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Climate Change, Its Effect on Migration Patterns of the Cackling Goose and White-Fronted Goose in the Willamette Valley, and Implications for Goose Management

By Kelly Warren

Prepared for
The Pacific Flyway Council
September 1, 2010

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Abstract

This thesis considers the question of whether climate change is affecting the migration patterns of geese in the Pacific Flyway, specifically cackling geese (*Branta hutchinsii minima*) and Pacific white-fronted geese (*Anser albifrons frontalis*). Ancillary questions that are considered are as follows:

- If global warming is affecting these species, what is the nature of the effects?
- How are the changes affecting the human environment and what can be done about these effects?

In 1994, the majority of the cackler population in the Pacific Flyway began to winter in Oregon's Willamette Valley rather than in their historical wintering areas in California's Central Valley. In recent years, the Pacific white-fronted goose has shown a change in behavior similar to that of cacklers just before their major shift. The reasons for this shift have not been clear, though climate change, agricultural shifts, or competition with other species were thought to be possible causes.

Analyses of historical breeding and wintering surveys, bird band data, harvest data, agricultural data, and climate and weather data were undertaken in the course of this thesis to see if the cause or causes could be identified. The results showed that climate and weather data, i.e. an increase in average annual temperature coupled with occasional severe winters, most closely correlated with the cacklers' shift northward. The data comparison revealed that there is a direct relationship between cacklers and a warming shift seen on the wintering grounds. There also was a secondary correlation between the northward shift and recent changes in agricultural crops in the Willamette Valley. Substantially less data are available for white-fronts, and the relationship between their recent migration changes and climate and/or other factors is much less clear.

The following recommendations for management and further study are aimed at more completely understanding the scope and causes of migration shifts and formulating well-founded management plans for geese in the Pacific Flyway:

- Continue research to determine if climate change is causing changes in goose population numbers and behavior.
- Expand breeding ground flight surveys to include cacklers and habitat preference to learn how habitat change on the Y-K Delta is altering cackler behavior and breeding success.
- Expand radio transmitter studies and collar programs for cacklers in Oregon and Washington to verify northerly wintering shifts.
- Expand collar programs for cacklers wintering in the Willamette Valley to determine if the population is continuing to shift northward.
- Expand banding programs for white-fronted geese to gather more data about migration patterns.
- Develop models that will allow researchers and managers to correlate migration behavior with various environmental factors including climate change in order to: 1) determine which factors are causing migration changes in specific waterfowl populations and 2) allow managers to make changes to management plans in advance of rapid changes.

- Inform the public about how it can assist in collar surveys or volunteer for the U.S. Fish and Wildlife Service (USFWS). This will enable USFWS to have more concrete data and give the public an opportunity gain a greater understanding of geese and goose management.
- Expand research on urban cackling geese to determine the nature and scope of their effect on the human environment and to devise management strategies.
- Research energetics in migrating geese to determine whether the shift in migration patterns has its basis in climate change.
- Increase data exchange and coordination among agencies.
- Formulate and implement plans at the city and county levels to manage growing numbers of geese in urban areas.
- Recognize and anticipate the possibility that goose populations may move into new wintering areas and formulate plans for management of those species.
- Implement low cost techniques, such as more liberal bag limits and seasons, hazing, etc., to assist agricultural landowners in decreasing goose-related crop damage.

1. INTRODUCTION

Until recently, very few geese used western Oregon and southwest Washington for wintering. California was the primary wintering ground for goose subspecies such as cackling geese (*Branta hutchinsii minima*), white-fronted geese (*Anser albifrons frontalis*), Taverner's geese (*Branta hutchinsii taverni*) and lesser Canada geese (*Branta canadensis parvipes*). Within the last 25 years, geese have been rapidly shifting from traditional wintering areas in California to western Oregon and southwest Washington (Warren 2007). Increased winter temperatures may be a major contributor to this change. Over the last 20 years, average fall and winter temperatures have increased 1.89°F in the Willamette Valley (Flowers 2010). This phenomenon has had, and is expected to continue to have, a significant impact on goose behavior and, consequently, management of goose populations in the Willamette Valley.

This thesis considers the question of whether climate change is affecting the migration patterns of geese in the Pacific Flyway, specifically cackling geese (cacklers) and Pacific white-fronted geese (white-fronts). Ancillary questions that are considered are as follows:

- If global warming is having an effect on these species, what is the nature of the effects?
- How are the changes affecting the human environment and what can be done about these effects?

Indications are that these goose species have altered their migration timing and wintering areas in recent years. The changes are presenting challenges to waterfowl managers, farmers, and hunters.

Background information containing pertinent information about goose behavior, migration routes, wintering areas, habitat, behavior, and management is presented in Section 2. Section 3 describes the methods employed in the study. Data was obtained from both existing literature and original data collection. In Section 4, the results of the data collection are presented. Sections 5 and 6 contain a discussion of the information obtained, conclusions, and recommendations. A reference list appears in Section 7.

2. BACKGROUND

Anthropological data have shown that the Willamette Valley has been an important wintering area for geese since the end of the last Ice Age nearly 15,000 years ago (Pacific Flyway Council 1999a). Bellrose (1981) indicates that the wintering population and numbers appeared to be quite stable. The main species wintering in the valley was the dusky Canada goose; an average of approximately 19,000 dusksies overwintered annually in the Willamette Valley (Pacific Flyway Council 2008a). Remnants of geese found by archeologists as well as fossil records indicate that only the dusky wintered in the Willamette Valley in the past; there is no evidence that cacklers or other subspecies of Canada goose wintered in the valley. However, beginning in the 1980s, greater numbers of cacklers began to show up in the Willamette Valley as that species shifted northward from traditional wintering grounds in California. This shift has continued at a rapid pace until, today, nearly 90 percent of the geese that overwinter in the Willamette Valley are cacklers.

In addition to the cacklers, four other goose subspecies appear to have shifted, or to be in the process of shifting, their traditional wintering grounds to the Willamette Valley and the Oregon coast. These four subspecies are Taverner's, Aleutian (*Branta hutchinsii leucoparidea*), Lesser, and Western (*Branta canadensis moffitti*). White-fronted geese are beginning to exhibit the same signs exhibited in the 1980s by cacklers prior to their shift.

This thesis focuses on the cackling goose and the Pacific white-fronted goose. These species were chosen because they make up the majority of the goose populations within the Pacific Flyway. If these species begin to winter farther north, the natural and human environments and goose management in the Pacific Flyway will be greatly affected.

The reasons for the changes have not been precisely determined, but it is hypothesized that climate change is a major contributor. For example, surveys on the Yukon-Kuskokwim Delta (Y-K Delta) in western Alaska have shown that river channels that used to be around 10 feet wide have grown to nearly 50 feet in width due to increased erosion. Erosion of river channels was, until recently, kept in check by the underlying layers of permafrost on the Delta. However, average summer temperatures have risen in Alaska, which has resulted in melting of exposed permafrost. This has caused river channels to widen and has shortened the length of time water is held in potholes in the Delta's wetlands. In turn, the nesting success of waterfowl species that are more dependent on a large quantity of water has been adversely affected. Birds that nest in upland areas, however, appear to be more successful (C. Dau, USFWS, personal communication, June 2009).

Within the past 15 years, the number of geese wintering in the Willamette Valley has increased from about 100,000 to about 400,000 (Pacific Flyway Council 2009). The shift of wintering goose populations into western Oregon has posed a number of management problems for the U.S. Fish and Wildlife Service (USFWS) and the Oregon Department of Fish and Wildlife (ODFW). The geese feed upon Willamette Valley grain and grass fields, which are an important component of Oregon's agricultural economy. Larger numbers of geese mean greater depredation of the fields and requests by farmers for help controlling the damage.

2.1 GEESE IN THE PACIFIC FLYWAY

2.1.1 Cackling Geese

Flock of Cacklers in Willamette Valley

Migration and Breeding Areas

Cackling geese migrate north in the spring to the Y-K Delta (Figure 1), stopping in the intertidal marshes of Cook Inlet to rest and increase energy reserves for breeding. They also use the pastures and other agricultural lands near Palmer, Alaska. Nearly all of the primary spring habitats in Cook Inlet are within protected state wildlife refuges. Cacklers are an important subsistence harvest species for Alaska Natives.

Nesting occurs in the extensive pond and meadow mosaic habitats of the outer Y-K Delta (Mickelson 1975; Ely et al. 1996). Most nests are established on small islands in pothole ponds; nest densities are somewhat “clumped.” Cacklers also make extensive use of wet tundra and river/slough bank meadows of *Carex* sp. and other wetland vegetation (Babcock and Ely 1994).

Cacklers nest somewhat earlier than other goose species. Placement of nests on the small islands allows them to escape from terrestrial predators and to distance themselves from the nests of more aggressive goose species and subspecies. Cacklers also remain fairly close to water during the nesting season; they are rarely found more than 30 yards from water and, if threatened, will go to the water to escape the threat.

Cacklers leave the breeding grounds in mid-October. Migration appears to coincide with the onset of fall storms and associated strong northwest winds in western Alaska (Gill et al. 1997). The intertidal marshes and coastal wetlands, particularly Ugashik Bay on the north side of the Alaska Peninsula, are vital fall staging habitats (Figure 2). Cacklers use these areas, grazing on pond shorelines, to build up body mass for the southward migration. Roosting occurs mostly on exposed intertidal bars (Gill, Bollinger, and Petersen 1986; Sedinger and Bollinger 1987). Most of the primary use areas in Ugashik Bay are in protected status as are portions of cackler habitat within the Cinder River Critical Habitat Area.

Figure 1: Yukon Delta National Wildlife Refuge (USFWS 2003)

Figure 2: Important Fall Staging Areas in Alaska for Cackling Canada Geese (Pacific Flyway 2003)

In some years, e.g. 1987, large portions of the population may bypass traditional Alaskan staging grounds and fly directly to wintering grounds (Gill et al. 1997). It appears that cacklers can fly non-stop from the Alaska Peninsula to the lower Columbia River.¹ Occasionally, cacklers are sighted in northern Puget Sound (primarily Skagit Flats (Figure 3)), the northern Olympic Peninsula, and eastern Washington during fall migration.

Figure 3: Skagit Flats in Washington State

The geese generally begin to arrive in southwest Washington and northwest Oregon in mid- to late October, with the peak of the population arriving between October 25 and November 7. In some years, the population arrives early. In 2009, for example, a majority of cacklers were recorded in late September. Cacklers are an important species for sport hunters in Washington and Oregon.

Wintering Areas

Historically, most cackling geese wintered in central California (Figure 4) (Nelson and Hansen 1959; King and Lensink 1971; Raveling 1984). Banding and marking studies were conducted between 1982 and 1984 on the Y-K Delta and in northern California. Subsequent observations of these geese in 1984 and 1985 illustrated the typical winter distribution prior to the population increase and geographic shifts of the 1990s.

¹ Gill et al. (1997) documented 11 marked birds that departed the Alaska Peninsula and arrived in the Klamath Basin within 48 to 72 hours.

Figure 4: Central Valley, California

The winter distribution of Cackling geese has shifted markedly northward in recent years. Since 1985, all banding and marking has occurred on the Y-K Delta and none has been done in California. Nonetheless, banding data (Section 3.1.3) illustrate the dramatic change in winter distribution in the 1990s. During the 10-year period between 1988 and 1997, observations of marked cackling geese in southern Oregon and California dropped to very low levels. Concurrently, the number of geese observed in the Willamette Valley to Lower Columbia River region of Washington and Oregon has increased greatly (Figure 5).

Figure 5: Distribution of Cackling Geese (Warren 2007)

This shift coincided with drought conditions in California between 1986 and 1992, which may have affected winter habitat quality and, consequently, use by cacklers. The average winter temperature in the Willamette Valley was also nearly four degrees higher in the mid-1990s than 50 years ago (Flowers 2010). Since 1993, the majority of cackling geese have wintered in Oregon and Washington. Starting in 2006, cacklers have been seen in areas of southern British Columbia as late as December. In the fall of 2008 and 2009, cacklers established a small wintering population in southern British Columbia (J. Fischer, USFWS, personal communication, February 2010).

Population History

The cackler population numbered around 400,000 birds in the late 1960s, but dropped to around 20,000 in the mid-1980s. This decline was thought to be due to a combination of effects from subsistence harvest in Alaska and sport harvest on the wintering grounds, especially in California (Pacific Flyway Council 2008). However, it is now known that the decline was likely a combination of low population numbers and a geographic shift in wintering. The geese formerly were found primarily in the Klamath Basin and Central Valley during the winter where they were routinely counted in wintering ground surveys. They were not specifically included in Willamette Valley counts, so were not recorded until the shift northward became more apparent (B. Bales, ODFW, personal communication, December 2009). Populations rebounded following harvest restrictions implemented in 1979 and concerted flyway-wide restoration efforts that started in 1983 (Pamplin 1986). Figure 6 shows the 20-year decrease in cackler numbers on their staging grounds in Central Valley and the Klamath Basin due to their shift to the Willamette Valley.

Figure 6: Total and Regional Cackler Population (Pacific Flyway Council 2010)

Prior to the 1990s, the cackler was an infrequent resident in the Willamette Valley and lower Columbia River, spending staging in the Klamath Basin and wintering in California's Central Valley (Figures 4 and 5). Now, 95 percent of the cackler population winters in Oregon. The shift to wintering grounds in Oregon coincided with a population rebound; by 1997, there were about 200,000 geese wintering in the Willamette Valley and lower Columbia River (Pacific Flyway Council 1999). Since then, the number has fluctuated, but has remained between 150,000 and 200,000 birds. The overall trend currently is for continued increases in the cackler population.

The 2010 estimate projected by USFWS is 188,000. The three-year average estimate is 180,000, which is the highest three-year trend in many decades (B. Reishus, ODFW, personal communication, July 2010). However, the population has fluctuated over the past five years, making it difficult to identify a long-term population trend. The population is still below management objectives and, therefore, is being carefully managed in order to eventually meet the management objective set by the Pacific Flyway Council (Section 2.2.1).

2.1.2 Pacific White-Fronted Geese

Breeding Areas

Nearly all Pacific white-fronts breed from the Alaska Peninsula north to the Yukon River, with the majority nesting on the Y-K Delta (Palmer 1976; Timm and Dau 1979). Aerial surveys, which are usually conducted in June, indicate that the Y-K Delta has hosted an average of nearly 97 percent of Pacific white-fronts over the past 10 years (Eldridge and Dau 2002; Conant and Groves 2002). About 75 percent of the population breeds in the narrow coastal zone while another 22 percent are dispersed across the interior of the Delta. The remainder nest in Bristol Bay and the Innoko River basin.

Migration and Wintering Areas

The fall migration of Bristol Bay Pacific white-fronts begins in early to mid-August. Geese that migrate along the Alaska Gulf Coast in late August and early September and pass through Cook Inlet and the Copper River Delta (Figure 2) before the hunting season opens may be of Bristol Bay origin (Hawkings 1982, Ely and Dzubin 1994); this assumption is based on a few band recoveries from Cook Inlet. The Y-K Delta Pacific white-fronts, unlike cackling geese, do not usually aggregate in concentrated staging areas. They apparently remain on the Y-K Delta or east of the Delta until late September (Figure 7) (Ely and Dzubin 1994).

The numbers shown in Figure 7 denote the primary wintering and staging spots of white-fronts and are in order of importance with “1” being high importance and “12” being lesser importance (Ely and Takekawa 1996). Fewer than 10,000 Pacific white-fronts winter in the Klamath Basin of northeastern California and southeastern Oregon; several hundred Pacific white-fronts overwinter in the lower Columbia River.

Alaska’s Copper River Delta (Figure 2) is the last known major use area north of the Klamath Basin (Figure 4). There have been only two band recoveries in Southeast Alaska and one in British Columbia. As the population has increased, more Pacific white-fronts have been observed in western Washington and Oregon during September.

Figure 7: Important Staging and Wintering Areas for White-Fronted Geese (Pacific Flyway Council 1999)

It appears that most Pacific white-fronts move nonstop from the Y-K Delta to the mouth of the Columbia River, migrating through central and eastern Oregon in October before arriving at wintering grounds in the Klamath Basin and Sacramento Valley. The geese move through the same area again in January and February before heading northward to the breeding grounds in Alaska. In recent years, however, most of

the population apparently has bypassed the traditional Klamath Basin staging area in the fall, migrating directly to the Central Valley of California. When migrating north however, white-fronts have increased in number in the Klamath Basin. The geese mainly concentrate on national wildlife refuges on the west side of the Sacramento Valley in the early fall because other habitats are limited. Increasing urbanization, changes in agriculture, hunting pressure and the large influx of Pacific white-fronts has limited habitat and resources in their wintering area.

As the fall and winter progresses, the Pacific white-fronts disperse into other parts of the Sacramento Valley and the Sacramento-San Joaquin River Delta. Recent trends (1998-2002) show significant numbers of Pacific white-fronts arriving in the Sacramento Valley by late September, with 100,000-200,000 present by the first week in October. Although diminished in numbers from past years, the first arrivals in the Klamath Basin are seen about the end of August with the peak occurring in mid-October (USFWS 1999). These arrival dates are still true today according to USFWS surveys. A small percentage of Pacific white-fronts, mostly from Bristol Bay, migrate early through the Klamath Basin in September, overfly the Sacramento Valley, and winter in the northern highlands of Mexico (see below) (Ely and Takekawa 1996).

Recoveries from Pacific white-fronts banded in Alaska show a relationship between breeding and wintering areas (Lensink 1969). It appears that birds from the Y-K Delta stage and winter in the Pacific Flyway. The majority of recoveries from the three banding regions on the Y-K Delta occurred in California (Pacific Flyway Council 1987).² Only 7 percent of the Pacific white-fronts banded in the Innoko River basin (Figure 2) have been recovered in California. These are likely “molt migrants”³ and comprise both Pacific white-fronts from the Y-K Delta and Tule white-fronts from Cook Inlet. The Innoko River basin hosts Pacific Flyway white-fronts, Mid-Continent white-fronts, and Tule white-fronts during the molt. The westernmost banding sites in the Innoko basin have produced the highest proportion of California band recoveries (>20 percent), which is congruent with the distribution of molting Tule white-fronts in the region.

Past banding in the Klamath Basin has indicated that Pacific white-fronts migrating through the Klamath Basin in September and early October were apt to be recovered in Mexico, whereas geese banded after 15 October are rarely recovered there (C. Ely, USGS, personal communication, 2010). The earlier birds are now known to be primarily from the Bristol Bay group (Ely and Takekawa 1996). At least 10,000 Pacific white-fronts winter in Mexico. Winter survey counts in Mexico conducted every third year by the USFWS indicate that the numbers of wintering geese range from 10,000 to more than 20,000 (USFWS 2001). Band recovery data indicate that the propensity of Pacific white-fronts to winter in Mexico is highest in birds from the southern part of the breeding grounds, particularly Bristol Bay. Bird banding data showed that over 90 percent of Pacific white-fronts from Bristol Bay wintered in the interior of Mexico (Ely and Takekawa 1996).

Recoveries in Mexico varied among geese banded in the north Y-K Delta (none in Mexico), middle Y-K Delta (2.5 percent), and south Y-K Delta (23 percent). Analyses of historical banding have shown that 9 to 10 percent of birds from the primary Y-K Delta breeding grounds are recovered in Mexico, primarily from the states of Sinaloa, Nayarit, and Sonora (Lensink 1969, 1986). Between 20 percent and 25 percent

² Bands recovered in California were as follows: 70.0 percent from the south Y-K Delta region, 90.5 percent were from the middle Y-K Delta region, and 84.6 percent were from the north Y-K Delta region.

³ Molt migrants are defined as non-breeding yearlings that migrate to unfamiliar areas to clear habitat for young of that year.

of band recoveries are from the interior highlands of Chihuahua and Durango. Ely and Dzubin (1994) suggest that the Pacific Flyway white-fronts wintering in the interior highlands may not be sympatric with Mid-Continent birds using areas further south and east in Mexico.

Population History

There are two subspecies of white-fronted geese that breed in Alaska and winter mainly in California: the greater white-fronted goose (*A. albifrons frontalis*), also called the Pacific Flyway Population of Greater White-Fronted geese, or Pacific white-front, and the Tule greater white-fronted goose (*A. a. gambelli*). Each of these subspecies is managed through different plans in the Pacific Flyway (Section 2.2).

In addition to the Pacific Flyway Population of white-fronted geese, there is a Mid-Continent Population of white-fronted geese (another population of *A. a. frontalis*). Some of the geese from Mid-Continent Population breed in interior and northern Alaska and are managed through a separate plan adopted by the Central, Mississippi, and Pacific Flyway councils in 1998.

Fall counts of Pacific white-fronts declined from a population peak estimate of 480,000 birds between 1966 and 1968 to a low of 73,100 in 1979 (O'Neill 1979; Timm and Dau 1979; Raveling 1984). Harvest restrictions instituted in the late 1970s and a conservation program begun in 1984 (Section 2.2.2) helped return the population to acceptable levels by 1996. Though growth slowed somewhat in the late 1990s, the population numbered 433,400 in 2001 and 600,000 by 2004, as determined by breeding and wintering ground surveys (Pacific Flyway Council 2004). The population this past year has grown to nearly 650,000 white-fronts (Figure 8).

Figure 8: Total Population of White-Fronted Geese 1979-2010 (Pacific Flyway 1999)

At the present time, the white-front population is higher than it has ever been, according to USFWS surveys (J. Fischer, USFWS, personal communication, 2010; Pacific Flyway Council 2010). The estimated population is nearly 350,000 birds greater than the management objectives set by the Pacific Flyway Council (Section 2.2.1) which has resulted in large impacts on agriculture. Special hunts have been initiated in an effort to alleviate crop depredation. However, so far there has been little success in lowering the population.

Lowering the population through hunting has been hampered by the fact that protection of the Tule white-front is a top priority. Conservative bag limits are still in place and hunt areas are closed in California to protect this species. Until the Tule rebounds, it is unlikely that hunting will be a means of controlling the white-front population. Therefore, because conditions on breeding areas have been favorable and sport hunting continues to be controlled, it is likely that the Pacific white-front population will continue to increase.

2.2 GOOSE MANAGEMENT

2.2.1 Pacific Flyway Council

The federal governments of the United States, Canada, and Mexico, under the authorities of bilateral treaties and federal legislation, are ultimately responsible for the protection and conservation of migratory birds in North America. In the United States, this responsibility has largely been delegated to the USFWS.

The Migratory Bird Treaty Act implements various treaties and conventions between the U.S. and Canada, Japan, Mexico and the former Soviet Union countries for the protection of migratory birds. Under the Act, taking, illegal killing or possessing migratory birds is unlawful. The act also states that hunting seasons must fall between September 1 and March 10. The Migratory Bird Treaty Act authorizes state governments to adopt and enforce laws and regulations protecting migratory birds, as long as they are not inconsistent with those of the federal government. That is, state authority may be more restrictive than the federal authority, but not more liberal. Each state has constitutional and legislative mandates and a body of laws and regulations that direct the conservation and public uses of migratory game birds within their borders.

Migratory birds use four major migratory routes (Pacific, Central, Mississippi, and Atlantic flyways) in North America. Because of the unique biological characteristics and relative number of hunters in these regions, state and federal wildlife agencies adopted the flyway structure for administering migratory bird resources within the United States. Each flyway has its own council. In the U.S., the Pacific Flyway includes Alaska, Arizona, California, Idaho, Nevada, Oregon, Utah, Washington, and those portions of Colorado, Montana, New Mexico, and Wyoming west of the Continental Divide.

The Pacific Flyway Council is an administrative body that fosters cooperation among public wildlife agencies for the purposes of protecting and conserving migratory birds in western North America. The Council is composed of the director or an appointee from the public wildlife agency in each state and province in the western United States, Canada, and Mexico.

Each species and subspecies of waterfowl in the United States is managed separately by region. Management in each region is established by a regional council consisting of representatives from management agencies. Management strategies for waterfowl populations in the Pacific Northwest are developed by the Pacific Flyway Council. Plans are the primary tool for managing and making management decisions about individual species, subspecies, and populations. The management plans are subject to revision as new data and information about a waterfowl population are developed.

Management protocols and implementation are first established by the Pacific Flyway Council and then by the USFWS and state fish and wildlife agencies. Because birds fly over more than one state in their migrations, management is handled by the federal government through the Pacific Flyway Council and the USFWS. Once protocols and strategies are agreed upon, they are incorporated into the management plan for that particular subspecies.

Scientific data is gathered annually on waterfowl populations. Changes in population dynamics and migration patterns within the Pacific Flyway require revision of management plans. These revisions, in turn, require research to determine the most effective ways to manage each goose species (J. Fischer, USFWS, personal communication, 2010). Targeting management strategies for changes in wintering and breeding areas can help forestall problems for Willamette Valley farmers while simultaneously maintaining the goals set by agency management plans for individual goose species.

The focal species for goose management in Oregon and southwest Washington is the dusky Canada goose. The dusky Canada goose is considered a “less successful” subspecies that has been displaced on wintering grounds due to the increase in cacklers (Pacific Flyway Council 2008).

In recent years, managers have had to act quickly to accommodate the dramatic increase in cackling geese in the Willamette Valley. In the 1980s and 1990s, little action was taken by the agencies because the cacklers were not expected to shift in such large numbers. When the rapid shift occurred, managers were not prepared to implement new management strategies that would accommodate cacklers in their newly chosen wintering ground. The agencies’ lack of preparation resulted in larger than necessary expenditures of public funds and in actions that had little or no effect on the problem. Today, agency personnel recognize that it will be essential to plan for the worst-case scenarios in terms of migration shifts to prevent the crisis-mode actions that occurred with the rapid increase in the cackler population in the 1980s and 1990s (J. Fischer, USFWS, personal communication, 2010).

The Y-K Delta Goose Management Plan has guided conservation and harvest of the cackling goose for the past 15 years. The precursor of the Y-K Delta Management Plan was the Hooper Bay Plan, which was signed in January 1984 by representatives of the coastal states, the USFWS, and Alaska subsistence hunters. Representatives from Alaska, Washington, Oregon, and California attended a series of meetings in 1983, which led up to the 1984 agreement. The intent of the meetings was to identify critical problems with goose nesting, to agree on harvest restrictions, and to develop a broad-based conservation program (Pamplin 1986). Similar annual meetings have continued under the Y-K Delta plan to assure consistency between management plans for the Pacific Flyway and for the Y-K Delta. Through these efforts, the cackler population rose to about 192,000 birds in 2008 (J. Fischer, USFWS, personal communication, 2010).

Subsistence harvest is also covered by the Y-K Delta plan. This is a very important issue for Native people in both Alaska and Canada. Native people rely on subsistence hunting for food and as well as an important cultural activity. The Y-K Delta Goose Management Plan calls for restrictions on both the breeding and wintering grounds to protect cackling, white-fronted, and emperor geese (*Chen canagica*) as well as black brant (*Branta bernicla nigricans*). In order to ensure a viable supply of birds for subsistence harvest, the Y-K Delta Goose Management Plan calls for restrictions on hunting, egg harvest, and other activities that affect populations depended upon by subsistence users. These measures are aimed at protecting cackling, white-fronted, and emperor geese while maintaining subsistence opportunities for Alaskan and Canadian Natives. The plan requires that federal harvest management for all geese on the wintering grounds be weighed against the needs of subsistence users. The current restrictions are to ensure that the population reaches a level where harvest will have little impact on the population while still maintaining the target population objective. The plan requires that federal harvest management for all geese on the wintering grounds be weighed against the needs of subsistence users.

2.2.2 Management of Cackling Geese and White-Fronted Geese

Goose species and subspecies are defined by the USFWS both geographically and by physical characteristics. For example, a cackling goose is any goose with a culmen (bill length) of less than 32 mm that breeds on the Y-K Delta in Alaska. Separating management by region and species/subspecies means that different management strategies are instituted for each species, subspecies, and population. Management strategies are based on population status, harvest, and migration change. Of these, population level is the most important factor in management of any particular subspecies. Another significant factor that can alter management plans involves human-geese conflicts on wintering grounds. For example, as goose depredation on agricultural lands escalates, hunts are enacted to lower the goose population.

