigation Center, http://www.drought.unl.edu/whatis/palmer/pdsihist.htm

[7] Much of this table was taken from the Washington State 2001 Hazard Identification and Vulnerability Assessment, Washington State Military Department, Emergency Management Division, April 2001, p. 7.

[8] Washington State Hazard Mitigation Plan, Washington State Military Department, Emergency Management Division http://www.emd.wa.gov/plans/documents/DroughtNov2007Tab5.3.pdf

[9] Pierce County Hazard Identification and Vulnerability Analysis, Pierce County Department of Emergency Management, September 2002, p. 18.

[10] Portions of this section on impacts were taken from http://library.thinkquest.org/16132/html/droughtinfo/effects.html and http://library.thinkquest.org/16132/html/droughtinfo/effects1.html and then modified to fit more accurately the Pierce County experience.

[11] National Drought Mitigation Center. Retrieved March 14, 2015 from http://droughtreporter.unl.edu/ The Drought Impact Reporter is an active map that can be narrowed down by County. The figure provides the list of impacts effecting Pierce County directly.

[12] Fire flow is the quantity of water needed to put out a fire of expected size. It can be specified by the equation (quantity = rate x duration). This means that the specific quantity of water for an individual fire in a combination of the rate the water can be applied to the fire and the length of time that flow must be maintained. Distribution system requirements for fire protection, by American Water Works Association, ,AWWA Manual M31, pps. 1-2.

[13] Columbia River Basin, Department of Ecology, 12/16/02, http://www.ecy.wa.gov/programs/wr/cri/Images/crb-shd.pdf

[14] Established by the Watershed Management Act of 1998 (ESHB2514) and formalized under Washington Administrative Code (WAC) 173-500-040 and authorized under the Water Resources Act of 1971, Revised Code of Washington (RCW) 90.54. The Water Resource Inventory Areas were created to complete an inventory of water resources and develop strategies for their future use. Within Pierce County these include the Puyallup-White River Basin, (WRIA 10), the Nisqually (WRIA 11), the Chambers/Clover (WRIA 12), the Kitsap (WRIA 15) and the Cowlitz (WRIA 26).

[15] This can be the case at both private and state hatcheries run by the Washington Department of Fish and Wildlife.

[16] Drought Planning, Washington Department of Fish and Wildlife, http://wdfw.wa.gov/drought/

[17] Young, Leroy, Fish Habitat and Flow: What's the Connection? Aquatic Resources Section in the Commission's Division of Environmental Services, http://www.fish.state.pa.us/anglerboater/2001/ma2001/habtflow.htm

[18] The Climate Zone Map was from http://growingtaste.com/usda_map.shtml

[19] C.P. Lyons, J.M. Dent & Sons Trees, shrubs and flowers to know in Washington, , Canada, Limited, Toronto, 1977, pp7-11.

[20] Terrell, Cindy The Damaging Effects of Drought, monograph published by the Morton Arboretum., July 1, 2005 http://mortonarboretumphc.org/ feature%20articles/ Plant%20Care%20and%20Management/ The%20Damaging%20Effects%20of%20Drought%20July%201%202005.pdf

[21] Research: Snails were overlooked contributors to marsh destruction, University of Florida News,12/15/05 http://news.ufl.edu/2005/12/15/snail-marsh/

[22]National Drought Mitigation Center, http://www.drought.unl.edu/risk/environment.htm