Cackler Management

The current plan Pacific Flyway Management Plan contains measures that attempt to address the complexities of having two subspecies (duskies and cacklers) occupying the same wintering area. The objectives set by the plan are as follows:

- Achieve a population of 250,000 geese as measured by a 3-year average index of indicated breeding pairs, i.e. 27,660 breeding pairs, as determined by the Y-K Delta aerial breeding goose survey
- Promote an average annual population increase of 5 percent to 10 percent
- Manage for a winter distribution that allows for no more than 20 percent of the current population in the agricultural areas of the lower Columbia River and Willamette Valley⁴
- Maintain, manage, and enhance, where feasible, nesting, migration, and wintering habitats in sufficient quantity and quality to meet population objectives and public use goals
- Manage habitats and harvest to minimize crop damage consistent with Pacific Flyway plans and policies (Pacific Flyway 1999)

Increasing numbers of cacklers may result in more liberal season dates and bag limits as the population gets closer to its objective of 250,000. The Migratory Bird Treaty states that hunting cannot extend beyond March 10 so that the birds can feed and build up fat reserves for the long migration to the breeding grounds (Flowers 2010).

As the goose population increases, so will damage to agricultural crops and encroachment into urban areas. Revised management plans must include input from the Oregon Farm Bureau, Oregon Department of Agriculture Washington Farm Bureau, and Washington Department of Fish and Wildlife. The effects on agriculture were taken into account to a certain extent in the last management plan, but with increase in cacklers and white-fronts, more attention must be focused on crop damage.

The most dramatic changes in cackler numbers on the wintering grounds occurred in 1994 and 1995. During this time, numerous meetings of the Pacific Flyway Council were held in order to formulate an emergency management plan until a more permanent approach could be established. The result was a treaty among USFWS, the states of Oregon and Washington, Alaska Department of Fish and Game, and

⁴ This objective is aimed at removing cacklers from the agricultural areas in the lower Columbia and Willamette Valley; the remaining 80 percent of birds would overwinter away from agricultural areas.

the Alaska Natives. The agreement called for collar and banding studies aimed at monitoring harvest levels so that the cackler population could be managed to ensure that it would not be overharvested in either Alaska or the Pacific Northwest.

Currently, in Oregon, farmers feel goose depredation is affecting their crops to the point that their livelihoods are at risk. Starting in fall 2010, the Agricultural Depredation Plan formulated by the Pacific Flyway Council will be re-written to reflect current impact of cacklers on new areas in Oregon and southwest Washington. The cackler management plan will also be opened and proposals will be presented to lower the population goal to a level that will not pose further risk of depredation.

In Oregon, the cackler wintering population has grown from 25,000 in the late 1970s to nearly 400,000 in 2009 (Section 2.1.1) and is continuing to increase. In the late 1980s, Oregon and the lower Columbia River were included in the cackler surveys. Adding these areas caused the overall population estimate to increase, but managers still decided to institute changes aimed at returning the cackler population to return to its historical levels.

In recent years, there have been increasing numbers of migratory geese using urban areas. For example, the number of urban geese within the city limits of Salem has increased nearly 50 percent between 2005 and 2010 (B. Bales, ODFW, personal communication, 2010). Urban areas provide safety from hunting and agricultural hazing, lower concentrations of predators, and optimal food sources such as fine grasses in golf courses and recreational fields. Increased numbers of geese in urban areas have resulted in negative effects such as water contamination and damage to athletic fields and golf courses due to large concentrations of feces that make areas cosmetically less appealing and pose human health risks.

Management of White-Fronted Geese

The Pacific Flyway Goose Management Plan contains the following management goal and objectives for Pacific white-fronted geese (Pacific Flyway Council 2003):

- Goal: Identify the needs and responsibilities necessary to cooperatively manage numbers and distribution of Pacific white-fronts in order to maintain population viability and to provide for aesthetic, educational, scientific, and hunting uses throughout their range
- Maintain a population index of 300,000 as measured by a 3-year average projected fall index derived from indicated total geese on aerial surveys covering the Y-K Delta and Bristol Bay areas
- Maintain, manage, and enhance nesting, migration, and wintering habitats in sufficient quantity and quality to meet the population objective and public use needs

White-fronts have recently been exhibiting changes in behavior that are thought to foreshadow a similar northward shift in wintering areas. For example, it has been observed that goose populations have “scout” birds that look for better habitat and food sources (Pacific Flyway Council 2008). Once the scout birds have identified a suitable wintering area, increased numbers of geese are seen in those areas during spring and fall migrations. Within a few years, the main population is staging longer in these areas and eventually will remain on the former staging grounds throughout the winter.

This is the same type of trend observed with cacklers starting in 1985. At first, several hundred cacklers started wintering in the Willamette Valley. By fall 1994 and winter 1995, the number of cacklers wintering in the valley had increased nearly 50 percent as the geese shifted from the Sacramento Valley northward (Warren 2007).

3. STUDY METHODS

Data and information for this thesis were obtained from a review of pertinent literature and unpublished data as well as from original field data.

3.1 LITERATURE REVIEW

Several types of data were analyzed in order to address the questions presented in Section 1:

- Historical breeding and wintering surveys
- Bird band data
- Harvest data
- Agricultural data
- Climate and weather data

Pertinent literature included USFWS data (published and unpublished), studies conducted by universities, ODFW data, journal articles, and some unpublished data. Of these, the most pertinent were the USFWS data. ODFW harvest data also played a significant role in addressing the project's questions and aided in identifying patterns during the comparison of climate and agricultural data (Section 4).

Only data and information from 1975 to 2010 were considered for this thesis. This time frame was chosen because it encompassed the period before, during, and after the postulated shift northward. Trends in migration changes (if any) would be evident in data generated in these years. The same time frame was used for weather and climate data also.

3.1.1 Historical Breeding and Wintering Surveys

Data from past breeding and wintering surveys between 1975 and 2005 were compared with current surveys (2005-2010) in order to detect changes in area usage, migration patterns, and timing. Very little data prior to 1975 exist. The most complete set of data is derived from annual breeding and wintering ground surveys conducted by the USFWS. USFWS began collecting these data in the 1950s from field observations and aerial surveys. Combining these data produces an average that is the most realistic population estimate for any given year. The data from USFWS current surveys are derived from the surveys conducted over several decades. All aspects of the survey method have been refined over the years so that errors are minimized and so that the surveys result in an accurate picture of the total population and any changes that may have occurred. In addition to ground surveys, USFWS uses photographic data, banding, and aerial surveys. The protocols also assure the consistency of data collection from one year to the next, allowing easy comparison of data collected decades ago to that collected more recently.

3.1.2 Historical Breeding Ground Information

Breeding ground surveys occur in Alaska's Y-K Delta (Figure 1) where USFWS randomly samples waterfowl nests to determine annual breeding success. USFWS protocols are followed yearly on the Y-K Delta for both cacklers and Pacific white-fronts in mid- to late June. USFWS provided an opportunity to

participate in a Y-K Delta ground survey crew during the summers of 2009 and 2010. Aerial surveys were conducted in July when the geese are in molt and unable to fly. During this time, the surveys are easier to conduct because the geese tend to gather together. The colony locations are marked with GPS coordinates which ensures that they are not counted twice.

3.1.3 Banding Data

Bird banding is an important source of information about bird populations, bird longevity, and behavior (territorial behavior, territory size, fidelity to territory, and reproductive behavior), especially dispersal and migration. Banding is supervised by the Federal Bird Banding Laboratory for USFWS and the Canadian Wildlife Service. This laboratory holds the database for all band data in the U.S. and Canada. All data from birds marked with a federal band are submitted to this laboratory; 99 percent of the banded birds in North America carry federal bands. The other 1 percent includes aviary, or private collection, birds.

Banding can be accomplished with metal leg bands or with other methods that are more visible to the observer, such as a “tarsus” band⁵ or neck collar. These bands are more visible than other types of bands, which means that they can be tracked without handling the bird again. A “mark-capture” technique can be used to estimate population sizes. Birds are marked and then recaptured. The ratio of the number of birds marked originally compared to those recaptured allows the total population to be estimated.

Analysis of banding information from waterfowl is completed annually. These data are used in development of hunting regulations and for detecting changes in waterfowl populations. Banding data can be used to assess hunting pressure, estimate productivity and survival and to measure the vulnerability of the age/gender classes to hunting pressure.

Band data specific to pertinent areas were reviewed for this project. Most data were obtained from USFWS’ Bird Banding Laboratory. For cacklers, the geographic area encompassed by the data used for this project extended from the southern Willamette Valley in Oregon through the State of Washington. Washington State data were included because it was speculated that it could reveal any northern shifts of this species. Data reviewed included live sightings of collared or banded geese and data reported from harvested geese or those found dead.

For white-fronts, the geographic range of the data included Washington, Oregon, and California. Because so few white-fronts have been included in banding studies in the past, any band data at all for this species were considered useful to the project.

3.1.4 Harvest Data

Harvest data were obtained from three sources: 1) wing and parts survey⁶ information, 2) Harvest Information Program (HIP) data, and 3) permit zone data. The first two types of data were obtained from USFWS. Permit zone data are collected at check stations in the Northwest Permit Zone Area (Figure 9) and were obtained from ODFW. Combining the data from these three sources was expected to show migration trends based on the number of cacklers and white-fronts harvested over the years.

⁵ A tarsus band is placed on the leg and has three characters that can be read from a distance with a spotting scope.

⁶ USFWS looks at certain features on wings and tail feathers of harvested birds. The bird “parts” are voluntarily donated to USFWS by hunters for this purpose.

Figure 9: NW Permit Zone (Warren 2007)

USFWS conducts a voluntary “wing and part” survey on an annual basis. This information, combined with harvest rates in the HIP allows USFWS to estimate total harvest numbers for hunting zones nationwide. In addition, USFWS can determine the species and subspecies harvested by hunters.

Through HIP, state wildlife agencies and USFWS are developing more reliable estimates of all migratory birds harvested throughout the country. These estimates give biologists the information they need to make sound decisions concerning hunting seasons, bag limits, and population management. HIP is based on a voluntary survey of selected migratory bird hunters in the United States. In simplest terms, the state wildlife agencies collect the name, address, and some additional information from each migratory bird hunter in their state and send that information to USFWS. USFWS then randomly selects a sample of those hunters and asks them to provide information on the kind and number of migratory birds they harvest during the hunting season. Those hunters' reports are then used to develop reliable estimates of the total harvest of all migratory birds throughout the country.

Harvest data is also gathered from the Northwest Permit Zone in Oregon and Washington (Table 1) where, by law, all hunters must submit every goose harvested at check stations for examination to determine species and subspecies.

Table 1: Permit Zone Harvest Data for Cacklers and White-Fronts, 1985-2010 (ODFW 2010)

	Cacklers	White-Fronts
1984-85	0	not included
1985-86	8	not included
1986-87	19	not included
1987-88	54	not included
1988-89	26	not included
1989-90	16	not included
1990-91	18	not included
1991-92	42	not included
1992-93	36	not included
1993-94	72	not included
1994-95	1,220	not included
1995-96	1,758	not included
1996-97	2,503	not included
1997-98	3,446	44
1998-99	5,641	45
1999-00	7,302	18
2000-01	4,972	45
2001-02	3,676	14
2002-03	4,381	26
2003-04	3,631	16
2004-05	6,789	46
2005-06	4,734	47
2006-07	5,505	20
2007-08	5,899	50
2008-09	6,221	172
2009-10	6411	68

Checking species and subspecies is necessary in order to monitor whether or not Dusky Canada geese are inadvertently being taken. Because duskies are a “species of concern,” there are limits on how many duskies can be harvested per season. If that quota is reached, hunting is closed. Check station personnel measure certain physical attributes of each goose and record species and subspecies. This further refines the data on specific numbers of Canada geese, cackling geese, and Pacific white-fronted geese.

3.1.5 Radio Transmitter Data

Data on goose movements and locations can be revealed through use of radio transmitters. Information for this thesis was obtained by placing radio transmitters on geese as part of a study being conducted by a Ph.D. candidate at Portland State University. The study focused on Benton, Linn, Lane, and Polk counties. Geese were captured on the Finley Wildlife Refuge near Monroe, Oregon, using bait traps. The radio transmitters were mounted on neck collars and placed around the necks of the geese. Approximately seventy birds were radio-collared over a two-year span. The birds were then tracked during their wintering movements using “relocators” which send a signal when an observer is near a radio-collared goose. The transmitters’ batteries last about six to seven months in a radio collar. Since collaring occurred in December, January, and February, the radios cease to operate in June, July or August respectively.

3.1.6 Interpretation Aerial and Still Photographs

Historical and current aerial photographs of the Y-K Delta were obtained and topographical features analyzed for this thesis. In conjunction with other breeding ground surveys, aerial surveys are conducted to estimate nesting success and adult bird populations. Random transects are generated using a computer program (ArcGIS)⁷. The plane flies transects and “scatter shoots” the entire transect with a digital camera to ensure all waterfowl are recorded. The photographs are then analyzed to determine species and subspecies of geese. Aerial photos taken for this project were interpreted by USFWS and the data were made available to the author.

Counts of geese on the ground from still photos are often more accurate than counts made in the field (J. Fischer, USFWS, personal communication, 2010). Geese typically land in massive flocks and are constantly moving across a field while feeding. The movement can be “stopped” by taking still photos of the flock at times in sequence. The photos can then be analyzed to identify each species and subspecies, including marked birds. The number of birds of each species and subspecies in each flock can also be obtained. Though on-site viewing through a spotting scope is useful, a more definitive estimate can usually be obtained with photography.

3.1.7 Agricultural Data

Agricultural data was gathered from U.S. Department of Agriculture, Oregon Department of Agriculture, and California Food and Agriculture Department. Each provided historical, current, and future trends in agriculture. This project focused on the period between 1970 and 2010. The agricultural data reviewed included farming practices in Central Valley California and the Willamette Valley in Oregon prior to the migration shift of cacklers. Agricultural practices during and after the migratory shift were examined to identify changes in potential food sources for the geese. Records from the Oregon Department of Agriculture were reviewed to determine the crops grown in the Willamette Valley and the percentage of each crop between 1980 and 1995 (ODA 2009), the greatest period of expansion for cacklers. Analysis of

⁷ ArcGIS is a highly accurate, geography-based system designed to provide useful information for decision-makers. It allows easy production of data, maps, globes, and models that can be easily accessed by the user in the field and the office.

more recent data was expected to reveal if the northward shift of cacklers is expected to be maintained or expanded and if a similar shift based on preferred foods would be expected for white-fronts.

3.1.8 Climate and Weather Data

Analysis of weather patterns and data was an important part of determining the correlation between the cacklers' and white-fronts' northward shift and climate change. Average winter temperatures, snow levels, and frequency and severity of winter storms in the Willamette Valley, central Washington, and California's Sacramento and Central valleys were reviewed and compared to increased usage of the Willamette Valley by geese for wintering.

3.2 FIELD STUDIES

In addition to analyzing historical survey data, original data were collected in the field and were used to address the questions posed in this thesis. The data were also entered into the USFWS database. Data for both breeding grounds and wintering grounds were collected. The data were collected by the author in strict adherence with USFWS protocols, which allows the data to also be used by the Oregon Department of Fish and Wildlife and by the Pacific Flyway Council. Collected data were submitted to the USFWS database managers to assure that its acceptability for inclusion in the database.

Winter data collection occurred in coordination with USFWS' annual wintering ground surveys. The annual survey involved ground and aerial surveys as well as reading "collars." More than 400 hours were spent in the field and more than 300,000 geese were logged. Data collected during the wintering ground survey were compared to those obtained on the breeding grounds for that year. Consistency or inconsistency of the numbers gives managers important information about the welfare of the population for that particular year including, breeding success, hatching survival, percent of eggs per female, and more. This information is used in establishing sport bag limits, subsistence harvest or in identifying special needs a particular species or population might have.

Winter fieldwork for this project was carried out in two consecutive years: 2008/09 and 2009/10. The area covered extended from Eugene, Oregon, to the Ridgefield National Wildlife Refuge in southwest Washington. USFWS, ODFW and Washington Department of Fish and Wildlife staffs have certain areas in which they collect data; the fieldwork performed for this project looked at areas not already covered by biologists from those agencies.

Areas are typically broken up by county with one survey per week in each county. In addition to specific areas that are surveyed weekly, the "Oregon General Zone" was surveyed by the author for a more complete survey (Figures 9 and 10). The general zone is rarely surveyed so additional data was collected beyond what was collected within the permit zone boundaries. The General zone extends from Portland to Eugene east of the I-5 freeway. Surveys were done three days a week, each day in a different survey area (county) in both the permit and the general zone.

Surveys typically begin in early morning at roosting areas as the geese are leaving for preferred feeding areas. The birds were followed by car to the feeding areas where they were counted and species/subspecies identified. The surveys were conducted with a spotting scope and binoculars as well as a digital camera. Photographs were particularly useful because counts could be conducted later from the pictures, which served as a verification of counts done in the field, thus lowering the margin of error.

Figure 10: Areas Surveyed for Wintering Geese, 2008/09 and 2009/10

Each road in a survey area was covered to assure that the observer was seeing as many geese as possible. In some cases, access was limited because roads were private. Some areas had very few roads. This limited counts to areas that could be easily seen which meant, in some cases, that the counts were merely representative of the total number of birds in an area. In cases where roads were far from the goose flocks, it was difficult to identify species and subspecies. These limitations were noted on each data sheet. Inconclusive data sheets were eliminated from the final documentation.

A data sheet (Appendix A) was completed for each group of geese encountered. Information collected included date, time, bird location, number of birds of each subspecies, number of marked birds, name of the closest refuge, the latitude and longitude of the encounter location, and the total number of geese observed. The data were obtained from direct observation using binoculars, spotting scope, and camera with telephoto lens. The camera enabled groups of geese to be recorded for later species confirmation and, because the telephoto lens was more powerful than the spotting scope, made bird collars easier to read. This method allowed 100 percent success in reading collars on cackling geese in the 2009-2010 field season.

3.3 BREEDING SURVEYS

The USFWS conducts breeding ground surveys in Alaska's Y-K Delta. Waterfowl nests are randomly sampled to determine annual breeding success. Random sample areas are generated by computer; usually 80 to 85 sites are surveyed. A customized program within ArcGIS generates the randomized selection of 85 plots each year. Plots selected do not overlap any plots surveyed in the past 5 years. Boundaries of the survey area include lands on the Yukon Delta National Wildlife Refuge (Figure 1) containing medium and high nest densities of spectacled eiders because of their Endangered Species Act listing and geese. The nest densities are based on aerial and ground observations made between 1985 and 1993 (USFWS unpublished data). Because annual access cannot be assured, privately owned high density nesting habitat near Kokechik Bay, two parcels on south Nelson Island, and several tracts near Hazen Bay are excluded.

Between 1994 to 1997 and 2000 to 2010, plots were selected within an area 716 km square that comprised 5.6 percent of the total coastal zone of the Y-K Delta. Prior to 1994 and in 1998 and 1999, plots were selected within a slightly larger portion of the coastal zone. Each plot measures 800 m by 400 m and is surveyed on foot. The location of each nest found is recorded along with the number of eggs, egg condition, species, and estimated date of hatching.

Hatching is estimated by using historical data from past breeding ground surveys and studies that focus on incubation and hatch. During the nest plot survey, eggs are floated in water to determine hatch date. Eggs will float differently depending upon their maturity. A hatch date for the season can be determined by averaging the number of floating eggs for each species. Each species or subspecies typically will lay eggs at slightly different times, resulting in a range of hatch dates for any given season on the Delta.

Breeding surveys are time-critical and must be conducted as soon as the ice melts on the Delta, usually between May 26 and June 15. For this project, 17 nest plots within a 20-square mile area were sampled within a 15-day period. The nests occurred in a variety of habitats including upland, coastal, riparian, grassy plains, mudflats, and "pothole" ponds.

Each plot is surveyed by two people. Each person walks half the plot area following a GPS and proceeding in a zigzag manner, checking to make sure that all the area is covered. During the survey, birds flushing from nests are noted and the species identified. If unoccupied nests are found and no bird flushes, down and feathers in the nest are used to determine the species. All species of bird including waterfowl (duck, goose, swan), gulls, shorebirds, and songbirds are noted. An example of the survey form is found in Appendix A. For each nest, the following information is recorded:

- Plot number
- GPS location
- The name of the observer
- Goose species
- Nest location
- Number of eggs
- Maturity of the eggs (estimated hatching date)
- Evidence of predation in the nest
- Nest status (active or non-active)

During the 2009 and 2010 survey periods, 15 and 10 plots, respectively, were surveyed for this project. Figure 11 depicts the plots surveyed in 2010.

Figure 11: Nest Plot Survey Area, 2010 (USFWS 2010)

4. RESULTS

All data and collected from sources identified in Section 3 were reviewed and analyzed for completeness and applicability. Data that were not considered complete or accurate were excluded from the analysis. Data and information from studies that were not yet complete or appeared to be less applicable to the questions addressed by this thesis were not used in the data synthesis and analysis. For example, the radio transmitter study has not yet been concluded and the data from it were not included in this thesis.

In addition, the HIP harvest data, while helpful, was not as useful because its scale was too broad. The numbers harvested gave an idea of the overall harvest, but with a large margin of error. It also did not clearly identify where the birds were harvested, e.g. birds were identified only as having been harvested in Oregon. The USFWS data from breeding and wintering areas was much more useful because it could be used to cross-check other population estimates.

4.1 WINTERING AND BREEDING GROUND SURVEYS

Data obtained in the course of this project indicate that cacklers are arriving on the breeding grounds and nesting later than in previous years. The incubation date for broods is beginning to extend beyond the historical May 26 to June 10 “window” according to results from the nest plot survey. It is thought by USFWS biologists that this is due to the fact that cacklers and white-fronts are remaining on their wintering grounds past their historical departure dates (J. Fischer, USFWS, personal communication, 2010; USFWS 2009).

Cacklers also appear to be arriving on the wintering grounds earlier as well. This year, large flocks of cackler were sighted in the Willamette Valley during surveys in late September, nearly a month earlier than usual. This trend has been seen in years past, but this past fall was an extreme case. Data collected from surveyors corroborates this behavior (ODFW 2010). Comparison of this information with historical arrival and departure dates indicates a change in migration patterns nearly as significant as the northward shifts of the 1990s (Figure 12).

Figure 12: Departure Date of Cackling Geese from Wintering Grounds, 1999-2010

Direct observations of the breeding grounds as part of this project revealed that cacklers prefer potholes, uplands, and grass plains near a water source for nesting. White-fronts seemed to prefer uplands and grassy plains, but seemed to have little trouble nesting elsewhere as this species was observed in a variety of habitat types. According to data from nest plot surveys conducted over the past 30 years, the habitat of the Y-K Delta is changing. Winter temperatures have increased 2.2°F on the Delta between 1949 and 1998 (USFWS 2009). Substantial warming has also been documented in the Arctic, especially in the fall and winter months (USFWS 2009).

As a result, potholes appear to be holding water for a shorter time each year, likely because moisture is being lost from the ground in the Y-K Delta (USFWS 2009). This, in turn, is due to permafrost melting because of the warmer temperatures. Permafrost, i.e. permanently frozen ground, comprises soil, sediment, or rock that remains at or below 32°F for at least 2 years (USFWS 2009). North of the Brooks Range in Alaska, permafrost is continuous, extending from a few inches to nearly 1,000 feet below the ground surface (USFWS 2009). Permafrost supports the ground surface, controls soil temperature and moisture, modifies micro-topography, controls subsurface hydrology and rooting zones, and influences nutrient cycling. Recent studies have shown that permafrost is warming throughout most of the region. For example, the soil in the Arctic Coastal Plain in Alaska has warmed 5°F to 7°F over the period from 1977 to 2003 (USFWS 2009). During the 2009 and 2010 surveys on the Y-K Delta, erosion was evident on shorelines of the waterways and the Bering Sea. Because permafrost previously held them together, river banks and coastal cliffs are beginning to collapse in areas where melting has occurred. The alteration of the Delta due to permafrost melting may have significant impacts on waterfowl habitats in the future.

As mentioned in Section 2.1.2, the Pacific white-front population declined precipitously between 1966 and 1979, resulting in revised management including harvest restrictions. The population subsequently rebounded and, today, the white-front population exceeds the management objectives by more than 300,000 birds. In the last few years, USFWS ground survey crews have seen an 18 percent increase in white-front sightings in the Willamette Valley (Figure 13). These sightings have occurred mostly in early October when the geese may have been staging to migrate south. Though white-fronts previously overwintered in California, the numbers remaining through the winter in the Willamette Valley and southwest Washington are increasing. The highest count of white-fronts took place during the 2008/2009 season. During this time period, thousands, rather than the expected hundreds, of white-fronts were counted in the wintering ground surveys. The overall numbers were combined by USFWS to come up with an index of the white-front population for that winter.

Figure 13: September Sightings of Cacklers in the Willamette Valley, 1999-2010 (Pacific Flyway Council 2010)

4.2 BIRD BANDING DATA

Bird banding data was obtained from the Bird Banding Laboratory in 2009. More than 10,000 band reports for cackling geese between 1985 and 2010 and 1,000 reports for white-fronted geese for 1995 to 2010 were analyzed for this thesis.

Correlation data analyses indicated that there was a direct relationship between temperature and the number of banded cacklers harvested in Oregon (Figure 14). Starting in the 1994-1995 season, the majority of cackler band returns have been from Oregon. Cackler band returns for California decreased at a rapid rate starting in 1994. Band data also showed that the number of bands recovered in Washington increased by 225 percent between 1999 and 2010.

Figure 14: Number of Cackler Band Returns in Washington State, 1995-2009 (Pacific Flyway Council 2009)

In years with warmer than average winter temperatures, more banded cacklers were harvested in the Willamette Valley. In cooler winters, more bands were reported from California. A similar analysis was conducted with data from Oregon and Washington recorded over the past five years. The Pacific Northwest experienced a much more severe winter than usual in 2008-2009. Snow and unusually cold temperatures occurred over a two-week period in December 2008. USFWS data showed that, during this time, California reported the largest count of cacklers since the early 1990s (Pacific Flyway Council 2005).

In contrast to cacklers, very little banding was done with white-fronts in the past. The white-front population had remained relatively stable and there seemed little reason to expend resources in banding studies. Recently, however, there has been an increased effort to band white-fronts due the apparent increase in population. Banding data have revealed that white-fronts banded on the Y-K Delta are harvested in California, Oregon, and Texas. Also, increasing numbers have been taken from Oregon over the 2007 through 2010 hunting seasons.

4.3 HARVEST DATA

Northwest Permit zone harvest data and voluntary wing and part survey data was analyzed for this thesis. Because, by law, all hunters must submit each goose taken to a check station for identification, the data is fairly detailed and accurate. Regional counts are available for each species and subspecies of goose harvested in the Northwest Permit Zone.

In Oregon, eight cacklers were recorded during the 1986 hunting season-- the first year that cacklers were recorded in the State. The numbers of harvested cacklers dramatically increased between the 1993-1994 and 1994-1995 seasons. In 1993-1994, 72 cacklers were recorded while in 1994-1995, 1,220 cacklers were recorded.

The data seem to indicate that cacklers are continuing to shift their migration northward into Washington and British Columbia. Wing and parts survey data have shown dramatic increases in cackling geese taken in Washington. Increasing numbers of cacklers are being harvested from Olympia northward than have been noted previously (B. Reishus, ODFW, personal communication, 2010). There is even a small wintering population of cacklers near Vancouver, B.C., according to the Canadian Fish and Wildlife Service (CWS 2010). This trend to more northerly wintering areas is expected to continue, according to the 2010 wing and parts report (D. Collins, USFWS, personal communication, 2010).

White-fronted geese have historically been harvested in eastern Oregon in October during their fall migration and again in January and February on their northward migration. In recent years, however, white-fronts have been showing up in the Willamette Valley harvest. Consistent data on white-front harvest in western Oregon were not collected until 1997. In that year, 44 white-fronts were counted in the harvest; in 2008, 172 white-fronts were recorded. It appears that this trend is similar to that exhibited by cacklers in the 1980s just before the huge increases of the 1990s (table 1).

The wing and parts surveys show that there has been a significant increase in white-front harvest in all counties in Oregon with the greatest increase (45 percent) noted in Coos County on the southern Oregon coast. The parts survey coincides directly with the harvest data of the permit zone in that there were large sums of White-fronts harvested in 08/09 and still some but less in 09/10.

4.4 AGRICULTURAL DATA

Since the early 1900s, agriculture in the Willamette Valley has primarily centered on row crops. Between 1970 and 1980, the primary crop shifted to grass seed for lawns. Grass is particularly attractive to geese because of its high nutrient content and because geese can consume great quantities of grass with little expenditure of energy.

The primary grass types grown in the valley include fescue, perennial ryegrass, and annual ryegrass. Geese prefer annual ryegrass, which must be planted annually and, therefore, produces new shoots each year. Geese prefer the fresh shoots because they are very nutritious and easy to graze. Fescue and perennial ryegrass fields are also used by geese for the first few years after they are planted, though the new shoots of these grass varieties are tougher than those of annual rye. Usage of fescue and perennial ryegrass drops off after the second year because, by this time, the roots are more mature and harder for the geese to pull up (Flowers 2010).

By the late 1980s and through the 1990s, the acreages planted to fescue and perennial ryegrass decreased and those planted to annual ryegrass increased due to market prices caused by increased demand in Japan. This shift in crops paralleled the increase in the wintering cackler population in the valley.

In recent years, grass prices have decreased and wheat prices have increased (Figure 15). This has resulted in some farmers changing crops from grass to winter wheat. A decade ago, only 30,000 acres of farm land in the Willamette Valley were planted to wheat; in 2010, about 250,000 acres of wheat will be harvested (Capital Press 2009).

Figure 15: U.S. Wheat Prices, 1998-2009 (ODA 2009)

Winter wheat is also being targeted by geese. The crop is planted in late September and the fresh shoots appear in late October and early November—about the time when geese are arriving from Alaska. Some farmers have reported losing nearly 70 percent of their wheat crop to goose depredation. Each year, nearly a million dollars per 1,000 acres of wheat are lost due to crop damage from geese (ODA 2009). Until the grass seed market improves, it is likely that more farmers will convert to winter wheat, which will, in turn, be targeted by wintering geese, resulting in continued lost revenue. Currently, the price for annual ryegrass is about \$2.25 per bushel and wheat is \$12.00 per bushel. At \$12.00 per bushel, wheat is the most economically beneficial crop for Oregon farmers (ODA 2009).

Agriculture in the Central Valley of California has changed very little in the last 50 years. Major crops in this area include wheat and rice; the acreage planted to these crops has changed less than 10 percent in the last 25 years. The component that has changed the most, however, is the availability of water for goose habitat. Over the past 50 years, nearly 4 million acres of prime agricultural land and waterfowl habitat has been lost to urbanization (USFWS 2010). In addition, California has experienced severe drought over the past 15 years, which also has limited waterfowl habitat, especially for white-fronts.

California's population is expected to continue to grow and another 2 million acres of farm land and habitat are expected to disappear by 2030. Over this same time frame, the white-front population is expected to increase. Diminishing habitat and increased human interference may stimulate the geese to migrate to other, more suitable winter habitats.

4.5 WEATHER AND CLIMATE DATA

A comparison of temperature data shows a direct correlation between the northerly migration shifts and warming temperatures. The data show that there was a nearly 1.8°F in California change during the primary years (1991-1997) of the cackler migration change (Table 2). During this same period, the data show that there were no other major weather occurrences that could have had an effect on goose migration patterns. Since cacklers prefer cool temperatures, they may have shifted north to more suitable temperatures (Jarvis 1996). According to a study in 1996, it was found that cacklers were sensitive to warm (>65°F) and very cold conditions. Because of their small bodies they lose heat or get overheated more easily than the larger subspecies of geese (Jarvis 1996).

Table 2: Average Winter Temperatures in Oregon and California, 1986-2010 (NOAA 2010)

Date	Average Winter Temperature		Date	Average Winter Temperature	
	California	Oregon		California	Oregon
1986	63.2	49.1	1999	65.7	50.4
1987	63.7	49.7	2000	65.7	50.3
1988	63.9	49.8	2001	66.1	51
1989	64.4	50.1	2002	66.5	51.3
1990	64.8	50.3	2003	66.8	51.6
1991	64.6	50.4	2004	67.3	52.1
1992	66.1	50.5	2005	66.5	51.4
1993	66.4	51	2006	66.8	51.8
1994	66.8	51.2	2007	66.5	51.5
1995	66.6	51	2008	66.9	51.4
1996	66.3	51.1	2009	67	52
1997	66.4	51.2	2010	67.1	52.1
1998	65.4	51.1			

Weather data shows that for the period between 1993 and 1998, during the cacklers' northward shift, the average winter temperature in the Willamette Valley increased more than 2°F (Table 2). Weather in the Pacific Northwest is greatly affected by alternating conditions called "El Niño" and "La Niña." El Niño years are characterized by the appearance in December or January of unusually warm water in the Pacific Ocean. This results in warmer, wetter winters in the Willamette Valley. La Niña sequences are characterized by colder than usual ocean water, which results in unusual weather patterns including snow on the valley floor and more unpredictable weather patterns. Both La Niña and El Niño patterns typically last a year, but can last longer. These recurring weather patterns are considered evidence that climate change is occurring (NOAA 2009).

Since 1998, average temperatures have stayed fairly stable, though the storm sequences characterizing La Niña years have caused annual winter average temperatures to drop about 1°F. Snow packs in the Pacific Northwest have also declined on average (Table 3).

Table 3: Three-Month-Average Snowpacks in El Niño vs. La Niña Years
(La Niña =blue and El Niño = red).

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1975	-0.6	-0.6	-0.7	-0.8	-0.9	-1.1	-1.2	-1.3	-1.5	-1.6	-1.7	-1.7
1976	-1.6	-1.2	-0.8	-0.6	-0.5	-0.2	0.1	0.3	0.5	0.7	0.8	0.7
1977	0.6	0.5	0.2	0.2	0.2	0.4	0.4	0.4	0.5	0.6	0.7	0.7
1978	0.7	0.4	0.0	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.2	-0.1
1979	-0.1	0.0	0.1	0.1	0.1	-0.1	0.0	0.1	0.3	0.4	0.5	0.5
1980	0.5	0.3	0.2	0.2	0.3	0.3	0.2	0.0	-0.1	-0.1	0.0	-0.1
1981	-0.3	-0.5	-0.5	-0.4	-0.3	-0.3	-0.4	-0.4	-0.3	-0.2	-0.1	-0.1
1982	0.0	0.1	0.1	0.3	0.6	0.7	0.7	1.0	1.5	1.9	2.2	2.3
1983	2.3	2.0	1.5	1.2	1.0	0.6	0.2	-0.2	-0.6	-0.8	-0.9	-0.7
1984	-0.4	-0.2	-0.2	-0.3	-0.5	-0.4	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-0.9	-0.8	-0.7	-0.7	-0.7	-0.6	-0.5	-0.5	-0.5	-0.4	-0.3	-0.4
1986	-0.5	-0.4	-0.2	-0.2	-0.1	0.0	0.3	0.5	0.7	0.9	1.1	1.2
1987	1.2	1.3	1.2	1.1	1.0	1.2	1.4	1.6	1.6	1.5	1.3	1.1
1988	0.7	0.5	0.1	-0.2	-0.7	-1.2	-1.3	-1.2	-1.3	-1.6	-1.9	-1.9
1989	-1.7	-1.5	-1.1	-0.8	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.1
1990	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4
1991	0.4	0.3	0.3	0.4	0.6	0.8	1.0	0.9	0.9	1.0	1.4	1.6
1992	1.8	1.6	1.5	1.4	1.2	0.8	0.5	0.2	0.0	-0.1	0.0	0.2
1993	0.3	0.4	0.6	0.7	0.8	0.7	0.4	0.4	0.4	0.4	0.3	0.2
1994	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.9	1.2	1.3
1995	1.2	0.9	0.7	0.4	0.3	0.2	0.0	-0.2	-0.5	-0.6	-0.7	-0.7
1996	-0.7	-0.7	-0.5	-0.3	-0.1	-0.1	0.0	-0.1	-0.1	-0.2	-0.3	-0.4
1997	-0.4	-0.3	0.0	0.4	0.8	1.3	1.7	2.0	2.2	2.4	2.5	2.5
1998	2.3	1.9	1.5	1.0	0.5	0.0	-0.5	-0.8	-1.0	-1.1	-1.3	-1.4
1999	-1.4	-1.2	-0.9	-0.8	-0.8	-0.8	-0.9	-0.9	-1.0	-1.1	-1.3	-1.6
2000	-1.6	-1.4	-1.0	-0.8	-0.6	-0.5	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7
2001	-0.6	-0.5	-0.4	-0.2	-0.1	0.1	0.2	0.2	0.1	0.0	-0.1	-0.1
2002	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.1	1.3	1.5	1.4
2003	1.2	0.9	0.5	0.1	-0.1	0.1	0.4	0.5	0.6	0.5	0.6	0.4
2004	0.4	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.9	0.8	0.8	0.8
2005	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.2	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.1	1.1
2007	0.8	0.4	0.1	-0.1	-0.1	-0.1	-0.1	-0.4	-0.7	-1.0	-1.1	-1.3
2008	-1.4	-1.4	-1.1	-0.8	-0.6	-0.4	-0.1	0.0	0.0	0.0	-0.3	-0.6
2009	-0.8	-0.7	-0.5	-0.1	0.2	0.6	0.7	0.8	0.9	1.2	1.5	1.8
2010	1.7	1.5	1.2	0.8	0.3	-0.2						

The average annual winter temperatures in central Washington and British Columbia have also increased (Figure 16) and the snow packs have declined. For example, British Columbia's snow pack has declined nearly 10 percent over the last 5 years (CWS 2010). This will have dramatic effects on water availability for human use and wildlife. These more extreme weather patterns are causing drought, significant storms, vegetation changes, increased wildfires, decreases in precipitation, increased evaporation, and decreases in snow pack.

Figure 16: Average Temperatures in the Northwest, Observed and Modeled (Mote et al. 1999)

In the next 50 years, precipitation levels are projected to decrease in the southernmost regions. Conditions in California are already showing evidence of this drying trend. It is likely that continued drying will have effects on goose migrations to and through California.

During the winter storms in 2009 and 2010, cacklers have sought refuge in areas with the least amount of snow pack in Oregon. During the winter of 2008-2009, an unusually snowy winter in western Oregon and Washington, cacklers wintered at Fern Ridge Wildlife area near Eugene Oregon, which had the least amount of snow recorded in the Willamette Valley and southwest Washington at the time (Reishus 2010). Nearly 62,000 cacklers were counted on or within a 5-mile radius of the Fern Ridge Wildlife area. Some geese moved south within the valley during the severe weather; but moved back to the north after the weather warmed.

A storm during the winter of 2009-2010 dropped snow in the foothills and in the Willamette Valley. The least amount of snow was on the valley floor. During this event, Baskett Slough Wildlife Refuge near Dallas, Oregon, hosted nearly 65,000 cacklers. Because of the snow, the cacklers were pushed onto Baskett Slough, and other areas that typically contained large numbers of cacklers held very few.

During the last two winter storm periods, Southwest Washington recorded a 20 percent increase in cacklers. Ridgefield Wildlife Refuge near Ridgefield, Washington, produced the highest counts on record for cackling geese in 2007 through 2010 (USFWS 2010).

4.6 INTERPRETATION OF AERIAL PHOTOGRAPHS

Comparison of aerial photographs of the Y-K Delta taken in the 1970s with those taken in recent years reveal that river channels that were previously quite narrow are now up to 3 times wider. This is most likely due to de-stabilization of the permafrost soils. Erosion of thawed soils into river channels was observed several times during the June breeding season survey on the Y-K Delta. The river banks slough off, causing the river channel to widen.

5. CONCLUSIONS

As stated in Section 1, the questions this thesis considers are: 1) why cackling geese and Pacific white-fronted geese are shifting their migratory patterns, 2) how the shifts are affecting the natural ecosystem and human environment, and 3) how changes in migratory patterns will affect goose management.

The data presented in Section 4 clearly show that cacklers have shifted their wintering areas northward and that white-fronts are most likely also in the process of changing their migratory behaviors. Goose population data was compared with weather data as well as with agricultural data. It appeared that the northerly wintering data correlated more closely with weather data over the same time period than with agricultural data. This was determined by analyzing the farming practices at the time of the migration shift. Since the agriculture had little change during the years in which goose migrations experienced the most change, it was concluded that agricultural practices were not a major cause of the northerly shift.

Agriculture may, however, be augmenting the shift and could play a larger part in the continuation of the northerly shift. The type and quantity of available food in California has remained stable in the last 50 years. Recently, however, there has been a shift in the Willamette Valley crops. The primary farmed crop in the Willamette Valley is now winter wheat (Section 4.4). Winter wheat is a preferred food for cacklers and white-fronts according to food behavior studies conducted by OSU (USFWS 2005). With the current favorable market for wheat and the overall long-term increase in temperature, it is likely that the preferred food source for geese will be increasingly available in Oregon and southwest Washington. This will be a large draw for cacklers and other goose species to the Willamette Valley. Geese headed to traditional wintering areas in California may stop in southwest Washington and Oregon if there is ample forage available.

Population data were then compared to weather data. This comparison revealed that, during the cacklers' shift northward, significant climate and weather changes were occurring in the Pacific Northwest and Alaska, including increased average temperatures and severe storms. Goose population data and geographic data from several sources were compared with data on increased winter temperatures. The population data—taken from field surveys, band surveys⁸ and wing and parts data—revealed a probable direct correlation between increased winter temperatures and the northerly shift of cackler wintering grounds. However, the same correlation with white-fronts was not obvious because data have been consistently collected over a much shorter period. It is likely, however, that white-front populations will continue to increase in Oregon due to changes on the Alaska breeding grounds as well as in the California wintering grounds.

The two species are very different in their habitat requirements and behavior and tend not to associate much with one another. Cacklers feed in dry, open fields and go to water in the afternoons. White-fronts are highly dependent on water and prefer muddy grazing conditions (J. Fischer, USFWS, personal communication, 2010). Yet even with their differences, each population appears to be abandoning their historical wintering grounds.

⁸ Because banding of white-fronts has not been extensive or consistent, the data for this species was insufficient to conclude on the basis of this type of data alone that climate change is a cause for the birds' shift in wintering areas from California to Oregon.

Climate change is thought to be the cause of habitat changes on the nesting grounds of the Y-K Delta (Section 2.1.2). As the area dries out, nesting habitat for species and subspecies dependent upon water will be reduced and the populations will either adapt, shift to new breeding grounds or be reduced or both. Currently white-fronts, which prefer drier nesting areas, are showing a positive reaction to the decrease of water levels as formerly wet habitat converts to drier uplands.

Subsistence hunters in Alaska and sport hunters in the Pacific Northwest will be affected by changes in the numbers and species comprising wintering populations. The affect may be positive because the goose population in the Y-K Delta appears to be increasing. More birds per square mile will make finding and harvesting them easier.

Increased population numbers for one species or subspecies could mean potential problems for other species or subspecies through alteration of habitat or displacement from traditional habitats. The focal species for goose management in Oregon and southwest Washington is the dusky Canada goose. The dusky Canada goose is a “less successful” subspecies that has been displaced on wintering grounds due to the increase in cacklers (Pacific Flyway 2008). If the current management approach is continued, the revised management plans would favor the dusky. This could affect the overall population levels of cacklers. Management plans must consider all pertinent species; conservation of one species at the expense of another must be avoided. As populations of species and subspecies not previously treated by the area’s management plan continue to increase, a wider perspective must be adopted before the effects of changed migration patterns becomes a problem.

Retention of good quality habitat to accommodate all goose species and subspecies in western Oregon is essential to maintaining a healthy ecosystem with species diversity. The result of decreased natural habitat could be increased depredation of agricultural crops and intrusion of geese into urban settings.

Depredation caused by geese can dramatically affect a farmer’s ability to sustainably farm and make a living. This is especially true with the current economy, which has increased costs to successfully raise crops. Between goose depredation and the economy, farmers struggle to keep their farms in operation. Depredation of agricultural fields can be reduced by planting refuges and other wildlife areas with crops and habitat that are attractive to wintering geese. This will help draw wintering geese away from farms.

As goose populations increase, more geese will be found in urban settings, which will present problems for wildlife managers. Geese cause damage to sports fields and golf courses, contribute to water contamination, and can cause human health risks. Funding for goose control and research into more effective techniques will need to increase.

The agencies must devise strategies to manage increasing numbers and species of geese on wintering grounds as well as the effects of geese on hunting, agriculture, and communities. In order to devise strategies, agency personnel must identify the causes of the shifts.

More research is needed to determine if, in the long term, the cackler population will be negatively impacted by the habitat changes occurring in the Y-K Delta. USFWS theorizes that the Y-K Delta will be substantially drier by 2050. If this occurs, it appears that cacklers will have more difficulty in finding suitable nesting habitat while white-fronts, which are less dependent upon water, will likely thrive. Individual goose populations may rise or fall depending upon the extent of the changes and the species’ abilities to adapt to them (J. Fischer, USFWS, personal communication, 2010). Cacklers and white-fronts as well as other species and subspecies may continue to shift to new breeding and wintering areas. If cackler nesting habitat is reduced, though the northern migratory shift may continue, but the overall population may be smaller, resulting in fewer cacklers in the Willamette Valley.

Another cause of the northerly shift in goose populations could be that water levels in California are receding. Less water limits waterfowl habitat and restricts the birds to certain areas. The increase in the white-front population combined with decreasing habitat in traditional wintering areas is most likely resulting in a shift of this species northward to the Willamette Valley in an effort to find suitable habitat and food. However, without further research, it is difficult to determine whether this population's shift is occurring because of climate change or due to a combination of factors including an increasing goose population and decreased wetlands in California.

The cacklers' current migratory shifts have dramatically affected the dusky Canada goose. As cackler numbers increase, dusksies are being pushed out of their primary preferred habitats and, consequently, are moving into areas they have not previously used. In some of these areas, there are no regulations against harvesting dusksies (B. Bales, personal communication, 2010). The dusky is a "species of concern" indicating that its population is already stressed, and it is possible that it will not be able to withstand increases in the cackler population and subsequent loss of habitat.

It is likely that other species and subspecies will increase in number with continued mild climate conditions. Indications are that white-fronts are beginning a northerly shift. If projected trends are accurate, there will be an overall increase in geese the next 50 years (J. Fischer, personal communication, 2010). More geese over a wider area will ensure greater hunting opportunities as well as more liberal seasons and bag limits for sport hunters in the Pacific Northwest as well as for subsistence hunters in Alaska.

If the environment continues to warm, habitat type and availability will continue to change, favoring some species over others. The management agencies must be prepared to anticipate and meet these challenges as they arise. This will require a concerted cooperative effort among state and federal agencies in terms of research, data sharing, and formulation of management plans.

Computer models are good tools for formulating management plans. Currently, the primary models deal solely with population and breeding. No models focusing on the effects of climate change on waterfowl behavior currently exist. In fact, the concept of researching the effects of climate change in order to predict migration changes and other effects is quite new. The migration shifts discussed in this document were not evident before 1990. Since that time, waterfowl management has had to adapt quickly to the rapid shifts of goose populations.

Most waterfowl models in existence focus on population size or foraging and breeding behavior rather than migration. Oregon State University is currently conducting a study on goose feeding behavior. The University of Nevada is conducting a hatching study to determine the success of goslings based on hatch date and foraging behavior. The literature reviewed for this thesis did not reveal any studies that included modeling relating climate and migration; nor did any models focus on cacklers or white-fronts.

Climate change has not been recognized as an environmental concern until relatively recently. Therefore, little or no data exist which could support a model focusing on the relationship between increasing temperatures and waterfowl behavior. For example, very few wintering ground surveys have been conducted for geese.

Most agencies to date have focused on breeding ground surveys rather than wintering surveys. However, as population shift becomes more evident, management issues associated with fewer geese in some areas and more in others will rise in priority. Modeling that can predict where the changes are expected to take place and their magnitude will be invaluable to waterfowl managers in the Pacific Flyway. In the future, a migration model based on climate change may play a significant role in management of shifting populations.

Energetics and migration length are factors that may be contributing to waterfowl migration changes. Though these issues were outside the scope of this thesis, they are worth considering in the overall picture of migration pattern change. Many scientists believe that geese may be altering their migration patterns simply because suitable food sources are available closer to the breeding grounds.

Migration is costly from the energy standpoint. The distance from the Y-K Delta to the Willamette Valley is 2,000 miles. Radio telemetry studies have shown that cacklers and white-fronts can fly non-stop to their designated wintering area. During this flight, a goose loses nearly a third of its body weight. Muscles mass and fat are lost and must be replenished immediately upon reaching the wintering grounds or the bird's winter survival is in jeopardy. If geese headed to California can find suitable feed several hundred miles further north, they will conserve energy and avoid potentially detrimental weight loss by stopping in the Willamette Valley or southwest Washington.

5.1 OTHER EXAMPLES OF WATERFOWL MIGRATION CHANGE

The literature reviewed revealed that two other species of goose found in the Pacific Flyway were experiencing northward migrational shifts: Black Brant and Northern Pintails. Both Sedinger and Ward (2010) and Maender (2002) concluded that the cause of the migration shift was increasing temperature. Other documents reviewed described northerly migration shifts, but did not draw clear conclusions as the reasons. All of the studies reviewed appeared to be consistent with the findings of this thesis for cacklers and white-fronts.

5.1.1 Black Brant

Pacific black brant have traditionally wintered up and down the Pacific coast from Oregon to Baja, Mexico. Although records are sparse, it appears that fewer than 3,000 brant wintered in Alaska before 1977. Recently, however, at least 40,000 birds, nearly 30 percent of the Pacific black brant population, have begun to winter in Alaska. Sedinger and Ward (2010) state, "[T]his increase in wintering numbers of brant in Alaska coincides with a general warming of temperatures in the North Pacific and Bering Sea." Sedinger and Ward (2010) concluded that their "study suggests that the growth in the brant population wintering on the Alaska Peninsula is linked to this same climate change..." USFWS (2010) estimates the total brant population at 138,000 birds. The population typically fluctuates between 110,000 and 165,000 birds and has been in a slow decline for nearly 40 years (Sedinger and Ward 2010). It appears, however, that the decline is not due to hunting pressures, but rather to the availability of food on their Alaskan feeding grounds.

Brant feed extensively on eelgrass. It appears that coastal environmental conditions for eelgrass in Alaska have improved with warming temperatures. Higher temperatures mean less coastal sea ice, making nutrient-rich eelgrass more accessible. "Undisturbed access to sufficient amounts of eelgrass is likely crucial to the winter survival of this species," according to Sedinger and Ward (2010). It is expected that the number of Pacific brant wintering in Alaska will increase if the climate continues to warm. There is concern, however, that, because the population of Pacific brant is slowly declining, birds wintering in Alaska could be adversely affected by severe cold snaps, which would thin the already dwindling population.

5.1.2 Northern Pintail

Until recently, northern pintails migrated to Mexico, southern California, and California's Central Valley. However, starting in the mid to late 1990s "biologists noticed a significant decrease in the amount of wintering pintails in southern California. In 2002 biologists put satellite radio telemetry devices on 419 female Northern Pintails to attempt to find an explanation" (Maender 2002). By tracking the females and

using historical distribution data, biologists found that pintails are no longer wintering in southern California, but are shifting northward.

In southern California, climate change has increased temperatures causing a decrease in wetlands due to drought (Maender 2002). This has resulted in decreased habitat in the areas that historically provided sanctuary for pintails. Water is evaporating and cover vegetation is dying as the water subsides. The scientists found that neither contaminants nor disease accounted for the disproportionate declines in wintering pintails in the southern Central Valley, but rather, the birds had been “redistributed.” Maender (2010) states that more than 80 percent of the tagged pintails “shifted each midwinter from areas in the south having less abundant habitat for food and refuge, to locales in the Sacramento Valley more favorable for their survival.”

The change each winter in pintail distribution appears to be related to loss of suitable habitat, drought conditions, and the lesser-quality habitat of agricultural lands planted to cotton in the San Joaquin Valley. The San Joaquin Valley lands do not flood in the winter in contrast to the flooded rice fields of the Sacramento Valley. The environmental shifts are directly related to climate change and its effects on habitat change according to Maender (2002).

6. RECOMMENDATIONS

Analyses of observations and data have shown definite changes in wintering patterns along the Pacific Flyway. Goose data from various sources were compared to weather and temperature data as well as agricultural data. The comparison appeared to show a correlation relating to a northward shift in wintering. These types of analyses can aid agencies in altering their management programs by identifying migrational shifts and their causes. Agency plans and programs can accommodate changes that have already occurred and prepare for further changes. The following recommendations for management and further study are aimed at more completely understanding the scope and causes of migration shifts and formulating well-founded management plans for geese in the Pacific Flyway.

- Continue research to determine if climate change is causing changes in goose population numbers and behavior.
- Expand breeding ground flight surveys to include cacklers and habitat preference to learn how habitat change on the Y-K Delta is altering cackler behavior and breeding success.
- Expand radio transmitter studies and collar programs for cacklers in Oregon and Washington to verify northerly wintering shifts.
- Expand collar programs for cacklers wintering in the Willamette Valley to determine if the population is continuing to shift northward.
- Expand banding programs for white-fronted geese to gather more data about migration patterns.
- Develop models that will allow researchers and managers to correlate migration behavior with various environmental factors including climate change in order to: 1) determine which factors are causing migration changes in specific waterfowl populations and 2) allow managers to make changes to management plans in advance of rapid changes.
- Inform the public about how it can assist in collar surveys or volunteer for USFWS. This will enable USFWS to have more concrete data and give the public an opportunity gain a greater understanding of geese and goose management.
- Expand research on urban cackling geese to determine the nature and scope of their effect on the human environment and to devise management strategies.
- Research energetics in migrating geese to determine whether the shift in migration patterns has its basis in climate change.
- Increase data exchange and coordination among agencies.
- Formulate and implement plans at the city and county levels to manage growing numbers of geese in urban areas.
- Recognize and anticipate the possibility that goose populations may move into new wintering areas and formulate plans for management of those species.
- Implement low cost techniques, such as more liberal bag limits and seasons, hazing, etc., to assist agricultural landowners in decreasing goose-related crop damage.

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Appendices

YR	MO	DAY	OBS	PLOT	NEST#		
SPECIES			SITE	F	M	NL	NS

EGG CODES:

1	2	3	4	5	6	7	8	9	10	11	12	13
				Sink	Sink	Sink	Sink					
				STAGE 1	STAGE 2	STAGE 3	STAGE 4					
<hr/>												
				Neutral	Float	Float	Float	Float				
				STAGE 5	STAGE 6	STAGE 7	STAGE 8	STAGE 9				

YR	MO	DAY	OBS	PLOT	NEST#		
SPECIES			SITE	F	M	NL	NS

EGG CODES:

1	2	3	4	5	6	7	8	9	10	11	12	13
				Sink	Sink	Sink	Sink					
				STAGE 1	STAGE 2	STAGE 3	STAGE 4					
<hr/>												
				Neutral	Float	Float	Float	Float				
				STAGE 5	STAGE 6	STAGE 7	STAGE 8	STAGE 9				

YR	MO	DAY	OBS	PLOT	NEST#		
SPECIES			SITE	F	M	NL	NS

EGG CODES:

1	2	3	4	5	6	7	8	9	10	11	12	13
				Sink	Sink	Sink	Sink					
				STAGE 1	STAGE 2	STAGE 3	STAGE 4					
<hr/>												
				Neutral	Float	Float	Float	Float				
				STAGE 5	STAGE 6	STAGE 7	STAGE 8	STAGE 9				

YR	MO	DAY	OBS	PLOT	NEST#		
SPECIES			SITE	F	M	NL	NS

EGG CODES:

1	2	3	4	5	6	7	8	9	10	11	12	13
				Sink	Sink	Sink	Sink					
				STAGE 1	STAGE 2	STAGE 3	STAGE 4					
<hr/>												
				Neutral	Float	Float	Float	Float				
				STAGE 5	STAGE 6	STAGE 7	STAGE 8	STAGE 9				

GROUP CODE				GENERAL AREA				OBSERVER				REFUGE			
STATE		MONTH		DAY		YEAR		TIME		LATITUDE		LONGITUDE		FIELD	

CAACKLERS

Collar
color

Char.
color

Neck band code

MARKED

EXAMINED

#PRESENT

Totals: (Canada geese only)

Cackler

Dusky

Tav/Less

Western

Aleutian

Unident.

Total

Other
geese**DUSKYS**

Collar
color

Char.
color

Neck band code

MARKED

EXAMINED

#PRESENT

COLORS:

B = Black

L = Blue

N = Brown

G = Gray

E = Green

P = Pink

R = Red

W = White

Y = Yellow

OTHER:

(Specify)

MARKED

EXAMINED

#PRESENT

OTHER:

(Specify)

MARKED

EXAMINED

#PRESENT

Please return forms to Dan Collins, USFWS-DMBM, 911 NE 11th Avenue, Portland, OR 97232-4181. Tel:(503)231-6163, Fax:(503)231-6228, dan_collins@fws.gov

Appendix A3. Band Data Request Form

[NOTE – THIS TABLE IS 2 PAGES]

When requesting a BANDING data pull, here are the fields that can be included	When requesting an ENCOUNTER data pull, here are the fields that can be included
AGE CODE	B AGE CODE
AREA CODE	B AREA CODE
BAND EVENT DATE	B BAND ID
BAND ID	B BAND SIZE CODE
BAND SIZE CODE	B BAND STATUS CODE
BAND STATUS CODE	B BAND TYPE CODE
BAND TYPE CODE	B BIRD STATUS
BANDING DAY	B COMMENTS
BANDING MONTH	B COORD. PRECISION
BANDING YEAR	B DIRECTION CODE
BIRD STATUS	B EXTRA INFO CODE
COMMENTS	B FLYWAY CODE
COORD. PRECISION	B HOW AGED CODE
DIRECTION CODE	B HOW SEXED CODE
EXTRA INFO CODE	B LAT
FLYWAY CODE	B LAT FLOAT
HOW AGED CODE	B LON
HOW SEXED CODE	B LON FLOAT
LAT	B MARKER TYPE
LAT FLOAT	B PERMIT NUMBER
LON	B REMARKS
LON FLOAT	B REWARD BAND NUM
MARKER TYPE	B SEX CODE
OTHER BANDS	B SPECIES ID
PERMIT NUMBER	BANDING DATE
REMARKS	BANDING DAY
REWARD BAND NUM	BANDING MONTH
SEX CODE	BANDING YEAR
SPECIES ID	E AREA CODE
	E CERTIFICATE FLAG
	E CERTIFICATE LANGUAGE
	E COMMENTS
	E COORD. PRECISION
	E COUNTRY CODE
	E CREATE DATE
	E CREATE MONTH
	E CREATE YEAR
	E DIRECTION CODE

When requesting a BANDING data pull, here are the fields that can be included	When requesting an ENCOUNTER data pull, here are the fields that can be included
	E DIRECTION1
	E DIRECTION2
	E ENC COUNTY ORIGINAL
	E FLYWAY CODE
	E HOW OBTAINED CODE
	E HOW OBTAINED DESC
	E LAT
	E LAT FLOAT
	E LOCATION DESCRIPTION
	E LON
	E LON FLOAT
	E MARKER CODE COLOR ID
	E MARKER COLOR ID
	E MARKER DESC
	E MARKER TYPE
	E MARKER TYPE CODE
	E MILES1
	E MILES2
	E PLACE NAME
	E PRESENT CONDITION CODE
	E REMARKS
	E SPECIES NAME
	E STATE CODE
	E WHO OBTAINED CODE
	E WHY REPORTED CODE
	ENCOUNTER DATE
	ENCOUNTER DAY
	ENCOUNTER MONTH
	ENCOUNTER YEAR
	HSS
	OTHER BANDS

Appendix B. Washington Permit Zone Harvest Data

Canada Goose Subspecies

Season	Cackler	Dusky	Taverner	Lesser	Western	Vancouver	Other	Total
1984-85	0	37	63	0	20	0	0	120
1985-86	11	66	113	116	67	0	25	398
1986-87	8	36	172	51	241	0	0	508
1987-88	7	45	478	225	224	4	35	1,018
1988-89	17	43	617	136	763	0	7	1,583
1989-90	37	52	455	92	391	9	0	1,036
1990-91	28	65	555	165	383	20	3	1,219
1991-92	39	88	675	295	483	14	15	1,609
1992-93	84	91	1,340	270	722	25	2	2,534
1993-94	93	90	944	299	697	8	4	2,135
1994-95	422	77	1,011	246	704	31	6	2,497
1995-96	334	59	862	144	536	12	1	1,948
1996-97	1,030	35	1,705	475	932	18	3	4,198
1997-98	1,311	58	2,197	392	742	33	5	4,738
1998-99	1,820	46	1,877	306	833	34	9	4,925
Avg. 94-98	983	55	1,530	313	749	26	5	3,661

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1980	Jan.	High	55	51	43	42	46	39	37	45	44	35	54	57	55	50	46	51	46	41	46	42	48	49	47	46	48	34	32	30	32	34	33
1980	Jan.	Low	41	38	34	38	24	21	21	37	33	28	25	41	39	35	31	42	25	23	26	23	25	26	25	22	31	19	15	13	11	8	25
1980	Feb.	High	53	53	59	50	52	55	52	53	50	52	52	51	46	38	40	45	43	55	54	53	48	49	55	58	48	59	59	58	56	—	—
1980	Feb.	Low	32	41	39	30	36	40	32	25	26	31	28	22	25	31	31	33	37	39	40	36	29	32	38	42	43	48	50	38	32	—	—
1980	Mar.	High	53	63	55	56	48	53	55	56	57	52	48	48	49	48	45	53	52	53	54	52	55	55	53	53	60	53	55	59	52	54	49
1980	Mar.	Low	35	43	44	44	39	36	33	34	31	38	37	37	37	36	34	36	38	34	43	38	33	36	29	30	31	36	33	33	35	32	39
1980	Apr.	High	54	62	57	60	56	50	53	57	57	58	72	76	75	57	61	72	62	70	63	53	58	61	66	60	67	73	78	64	60	68	—
1980	Apr.	Low	29	27	27	36	37	35	34	47	41	35	29	35	40	44	42	34	40	40	50	47	45	39	45	38	37	47	44	44	40	32	—
1980	May.	High	75	63	73	73	66	63	68	59	58	56	60	62	59	62	62	67	74	74	72	73	62	61	59	60	57	55	64	69	68	67	72
1980	May.	Low	38	40	33	43	45	39	33	43	46	46	51	50	49	47	39	32	38	44	41	43	40	41	40	37	47	47	44	45	43	50	42
1980	Jun.	High	62	57	63	69	64	64	67	73	67	68	65	66	55	63	72	64	71	73	78	68	69	72	71	66	65	68	73	75	71	79	—
1980	Jun.	Low	43	45	45	39	42	48	51	54	46	51	52	51	52	52	51	48	47	44	44	47	44	48	50	52	43	40	51	48	45	40	—
1980	Jul.	High	83	71	60	66	70	79	87	79	70	78	75	76	82	74	84	80	80	84	81	89	101	84	80	81	86	91	96	93	86	86	88
1980	Jul.	Low	43	45	54	54	53	44	48	49	50	47	45	49	44	51	49	50	45	51	47	60	58	56	56	47	47	49	51	52	46	46	54
1980	Aug.	High	83	75	78	83	73	79	88	83	92	94	84	80	77	76	77	80	81	74	83	80	77	77	82	76	85	79	71	73	76	66	74
1980	Aug.	Low	43	54	55	42	55	42	44	48	47	51	46	48	54	45	42	56	48	50	42	45	39	41	43	49	41	40	47	36	40	50	51
1980	Sep.	High	80	72	77	84	87	81	75	88	94	90	80	73	61	75	84	86	83	63	65	68	70	74	78	78	89	82	67	77	82	75	—
1980	Sep.	Low	41	50	42	41	44	47	51	43	52	50	47	45	45	46	38	41	47	55	57	52	45	40	48	50	45	48	48	51	47	55	—
1980	Oct.	High	83	92	86	82	89	83	83	72	79	70	58	61	58	59	60	59	61	61	64	61	61	67	66	56	58	53	62	62	59	54	56
1980	Oct.	Low	44	47	47	40	45	45	45	47	40	41	38	51	48	45	38	31	35	36	38	43	33	28	31	40	41	44	38	31	32	38	46
1980	Nov.	High	61	65	65	57	65	65	62	58	57	48	50	50	48	52	54	44	54	60	60	56	55	45	50	43	54	49	59	56	56	47	—
1980	Nov.	Low	50	43	51	48	51	49	53	47	38	32	30	28	24	33	38	31	42	44	39	45	34	30	36	35	41	41	40	42	40	37	—
1980	Dec.	High	47	56	53	40	43	40	36	38	33	45	54	47	43	56	54	49	39	39	42	49	62	55	50	59	62	60	61	47	53	66	57
1980	Dec.	Low	40	41	35	35	35	32	22	20	19	29	27	28	27	35	30	33	35	37	38	40	42	46	36	45	58	55	41	37	39	48	36
1981	Jan.	High	54	50	47	51	54	53	47	45	48	48	47	47	48	47	49	44	45	55	50	50	52	53	52	51	49	54	46	43	49	49	47
1981	Jan.	Low	33	36	35	32	29	33	32	35	33	25	25	23	23	24	26	28	31	36	35	29	46	46	36	36	34	33	35	32	30	32	30
1981	Feb.	High	40	36	47	39	44	46	44	36	48	43	54	64	57	59	56	61	56	61	62	54	55	57	59	51	48	47	59	65	—	—	—
1981	Feb.	Low	30	34	28	25	31	23	22	30	32	29	31	44	47	49	48	49	45	49	38	35	31	29	35	35	28	29	33	27	—	—	—
1981	Mar.	High	65	63	50	51	51	57	56	58	66	60	62	64	60	61	53	58	57	59	56	59	55	60	58	58	60	59	59	58	52	51	49
1981	Mar.	Low	29	29	39	33	25	24	37	35	29	36	41	35	35	35	43	32	25	30	33	30	33	44	38	34	44	45	44	39	41	41	41
1981	Apr.	High	56	50	55	62	57	54	56	50	57	54	54	57	63	73	64	64	68	76	57	60	60	70	67	59	60	62	56	75	80	79	—
1981	Apr.	Low	36	33	36	40	36	34	39	40	32	36	39	32	28	33	43	38	33	37	46	44	46	51	47	36	33	39	40	51	48	52	—
1981	May.	High	63	60	57	57	56	57	61	64	65	67	66	72	73	62	58	63	62	60	60	61	60	73	76	68	68	70	73	81	74	69	72
1981	May.	Low	38	41	38	36	42	41	40	40	45	42	39	34	51	47	40	42	50	46	40	50	50	48	50	56	46	42	40	42	50	47	40
1981	Jun.	High	71	72	72	70	71	65	59	62	66	67	70	64	64	68	78	65	68	65	71	67	71	67	71	83	83	72	72	78	85	70	—
1981	Jun.	Low	41	50	51	54	49	44	46	54	53	45	38	48	47	42	40	47	44	54	55	51	52	50	51	46	48	47	40	46	47	53	—
1981	Jul.	High	75	91	91	90	79	63	68	77	71	71	74	76	74	82	88	86	79	76	80	78	77	79	78	74	89	96	98	81	76	76	81
1981	Jul.	Low	46	52	51	53	56	50	46	43	48	44	41	45	52	51	48	49	50	50	50	52	55	55	57	56	55	54	60	50	49	45	46
1981	Aug.	High	85	68	78	81	87	98	104	106	108	107	99	90	86	92	82	86	94	91	67	72	81	87	88	78	77	79	80	85	72	77	82
1981	Aug.	Low	48	50	54	55	48	53	55	58	63	62	58	54	51	54	52	48	52	54	54	49	46	45	51	57	48	44	41	46	47	49	44
1981	Sep.	High	76	78	81	76	79	95	99	90	71	80	86	84	84	89	96	86	81	81	68	67	64	64	67	67	66	59	72	66	66	70	—
1981	Sep.	Low	53	45	44	44	46	49	50	48	49	59	48	45	44	42	44	48	50	50	48	51	47	44	39	41	43	50	51	50	44	40	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1981	Oct.	High	74	66	62	64	61	63	64	55	59	62	56	56	61	63	65	66	66	70	67	58	69	70	62	66	58	56	64	54	48	55	67
1981	Oct.	Low	39	40	40	39	38	49	48	48	44	44	36	30	29	29	32	34	39	36	39	36	30	28	29	34	37	51	50	45	42	42	39
1981	Nov.	High	60	52	58	56	65	59	58	49	45	50	62	58	57	55	56	46	51	53	50	54	54	52	52	50	45	49	49	42	44	47	—
1981	Nov.	Low	38	41	33	26	24	30	33	38	39	40	46	43	44	41	41	38	43	37	38	47	45	42	40	35	35	28	25	17	28	39	—
1981	Dec.	High	54	55	55	60	57	57	52	50	51	50	45	42	53	55	55	51	47	55	58	50	49	41	43	53	48	43	43	46	39	42	40
1981	Dec.	Low	47	32	28	45	47	47	39	39	44	35	30	32	40	37	42	31	31	41	39	40	30	32	34	41	38	35	36	29	25	25	30
1982	Jan.	High	41	41	42	37	36	27	30	35	30	34	42	43	52	48	46	48	47	42	46	44	42	47	54	51	54	47	49	47	50	55	53
1982	Jan.	Low	33	31	33	27	20	16	15	20	20	28	32	32	32	36	43	44	41	39	35	31	33	35	47	41	40	41	39	33	36	42	34
1982	Feb.	High	46	48	50	41	43	42	49	39	42	46	49	53	57	57	60	56	57	54	63	60	48	43	44	49	50	47	54	44	—	—	—
1982	Feb.	Low	35	41	31	25	22	23	26	21	17	14	27	37	45	52	49	51	33	34	51	39	35	34	32	30	28	35	32	37	—	—	—
1982	Mar.	High	50	52	52	55	53	55	59	55	63	59	51	52	49	47	51	56	58	58	57	52	60	61	65	66	60	58	57	51	55	49	49
1982	Mar.	Low	39	42	43	31	29	25	26	36	47	47	32	32	45	30	31	29	24	26	29	33	26	27	28	30	35	42	40	37	34	36	32
1982	Apr.	High	54	47	50	48	54	51	55	62	63	56	60	56	49	46	52	57	52	53	62	73	77	80	64	60	65	64	63	58	62	67	—
1982	Apr.	Low	27	35	38	36	30	27	32	28	27	29	47	43	42	37	31	28	33	29	30	26	30	36	36	36	28	30	41	34	28	36	—
1982	May.	High	65	61	59	60	71	75	62	56	55	58	67	67	69	70	71	73	61	60	69	74	75	69	76	89	75	62	68	77	81	84	66
1982	May.	Low	41	37	40	29	35	38	41	38	44	39	36	43	42	40	37	46	46	41	32	42	42	45	42	51	48	36	40	43	43	42	47
1982	Jun.	High	64	67	66	64	65	66	73	81	90	92	68	58	69	72	83	90	94	102	97	87	79	87	93	89	83	75	70	68	77	74	—
1982	Jun.	Low	47	47	46	50	49	46	41	43	47	48	51	54	55	56	55	50	51	58	59	59	56	50	50	53	56	60	56	56	53	58	—
1982	Jul.	High	72	67	72	68	74	81	74	79	85	87	87	89	70	75	70	81	89	85	88	85	76	83	87	89	88	87	87	79	74	66	73
1982	Jul.	Low	58	50	50	47	52	46	51	48	50	50	53	53	56	51	41	55	51	52	56	59	52	42	45	48	49	51	53	59	60	58	57
1982	Aug.	High	71	75	75	80	85	90	94	87	65	71	78	80	76	76	78	83	85	88	85	90	89	93	92	97	87	78	74	83	70	76	79
1982	Aug.	Low	58	53	47	45	45	49	53	63	59	60	53	53	50	47	45	46	48	53	51	57	51	50	51	52	52	47	48	44	59	51	48
1982	Sep.	High	87	93	69	79	84	86	83	83	67	69	62	75	76	74	77	83	81	79	70	60	74	79	82	72	67	64	66	64	62	72	—
1982	Sep.	Low	49	56	58	58	54	50	50	48	49	46	45	48	41	42	42	37	43	51	56	55	55	45	47	57	55	47	42	41	36	40	—
1982	Oct.	High	73	62	64	63	70	61	57	63	73	76	73	79	76	74	67	61	58	59	64	61	57	66	69	69	70	58	58	52	54	55	54
1982	Oct.	Low	40	47	34	45	37	47	45	53	51	41	39	39	39	39	45	45	40	35	27	32	47	53	47	43	50	47	44	39	42	35	43
1982	Nov.	High	59	59	58	58	51	52	52	50	52	53	45	48	45	52	52	54	59	52	52	48	46	50	48	44	41	40	54	56	53	50	—
1982	Nov.	Low	34	28	38	37	38	35	30	29	26	24	23	30	31	23	33	45	48	43	42	38	31	23	30	23	23	30	37	48	44	43	—
1982	Dec.	High	49	55	59	51	51	48	45	42	43	48	44	45	50	51	55	56	47	52	47	49	48	46	46	40	49	46	47	41	39	41	41
1982	Dec.	Low	40	42	49	41	43	32	32	31	26	25	23	34	41	44	47	45	40	40	40	41	41	40	32	30	33	34	28	22	24	19	18
1983	Jan.	High	38	43	49	55	53	54	58	54	49	52	45	41	48	39	40	43	47	52	48	47	41	48	51	57	54	58	54	50	55	47	52
1983	Jan.	Low	21	31	40	48	51	50	51	43	39	32	26	29	26	35	34	38	40	44	37	29	30	36	43	45	41	47	36	31	38	33	34
1983	Feb.	High	52	57	53	48	50	49	49	48	48	51	55	56	55	51	50	57	55	54	55	54	55	60	60	55	53	54	54	60	—	—	—
1983	Feb.	Low	28	27	23	23	23	36	37	40	42	38	42	47	39	34	34	45	45	42	42	47	47	51	48	42	42	39	40	37	—	—	—
1983	Mar.	High	53	60	57	57	58	55	55	55	60	60	61	63	58	49	56	62	61	63	63	58	56	52	57	60	57	52	55	53	55	60	56
1983	Mar.	Low	37	41	41	43	44	45	47	48	51	47	39	43	43	42	34	30	35	30	33	31	39	41	43	36	38	36	42	42	48	45	42
1983	Apr.	High	53	52	56	61	66	66	61	56	48	51	52	56	62	66	72	75	75	73	68	65	63	60	63	60	60	63	71	69	66	68	—
1983	Apr.	Low	42	39	36	29	33	31	38	29	38	35	36	27	29	29	32	34	35	45	47	50	45	47	45	38	41	39	34	45	43	38	—
1983	May.	High	60	60	64	66	63	63	59	52	55	64	65	75	76	60	62	63	69	69	75	80	74	83	87	87	78	79	87	100	80	64	61
1983	May.	Low	45	45	40	34	42	40	43	42	40	42	37	39	41	47	46	37	42	49	38	43	49	42	48	45	46	43	45	53	58	56	55
1983	Jun.	High	63	68	68	70	73	81	87	78	69	66	68	72	80	70	72	73	70	66	66	70	76	64	66	72	76	75	79	75	74	63	—
1983	Jun.	Low	54	50	48	43	45	44	46	49	50	49	47	48	47	51	53	44	53	53	52	43	40	55	49	47	47	54	55	48	50	52	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1983	Jul.	High	70	70	75	82	70	72	67	69	73	78	87	76	70	73	72	76	77	79	76	78	84	85	81	75	75	78	73	76	84	93	79
1983	Jul.	Low	55	48	45	45	50	50	54	48	40	46	50	60	50	47	50	52	52	56	60	57	47	52	56	59	59	56	60	53	45	56	57
1983	Aug.	High	79	81	80	83	79	88	86	81	83	77	80	86	93	90	84	85	86	85	81	81	85	81	73	77	82	81	83	72	71	73	76
1983	Aug.	Low	61	61	51	45	53	48	54	56	61	60	53	54	53	61	53	48	50	50	50	51	47	49	60	54	46	57	55	56	62	61	58
1983	Sep.	High	75	77	79	74	75	78	73	69	73	72	76	82	82	75	80	74	70	68	71	79	85	81	75	76	78	70	68	70	74	76	—
1983	Sep.	Low	56	54	48	51	45	43	45	45	45	55	54	46	48	50	45	46	40	43	40	36	46	48	50	50	43	49	42	34	33	33	—
1983	Oct.	High	74	66	74	70	69	67	73	68	66	71	73	71	61	67	65	63	65	59	60	63	63	63	63	63	66	66	57	51	54	64	57
1983	Oct.	Low	34	41	50	42	35	39	34	41	48	43	40	40	44	49	35	31	39	37	41	43	42	47	37	32	33	34	38	43	46	51	44
1983	Nov.	High	60	63	64	60	58	56	55	47	60	60	60	57	55	55	64	58	55	55	56	49	50	47	57	59	51	52	55	55	51	44	—
1983	Nov.	Low	52	54	51	37	35	44	35	33	44	47	46	44	45	45	51	50	47	44	45	42	35	39	44	43	42	43	48	35	34	36	—
1983	Dec.	High	45	50	45	45	49	45	50	54	55	54	49	50	55	52	49	42	43	39	44	34	25	24	27	26	40	41	44	35	36	52	55
1983	Dec.	Low	35	40	37	35	41	41	40	43	39	45	37	42	49	42	39	35	32	35	29	22	19	12	11	16	25	29	30	20	32	35	39
1984	Jan.	High	42	54	63	65	60	54	57	53	51	51	53	45	49	44	45	41	43	38	41	35	50	56	52	61	55	51	59	57	61	61	53
1984	Jan.	Low	35	37	53	51	47	48	36	38	36	42	41	33	24	25	21	16	15	19	30	20	33	47	45	52	39	35	35	35	36	29	25
1984	Feb.	High	52	50	52	64	58	62	56	61	49	50	55	55	51	50	52	53	54	57	54	55	48	46	47	46	54	50	58	59	55	—	—
1984	Feb.	Low	26	24	26	27	26	34	29	44	42	39	42	47	36	36	40	31	25	37	35	43	34	33	41	41	35	31	31	35	39	—	—
1984	Mar.	High	56	55	53	65	64	66	63	67	67	64	52	56	59	55	60	56	55	53	62	62	56	62	57	56	50	57	59	54	57	60	64
1984	Mar.	Low	41	39	30	27	28	30	35	39	43	36	33	41	44	46	45	42	41	45	47	43	44	44	37	39	39	36	34	42	33	26	44
1984	Apr.	High	57	58	57	52	56	59	54	52	50	54	55	56	57	77	55	58	60	61	58	61	59	65	59	55	55	62	66	56	56	56	—
1984	Apr.	Low	37	38	42	42	37	32	42	41	40	41	41	35	32	36	46	35	30	45	39	41	43	35	35	35	33	29	28	34	41	44	—
1984	May.	High	57	58	60	58	55	61	76	65	60	60	66	67	66	59	61	65	69	71	62	61	64	56	63	60	60	66	76	85	85	62	65
1984	May.	Low	46	46	37	33	34	30	30	42	43	42	51	50	47	42	41	42	46	41	42	40	37	41	39	37	44	44	42	43	46	45	37
1984	Jun.	High	69	67	64	62	59	62	63	61	62	66	70	73	72	78	72	67	73	75	76	59	63	76	84	84	85	69	82	77	67	72	—
1984	Jun.	Low	41	45	39	50	48	47	43	38	42	39	48	44	45	44	44	36	36	38	42	52	40	36	45	44	49	50	60	57	51	41	—
1984	Jul.	High	80	78	83	86	77	72	77	79	80	81	69	73	79	86	93	97	92	84	81	78	78	92	80	94	72	82	80	80	83	92	85
1984	Jul.	Low	44	53	48	50	50	44	39	45	49	49	44	52	44	46	51	59	54	45	45	49	46	46	52	58	53	46	47	53	48	50	55
1984	Aug.	High	78	81	80	82	76	81	90	95	94	87	81	75	79	82	87	84	83	80	82	86	86	80	76	80	88	94	79	76	85	74	69
1984	Aug.	Low	60	60	53	48	52	46	49	56	56	52	52	54	47	46	49	54	55	54	46	44	49	50	52	50	48	52	51	51	46	49	58
1984	Sep.	High	73	81	83	83	71	65	76	80	72	73	71	74	81	87	81	83	87	86	67	71	70	63	64	67	70	73	76	81	80	68	—
1984	Sep.	Low	47	39	43	46	51	51	60	63	54	44	49	47	46	45	50	49	48	50	61	56	47	44	41	35	42	42	42	39	40	49	—
1984	Oct.	High	70	73	73	68	63	75	85	76	72	59	61	62	63	55	52	55	56	50	50	48	51	53	51	55	61	53	52	56	53	53	50
1984	Oct.	Low	43	44	47	46	44	54	54	52	52	50	45	47	48	42	35	34	36	43	47	34	33	33	31	46	51	44	45	40	38	40	34
1984	Nov.	High	53	58	59	59	52	55	59	47	50	57	54	60	51	53	49	53	51	55	53	51	43	46	51	42	45	41	48	50	47	49	—
1984	Nov.	Low	37	50	46	32	31	44	34	32	42	49	49	49	34	35	31	31	30	43	43	34	33	31	33	34	35	28	39	37	41	36	—
1984	Dec.	High	40	45	47	45	44	42	42	43	45	45	41	48	47	48	40	43	41	33	30	39	46	50	52	40	37	49	45	44	45	48	40
1984	Dec.	Low	31	31	32	28	26	22	25	32	40	27	28	39	37	34	31	32	30	20	17	13	39	43	38	33	35	37	35	34	40	40	27
1985	Jan.	High	39	42	42	36	38	39	41	42	43	41	41	43	43	50	41	50	47	45	42	47	54	52	47	47	47	46	37	40	43	36	40
1985	Jan.	Low	23	24	22	20	23	30	29	25	23	20	21	23	20	28	37	30	27	27	32	35	34	26	24	24	22	20	22	23	23	20	27
1985	Feb.	High	46	34	36	33	42	48	44	43	42	46	52	47	51	58	52	49	52	51	47	49	51	58	62	56	51	53	58	58	—	—	—
1985	Feb.	Low	30	30	21	11	30	37	33	35	34	37	37	30	24	27	31	25	25	23	37	37	39	38	36	30	27	29	27	28	—	—	—
1985	Mar.	High	53	51	46	46	50	52	55	57	60	61	58	53	56	56	61	61	57	58	57	56	49	48	51	46	51	46	47	53	48	53	60
1985	Mar.	Low	30	23	34	36	32	28	23	26	29	30	25	30	26	27	27	31	31	28	32	36	36	38	38	32	33	33	36	37	32	45	50

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1985	Apr.	High	67	69	61	60	67	76	62	70	76	65	65	72	74	73	64	58	60	51	51	53	51	52	58	53	55	57	66	57	65	69	—
1985	Apr.	Low	48	37	45	36	36	38	44	45	39	46	47	37	39	39	44	45	44	39	34	36	41	42	40	41	30	43	50	35	32	33	—
1985	May.	High	75	73	58	58	61	61	62	60	65	59	58	64	63	61	81	83	75	72	68	70	80	85	72	70	69	69	67	63	62	68	63
1985	May.	Low	45	40	36	36	32	44	38	33	36	38	28	30	35	40	39	45	44	46	44	49	40	47	53	55	54	54	46	49	47	50	50
1985	Jun.	High	62	71	67	72	68	65	65	70	74	80	85	81	81	78	75	82	95	96	88	81	82	75	68	66	79	83	69	78	69	75	—
1985	Jun.	Low	48	47	43	54	49	55	48	41	43	41	46	53	49	54	50	40	46	51	53	43	45	50	43	37	39	48	43	42	45	46	—
1985	Jul.	High	87	89	88	83	80	88	90	92	96	86	89	86	86	92	88	83	85	99	101	96	90	89	84	80	91	95	94	93	84	62	76
1985	Jul.	Low	44	52	46	51	48	53	54	52	55	51	53	52	50	48	49	50	56	55	58	54	54	59	58	56	50	51	49	50	52	59	57
1985	Aug.	High	77	80	87	82	82	85	70	75	77	74	84	82	94	94	86	92	91	68	70	73	75	86	92	84	91	92	74	76	77	73	77
1985	Aug.	Low	57	52	51	56	47	47	56	55	46	50	45	49	50	51	51	50	51	53	51	48	42	45	49	61	53	48	46	41	42	48	43
1985	Sep.	High	70	72	79	77	70	72	70	68	66	67	68	61	68	63	70	64	66	66	67	73	74	72	80	78	88	84	80	76	75	76	—
1985	Sep.	Low	52	50	42	50	58	48	43	41	44	47	44	54	53	53	46	42	46	39	45	39	48	42	42	43	44	42	40	35	34	34	—
1985	Oct.	High	73	75	73	81	78	64	62	57	62	62	63	60	62	70	62	65	63	67	57	63	54	57	58	60	59	63	67	53	54	52	50
1985	Oct.	Low	39	50	45	38	40	45	39	30	25	36	45	36	32	38	41	39	33	34	45	45	44	47	52	55	37	43	45	34	28	33	34
1985	Nov.	High	59	66	66	55	52	54	53	48	44	45	42	45	49	45	51	51	44	46	42	40	40	33	27	28	39	39	46	32	28	26	—
1985	Nov.	Low	50	54	52	39	41	47	40	35	34	29	23	23	19	19	37	40	30	27	30	28	31	20	16	11	12	31	30	20	17	17	—
1985	Dec.	High	24	46	47	45	52	51	51	48	38	46	40	41	39	41	43	43	43	41	42	39	40	41	43	45	42	40	37	36	40	38	43
1985	Dec.	Low	21	22	37	34	37	44	42	33	30	26	19	18	20	21	26	23	22	21	19	17	19	20	26	26	19	16	17	15	19	16	30
1986	Jan.	High	51	46	53	47	53	54	46	57	55	52	49	44	48	46	49	56	54	63	49	50	46	51	52	44	54	50	53	47	44	57	52
1986	Jan.	Low	30	27	31	24	38	30	29	36	47	38	32	33	29	37	38	46	40	49	38	37	32	41	36	30	28	26	42	39	41	43	39
1986	Feb.	High	58	57	53	49	48	41	50	51	49	41	40	37	56	39	55	50	40	40	46	50	52	58	59	65	58	63	70	59	—	—	—
1986	Feb.	Low	42	39	43	39	34	33	33	27	22	22	33	32	34	35	35	40	32	33	30	38	39	50	54	53	46	46	44	41	—	—	—
1986	Mar.	High	64	65	62	66	67	60	59	53	56	64	57	54	54	56	58	60	54	57	64	70	59	60	57	55	58	69	68	67	68	58	62
1986	Mar.	Low	40	33	36	39	37	46	45	42	44	40	44	42	35	36	39	39	43	42	39	37	35	31	45	40	39	48	39	42	42	38	31
1986	Apr.	High	55	57	58	57	63	71	68	61	55	59	52	53	55	60	61	54	57	59	69	77	78	57	55	54	54	53	60	54	56	63	—
1986	Apr.	Low	41	34	32	42	33	35	36	51	42	30	32	38	38	36	43	42	35	32	38	40	44	35	31	28	40	42	40	37	36	33	—
1986	May.	High	55	57	63	59	53	58	56	63	55	52	56	63	59	61	65	69	76	70	75	58	58	62	67	81	85	72	74	79	84	91	91
1986	May.	Low	48	43	35	33	42	42	48	44	38	39	41	39	40	33	40	35	40	45	44	38	37	36	44	52	57	58	52	50	48	55	61
1986	Jun.	High	86	88	74	72	71	66	69	68	81	89	88	89	93	68	74	67	65	68	72	74	78	89	92	83	85	88	84	63	72	84	—
1986	Jun.	Low	56	57	54	53	55	54	51	47	42	48	52	49	49	44	44	55	53	47	40	51	47	50	53	52	51	56	55	54	48	43	—
1986	Jul.	High	84	75	71	67	71	83	77	79	73	69	76	73	76	71	67	67	73	78	86	90	87	78	75	79	80	73	71	80	77	82	89
1986	Jul.	Low	52	58	46	46	42	45	50	54	58	58	58	55	51	52	50	50	48	43	46	50	48	48	55	46	48	51	53	44	54	49	49
1986	Aug.	High	97	98	91	87	84	93	95	97	94	83	81	82	88	93	89	81	88	77	82	92	89	88	85	86	92	98	87	73	70	73	77
1986	Aug.	Low	57	62	51	47	48	52	58	58	56	54	51	53	53	53	54	46	46	50	46	50	53	48	50	46	51	55	60	57	60	59	55
1986	Sep.	High	84	81	88	93	91	90	78	68	72	68	71	71	64	72	70	70	61	68	72	61	68	69	58	59	62	55	61	64	64	61	—
1986	Sep.	Low	50	59	54	53	50	53	48	46	53	45	37	44	41	39	46	46	52	48	43	51	46	40	46	46	48	47	46	46	50	48	—
1986	Oct.	High	62	63	68	67	78	78	76	69	63	76	76	73	71	69	70	64	57	63	61	64	52	56	57	65	64	61	66	58	62	59	61
1986	Oct.	Low	42	37	45	44	45	45	43	45	42	41	36	32	33	35	36	36	45	39	38	39	37	42	43	45	55	55	42	42	45	52	41
1986	Nov.	High	63	63	62	54	60	56	56	56	49	46	57	53	47	47	51	51	56	56	55	59	52	51	60	57	48	53	52	49	51	41	—
1986	Nov.	Low	45	39	35	34	39	37	39	39	34	29	40	36	32	43	45	47	36	46	48	47	45	40	51	38	31	46	44	41	32	29	—
1986	Dec.	High	46	49	47	44	46	46	37	43	49	44	36	43	53	52	47	42	45	37	45	42	56	53	53	53	48	57	53	41	55	42	52
1986	Dec.	Low	36	31	27	36	35	32	26	33	28	24	25	36	38	38	28	23	22	30	31	26	37	42	42	41	37	32	30	29	37	31	35

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1987	Jan.	High	49	51	54	49	49	47	45	40	43	48	56	50	43	45	39	38	39	45	41	42	40	39	50	49	53	56	49	50	56	53	54
1987	Jan.	Low	38	41	43	38	32	26	21	19	20	26	28	39	36	24	21	19	19	25	25	21	23	27	33	44	43	43	44	42	43	40	43
1987	Feb.	High	53	51	54	56	58	55	52	57	53	57	60	52	53	53	51	49	50	52	53	51	52	52	50	50	51	50	50	51	—	—	—
1987	Feb.	Low	42	40	40	34	35	31	29	39	33	42	35	33	45	38	43	42	36	32	32	35	31	32	33	25	23	25	36	37	—	—	—
1987	Mar.	High	54	59	60	62	57	54	57	56	54	61	54	54	54	53	55	56	56	50	53	56	61	60	55	55	54	55	55	61	65	71	72
1987	Mar.	Low	45	45	51	45	41	35	33	38	46	44	45	50	46	35	31	36	41	35	33	40	30	32	35	29	30	29	28	27	32	29	35
1987	Apr.	High	78	72	56	63	55	59	61	58	64	55	57	60	69	73	68	61	50	53	56	64	70	69	69	64	68	85	84	71	77	60	72
1987	Apr.	Low	37	42	40	35	41	35	36	42	33	43	35	34	36	39	46	41	38	35	30	32	38	44	43	33	38	37	44	50	41	47	35
1987	May.	High	57	58	74	69	79	90	94	94	86	84	83	68	74	71	64	67	63	63	64	70	74	68	71	66	61	67	64	63	71	61	63
1987	May.	Low	45	45	48	46	41	49	54	56	49	46	44	54	54	58	47	37	39	33	36	34	39	36	37	49	46	49	50	47	38	50	41
1987	Jun.	High	66	77	90	76	65	76	82	75	74	76	83	84	87	80	64	63	73	80	84	65	69	72	79	87	98	97	90	87	95	92	—
1987	Jun.	Low	42	43	46	51	54	52	46	51	47	46	41	49	50	50	50	47	44	42	43	51	47	45	45	48	56	54	53	49	55	55	—
1987	Jul.	High	82	77	80	70	72	73	74	73	72	79	90	94	95	97	79	65	65	60	78	87	84	67	79	78	77	73	78	79	77	73	75
1987	Jul.	Low	55	54	49	54	55	44	48	55	47	58	53	54	55	54	42	51	54	54	52	50	53	52	51	57	55	54	52	52	48	54	52
1987	Aug.	High	81	87	95	88	78	77	93	99	80	72	76	80	69	72	73	74	80	88	86	76	80	88	85	87	89	90	89	86	91	97	100
1987	Aug.	Low	49	45	53	52	54	50	51	56	53	57	54	49	56	56	55	50	45	52	47	47	44	52	58	48	47	53	50	49	53	53	60
1987	Sep.	High	95	77	77	85	94	87	79	76	87	73	65	67	71	66	66	69	80	81	82	84	85	93	81	66	67	69	74	84	89	88	—
1987	Sep.	Low	54	51	42	45	49	50	50	48	46	50	57	57	50	49	42	39	39	42	42	44	44	46	49	52	54	47	39	40	44	44	—
1987	Oct.	High	89	73	73	77	85	88	84	65	83	83	82	72	69	64	65	71	67	68	79	75	67	63	66	64	67	70	72	74	62	67	60
1987	Oct.	Low	45	49	50	48	44	45	45	44	43	44	38	40	35	37	32	33	32	38	37	37	32	34	34	35	34	37	33	34	38	54	52
1987	Nov.	High	62	60	54	56	58	57	63	62	64	58	56	61	57	51	47	54	55	54	58	59	53	53	52	52	51	45	42	48	40	57	—
1987	Nov.	Low	50	47	42	37	38	48	41	40	45	38	51	52	41	40	39	38	35	31	33	37	43	38	38	39	35	34	35	29	28	33	—
1987	Dec.	High	57	57	56	48	51	51	56	53	59	50	45	40	36	43	35	35	37	37	35	44	45	47	40	34	36	38	35	37	39	38	43
1987	Dec.	Low	46	47	45	44	45	45	42	42	43	36	29	28	31	31	32	33	30	32	32	33	35	34	28	25	24	20	27	30	26	23	34
1988	Jan.	High	42	39	36	36	40	36	40	48	54	47	50	45	52	56	47	47	40	41	44	53	44	45	42	45	43	45	50	60	53	44	41
1988	Jan.	Low	27	19	31	32	27	30	31	33	39	40	37	35	40	41	39	36	30	33	32	36	29	35	37	30	29	29	36	38	37	34	32
1988	Feb.	High	39	41	52	40	43	52	52	56	52	60	52	53	50	50	50	52	48	52	53	46	58	53	62	59	61	66	66	67	59	—	—
1988	Feb.	Low	22	19	29	25	27	33	40	45	47	35	34	41	35	33	37	33	30	38	33	30	32	29	25	29	31	37	36	37	47	—	—
1988	Mar.	High	56	52	54	54	51	49	54	49	51	50	57	58	57	60	63	66	65	69	70	59	54	59	54	49	61	53	54	55	52	56	62
1988	Mar.	Low	39	39	34	36	35	31	28	37	36	30	24	26	27	28	28	27	29	29	33	48	39	43	42	42	48	37	36	34	39	36	33
1988	Apr.	High	67	53	53	56	62	55	53	56	73	77	75	79	59	53	60	59	56	64	62	59	51	59	60	57	64	73	73	64	56	51	—
1988	Apr.	Low	34	47	41	39	45	36	33	28	33	38	39	41	48	48	47	49	40	34	48	47	43	43	38	38	30	43	50	49	40	38	—
1988	May.	High	54	56	52	57	56	51	66	57	65	79	83	74	61	68	75	62	61	65	67	75	89	68	64	68	69	66	67	62	62	62	61
1988	May.	Low	35	40	38	36	39	41	46	42	39	44	48	49	50	47	45	43	43	41	37	39	44	40	35	40	40	43	55	42	40	37	49
1988	Jun.	High	61	65	68	66	63	66	63	68	64	68	74	73	81	90	82	80	74	75	81	79	86	79	73	85	74	70	71	65	69	77	—
1988	Jun.	Low	49	46	46	48	39	38	49	47	49	49	44	41	43	49	49	48	50	54	50	46	52	56	52	48	52	55	53	47	49	41	—
1988	Jul.	High	77	72	70	68	67	72	86	88	86	82	69	73	67	75	77	82	83	92	103	101	89	84	87	94	102	103	89	87	88	90	79
1988	Jul.	Low	46	57	50	46	43	38	45	47	47	50	54	57	57	54	50	44	48	47	50	56	49	54	45	50	50	59	51	55	58	54	47
1988	Aug.	High	76	86	95	96	82	73	78	86	86	79	70	76	71	73	75	75	74	78	83	76	86	97	102	88	87	84	93	96	79	77	87
1988	Aug.	Low	43	46	52	52	52	45	45	47	53	56	50	53	53	56	48	58	51	44	46	44	41	45	50	49	44	46	53	54	52	44	44
1988	Sep.	High	102	104	94	88	86	82	77	84	76	71	82	88	90	87	66	69	70	74	67	68	73	69	75	77	67	68	70	75	84	86	—
1988	Sep.	Low	47	54	51	51	51	47	53	44	42	38	40	44	43	45	42	44	41	34	47	46	40	39	43	51	56	54	44	41	44	50	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1988	Oct.	High	92	76	63	64	68	66	65	70	75	72	62	71	62	66	75	76	69	66	71	65	65	63	68	64	59	60	63	61	62	73	67
1988	Oct.	Low	49	46	45	44	55	46	55	49	47	46	52	47	52	57	59	57	48	45	51	44	44	39	37	42	39	34	27	31	38	45	42
1988	Nov.	High	56	58	61	61	65	57	50	55	50	57	56	54	50	50	54	51	51	48	48	52	54	57	47	44	50	51	50	54	48	39	—
1988	Nov.	Low	42	53	50	48	49	38	39	44	42	43	41	41	34	42	45	43	39	41	37	46	45	43	37	37	41	33	40	37	30	31	—
1988	Dec.	High	38	42	45	38	58	60	52	48	50	49	49	58	52	45	49	53	49	48	49	44	48	45	43	39	38	41	42	40	49	49	47
1988	Dec.	Low	31	30	30	29	36	47	34	33	45	45	45	42	29	29	25	34	24	20	33	39	38	37	37	33	27	26	33	30	39	39	36
1989	Jan.	High	49	50	59	50	47	42	42	48	52	46	46	50	44	42	48	50	51	55	51	50	44	45	35	43	44	40	49	49	60	57	48
1989	Jan.	Low	40	42	44	38	35	32	33	35	42	36	36	34	33	34	41	47	46	40	35	37	37	26	24	30	27	32	29	28	33	35	33
1989	Feb.	High	34	23	16	24	34	36	36	42	45	37	45	43	44	45	48	49	50	46	51	57	48	53	51	53	55	50	49	53	—	—	—
1989	Feb.	Low	23	12	6	3	-1	6	8	12	24	26	33	35	34	27	23	39	45	39	39	35	35	39	38	29	33	29	28	29	—	—	—
1989	Mar.	High	49	41	46	39	58	56	55	62	64	56	62	56	45	51	61	53	52	55	57	59	58	56	58	54	56	48	52	57	56	52	57
1989	Mar.	Low	32	31	29	29	37	42	36	34	45	42	47	45	39	40	43	41	41	37	33	29	42	40	34	44	37	40	45	42	41	35	42
1989	Apr.	High	55	52	58	59	70	72	69	69	78	71	71	78	78	76	64	64	72	73	75	60	61	57	62	62	59	58	64	73	80	64	—
1989	Apr.	Low	40	34	35	45	48	43	45	39	41	45	39	40	42	50	48	42	39	49	54	48	43	41	40	46	48	38	35	34	36	43	—
1989	May.	High	70	73	66	81	81	78	79	76	57	61	63	63	72	77	80	70	65	61	64	71	61	68	56	62	62	65	64	65	62	70	78
1989	May.	Low	43	43	39	48	54	53	49	43	46	46	42	39	34	41	41	43	42	42	42	34	46	46	43	46	46	47	48	45	45	46	43
1989	Jun.	High	85	86	88	90	87	76	76	73	71	79	85	64	76	65	71	70	75	74	68	71	80	80	91	96	89	73	70	69	61	67	—
1989	Jun.	Low	48	50	48	50	50	49	42	46	52	42	47	48	56	55	52	43	44	51	50	49	47	48	56	55	55	52	49	53	53	51	—
1989	Jul.	High	64	77	75	77	80	86	81	71	69	75	82	86	76	81	75	67	80	84	80	72	77	86	83	82	87	68	77	84	73	76	68
1989	Jul.	Low	50	52	57	45	44	46	49	50	56	56	46	52	57	54	58	54	57	61	55	52	52	46	49	52	48	56	56	47	51	47	50
1989	Aug.	High	64	75	76	79	88	91	90	84	77	78	80	82	80	79	78	76	77	87	78	78	74	67	74	72	78	85	82	82	74	69	73
1989	Aug.	Low	49	54	51	57	50	53	53	57	55	49	45	49	49	50	45	48	56	49	49	58	60	57	50	51	47	50	49	54	51	53	50
1989	Sep.	High	74	74	77	81	73	82	86	89	86	88	87	90	93	92	88	74	70	71	73	82	89	95	89	84	72	67	73	90	69	60	—
1989	Sep.	Low	49	47	41	43	49	42	44	47	49	41	42	43	41	46	43	45	48	37	37	39	44	47	47	50	51	52	56	47	54	47	—
1989	Oct.	High	65	69	70	69	72	70	67	74	77	72	69	69	67	62	63	64	73	62	61	65	57	65	58	55	59	57	55	53	58	52	64
1989	Oct.	Low	49	42	36	37	43	46	45	47	45	46	38	47	50	36	32	34	35	41	51	48	51	49	44	44	42	46	39	35	30	29	33
1989	Nov.	High	62	56	62	61	58	52	58	56	66	64	63	56	50	53	52	49	53	51	54	58	56	50	55	51	46	52	53	43	42	48	—
1989	Nov.	Low	33	28	33	44	39	42	44	42	55	53	51	44	38	34	33	33	48	47	46	45	37	36	44	43	42	40	36	35	34	32	—
1989	Dec.	High	50	46	60	61	54	57	55	57	53	46	47	39	40	35	38	40	35	34	38	40	39	40	58	50	46	37	39	44	45	41	51
1989	Dec.	Low	31	31	44	50	49	41	40	36	33	33	24	28	27	31	31	33	33	32	32	31	33	33	40	29	25	23	29	33	32	36	35
1990	Jan.	High	48	50	48	50	55	55	59	58	61	45	49	48	50	50	47	47	49	47	49	46	47	51	47	43	46	45	51	48	47	45	42
1990	Jan.	Low	31	35	38	44	49	47	47	48	41	41	38	35	41	39	40	34	27	22	24	25	26	40	31	25	35	33	37	44	38	37	36
1990	Feb.	High	49	52	49	47	44	39	40	48	51	54	48	38	37	34	35	39	42	45	47	47	58	51	53	58	64	65	68	68	—	—	—
1990	Feb.	Low	35	43	36	33	35	32	32	40	46	46	32	29	21	18	32	34	30	22	21	35	45	39	36	37	38	33	34	27	—	—	—
1990	Mar.	High	64	54	57	54	54	56	50	49	49	51	47	51	48	57	60	63	62	61	63	66	66	55	61	62	65	64	68	72	63	64	64
1990	Mar.	Low	27	31	41	36	34	45	38	34	39	35	33	31	27	37	32	40	47	47	48	45	35	44	41	38	33	33	30	34	35	33	40
1990	Apr.	High	70	61	71	74	72	68	54	59	68	73	69	66	78	77	81	63	60	67	62	67	65	57	56	59	62	59	55	58	59	68	—
1990	Apr.	Low	36	39	35	36	36	35	34	36	30	36	41	34	38	43	48	49	50	48	47	50	47	47	45	41	38	38	39	39	39	32	—
1990	May.	High	72	72	76	86	78	62	61	67	77	58	59	63	64	64	65	70	61	60	68	61	63	65	60	63	69	70	73	66	64	64	65
1990	May.	Low	38	47	50	45	41	36	36	31	39	41	47	46	42	38	44	38	48	45	39	49	48	50	42	42	35	50	56	51	50	46	47
1990	Jun.	High	65	74	69	67	69	62	70	71	64	65	69	63	68	80	81	65	69	80	81	83	97	80	70	80	74	79	76	80	84	78	—
1990	Jun.	Low	49	51	51	50	43	55	51	52	49	46	47	50	45	49	47	52	50	47	50	56	53	60	57	53	50	51	47	57	53	52	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1990	Jul.	High	74	70	73	82	78	75	83	89	87	92	95	98	91	91	96	85	87	91	95	98	100	95	78	75	75	77	83	90	99	87	81
1990	Jul.	Low	52	49	44	53	53	53	47	52	52	54	60	64	57	50	52	48	47	49	55	52	58	55	51	58	54	56	54	50	56	56	54
1990	Aug.	High	82	84	92	99	95	88	92	90	92	98	101	90	82	86	77	79	70	74	80	86	68	75	74	74	78	80	83	80	65	79	81
1990	Aug.	Low	56	51	53	57	56	50	59	63	58	56	59	57	55	49	56	55	56	57	56	59	59	60	50	42	49	55	59	57	60	54	48
1990	Sep.	High	79	78	84	92	85	87	78	81	82	88	67	71	87	79	67	75	75	79	75	85	95	95	76	70	73	73	76	82	76	75	—
1990	Sep.	Low	51	52	48	54	53	50	53	60	54	54	54	46	43	51	56	53	52	48	46	44	46	47	47	47	59	51	46	47	46	49	—
1990	Oct.	High	69	63	73	74	63	60	61	66	68	61	62	65	61	55	67	60	61	58	57	56	54	56	61	63	66	60	67	62	63	53	57
1990	Oct.	Low	44	44	52	50	38	34	30	32	35	36	31	50	43	39	51	36	36	40	38	36	38	37	40	41	41	43	43	46	40	50	38
1990	Nov.	High	55	50	57	60	55	49	53	58	61	66	59	58	54	54	61	56	50	49	46	47	51	55	55	59	55	47	52	50	51	49	—
1990	Nov.	Low	34	34	45	45	37	37	43	49	56	43	36	38	45	38	34	32	39	28	29	38	43	48	51	54	36	34	35	35	39	35	—
1990	Dec.	High	47	47	50	54	50	43	39	59	52	51	47	39	45	48	50	43	51	49	32	18	18	21	24	26	36	43	46	38	24	34	45
1990	Dec.	Low	38	40	41	38	32	33	34	35	48	37	32	33	34	33	29	28	41	29	12	9	8	7	11	10	25	36	37	19	14	11	32
1991	Jan.	High	48	37	42	39	36	33	48	51	47	52	56	60	61	56	51	48	45	44	51	52	49	49	43	48	51	48	46	46	43	48	51
1991	Jan.	Low	31	28	24	20	18	29	32	29	29	46	48	53	46	48	38	34	35	37	34	30	27	25	26	27	25	22	19	30	22	24	34
1991	Feb.	High	60	59	60	56	53	52	55	55	51	49	58	51	58	58	57	54	54	54	58	57	56	58	59	64	71	68	65	62	—	—	—
1991	Feb.	Low	42	50	50	49	37	32	33	34	34	34	40	47	51	51	48	35	39	43	51	46	39	36	32	30	36	33	30	29	—	—	—
1991	Mar.	High	59	51	57	49	47	50	50	54	53	49	46	55	53	50	52	58	64	53	53	55	51	50	51	54	50	58	60	55	60	68	69
1991	Mar.	Low	45	46	44	34	32	33	32	35	35	31	32	35	34	34	34	31	30	40	35	29	36	39	35	38	31	32	31	34	30	33	42
1991	Apr.	High	58	58	56	60	58	48	55	50	53	51	58	68	67	55	57	64	61	66	73	71	62	63	55	53	54	55	60	59	61	74	—
1991	Apr.	Low	46	44	45	51	35	33	38	36	40	35	29	29	35	44	39	39	38	43	36	48	43	40	42	40	39	40	38	36	31	36	—
1991	May.	High	74	72	67	70	57	66	58	55	58	56	59	58	63	65	67	72	50	55	55	65	68	64	72	64	60	64	63	66	57	63	68
1991	May.	Low	40	41	39	35	48	51	48	38	37	45	49	49	47	32	40	44	45	46	49	50	45	42	41	42	42	48	42	45	43	40	37
1991	Jun.	High	74	74	64	67	68	67	69	73	83	84	71	64	65	70	65	65	72	81	61	54	60	68	73	66	65	70	77	68	66	71	—
1991	Jun.	Low	42	46	35	33	34	53	50	51	43	48	45	44	48	48	47	39	35	46	51	50	48	48	50	55	54	48	43	56	56	52	—
1991	Jul.	High	85	95	89	82	79	81	89	84	74	79	87	89	76	80	72	73	75	79	75	83	83	95	98	73	74	83	88	88	89	90	92
1991	Jul.	Low	50	54	54	49	51	46	50	48	47	56	50	53	56	49	54	59	57	48	52	44	47	56	63	59	57	49	57	54	54	56	55
1991	Aug.	High	80	85	88	85	79	85	83	91	76	74	82	86	86	89	88	82	90	87	91	93	91	88	73	76	74	79	65	65	89	83	66
1991	Aug.	Low	49	54	51	53	56	54	58	61	59	57	50	51	53	51	57	53	56	54	57	53	54	56	55	43	42	43	54	57	58	52	52
1991	Sep.	High	73	80	92	93	93	87	72	70	81	83	79	81	74	75	87	90	95	93	89	72	73	83	84	95	94	82	68	72	77	85	—
1991	Sep.	Low	44	46	51	53	54	50	57	52	49	49	44	47	50	41	44	49	53	53	51	40	37	39	51	52	52	48	48	56	44	47	—
1991	Oct.	High	80	76	74	81	84	71	71	75	81	87	86	75	78	82	85	64	62	66	72	73	64	53	56	57	51	51	54	47	50	51	53
1991	Oct.	Low	46	43	44	40	41	47	45	37	39	42	41	46	40	42	39	44	33	40	38	45	40	44	42	46	47	39	34	38	33	27	29
1991	Nov.	High	50	55	51	56	62	56	56	60	57	54	64	61	56	52	40	55	54	54	54	55	54	45	46	56	59	51	52	49	48	43	—
1991	Nov.	Low	40	40	39	45	55	50	51	48	42	45	50	51	41	32	32	36	44	45	48	42	32	31	33	44	50	40	35	36	28	27	—
1991	Dec.	High	48	54	54	52	53	53	53	52	48	41	48	52	42	40	37	35	37	45	48	36	46	47	46	47	46	46	49	48	44	47	43
1991	Dec.	Low	42	38	38	43	49	44	42	40	39	34	37	35	28	29	27	30	27	35	32	31	35	42	40	42	39	36	41	37	38	36	36
1992	Jan.	High	45	50	51	52	46	46	44	45	46	49	51	38	45	50	50	52	50	52	48	44	54	54	57	60	56	53	57	58	63	55	61
1992	Jan.	Low	37	40	41	41	40	38	27	27	31	31	30	28	36	42	43	39	32	29	23	22	37	36	50	42	37	34	45	49	51	47	47
1992	Feb.	High	53	59	56	60	54	51	53	42	56	58	55	64	57	52	57	51	52	52	49	53	62	59	55	64	68	67	66	62	56	—	—
1992	Feb.	Low	40	39	34	29	28	28	29	29	42	39	39	39	42	41	31	36	44	45	42	46	46	39	37	48	47	45	37	36	39	—	—
1992	Mar.	High	59	55	64	53	61	58	57	64	64	66	64	68	63	67	62	58	59	59	64	66	70	67	68	64	69	57	58	69	70	67	70
1992	Mar.	Low	40	37	39	42	43	42	44	34	30	32	33	34	35	43	39	46	38	32	34	31	34	35	36	34	40	45	42	38	38	44	38

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1992	Apr.	High	76	76	62	53	51	55	53	55	62	63	58	65	65	69	67	63	59	65	64	62	57	57	65	74	79	71	74	76	72	61	—
1992	Apr.	Low	41	44	38	38	35	35	35	39	48	50	48	48	48	42	45	55	49	41	36	41	41	35	31	42	44	47	57	54	54	38	—
1992	May.	High	66	75	86	85	87	88	81	63	65	65	62	67	78	79	77	83	85	76	72	65	69	80	86	92	78	76	73	76	78	83	91
1992	May.	Low	34	37	42	48	51	50	48	39	42	46	43	38	45	41	39	38	47	46	50	39	33	37	43	48	55	51	47	47	55	54	51
1992	Jun.	High	80	79	85	78	80	83	78	80	74	77	65	70	69	72	71	68	73	85	86	89	99	105	99	99	88	88	87	72	74	76	—
1992	Jun.	Low	50	47	44	38	42	43	45	44	52	47	55	50	49	52	46	54	54	44	48	50	57	59	58	57	53	52	54	58	56	58	—
1992	Jul.	High	74	82	83	72	73	76	76	77	80	81	78	86	81	78	87	99	99	94	90	78	76	68	73	77	91	88	90	90	91	100	87
1992	Jul.	Low	51	50	54	54	51	58	52	56	49	53	55	54	52	56	51	57	59	62	54	55	62	54	57	59	51	53	55	55	53	57	57
1992	Aug.	High	79	85	85	74	85	69	71	79	86	99	105	88	100	95	90	88	95	89	89	86	73	68	78	85	91	92	90	82	85	82	73
1992	Aug.	Low	52	49	50	52	49	55	51	46	46	52	56	64	60	56	52	50	56	54	57	48	47	56	50	44	45	47	53	47	46	49	52
1992	Sep.	High	82	85	83	70	71	70	73	73	82	85	72	68	68	61	62	73	75	80	78	81	83	88	73	63	69	74	72	79	83	80	—
1992	Sep.	Low	56	50	47	55	50	40	39	52	49	51	54	46	43	39	50	54	45	42	53	48	58	52	58	53	50	50	44	40	44	52	—
1992	Oct.	High	68	58	66	63	67	75	72	67	69	74	76	75	65	60	60	59	67	67	75	59	63	73	75	69	64	63	63	60	60	54	59
1992	Oct.	Low	54	54	50	39	37	40	36	43	37	41	40	41	38	31	30	39	51	51	50	50	49	49	47	48	54	43	36	45	49	48	48
1992	Nov.	High	59	59	57	58	51	61	61	54	54	43	52	53	55	48	49	51	58	53	50	50	53	52	46	48	49	47	57	49	39	50	—
1992	Nov.	Low	52	43	43	43	46	47	48	44	36	32	38	48	40	44	42	44	46	42	39	41	44	38	30	25	34	35	37	30	31	39	—
1992	Dec.	High	42	46	47	44	37	38	39	49	47	50	45	49	48	50	48	42	38	39	45	47	51	50	46	49	40	48	47	47	41	42	36
1992	Dec.	Low	39	33	29	28	19	31	30	38	38	32	31	36	34	37	31	30	30	27	38	39	42	43	31	31	35	39	40	41	31	30	30
1993	Jan.	High	35	36	42	44	38	34	33	30	37	35	30	36	35	36	44	36	42	45	47	52	45	48	43	56	63	60	50	50	53	55	52
1993	Jan.	Low	25	25	35	35	27	26	25	28	22	13	13	26	24	30	30	27	21	21	33	40	39	31	28	43	45	35	30	46	34	28	25
1993	Feb.	High	50	54	50	56	52	58	63	53	58	50	57	52	53	43	45	38	44	41	35	38	39	42	43	46	47	48	49	56	—	—	—
1993	Feb.	Low	26	38	36	28	36	35	30	38	36	36	38	43	33	28	28	25	23	31	29	32	33	29	25	23	20	24	20	22	—	—	—
1993	Mar.	High	48	48	58	55	64	60	62	60	59	61	64	52	52	60	52	48	55	54	61	60	66	59	61	61	60	63	63	63	57	63	64
1993	Mar.	Low	34	33	42	48	41	40	36	46	40	46	34	40	34	48	44	43	45	42	41	39	35	44	39	40	32	32	40	33	38	39	44
1993	Apr.	High	56	57	60	61	60	61	68	62	57	54	57	60	59	64	60	63	60	61	68	68	65	56	57	64	57	61	64	62	68	66	—
1993	Apr.	Low	40	48	47	42	41	45	43	49	45	43	35	30	38	36	45	42	47	39	34	44	47	47	48	49	46	47	42	45	51	45	—
1993	May.	High	59	70	61	64	70	63	59	63	75	82	72	66	76	71	75	81	89	82	82	75	68	70	88	86	64	77	74	67	79	74	70
1993	May.	Low	43	43	46	44	39	43	41	41	40	49	44	52	51	51	50	45	45	54	56	51	54	52	48	49	53	48	53	50	50	58	55
1993	Jun.	High	62	67	72	72	69	65	67	71	69	65	64	70	75	78	70	73	80	84	77	81	66	66	72	81	88	76	72	72	75	79	—
1993	Jun.	Low	50	46	44	53	55	53	51	50	50	48	47	45	42	56	56	53	49	49	55	49	51	47	44	42	52	56	54	48	50	51	—
1993	Jul.	High	74	72	74	75	75	74	76	82	74	78	73	72	71	71	73	70	75	80	72	73	72	69	74	68	74	79	88	65	71	80	87
1993	Jul.	Low	54	55	53	57	47	54	42	46	44	45	55	48	51	53	57	56	52	46	57	54	49	57	57	57	56	49	49	54	52	49	50
1993	Aug.	High	93	97	100	98	91	82	76	79	78	79	80	74	71	70	75	72	81	87	83	72	78	88	73	71	71	81	79	73	84	90	89
1993	Aug.	Low	61	61	60	59	56	54	59	60	56	49	56	51	55	59	58	51	46	51	62	59	54	50	55	44	42	45	47	50	49	45	47
1993	Sep.	High	81	90	89	82	76	86	88	94	92	92	73	74	82	76	71	79	79	73	67	66	72	78	80	78	79	90	86	84	89	83	—
1993	Sep.	Low	48	48	50	48	56	51	53	55	52	52	45	50	47	44	47	44	44	40	40	40	35	35	36	39	44	43	45	43	47	48	—
1993	Oct.	High	85	85	84	78	68	61	67	73	80	72	69	68	70	61	63	65	63	62	67	68	67	68	71	63	68	75	67	72	73	72	63
1993	Oct.	Low	42	46	44	46	46	50	43	40	39	44	47	53	51	51	47	44	40	39	43	37	45	40	44	38	36	42	37	42	43	37	39
1993	Nov.	High	57	60	65	60	58	59	51	42	55	59	49	50	54	52	49	48	50	50	47	40	48	44	36	37	40	40	44	42	54	51	—
1993	Nov.	Low	32	31	37	39	33	29	27	29	31	31	27	37	30	24	28	43	34	34	37	36	36	33	23	18	23	18	32	34	36	36	—
1993	Dec.	High	61	53	57	53	41	49	50	51	64	68	50	50	50	51	50	41	43	44	45	44	44	34	37	38	32	36	43	42	42	49	51
1993	Dec.	Low	45	43	48	35	32	36	47	46	46	46	39	39	41	44	34	34	30	22	23	22	27	25	29	29	29	30	27	27	29	31	47

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1994	Jan.	High	60	57	59	56	52	53	50	54	57	51	55	56	50	50	58	53	40	39	37	42	50	51	58	49	43	40	43	54	53	57	53
1994	Jan.	Low	41	44	50	45	41	33	30	45	41	40	46	47	43	46	35	32	31	34	33	34	35	44	43	36	36	36	38	30	27	25	24
1994	Feb.	High	52	49	49	46	50	46	44	43	51	49	52	50	50	55	56	51	48	49	56	52	47	49	53	50	53	58	54	62	—	—	—
1994	Feb.	Low	25	23	21	24	21	24	29	23	36	32	33	32	41	40	46	42	37	36	34	32	39	39	46	38	40	48	47	53	—	—	—
1994	Mar.	High	67	57	66	59	54	59	61	61	67	58	58	67	70	70	63	55	55	52	53	54	52	48	54	66	68	74	77	75	74	58	54
1994	Mar.	Low	51	52	51	41	34	32	30	32	38	42	34	31	40	37	34	44	45	37	37	40	37	36	36	41	34	32	35	38	35	50	49
1994	Apr.	High	61	62	60	59	52	58	55	57	59	62	70	62	58	61	76	78	74	74	70	74	67	66	63	62	67	64	65	70	59	64	—
1994	Apr.	Low	43	42	40	39	33	44	44	47	47	42	36	38	37	36	38	44	47	48	44	40	46	38	42	47	47	47	45	40	43	39	—
1994	May.	High	64	62	63	70	81	86	85	78	80	87	76	70	71	68	61	62	63	67	65	63	70	77	82	84	75	67	69	59	67	76	69
1994	May.	Low	36	47	45	51	49	52	50	47	45	44	54	42	39	44	50	49	49	50	48	53	47	46	45	46	52	48	37	49	50	37	52
1994	Jun.	High	71	75	75	70	64	64	69	75	82	86	83	75	64	64	69	76	70	72	83	85	83	78	73	78	73	75	88	87	80	81	—
1994	Jun.	Low	48	45	39	53	50	48	46	40	46	49	54	54	50	49	47	42	46	43	43	48	49	58	48	41	45	54	50	48	48	50	—
1994	Jul.	High	76	74	74	70	76	82	93	90	87	87	90	88	88	82	82	93	91	86	100	103	103	100	97	76	87	90	93	87	79	80	88
1994	Jul.	Low	47	51	44	46	51	45	55	51	45	42	43	43	46	46	55	51	48	58	54	60	59	65	61	55	56	50	53	52	53	55	50
1994	Aug.	High	88	90	87	78	80	84	72	74	82	88	85	86	87	82	81	82	81	81	79	79	76	79	80	80	83	83	91	80	78	85	83
1994	Aug.	Low	50	53	55	55	53	49	52	54	53	51	52	52	52	54	52	53	53	51	57	53	52	56	53	47	48	50	50	55	50	46	51
1994	Sep.	High	76	75	74	77	88	87	84	66	68	68	71	76	77	77	83	93	85	83	84	87	95	95	86	76	85	82	85	70	65	71	—
1994	Sep.	Low	47	43	51	52	47	51	48	57	52	50	49	44	45	52	49	50	56	52	52	54	56	50	48	48	48	52	49	56	57	55	—
1994	Oct.	High	76	69	72	75	74	69	68	76	76	61	64	64	61	59	61	61	55	60	66	64	64	60	63	69	65	61	60	61	48	55	56
1994	Oct.	Low	57	45	41	42	38	46	40	39	44	43	32	39	35	41	38	34	37	34	42	50	41	34	38	36	36	57	50	39	35	43	44
1994	Nov.	High	52	50	44	46	51	54	53	49	54	45	45	52	51	54	50	46	43	38	47	50	34	44	46	50	47	44	51	49	54	56	—
1994	Nov.	Low	38	34	33	34	30	31	36	32	35	32	40	37	40	36	43	37	29	25	31	28	24	30	41	41	36	34	37	37	43	48	—
1994	Dec.	High	52	45	40	39	36	41	47	42	51	46	45	48	40	45	49	56	58	53	62	63	48	46	43	52	50	57	58	51	43	50	47
1994	Dec.	Low	43	33	29	25	25	30	30	28	31	33	38	30	26	34	41	48	48	47	49	47	41	41	39	40	36	49	46	29	26	28	26
1995	Jan.	High	43	45	46	45	38	40	44	56	54	56	50	54	55	52	47	50	48	51	53	59	56	51	52	53	49	52	51	48	59	62	62
1995	Jan.	Low	33	31	32	29	30	34	35	39	45	46	43	43	47	44	42	33	33	35	35	32	30	35	37	30	32	35	38	43	45	52	56
1995	Feb.	High	58	53	59	57	56	56	58	62	60	52	55	46	30	36	44	49	53	65	67	64	62	55	63	57	57	55	57	57	—	—	—
1995	Feb.	Low	46	39	42	39	42	43	40	34	30	30	44	27	25	18	35	41	46	49	53	46	44	39	34	37	41	36	29	31	—	—	—
1995	Mar.	High	56	58	49	47	51	52	55	55	66	54	61	56	60	61	61	63	61	59	53	53	49	53	55	51	52	59	66	71	72	75	60
1995	Mar.	Low	25	35	39	39	32	29	26	43	49	44	45	40	48	42	43	33	43	44	39	43	34	34	30	38	33	29	31	31	30	34	41
1995	Apr.	High	62	63	74	56	55	63	55	49	55	57	60	57	55	54	60	66	53	54	53	53	60	71	75	77	71	60	53	65	64	68	—
1995	Apr.	Low	36	32	37	39	41	43	44	42	38	38	44	45	40	36	37	32	42	35	33	40	37	32	38	41	37	41	39	46	46	47	—
1995	May.	High	60	64	66	64	59	62	61	70	62	61	61	63	72	81	79	67	59	64	76	83	78	81	75	81	83	84	76	87	90	82	81
1995	May.	Low	52	45	41	50	47	49	49	41	49	46	45	46	41	40	47	53	49	43	37	42	44	49	44	43	47	43	46	47	51	48	51
1995	Jun.	High	84	77	79	71	61	60	73	81	82	66	71	69	59	65	67	68	70	61	68	66	69	79	87	86	85	86	92	93	97	98	—
1995	Jun.	Low	50	46	46	49	45	47	47	44	48	43	38	53	53	54	53	53	53	51	51	52	49	46	51	53	53	49	52	49	51	56	—
1995	Jul.	High	90	76	74	80	79	71	77	86	68	74	78	79	76	78	84	95	101	92	95	90	83	78	74	81	84	74	85	83	74	83	90
1995	Jul.	Low	53	55	57	57	58	51	58	59	52	49	50	47	48	53	50	59	62	61	62	58	54	61	62	60	52	61	60	54	50	46	56
1995	Aug.	High	89	83	86	94	85	78	70	76	85	68	78	74	77	85	72	65	69	76	84	90	80	82	76	75	79	76	79	75	72	78	85
1995	Aug.	Low	55	55	53	61	54	56	53	50	52	55	53	51	46	47	59	53	48	45	46	52	50	49	53	45	46	46	46	55	57	52	50
1995	Sep.	High	89	71	68	76	74	68	72	81	86	84	82	84	86	88	79	67	70	76	82	87	86	87	80	78	70	64	70	66	67	68	—
1995	Sep.	Low	53	54	54	51	57	53	54	53	53	54	54	54	50	53	53	58	60	48	48	53	45	43	46	49	53	53	58	55	55	48	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1995	Oct.	High	66	70	64	66	70	65	67	60	66	64	61	61	64	71	73	65	59	61	71	61	59	53	56	55	55	62	61	60	58	56	55
1995	Oct.	Low	41	50	48	46	39	46	41	47	48	54	48	41	38	40	42	48	44	36	32	46	41	35	40	49	49	49	39	38	37	34	24
1995	Nov.	High	58	54	57	52	51	52	59	60	51	57	57	57	67	64	59	62	61	60	57	58	57	60	59	62	56	52	56	58	57	54	—
1995	Nov.	Low	28	26	25	28	44	45	52	47	42	43	48	48	52	53	54	51	51	42	38	34	40	50	52	53	43	44	47	55	53	52	—
1995	Dec.	High	53	51	53	48	44	42	47	40	36	58	55	61	50	50	47	49	44	43	47	47	48	49	47	45	43	40	40	49	55	58	55
1995	Dec.	Low	45	38	37	38	31	29	38	30	30	35	50	48	45	43	35	39	38	39	42	40	30	25	25	22	22	24	35	32	48	52	39
1996	Jan.	High	51	57	52	49	50	58	55	56	52	53	41	41	47	53	54	50	46	48	49	46	45	41	44	41	45	43	37	43	40	32	34
1996	Jan.	Low	42	46	38	39	43	49	50	47	38	36	36	37	37	45	47	34	32	31	42	41	33	33	37	35	34	35	33	35	23	19	19
1996	Feb.	High	35	35	28	35	55	57	61	62	50	59	59	60	62	61	64	55	57	58	56	56	44	47	41	45	38	41	46	50	56	—	—
1996	Feb.	Low	17	15	17	27	32	48	52	50	37	34	33	31	31	30	31	36	47	46	44	39	35	34	35	33	29	24	24	32	30	—	—
1996	Mar.	High	57	57	59	49	62	59	54	60	58	61	54	54	61	67	57	59	61	69	56	58	55	50	55	49	55	62	48	58	53	56	54
1996	Mar.	Low	27	27	44	38	42	45	46	45	46	49	45	45	40	36	39	31	39	34	36	34	33	37	39	35	27	25	31	30	35	36	45
1996	Apr.	High	62	54	61	68	73	76	78	72	62	55	52	52	62	71	65	54	53	53	52	53	56	58	61	59	61	58	59	68	70	68	—
1996	Apr.	Low	48	42	34	35	42	46	49	50	48	44	44	42	41	38	48	40	37	39	40	41	41	49	50	45	39	37	38	33	44	41	—
1996	May.	High	62	55	52	60	65	64	57	59	60	62	65	66	64	65	65	66	62	62	62	64	56	59	59	72	78	67	63	60	60	63	70
1996	May.	Low	46	36	36	32	36	36	35	31	34	42	46	52	55	54	52	47	51	48	44	40	48	45	47	44	46	49	39	46	47	45	41
1996	Jun.	High	80	87	78	69	77	84	73	72	68	74	71	79	73	75	72	68	62	68	80	76	69	71	69	65	73	78	69	68	77	82	—
1996	Jun.	Low	50	53	51	50	50	48	52	49	49	43	47	43	47	45	43	45	42	45	47	46	47	47	53	52	51	47	56	53	46	48	—
1996	Jul.	High	86	83	79	72	77	86	94	86	76	82	90	96	99	98	85	78	59	67	73	76	82	96	98	95	95	95	92	80	91	85	83
1996	Jul.	Low	51	56	54	52	42	52	54	56	55	49	53	57	60	62	56	50	54	52	55	52	58	59	62	62	56	59	60	62	59	58	52
1996	Aug.	High	79	71	74	73	73	81	94	95	97	99	75	87	92	90	85	82	74	70	77	76	83	92	95	94	81	72	73	83	91	80	77
1996	Aug.	Low	49	55	54	52	55	47	53	57	55	58	51	54	56	54	49	52	46	45	45	54	49	51	52	58	61	60	55	50	54	56	50
1996	Sep.	High	78	73	75	66	69	74	81	81	78	85	82	66	66	61	66	64	66	66	68	66	65	64	73	72	74	79	82	82	78	70	—
1996	Sep.	Low	47	46	48	46	45	45	48	50	55	48	53	54	56	56	50	50	48	43	51	45	41	42	41	41	39	45	46	49	47	52	—
1996	Oct.	High	72	72	76	74	65	70	78	80	81	67	65	61	62	57	58	53	58	53	51	55	54	55	56	59	56	50	56	50	53	62	58
1996	Oct.	Low	49	46	51	57	49	46	48	54	51	54	54	49	46	47	41	37	32	41	38	36	33	43	41	45	38	33	33	37	37	34	33
1996	Nov.	High	58	56	57	51	52	53	53	59	49	50	58	62	56	53	52	50	53	46	46	51	40	43	40	57	53	45	56	52	48	54	—
1996	Nov.	Low	30	32	43	36	34	37	39	38	36	40	41	50	45	44	42	44	45	34	35	34	37	27	27	39	39	40	45	40	40	45	—
1996	Dec.	High	48	44	55	54	47	44	51	48	50	52	46	49	51	41	40	43	47	41	46	50	42	44	47	51	53	53	49	38	56	54	65
1996	Dec.	Low	37	37	30	35	40	40	41	43	39	41	39	42	35	29	34	33	31	27	23	38	39	32	38	46	36	34	37	29	33	46	49
1997	Jan.	High	58	56	49	39	42	43	49	48	51	55	47	40	39	40	42	38	43	49	49	51	46	48	46	45	39	43	38	49	53	56	57
1997	Jan.	Low	52	43	35	30	36	37	36	37	41	41	38	27	19	19	19	29	35	38	41	43	38	31	32	34	34	29	28	35	35	49	48
1997	Feb.	High	50	49	45	50	49	44	39	44	45	50	47	50	49	60	54	57	55	52	52	52	51	57	59	63	52	49	46	49	—	—	—
1997	Feb.	Low	43	32	32	33	27	24	35	32	28	28	29	38	38	48	33	37	39	39	39	36	33	27	28	31	34	41	32	34	—	—	—
1997	Mar.	High	48	44	45	48	46	52	51	51	55	47	49	48	51	51	57	53	60	61	59	59	60	62	59	65	72	58	54	55	58	58	49
1997	Mar.	Low	41	37	34	35	35	45	38	29	47	40	39	36	34	36	41	48	45	46	53	39	32	38	44	36	39	36	32	32	30	37	37
1997	Apr.	High	53	59	54	56	62	62	55	56	53	56	61	58	53	57	73	66	63	56	60	60	56	61	59	59	71	71	59	54	61	57	—
1997	Apr.	Low	33	29	35	29	30	29	45	35	30	37	32	30	47	49	47	42	37	48	53	47	37	48	42	40	40	46	38	47	44	39	—
1997	May.	High	58	66	58	67	69	63	73	77	76	83	91	81	83	79	78	82	81	82	80	68	71	67	64	63	62	74	75	69	77	77	68
1997	May.	Low	38	35	49	49	50	45	40	42	45	49	51	50	46	54	57	51	50	45	45	41	42	42	46	42	41	41	60	60	62	61	52
1997	Jun.	High	66	75	68	65	69	74	69	72	80	79	65	67	74	75	82	82	71	72	71	75	63	65	67	73	74	72	73	69	74	71	—
1997	Jun.	Low	49	45	54	48	44	45	52	48	46	50	49	51	47	48	52	54	59	54	45	44	52	50	52	44	49	48	48	52	49	52	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1997	Jul.	High	71	78	88	90	79	79	80	75	69	70	74	77	83	85	80	83	75	79	88	88	75	80	83	83	81	84	89	87	80	81	81
1997	Jul.	Low	53	47	53	57	57	58	49	58	51	52	55	49	52	56	55	55	56	54	51	57	53	51	52	51	52	49	53	55	55	57	51
1997	Aug.	High	85	83	87	88	91	91	87	81	91	92	91	96	91	94	76	92	78	75	87	70	82	83	82	77	80	74	77	77	79	80	80
1997	Aug.	Low	50	52	54	55	59	62	54	52	54	56	53	55	58	56	53	54	59	56	54	61	61	55	55	59	60	56	56	58	57	51	54
1997	Sep.	High	80	83	81	80	75	77	82	93	82	74	71	72	65	73	61	64	68	68	76	81	82	81	86	88	79	65	69	74	75	66	—
1997	Sep.	Low	61	54	58	57	55	47	46	51	57	60	57	51	49	57	54	56	55	48	46	45	45	49	50	54	54	54	50	46	53	56	—
1997	Oct.	High	62	66	63	62	61	60	59	58	54	55	57	58	60	65	69	66	64	57	59	63	60	59	58	54	57	56	58	54	59	62	62
1997	Oct.	Low	52	53	54	54	46	44	40	50	47	46	40	49	42	39	44	45	50	46	42	35	34	36	42	35	34	36	41	42	51	53	44
1997	Nov.	High	61	57	62	61	63	61	55	47	62	60	55	58	52	58	57	53	55	49	51	54	56	49	56	53	56	54	54	57	50	50	—
1997	Nov.	Low	39	36	39	49	51	50	40	37	33	40	41	38	33	37	31	35	43	36	48	46	43	44	47	45	38	34	36	47	41	37	—
1997	Dec.	High	49	54	49	50	47	46	45	45	45	51	39	39	37	49	49	54	51	37	47	47	47	34	45	41	38	45	49	52	47	45	50
1997	Dec.	Low	33	26	27	34	32	28	32	32	36	32	32	30	29	33	35	46	35	29	30	32	29	26	33	38	35	34	41	37	39	34	37
1998	Jan.	High	50	44	43	47	46	47	49	38	38	39	38	45	51	51	52	56	55	53	47	51	48	51	55	50	53	53	55	54	56	57	57
1998	Jan.	Low	40	28	34	36	41	43	29	28	27	35	30	26	44	44	39	43	48	44	43	38	37	44	46	45	41	47	43	42	43	37	31
1998	Feb.	High	53	55	53	56	56	67	52	50	50	49	52	54	55	53	53	51	56	57	51	48	48	50	52	50	49	50	49	54	—	—	—
1998	Feb.	Low	34	36	43	38	40	46	33	40	35	39	44	43	41	42	42	32	40	44	44	44	41	33	31	29	36	31	29	43	—	—	—
1998	Mar.	High	53	51	47	50	54	52	51	51	53	51	68	59	63	65	57	57	56	63	66	68	55	61	60	60	59	52	46	50	58	50	52
1998	Mar.	Low	47	39	36	32	28	27	26	41	38	33	47	48	49	44	48	36	31	35	33	39	43	51	44	47	40	39	34	31	30	36	40
1998	Apr.	High	54	56	48	55	56	58	51	57	58	56	55	54	55	55	58	59	63	59	59	71	71	70	57	58	57	67	74	79	83	82	—
1998	Apr.	Low	40	43	43	41	36	41	34	33	42	41	37	39	35	37	38	32	33	45	36	35	38	48	46	38	37	36	42	44	50	51	—
1998	May.	High	84	68	70	69	69	71	67	54	52	55	57	51	53	57	56	50	61	66	62	55	60	60	65	60	58	60	65	76	60	65	78
1998	May.	Low	52	51	52	54	52	52	50	45	43	48	47	46	47	45	42	45	42	42	49	48	44	44	52	45	42	38	40	42	52	51	47
1998	Jun.	High	74	68	74	64	72	80	76	73	77	65	70	75	71	73	67	68	75	62	71	80	83	71	73	68	64	68	75	83	82	67	—
1998	Jun.	Low	49	48	46	54	51	51	50	50	51	53	52	52	51	49	51	50	45	44	51	49	52	50	53	53	52	52	47	50	50	52	—
1998	Jul.	High	67	74	66	70	77	85	78	82	85	75	77	77	80	84	86	95	91	84	79	85	91	94	87	84	86	100	101	99	82	79	73
1998	Jul.	Low	55	56	56	57	58	56	59	53	56	55	49	54	54	55	53	57	54	55	58	53	54	57	56	57	56	62	65	60	56	57	60
1998	Aug.	High	78	90	93	94	86	81	80	86	84	86	90	93	96	91	74	75	76	75	81	81	76	80	71	78	80	77	87	92	88	88	96
1998	Aug.	Low	57	52	53	61	59	57	49	53	51	50	61	58	60	60	60	57	50	50	49	51	55	52	56	48	47	51	54	54	50	56	54
1998	Sep.	High	96	92	93	89	86	88	86	71	72	76	84	86	83	85	88	81	77	69	69	69	80	75	80	67	65	73	82	77	68	77	—
1998	Sep.	Low	58	56	58	56	50	44	53	53	44	43	50	52	49	56	52	48	49	57	51	47	48	48	47	44	45	44	49	46	45	42	—
1998	Oct.	High	63	58	61	66	69	74	76	64	55	61	62	60	64	62	59	55	59	60	69	75	75	73	51	63	63	64	59	57	43	49	51
1998	Oct.	Low	51	50	50	46	41	43	48	52	46	43	42	52	49	45	41	36	38	41	37	38	38	40	40	46	46	42	45	36	34	35	35
1998	Nov.	High	57	59	54	59	55	52	46	50	53	49	48	53	56	58	61	48	57	55	51	56	56	49	55	51	64	52	52	44	48	47	—
1998	Nov.	Low	49	43	44	48	44	41	40	35	33	43	44	42	50	45	47	42	40	40	39	50	43	42	40	43	50	44	35	32	39	40	—
1998	Dec.	High	50	51	45	45	41	42	45	45	46	48	52	61	56	49	49	46	46	41	35	25	22	30	26	43	52	47	52	55	58	53	
1998	Dec.	Low	44	38	34	33	35	34	40	32	28	38	48	50	43	32	32	28	33	28	23	14	12	15	12	26	42	39	43	49	51	51	39
1999	Jan.	High	47	45	50	45	40	46	50	39	49	57	48	49	49	52	52	48	54	50	51	48	50	45	46	40	37	42	44	48	56	46	49
1999	Jan.	Low	31	30	26	26	27	30	32	31	34	32	31	37	38	47	43	40	42	46	44	44	44	36	37	28	30	32	35	43	43	40	37
1999	Feb.	High	49	50	49	48	46	50	46	41	43	43	47	54	50	50	54	48	50	49	52	52	47	50	53	53	46	49	55	56	—	—	—
1999	Feb.	Low	37	35	34	34	32	44	36	34	33	33	33	33	39	31	34	43	39	40	31	27	40	44	46	44	37	35	44	40	—	—	—
1999	Mar.	High	49	48	46	46	45	50	50	51	48	54	57	50	58	50	52	52	54	57	69	59	61	61	62	53	52	49	50	47	48	46	50
1999	Mar.	Low	35	34	36	34	33	27	31	38	33	33	27	43	44	42	36	31	38	45	36	45	44	42	36	43	42	38	34	36	38	36	34

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1999	Apr.	High	56	56	50	48	56	59	54	51	49	55	68	55	58	70	81	80	71	61	57	57	52	62	75	79	57	54	50	58	69	68	—
1999	Apr.	Low	29	32	35	37	37	31	37	35	34	41	36	44	42	35	38	41	50	46	42	41	41	40	40	41	44	34	37	33	35	36	—
1999	May.	High	55	52	55	55	65	63	51	53	56	59	62	57	54	57	60	64	65	61	63	61	67	79	89	76	68	76	77	69	72	76	71
1999	May.	Low	45	44	42	38	37	40	36	34	35	40	48	43	41	43	43	42	48	46	42	43	43	44	49	50	46	40	45	46	40	38	48
1999	Jun.	High	59	65	69	65	64	59	55	61	67	75	83	83	85	85	69	77	76	72	72	68	68	73	82	66	65	63	68	71	82	76	—
1999	Jun.	Low	46	41	40	47	45	42	42	45	40	41	47	56	56	55	55	53	50	51	54	49	54	55	50	48	50	49	49	47	55	57	—
1999	Jul.	High	69	62	66	70	85	68	70	83	91	90	91	89	85	72	80	70	74	83	92	84	75	87	88	74	78	88	90	89	82	83	84
1999	Jul.	Low	52	51	45	51	47	54	51	48	49	52	51	55	52	49	48	49	53	50	54	53	58	54	56	54	56	49	52	56	51	51	53
1999	Aug.	High	78	89	88	86	77	70	66	78	88	89	67	79	74	70	78	88	90	78	80	83	81	89	87	89	85	89	88	84	65	67	67
1999	Aug.	Low	52	51	56	56	61	60	58	58	54	57	56	53	56	55	50	53	57	56	59	53	56	53	54	57	57	57	59	61	57	51	48
1999	Sep.	High	77	81	84	84	78	74	81	89	77	76	87	95	94	88	75	71	75	92	92	91	89	88	73	71	69	65	66	78	80	68	—
1999	Sep.	Low	42	46	46	49	50	53	46	47	46	42	47	48	48	47	48	47	52	49	49	53	49	51	49	39	44	40	35	37	41	45	—
1999	Oct.	High	76	77	77	65	65	68	70	61	63	68	70	74	73	63	59	69	71	77	77	73	71	71	60	64	58	54	57	59	61	63	58
1999	Oct.	Low	38	40	40	38	53	51	53	50	43	39	43	42	46	38	31	32	39	39	43	37	37	37	37	44	42	34	38	45	44	38	39
1999	Nov.	High	63	58	57	54	52	64	54	57	57	58	65	65	70	54	62	54	56	45	53	54	50	48	48	53	57	56	52	49	52	55	—
1999	Nov.	Low	35	34	36	34	37	47	45	48	47	50	50	60	49	46	51	47	37	35	41	43	41	42	43	46	53	41	39	33	37	42	—
1999	Dec.	High	49	50	50	45	50	50	46	47	47	46	53	51	43	47	53	54	56	53	50	48	53	56	50	48	50	51	50	45	42	42	43
1999	Dec.	Low	42	38	33	34	43	42	39	40	41	41	45	37	36	41	46	50	48	44	37	34	35	28	28	25	27	32	27	24	23	27	32
2000	Jan.	High	47	43	48	51	48	45	52	51	48	42	42	41	44	50	39	48	47	41	42	48	54	51	43	40	49	48	43	51	48	43	52
2000	Jan.	Low	39	38	40	41	29	28	44	43	40	36	33	33	38	31	28	37	29	27	26	37	42	32	29	34	35	35	30	24	25	31	35
2000	Feb.	High	55	49	61	54	50	51	51	53	50	51	46	47	43	48	52	57	50	44	50	51	53	50	51	51	46	51	55	49	52	—	—
2000	Feb.	Low	46	40	33	39	39	41	38	35	30	28	41	33	34	40	35	33	27	31	33	30	41	41	31	30	36	41	39	42	34	—	—
2000	Mar.	High	49	56	50	46	46	51	49	52	56	53	54	59	57	55	51	53	50	50	49	53	63	53	53	58	54	62	52	49	54	64	69
2000	Mar.	Low	32	38	35	34	29	32	30	34	33	35	35	32	38	34	30	38	37	40	35	37	39	39	36	31	35	32	39	37	31	31	34
2000	Apr.	High	74	68	76	55	55	56	68	65	56	67	72	74	57	59	57	58	69	62	60	69	66	55	53	53	58	68	61	55	62	69	—
2000	Apr.	Low	40	40	41	38	33	39	34	40	40	35	38	51	48	48	47	47	45	40	42	42	40	38	32	30	38	38	41	37	34	44	—
2000	May.	High	66	64	59	58	57	62	64	63	59	49	55	62	66	75	69	68	64	73	71	77	78	74	68	72	65	69	67	64	63	60	62
2000	May.	Low	46	49	47	45	39	33	39	50	43	41	42	38	50	48	51	48	41	45	50	48	47	53	51	48	46	51	50	52	49	46	47
2000	Jun.	High	78	77	84	82	70	65	66	64	65	59	58	67	78	83	73	83	88	73	72	81	81	75	75	78	87	92	99	94	88	76	—
2000	Jun.	Low	42	47	45	50	50	53	55	51	44	45	49	53	51	52	50	46	54	52	52	48	53	49	46	48	50	55	52	60	51	50	—
2000	Jul.	High	71	68	66	67	76	76	83	72	75	78	75	82	75	76	85	92	81	75	82	87	87	73	81	87	78	78	86	84	89	94	89
2000	Jul.	Low	52	46	47	49	53	53	49	51	57	54	53	46	48	56	48	51	55	55	47	53	58	56	49	51	50	56	52	55	55	59	57
2000	Aug.	High	84	85	86	89	90	88	85	90	84	72	75	78	77	76	75	80	78	68	73	77	83	90	89	75	78	75	74	82	82	77	69
2000	Aug.	Low	60	50	53	53	53	54	56	53	55	57	55	47	46	52	46	46	45	49	48	45	48	55	53	52	51	50	45	46	49	59	50
2000	Sep.	High	70	64	67	70	72	74	76	65	71	68	80	85	89	84	74	75	78	83	78	80	73	68	74	78	77	81	79	71	77	73	—
2000	Sep.	Low	49	51	46	43	47	50	45	48	44	55	58	54	53	58	55	53	49	57	60	52	56	37	32	35	40	40	44	46	57	62	—
2000	Oct.	High	65	64	66	69	78	80	77	73	59	54	60	57	60	62	61	70	71	66	63	61	58	58	67	65	61	56	58	58	61	58	59
2000	Oct.	Low	52	40	38	42	41	40	40	42	49	48	49	50	52	39	35	51	45	46	42	46	37	36	32	34	46	45	50	44	40	35	38
2000	Nov.	High	50	56	58	58	53	56	48	53	49	49	45	47	48	48	51	47	49	44	40	50	50	46	51	51	49	52	53	48	53	55	—
2000	Nov.	Low	44	48	46	39	43	35	35	42	36	29	25	23	32	26	29	23	22	20	21	30	26	22	27	35	39	42	29	28	38	35	—
2000	Dec.	High	49	50	46	49	51	46	41	41	49	47	38	37	40	50	48	57	49	45	44	45	51	51	49	51	46	47	51	48	43	47	56
2000	Dec.	Low	31	43	33	31	28	26	25	25	34	34	31	31	32	34	41	40	27	27	36	40	32	45	42	34	32	36	37	32	28	41	42

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2001	Jan.	High	45	49	50	57	57	50	50	48	46	50	52	50	45	48	42	43	40	46	52	44	52	54	47	47	42	53	50	49	50	49	46
2001	Jan.	Low	37	34	29	37	38	33	31	36	28	30	36	40	38	39	27	22	22	33	37	30	38	37	38	36	30	28	25	23	35	38	27
2001	Feb.	High	52	53	49	61	48	46	43	39	50	40	48	50	53	56	49	54	48	55	58	55	57	50	52	55	55	58	61	54	—	—	—
2001	Feb.	Low	31	40	37	47	33	31	22	29	33	28	33	26	24	27	40	37	36	35	32	30	41	35	32	29	27	27	26	23	—	—	—
2001	Mar.	High	48	51	49	50	65	72	71	52	51	51	51	61	57	55	50	45	53	62	55	61	62	65	68	61	56	54	51	54	59	60	55
2001	Mar.	Low	31	31	30	31	35	36	36	43	32	31	39	36	42	38	36	35	40	50	37	31	32	29	31	40	43	41	38	43	38	41	43
2001	Apr.	High	50	48	53	58	57	47	53	50	54	49	59	51	51	54	62	65	60	60	56	56	62	53	61	75	80	72	59	57	57	59	—
2001	Apr.	Low	40	34	34	28	30	33	31	35	31	42	39	38	31	31	31	40	41	46	44	43	36	37	47	43	46	44	41	41	44	42	—
2001	May.	High	57	60	71	69	59	69	78	71	68	70	81	73	68	55	59	63	59	64	71	71	85	93	86	80	82	82	69	59	66	78	91
2001	May.	Low	40	36	37	44	37	37	38	46	38	37	44	48	50	49	48	46	42	43	41	43	45	53	50	49	46	47	44	38	35	44	50
2001	Jun.	High	60	61	63	63	62	71	79	79	67	67	58	65	72	70	69	69	69	74	84	87	85	71	69	60	71	67	72	69	74	73	—
2001	Jun.	Low	43	48	47	39	47	49	46	54	53	50	47	43	38	41	48	47	45	44	45	50	48	55	49	43	40	50	58	52	49	46	—
2001	Jul.	High	78	85	91	85	76	78	83	87	90	84	86	86	81	78	69	68	72	74	77	69	78	82	84	83	85	83	80	76	63	72	75
2001	Jul.	Low	47	48	51	53	50	45	49	48	53	58	56	59	50	50	52	54	54	57	57	56	55	54	52	58	50	48	51	58	56	54	53
2001	Aug.	High	82	82	76	73	84	85	84	90	96	90	90	94	87	81	83	72	81	75	78	78	72	66	71	76	83	85	83	84	81	84	80
2001	Aug.	Low	50	54	55	53	49	53	58	53	57	54	51	53	53	55	53	54	49	57	48	49	50	59	55	47	50	49	49	55	55	54	56
2001	Sep.	High	77	78	76	76	68	70	76	87	86	83	86	87	84	80	82	79	75	70	72	78	77	84	84	81	60	65	64	71	77	87	—
2001	Sep.	Low	56	52	49	54	44	43	48	50	50	49	51	57	55	52	63	54	51	50	53	43	45	48	60	47	54	45	44	40	42	45	—
2001	Oct.	High	83	78	75	86	74	68	62	64	63	56	63	68	67	69	72	62	58	62	68	59	53	59	54	57	65	66	53	46	47	56	55
2001	Oct.	Low	46	48	45	43	43	46	42	43	37	39	40	41	50	47	42	40	35	35	36	35	34	48	37	37	45	41	40	38	42	46	49
2001	Nov.	High	56	62	57	59	56	55	54	56	57	57	54	52	58	68	64	52	51	52	57	58	53	53	51	45	50	48	41	52	48	48	—
2001	Nov.	Low	50	47	50	51	40	38	30	28	29	35	35	34	49	58	51	39	38	33	44	49	46	43	40	41	41	40	33	36	40	43	—
2001	Dec.	High	50	47	48	42	49	54	49	50	48	49	47	49	52	45	49	56	46	46	45	46	45	47	48	46	46	42	42	46	40	46	45
2001	Dec.	Low	44	38	39	37	32	42	38	38	34	36	36	41	44	34	38	45	34	40	32	41	32	29	27	22	26	29	37	31	30	29	37
2002	Jan.	High	44	56	54	43	52	60	60	54	47	49	47	51	42	43	44	38	42	45	47	47	41	41	44	47	47	41	36	40	39	42	43
2002	Jan.	Low	38	38	38	34	38	47	54	40	41	36	37	30	30	30	28	28	35	38	40	38	34	35	35	43	38	33	32	28	30	35	39
2002	Feb.	High	46	47	51	45	50	51	45	51	50	56	47	52	51	57	62	52	50	56	53	59	64	65	55	48	54	53	55	52	—	—	—
2002	Feb.	Low	34	31	30	30	30	40	34	33	29	31	29	28	24	30	28	35	30	44	38	40	52	46	43	35	31	32	28	28	—	—	—
2002	Mar.	High	52	57	60	62	48	48	44	44	49	51	53	50	46	47	44	45	46	43	53	58	54	52	60	54	61	55	54	55	57	59	59
2002	Mar.	Low	23	26	32	35	43	37	27	33	30	43	43	40	38	36	31	33	29	29	42	41	39	36	35	36	30	34	34	42	37	41	37
2002	Apr.	High	62	66	69	73	54	59	56	67	57	61	63	65	62	56	50	52	49	57	57	58	57	61	59	70	67	52	59	66	75	59	—
2002	Apr.	Low	38	38	35	38	46	47	37	33	50	51	50	50	54	40	39	38	39	38	36	40	35	40	31	37	36	35	38	33	42	42	—
2002	May.	High	66	55	59	62	56	51	57	63	58	63	70	82	56	65	66	71	65	64	59	63	61	61	65	74	73	74	71	67	67	73	70
2002	May.	Low	48	39	39	33	40	38	36	31	42	36	35	41	43	41	37	38	47	48	48	44	43	45	37	42	52	54	57	57	55	51	44
2002	Jun.	High	72	71	73	74	72	66	64	59	69	76	84	93	89	76	71	66	62	63	72	83	84	67	76	82	90	90	73	63	71	71	—
2002	Jun.	Low	48	42	46	56	51	45	42	44	43	43	48	53	56	50	47	52	52	52	43	49	51	53	48	53	54	58	56	55	54	53	—
2002	Jul.	High	74	79	72	71	81	84	75	78	94	97	92	92	87	79	85	86	84	80	77	86	92	94	86	85	84	80	79	87	87	80	79
2002	Jul.	Low	54	50	48	48	49	52	57	57	55	59	58	59	58	53	49	53	53	53	61	53	53	58	60	56	53	58	48	54	58	54	49
2002	Aug.	High	84	75	55	71	71	75	79	83	89	85	86	96	104	96	89	85	87	80	79	72	69	80	87	86	74	76	87	97	81	75	83
2002	Aug.	Low	51	50	54	51	48	48	46	49	53	59	50	56	63	58	51	49	52	51	49	53	48	49	53	52	55	57	53	62	57	48	49
2002	Sep.	High	82	85	73	74	73	72	71	72	82	84	87	88	89	78	69	67	64	74	78	75	82	86	89	82	85	80	76	79	64	62	—
2002	Sep.	Low	56	56	54	44	43	43	46	42	45	49	53	52	52	50	55	54	49	47	46	49	46	48	47	48	49	47	51	50	51	46	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2002	Oct.	High	61	66	56	65	63	65	69	68	66	64	59	72	69	77	81	83	76	64	69	64	61	64	70	58	58	58	52	59	58	52	56
2002	Oct.	Low	39	35	48	54	53	48	45	46	45	39	33	32	32	37	38	42	40	44	53	51	48	43	37	35	35	32	32	39	30	22	20
2002	Nov.	High	58	55	57	61	60	53	61	55	51	54	56	60	57	58	50	56	58	52	63	63	53	52	52	52	53	51	58	54	53	55	—
2002	Nov.	Low	22	20	25	27	36	35	42	47	46	45	46	47	47	46	37	35	41	41	46	43	42	47	48	33	27	26	28	29	29	28	—
2002	Dec.	High	43	52	41	43	51	50	48	41	46	50	55	60	55	60	54	51	47	47	46	47	49	46	42	48	53	47	54	45	47	48	52
2002	Dec.	Low	29	31	33	37	32	31	27	26	30	43	45	47	43	47	45	39	38	37	36	33	39	39	31	34	40	40	42	41	34	44	43
2003	Jan.	High	53	57	53	58	47	55	50	48	45	49	41	51	50	49	44	52	54	50	48	44	51	54	61	56	60	61	56	48	51	59	60
2003	Jan.	Low	43	49	47	37	31	28	28	24	26	36	35	41	40	31	32	29	36	32	26	32	36	42	39	48	52	45	42	41	45	50	47
2003	Feb.	High	50	52	50	47	52	58	52	53	55	51	59	59	54	59	56	51	50	54	51	49	56	54	54	48	53	50	54	45	—	—	—
2003	Feb.	Low	42	38	33	31	27	28	26	27	26	31	27	27	41	42	41	44	43	40	43	44	43	34	30	31	28	26	36	36	—	—	—
2003	Mar.	High	57	49	50	49	52	50	52	56	58	59	58	61	61	61	57	56	55	60	51	58	54	54	51	53	57	55	53	60	69	74	59
2003	Mar.	Low	36	31	36	37	45	45	46	45	47	46	48	51	50	48	45	37	33	38	40	46	45	43	37	29	45	38	39	38	40	42	43
2003	Apr.	High	53	50	48	51	47	55	62	68	61	59	65	62	59	56	57	60	57	56	64	61	53	58	54	53	54	57	65	59	64	64	—
2003	Apr.	Low	40	37	37	39	38	39	43	42	44	49	48	46	40	40	43	43	42	40	35	44	46	42	43	40	34	38	35	48	39	44	—
2003	May.	High	69	72	56	57	58	59	55	56	61	61	66	65	75	63	57	54	56	60	73	68	76	77	85	71	63	68	84	78	82	62	73
2003	May.	Low	39	41	41	46	41	39	41	43	47	47	44	50	43	44	41	41	37	34	37	45	47	51	52	54	52	50	45	56	52	51	47
2003	Jun.	High	75	74	81	90	96	96	89	78	68	70	74	66	65	72	77	84	84	70	66	65	66	66	63	75	84	91	90	97	86	75	—
2003	Jun.	Low	46	49	50	53	50	54	52	49	47	50	49	47	52	49	47	47	52	51	50	52	50	43	49	50	46	53	57	52	59	55	—
2003	Jul.	High	73	77	79	81	79	82	84	76	88	87	87	85	79	85	82	79	86	91	93	91	95	94	87	83	83	84	93	99	101	99	91
2003	Jul.	Low	53	48	46	51	54	55	50	56	51	54	51	54	55	51	54	59	53	52	53	56	65	63	57	54	49	51	55	58	57	58	58
2003	Aug.	High	86	74	80	87	73	80	81	81	81	82	79	80	84	92	78	81	88	90	83	84	90	69	77	85	90	78	76	84	87	92	87
2003	Aug.	Low	57	63	58	54	55	49	59	59	60	57	54	56	51	58	58	54	58	58	56	51	52	55	52	48	52	55	57	50	51	54	53
2003	Sep.	High	84	90	93	96	93	73	71	68	66	69	74	72	82	78	69	64	68	75	71	74	79	88	81	86	85	88	98	83	66	75	—
2003	Sep.	Low	46	52	57	56	55	56	54	51	53	58	58	50	48	46	43	47	46	43	55	45	49	50	49	49	50	59	54	50	52	48	—
2003	Oct.	High	77	65	70	64	67	74	68	61	63	60	55	62	61	62	60	74	77	70	69	77	80	72	62	64	70	73	74	71	55	51	48
2003	Oct.	Low	51	53	57	52	51	47	50	51	47	45	48	45	43	46	46	54	52	47	56	59	59	49	41	41	42	43	42	50	42	35	29
2003	Nov.	High	45	39	48	47	49	56	53	54	54	55	61	56	55	56	52	53	53	59	58	45	41	39	45	49	49	50	45	59	53	49	—
2003	Nov.	Low	22	32	27	35	29	32	41	38	35	41	36	33	31	47	44	47	46	52	35	34	26	24	34	36	40	35	31	40	49	43	—
2003	Dec.	High	49	56	49	51	56	50	46	50	42	48	49	51	54	46	44	50	49	50	44	53	51	46	45	48	45	43	43	44	39	35	39
2003	Dec.	Low	44	45	35	35	48	36	42	36	39	39	38	45	35	36	36	38	35	30	32	41	40	32	31	41	32	31	36	34	25	20	33
2004	Jan.	High	37	37	38	37	24	29	32	35	39	42	45	40	51	46	53	45	47	53	52	49	42	50	51	50	45	47	50	51	55	51	45
2004	Jan.	Low	30	33	33	24	19	19	28	32	32	34	30	29	34	42	40	42	41	40	40	30	27	33	45	36	36	41	42	46	51	37	36
2004	Feb.	High	43	49	48	50	46	49	50	48	46	53	60	57	43	55	58	50	51	55	52	57	56	56	57	50	53	50	51	51	48	—	—
2004	Feb.	Low	33	41	36	37	33	39	34	31	32	26	28	27	27	39	38	43	40	44	35	30	32	38	42	35	35	39	44	39	39	—	—
2004	Mar.	High	57	56	46	52	50	54	69	68	61	58	65	62	61	62	65	69	63	54	55	68	70	70	62	58	52	50	56	68	76	54	54
2004	Mar.	Low	41	31	34	41	41	35	46	42	40	33	44	35	38	42	36	32	41	41	38	32	40	42	37	45	43	41	38	32	38	33	30
2004	Apr.	High	58	70	73	63	56	60	60	66	75	80	81	63	60	57	52	57	58	57	56	49	58	67	60	63	78	84	72	66	76	83	—
2004	Apr.	Low	31	35	40	38	42	42	42	37	36	39	42	41	37	45	41	41	44	38	40	42	41	37	38	36	38	44	48	38	38	43	—
2004	May.	High	78	76	75	64	63	69	67	62	65	59	61	65	70	67	62	67	72	63	66	70	62	64	66	75	79	66	63	60	58	66	67
2004	May.	Low	46	47	47	50	45	37	51	42	43	43	47	43	39	52	49	47	42	53	48	44	51	50	48	43	45	55	52	49	47	49	47
2004	Jun.	High	73	76	81	82	67	62	64	66	61	60	62	67	65	68	77	87	93	89	87	90	88	65	68	73	78	77	80	84	84	84	—
2004	Jun.	Low	41	46	52	48	51	50	50	52	54	52	50	46	53	50	49	45	48	54	49	50	53	53	59	59	57	54	52	50	49	52	—

Appendix C1. Average Temperature Data for Willamette Valley by Month 1980-Present

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2004	Jul.	High	81	79	78	78	84	83	74	74	74	73	82	92	85	87	84	87	85	89	80	82	88	99	104	99	87	85	90	91	90	83	86
2004	Jul.	Low	51	50	56	51	53	53	53	46	52	52	48	58	57	56	53	55	58	57	60	62	56	59	60	62	58	53	54	56	56	57	53
2004	Aug.	High	87	82	82	76	77	74	80	96	99	94	96	92	91	90	85	87	89	90	91	91	85	72	69	70	70	74	77	79	84	90	91
2004	Aug.	Low	54	52	52	60	55	56	51	53	56	54	58	58	55	60	55	55	55	58	58	55	57	56	55	61	59	59	56	53	57	57	56
2004	Sep.	High	74	67	73	73	76	80	80	78	71	80	71	68	71	72	70	69	64	56	62	67	69	71	75	75	68	72	81	79	65	68	—
2004	Sep.	Low	51	51	51	54	49	47	50	49	52	48	57	55	55	49	54	49	50	48	46	42	41	43	47	48	47	56	51	49	52	49	—
2004	Oct.	High	76	77	76	77	75	72	71	67	61	62	68	71	79	77	65	63	58	54	61	59	60	55	54	56	54	56	54	54	57	57	54
2004	Oct.	Low	41	43	44	42	46	58	53	51	45	42	41	45	48	48	48	48	49	47	49	48	40	46	40	40	36	41	39	41	44	43	37
2004	Nov.	High	56	59	50	56	55	49	52	46	50	53	53	49	49	54	54	56	50	54	50	44	44	48	52	59	56	46	51	38	39	48	—
2004	Nov.	Low	42	43	37	32	27	30	34	34	44	38	37	44	46	41	44	41	41	40	33	28	26	35	41	52	36	35	31	26	32	38	—
2004	Dec.	High	49	37	40	46	47	47	49	51	58	59	56	54	51	56	45	43	48	52	50	48	43	48	43	37	49	46	54	47	47	48	47
2004	Dec.	Low	32	32	35	36	36	39	40	46	48	54	44	42	37	40	34	38	38	33	32	29	29	41	36	34	34	35	35	30	36	32	31
2005	Jan.	High	44	46	44	44	39	45	43	43	43	44	40	45	44	40	32	40	59	64	63	60	56	55	52	48	47	51	54	52	50	54	57
2005	Jan.	Low	31	30	29	28	20	32	37	36	35	30	23	37	35	27	29	31	38	57	46	42	41	39	36	35	39	40	43	41	41	34	33
2005	Feb.	High	48	42	43	50	47	45	47	38	44	53	49	49	49	47	51	56	57	57	56	55	59	64	66	63	48	52	63	54	—	—	—
2005	Feb.	Low	34	32	29	33	33	35	31	30	28	29	24	34	29	27	22	28	22	29	32	36	32	30	26	29	35	38	33	44	—	—	—
2005	Mar.	High	63	57	61	60	59	66	70	72	72	71	73	70	69	68	67	55	55	56	62	57	51	50	49	48	53	53	52	51	52	53	63
2005	Mar.	Low	36	36	34	38	31	33	40	39	37	38	38	42	33	29	30	38	30	37	44	39	36	38	41	38	37	45	42	42	40	38	38
2005	Apr.	High	57	56	50	54	61	64	55	58	55	56	54	49	55	55	56	57	51	57	65	67	66	76	57	65	63	70	72	65	57	66	—
2005	Apr.	Low	43	39	40	38	42	43	37	38	33	36	39	36	36	35	40	38	38	37	34	35	40	43	48	43	50	48	45	52	51	46	—
2005	May.	High	69	69	74	70	62	61	62	65	57	58	60	70	72	75	65	60	59	65	65	62	60	63	65	72	86	91	90	68	62	74	63
2005	May.	Low	40	49	45	52	52	50	50	50	48	49	42	42	53	56	54	48	48	50	49	44	40	45	41	38	47	52	53	53	51	54	50
2005	Jun.	High	63	66	69	65	58	57	59	71	76	67	64	67	70	65	71	68	68	72	80	78	70	71	75	79	77	66	63	69	79	83	—
2005	Jun.	Low	49	52	50	42	47	47	49	45	44	47	51	47	54	51	44	53	48	47	46	49	55	55	49	47	57	53	54	56	54	54	—
2005	Jul.	High	78	72	79	83	82	74	74	66	71	70	76	76	75	86	86	79	94	95	86	86	90	80	84	80	84	96	98	90	90	92	92
2005	Jul.	Low	54	55	48	50	52	58	54	54	55	55	62	59	58	53	53	53	56	61	55	53	56	59	54	52	49	59	59	56	53	56	54
2005	Aug.	High	77	83	94	97	94	88	86	88	87	80	82	94	96	92	81	78	83	89	88	84	81	75	86	92	87	87	82	70	76	82	
2005	Aug.	Low	58	51	50	54	55	58	55	52	53	55	53	52	55	55	56	52	57	53	53	51	52	55	52	47	48	50	49	51	51	50	52
2005	Sep.	High	88	78	78	75	77	80	87	86	65	69	71	76	77	71	60	68	74	76	73	75	69	71	69	75	78	73	78	79	69	—	
2005	Sep.	Low	51	53	53	52	46	48	51	52	49	47	47	47	46	47	53	49	46	41	42	47	44	39	40	37	37	41	47	41	45	55	—
2005	Oct.	High	61	55	59	61	69	69	65	60	67	64	66	63	63	70	60	65	70	66	62	66	68	66	61	65	64	59	52	57	54	57	59
2005	Oct.	Low	47	42	40	40	50	47	45	40	47	41	44	40	49	50	53	51	44	53	54	49	49	44	48	55	50	38	34	43	40	37	53
2005	Nov.	High	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2005	Nov.	Low	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2005	Dec.	High	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2005	Dec.	Low	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Appendix C2.

Average Temperature in the Willamette Valley and Southwest Washington 1971-2010

	January	February	March	April	May	June	July	August	September	October	November	December
1971-2010	46.5	50.7	55.9	60.6	66.8	73.3	81.5	81.9	76.6	64.6	52.1	45.7

	Average MAX		Average MIN			Average MEAN	
	warmest	coldest	warmest	coldest		warmest	coldest
January	52.0 1953	32.8 1950	42.6 1953	21.0	1949	47.3 1953	27.0 1950
	51.2 1981	34.6 1949	40.8 2006	21.2	1950	45.5 2006	27.8 1949
	50.7 2003	35.4 1979	38.8 2003	25.9	1957	44.7 2003	30.7 1979
	50.5 1992	36.4 1969	38.8 1994	26.0	1979	44.4 1994	31.2 1957
	50.4 1983	36.5 1957	38.5 1995	26.3	1943	44.4 1992	31.9 1969
	Climatic Normal 45.6		Climatic Normal 34.2			Climatic Normal 39.5	
Portland Int'l Airport Data							
February	57.8 1968	40.9 1956	42.6 1958	28.5	1989	48.8 1991	35.8 1956
	57.7 1991	43.5 1989	41.6 1961	30.6	1964	48.6 1958	36.0 1989
	56.2 1992	45.2 1949	41.2 1983	30.8	1956	48.2 1968	38.8 1950
	55.3 1963	45.5 1950	40.4 1998	32.1	1950	48.1 1992	39.1 1949
	55.1 1941	46.9 1969	40.2 1963	32.4	1969	47.8 1963	39.7 1969
	Climatic Normal 50.3		Climatic Normal 35.9			Climatic Normal 43.2	
Portland Int'l Airport Data							
March	63.7 1992	49.2 1955	43.7 1983	33.6	1954	52.3 1992	41.5 1955
	63.5 1941	49.4 1951	43.1 1984	33.8	1955	52.0 1941	41.9 1951
	60.9 1994	51.5 1950	42.5 2007	34.1	1969	51.2 2004	43.7 1971
	60.5 1986	51.8 1956	42.1 2003	34.5	1951	51.2 1986	43.8 1964
	60.5 1979	51.9 1967	42.0 2004	35.4	1971	51.1 1984	43.8 1954
	Climatic Normal 55.7		Climatic Normal 38.6			Climatic Normal 47.4	
Portland Int'l Airport Data							
April	67.3 2004	55.0 1955	46.5 1992	37.4	1964	56.3 2004	46.5 1955
	66.8 1989	55.9 1963	45.3 2004	37.6	1967	56.0 1989	46.7 1964
	66.0 1951	56.0 1964	45.2 1996	37.9	1955	55.4 1992	46.9 1967
	65.8 1941	56.2 1967	45.2 1993	38.0	1975	54.5 1990	47.3 1975
	65.3 1977	56.5 1948	45.2 1989	38.2	1968	54.5 1941	48.0 1972
	Climatic Normal 60.5		Climatic Normal 41.9			Climatic Normal 51.9	
Portland Int'l Airport Data							
May	76.6 1992	61.1 1962	51.8 2005	41.9	1964	63.1 1992	52.6 1964
	73.4 1958	62.3 1991	51.7 2004	42.8	1955	62.2 1997	52.9 1955
	73.3 1947	62.3 1977	51.7 1997	43.2	1950	61.8 1958	53.8 1977
	72.6 1997	62.4 1960	50.9 1993	44.0	1965	61.3 1947	53.9 1962
	71.6 1995	62.7 1998	50.4 1983	44.3	1966	61.1 1993	53.9 1960
	Climatic Normal 66.7		Climatic Normal 47.5			Climatic Normal 57.8	
Portland Int'l Airport Data							
June	79.5 1992	66.2 1954	57.1 1948	49.0	1964	67.4 1992	57.9 1954
	79.3 1987	66.4 1953	56.9 1969	49.7	1965	66.5 1987	58.6 1953
	77.9 1970	67.6 1956	56.8 1958	49.7	1954	66.5 1969	58.7 1964
	77.5 1967	68.3 1991	56.4 2006	49.9	1976	66.5 1948	59.0 1956
	77.4 1986	68.4 1964	55.2 2004	50.4	1956	66.3 2006	59.9 1991
	Climatic Normal 72.7		Climatic Normal 52.6			Climatic Normal 63.2	
Portland Int'l Airport Data							
July	87.5 1985	72.0 1963	61.2 1998	53.1	1964	74.1 1985	63.0 1963
	84.7 2003	72.2 1955	60.7 1985	53.5	1954	72.0 1996	63.0 1954
	84.7 1996	72.6 1954	59.9 2007	53.8	1962	71.6 2003	63.4 1955
	84.6 1994	72.8 1993	59.6 2004	54.1	1963	71.5 2004	64.3 1993
	84.5 1941	75.0 1989	59.5 2006	54.4	1953	71.4 1941	64.5 1964
	Climatic Normal 79.3		Climatic Normal 56.9			Climatic Normal 68.2	

	Average MAX		Average MIN			Average MEAN	
	warmest	coldest	warmest	coldest		warmest	coldest
August	88.1 1967	71.6 1954	60.7 2004	52.2	1964	72.9 1967	63.3 1954
	86.2 1986	74.2 1948	60.4 1997	53.4	1951	72.3 1986	63.7 1964
	85.5 1981	74.3 1976	59.6 1990	53.7	1969	72.1 1981	64.5 1957
	85.0 1972	75.2 1964	59.6 1971	53.7	1955	71.7 1977	65.3 1975
	84.1 1977	75.2 1957	59.5 1999	53.8	1959	71.7 1972	65.4 1960
	Climatic Normal 79.7		Climatic Normal 57.3			Climatic Normal 68.5	
Portland Int'l Airport Data							
Sept.	81.9 1974	68.8 1941	56.6 1995	46.5	1964	67.6 1994	58.4 1964
	81.4 1991	69.0 1978	56.0 1997	47.9	1965	67.4 1991	59.5 1961
	80.1 1993	69.3 1959	56.0 1990	47.9	1961	67.3 1974	60.2 1954
	80.0 1967	69.7 1977	55.8 1994	48.9	1955	67.1 1995	60.3 1959
	79.7 1989	69.9 1954	55.2 1979	49.3	1950	67.0 1990	60.4 1965
	Climatic Normal 74.6		Climatic Normal 52.5			Climatic Normal 63.6	
Portland Int'l Airport Data							
October	71.9 1987	57.6 1949	50.4 2003	39.5	1949	58.6 1952	48.5 1949
	71.8 1952	58.7 1950	49.9 2005	41.9	1972	58.5 1944	50.6 1946
	67.9 1944	58.8 1946	49.8 1988	41.9	1964	58.3 1988	51.7 1956
	67.8 1974	59.0 1956	49.5 1979	42.3	1970	58.2 2003	52.0 1968
	67.7 1993	59.8 1984	49.1 1944	42.5	1978	58.2 1987	52.4 1971
	Climatic Normal 63.3		Climatic Normal 45.2			Climatic Normal 54.3	
Portland Int'l Airport Data							
November	58.4 1949	42.9 1985	46.2 1995	31.2	1978	51.7 1995	37.2 1985
	57.1 1995	46.9 1978	44.7 1983	31.6	1985	50.1 1999	39.1 1978
	56.4 1981	46.9 1955	44.4 1998	31.8	1952	49.9 1949	40.7 1952
	56.1 1976	47.6 1964	44.2 1999	33.8	1993	49.8 1997	41.0 1964
	56.0 1999	48.3 1994	43.7 1997	34.4	1964	49.7 1965	41.4 1955
	Climatic Normal 51.8		Climatic Normal 39.8			Climatic Normal 45.8	
Portland Int'l Airport Data							
December	51.4 1950	39.2 1985	41.4 1950	26.8	1985	46.4 1950	33.0 1985
	50.2 1980	40.0 1990	39.7 1973	28.9	1978	44.7 1973	34.7 1990
	49.9 1979	40.2 1983	39.5 1966	29.4	1990	44.4 1979	35.2 1978
	49.6 1974	41.6 1978	38.9 1979	31.4	1964	44.2 1966	36.3 1983
	49.6 1973	42.2 1968	38.7 1999	31.7	1972	44.1 1974	37.0 1964
	Climatic Normal 45.4		Climatic Normal 35.0			Climatic Normal 40.2	
Portland Int'l Airport Data							
Annual	65.8 1992	58.7 1955	47.4 2004	40.8	1964	56.2 1992	50.1 1964
	65.2 1987	59.4 1964	47.4 1998	42.3	1955	55.7 2004	50.5 1955
	64.7 1958	60.0 1954	47.0 2003	42.7	1949	55.7 1995	51.6 1950
	64.6 1994	60.2 1956	46.9 1995	43.0	1950	55.6 2003	51.7 1956
	64.5 1995	60.2 1948	46.8 1983	43.1	1985	55.3 1998	51.7 1954
	Climatic Normal 62.1		Climatic Normal 44.8			Climatic Normal 53.5	
Portland Int'l Airport Data							
Water Year Oct 1 to Sept 30	66.4 1991-2	59.7 1954-5	47.5 2003-4	41.5	1963-4	56.6 1991-2	50.7 1963-4
	65.0 1993-4	59.8 1963-4	47.4 1997-8	42.0	1949-0	55.7 2003-4	51.1 1949-0
	64.8 1986-7	60.0 1955-6	46.7 1991-2	42.6	1964-5	55.5 2002-3	51.3 1954-5
	64.4 2002-3	60.2 1949-0	46.6 2002-3	42.6	1948-9	55.3 1997-8	51.4 1948-9
	64.4 1980-1	60.3 1953-4	46.6 1982-3	42.8	1954-5	55.3 1993-4	51.7 1955-6
	Climatic Normal 62.1		Climatic Normal 44.8			Climatic Normal 53.5	

Top 5 Warmest and Coldest Seasons and Averages Portland AIRPORT (Oct 1940 through May 2009)

	Average MAX		Average MIN			Average MEAN	
	warmest	coldest	warmest	coldest		warmest	coldest
Winter Season (Dec 22- Mar 21)	54.8 1991-2	42.8 1949-0	39.5 1982-3	29.9	1948-9	47.0 1991-2	36.3 1948-9
	53.8 1980-1	42.8 1948-9	39.2 1997-8	30.1	1968-9	45.9 1982-3	36.8 1949-0
	53.4 1940-1	44.1 1968-9	39.2 1991-2	30.7	1949-0	45.7 1980-1	37.1 1968-9
	53.0 2004-5	44.8 1956-7	39.0 2002-3	31.8	1956-7	45.4 1994-5	38.3 1956-7
	52.4 1982-3	45.0 1955-6	38.7 1952-3	31.8	1942-3	45.3 1940-1	39.1 1978-9
	average 49.1		average 35.6			average 42.3	
Portland Int'l Airport Data							
Deep Winter (Dec 1– Feb 14)	50.3 2002-3	38.8 1948-9	39.5 1952-3	27.7	1948-9	44.8 1952-3	33.2 1948-9
	50.3 1991-2	39.4 1949-0	38.8 1957-8	28.4	1949-0	44.5 1957-8	33.9 1949-0
	50.3 1957-8	40.1 1968-9	38.3 1950-1	29.1	1978-9	44.1 2002-3	34.7 1978-9
	50.1 1952-3	40.3 1978-9	38.2 1966-7	30.6	1968-9	44.1 1991-2	35.3 1968-9
	49.8 1980-1	42.4 1956-7	38.1 2005-6	30.8	1956-7	43.8 1966-7	36.6 1956-7
	average 46.3		average 34.8			average 40.6	
Portland Int'l Airport Data							
Spring Season (Mar 22- June 21)	71.5 1992	61.0 1964	49.3 2004	41.5	1964	60.1 1992	51.2 1964
	68.9 2004	61.3 1955	48.7 1992	42.4	1955	59.1 2004	51.9 1955
	68.9 1987	61.7 1953	48.3 2005	43.4	1954	58.0 1994	53.0 1953
	68.9 1969	62.2 2008	48.3 1993	43.4	1950	57.8 1987	53.1 1954
	68.3 1994	62.3 1991	48.2 2006	43.8	1966	57.7 1958	53.1 1950
	average 65.3		average 45.9			average 55.6	
Portland Int'l Airport Data							
Summer Season (June 22- Sept 21)	83.6 1967	71.2 1954	58.8 1998	50.8	1964	69.8 1990	62.3 1954
	81.8 1994	73.5 1955	58.6 2004	53.2	1955	69.8 1967	62.5 1964
	81.6 1972	73.8 1963	58.2 1997	53.3	1957	69.7 1998	63.4 1955
	81.5 2005	74.3 1964	58.2 1990	53.3	1954	69.4 2003	64.1 1963
	81.4 1990	75.2 1983	57.5 1995	53.6	1951	69.3 1994	64.9 1957
	average 78.4		average 55.6			average 67.0	
Portland Int'l Airport Data							
Deep Summer (July 1 – Aug 31)	85.4 1967	72.1 1954	60.2 1998	52.6	1964	71.7 1985	63.2 1954
	84.5 1972	74.3 1963	60.1 2004	54.1	1957	71.5 2004	64.1 1964
	84.2 1985	74.7 1955	59.4 1997	54.2	1955	71.3 1972	64.4 1955
	83.5 1996	75.2 1989	59.1 1985	54.2	1954	71.2 1996	64.6 1963
	83.4 1994	75.5 1948	59.0 1990	54.4	1969	71.1 1967	65.0 1957
	average 79.8		average 56.8			average 68.3	
Portland Int'l Airport Data							
Autumn Season (Sept 22- Dec 21)	61.3 1987	51.9 1985	45.0 1995	36.5	1985	52.0 1974	44.2 1985
	61.3 1974	53.4 1955	44.5 2003	37.1	1964	51.9 1995	45.6 1964
	59.5 1952	54.0 1984	44.4 1988	37.4	1978	51.8 1999	46.5 1978
	59.4 1991	54.0 1948	44.3 1947	38.4	1961	51.8 1987	46.6 1955
	59.4 1965	54.1 1964	44.1 2004	38.5	1972	51.7 2003	46.1 1961
	average 56.9		average 41.7			average 49.3	
Portland Int'l Airport Data							
Early Autumn (Sept 1 - Oct 31)	75.3 1952	65.4 1956	52.7 2003	44.2	1964	62.4 2003	55.7 1949
	75.1 1987	65.5 1946	52.3 1979	45.3	1949	62.1 1979	55.8 1964
	74.8 1974	65.6 1941	51.4 2004	45.6	1972	61.8 1987	56.2 1956
	74.0 1991	66.0 1985	51.3 1997	45.7	1970	61.8 1944	56.2 1946
	73.8 1993	66.0 1968	51.1 1995	45.9	1961	61.7 1952	56.3 1961
	average 69.1		average 48.6			average 58.9	

Portland Airport, Oregon

NORMALS, MEANS, AND EXTREMES

LATITUDE: 45 Deg. 36 Min. N LONGITUDE: 122 Deg. 36 Min. W ELEVATION: FT. GRND 21 BARO 27 TIME ZONE: PACIFIC WBAN: 24229

	(a)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE (Deg. F)														
Normals														
-Daily Maximum		45.4	51.0	56.0	60.6	67.1	74.0	79.9	80.3	74.6	64.0	52.6	45.6	62.6
-Daily Minimum		33.7	36.1	38.6	41.3	47.0	52.9	56.5	56.9	52.0	44.9	39.5	34.8	44.5
-Monthly		39.6	43.6	47.3	51.0	57.1	63.5	68.2	68.6	63.3	54.5	46.1	40.2	53.6
Extremes														
-Record Highest	55	63	71	80	87	100	100	107	107	105	92	73	65	107
-Year		1986	1988	1947	1957	1983	1992	1965	1981	1988	1987	1975	1993	AUG 1981
-Record Lowest	55	-2	-3	19	29	29	39	43	44	34	26	13	6	-3
-Year		1950	1950	1989	1955	1954	1966	1955	1980	1965	1971	1985	1964	FEB 1950
NORMAL DEGREE DAYS														
Heating (base 65 Deg. F)		787	599	549	420	249	91	28	35	102	326	567	769	4522
Cooling (base 65 Deg. F)		0	0	0	0	0	46	127	147	51	0	0	0	371
% OF POSSIBLE SUNSHINE	46	29	38	48	52	57	56	69	66	62	44	28	23	48
MEAN SKY COVER(tenths)														
Sunrise - Sunset	47	8.4	8.2	8.0	7.8	7.2	6.7	4.8	5.1	5.5	7.1	8.2	8.7	7.1
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	47	2.9	2.9	3.3	3.5	5.0	6.2	12.6	11.4	10.3	5.4	2.8	2.1	68.4
-Partly Cloudy	47	3.6	3.8	4.9	5.8	7.2	7.7	8.5	9.6	8.1	7.6	4.3	3.3	74.5
-Cloudy	47	24.4	21.5	22.8	20.7	18.9	16.1	9.9	10.1	11.6	18.0	22.9	25.5	222.4
Precipitation														
.01 inches or more	55	18.0	15.6	16.9	14.4	11.8	9.2	3.9	4.9	7.5	12.3	18.0	18.7	150.9
Snow, Ice Pellets, Hail														
1.0 inches or more	55	1.0	0.3	0.1	0.0	0.*	0.0	0.0	0.0	0.0	0.0	0.1	0.5	2.1

Appendix C4

Thunderstorms	55	0.*	0.1	0.5	0.9	1.5	0.9	0.8	1.0	0.7	0.4	0.3	0.1	7.1
Heavy Fog Visibility 1/4 mile or less	53	4.3	3.7	2.4	1.1	0.2	0.1	0.1	0.2	2.6	7.1	6.0	4.8	32.6
Temperature Deg. F -Maximum														
90 Deg. F and above	55	0.0	0.0	0.0	0.0	0.3	1.2	3.6	3.7	1.8	0.1	0.0	0.0	10.8
32 Deg. F and below -Minimum	55	2.1	0.3	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	3.5
32 Deg. F and below	55	13.0	8.1	4.6	0.9	0.1	0.0	0.0	0.0	0.0	0.6	5.1	9.6	42.1
0 Deg. F and below	55	0.*	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*
AV. STATION PRES. (mb)	23	1018.1	1016.6	1015.2	1016.7	1016.2	1016.1	1016.2	1015.2	1015.5	1017.2	1017.2	1018.4	1016.5
RELATIVE HUMIDITY (%)														
Hour 04	55	85	86	86	86	85	84	82	94	87	90	88	87	86
Hour 10 (Local Time)	55	82	80	73	69	66	65	62	64	67	78	82	83	73
Hour 16	55	75	67	60	55	53	49	45	45	48	62	74	78	59
Hour 22	55	83	81	78	75	73	71	68	70	75	94	84	85	77
PRECIPITATION (in.)														
Water Equivalent														
-Normal		5.35	3.85	3.56	2.39	2.06	1.48	0.63	1.09	1.75	2.7	5.34	6.13	36.30
-Maximum Monthly	55	12.83	9.46	7.52	5.26	4.57	4.06	2.68	4.53	4.30	8.41	11.57	11.12	12.83
-Year		1953	1949	1957	1993	1945	1984	1.83	1968	1986	1994	1942	1968	JAN 1953
-Minimum Monthly	55	0.06	0.72	1.10	0.53	0.10	0.03	0.00	T	T	0.19	0.77	1.38	0.00
-Year		1985	1993	1965	1956	1992	1951	1967	1970	1993	1988	1976	1976	JUL 1967
-Maximum in 24 hrs	55	2.61	2.46	1.83	1.47	1.47	1.82	1.09	1.54	2.38	4.44	2.82	2.59	4.44
-Year		1974	1994	1943	1962	1968	1958	1978	1977	1982	1994	1995	1977	OCT 1994
Snow, Ice Pellets, Hail														
-Maximum Monthly	55	41.4	13.2	12.9	T	0.6	T	0.0	T	T	0.2	8.2	15.7	41.4
-Year		1950	194	1951	1995	1953	1995		1989	1949	19.0	1955	1968	JAN 1950
-Maximum in 24 hrs	55	10.6	6.4	7.7	T	0.5	T	0.0	T	T	0.2	7.4	8.0	10.6
-Year		1950	1993	1951	1995	1953	1995		1989	1949	1950	1977	1964	JAN 1950
WIND														
Mean Speed (mph)	47	10.0	9.2	8.3	7.4	7.1	7.2	7.6	7.1	6.5	6.5	8.6	9.6	7.9

Appendix C4

Prevailing Direction through 1964		ESE	ESE	ESE	NW	NW	NW	NW	NW	NW	ESE	ESE	ESE	ESE
Fastest Mile														
-Direction(!)	41	S	SW	S	S	SW	SW	SW	SW	S	S	SW	S	S
-Speed(mph)	41	54	61	57	60	42	40	33	29	61	88	56	57	88
-Year		1951	1958	1963	1957	1960	1958	1983	1961	1963	1962	1961	1951	OCT 1962
Peak Gust														
-Direction(!)	12	SW	SE	S	SW	W	SW	NW	SW	E	S	SW	17	17
-Speed(mph)	12	63	61	59	45	46	40	32	31	44	52	52	71	71
-Date		1990	1989	1995	1992	1993	1994	1992	1995	1995	1994	1984	1995	DEC 1995

(a) - Length of Record in Years, although individual months may be missing.

0.* or * - The value is between 0.0 and 0.05.

Normals - Based on the 1961 - 1990 record period.

Extremes - Dates are the most recent occurrence.

Wind Dir.- Numerals show tens of degrees clockwise from true north. "00" indicates calm.

Resultant Directions are given to whole degrees.

California Statewide Mean Temperature Departure April

Linear Trend 1895-present: $+ 0.70 \pm 1.48^{\circ}\text{F}/100\text{yr}$

Linear Trend 1949-present: $+ 0.74 \pm 4.27^{\circ}\text{F}/100\text{yr}$

Linear Trend 1975-present: $+ 1.87 \pm 9.66^{\circ}\text{F}/100\text{yr}$

Warmest Year: 58.4°F ($+ 5.7^{\circ}\text{F}$) in 1934

Coldest Year: 43.5°F ($- 9.2^{\circ}\text{F}$) in 1967

April 2010: 49.2°F ($- 3.5^{\circ}\text{F}$)

MEAN 52.7°F

STDEV 3.05°F

RANK 12 of 116

REDDING, CALIFORNIA

NORMALS, MEANS, AND EXTREMES

LATITUDE: 40 Deg. 30 Min. N LONGITUDE: 122 Deg. 18 Min. W ELEVATION: FT. GRND 502 BARO 536 TIME ZONE: PACIFIC WBAN: 24257

	(a)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE (Deg. F)														
Normals														
-Daily Maximum		55.3	61.3	62.5	69.9	80.5	90.4	98.3	95.7	89.3	77.6	62.1	54.7	74.8
-Daily Minimum		35.7	40.0	41.7	46.0	52.3	61.8	64.7	63.1	58.8	49.2	41.4	35.2	49.2
-Monthly		45.5	50.7	52.2	58.0	66.4	76.1	81.5	79.5	74.1	63.5	51.8	45.0	62.0
Extremes														
-Record Highest	9	77	83	85	94	104	111	118	115	116	105	88	74	118
-Year		1994	1992	1988	1989	1987	1987	1988	1990	1988	1991	1995	1988	JUL 1988
-Record Lowest	9	19	21	28	33	36	42	54	51	40	33	23	17	17
-Year		1991	1989	1990	1995	1988	1990	1989	1995	1986	1989	1993	1990	DEC 1990
NORMAL DEGREE DAYS														
Heating (base 65 Deg. F)		605	400	397	252	63	0	0	0	0	122	396	62	2855
Cooling (base 65 Deg. F)		0	0	0	42	107	333	512	450	278	75	0	0	1797
% OF POSSIBLE SUNSHINE	9	73	83	84	90	91	94	97	97	94	92	84	73	88
MEAN SKY COVER(tenths)														
Sunrise - Sunset	9	6.7	6.2	6.4	6.1	5.0	3.5	1.5	1.8	2.2	3.6	5.4	6.3	4.6
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	9	8.2	8.2	7.9	8.1	11.4	16.9	25.2	24.7	22.4	17.7	11.0	9.8	171.6
-Partly Cloudy	9	5.0	6.2	6.6	8.4	9.2	8.4	4.3	4.8	4.2	6.8	7.9	5.2	77.1
-Cloudy	9	17.8	13.8	16.6	13.4	10.3	4.7	1.3	1.6	3.4	6.5	11.1	16.0	116.4
Precipitation														
.01 inches or more	9	13.1	8.7	12.3	7.9	7.2	4.0	0.6	0.9	2.1	4.1	6.8	10.2	77.9
Snow, Ice Pellets, Hail														
1.0 inches or more	9	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9

Appendix C6.

Thunderstorms	9	0.6	0.8	2.1	1.7	2.1	1.7	0.9	1.2	0.8	0.9	0.2	0.4	13.3
Heavy Fog Visibility 1/4 mile or less	9	5.1	1.4	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.4	1.6	5.6	15.0
Temperature Deg. F -Maximum														
90 Deg. F and above	9	0.0	0.0	0.0	1.1	6.2	16.2	27.6	25.4	18.6	6.7	0.0	0.0	101.9
32 Deg. F and below -Minimum	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
32 Deg. F and below	9	11.8	6.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	13.9	37.0
0 Deg. F and below	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AV. STATION PRES. (mb)	9	1002.3	1000.7	998.7	998.0	995.6	994.5	994.1	994.0	995.1	997.7	1002.2	1002.5	997.9
RELATIVE HUMIDITY (%)														
Hour 04	9	84	81	80	77	73	64	58	59	61	68	79	83	72
Hour 10 (Local Time)	9	76	66	62	51	44	37	32	32	34	42	61	75	51
Hour 16	9	58	46	48	38	33	25	19	18	22	30	45	58	37
Hour 22	9	79	72	71	64	58	48	40	40	45	56	73	78	60
PRECIPITATION (in.)														
Water Equivalent														
-Normal		6.06	4.45	4.38	2.08	1.27	0.56	0.17	0.46	0.91	2.24	5.21	5.51	33.30
-Maximum Monthly	9	22.93	10.15	14.7	4.26	6.72	1.93	0.49	1.06	4.83	6.26	10.11	10.81	22.93
-Year		1995	1992	1995	1995	1993	1995	1990	1990	1989	1992	1988	1995	JAN 1995
-Minimum Monthly	9	0.89	0.14	0.52	0.14	0.01	T	0.00	0.00	0.00	T	0.26	0.00	0.00
-Year		1991	1988	1988	1987	1987	1987	1990	1987	1988	1995	1995	1989	JUL 1990
-Maximum in 24 hrs	9	3.96	2.14	3.18	2.33	3.79	1.24	0.49	0.83	3.15	4.09	3.23	2.99	4.09
-Year		1990	1992	1995	1993	1993	1988	1990	1993	1989	1992	1988	1995	OCT 1992
Snow, Ice Pellets, Hail														
-Maximum Monthly	9	3.2	1.4	1.8	T	1.5	T	0.0	T	0.0	0.0	T	17.0	17.0
-Year		1989	1990	1987	1995	1990	1992		1993			1988	1988	DEC 1988
-Maximum in 24 hrs	9	2.0	1.4	1.8	T	1.5	T	0.0	T	0.0	0.0	T	10.0	10.0
-Year		1989	1990	1987	1995	1990	1992		1993			1988	1988	DEC 1988
WIND														
Mean Speed (mph)	9	6.7	6.7	8.1	7.4	7.7	8.1	7.4	6.7	6.3	6.5	6.1	6.6	7.0

Appendix C6.

Prevailing Direction through 1964														
Fastest Mile														
-Direction(!)	6	18	17	17	17	17	02	36	23	35	19	18	17	17
-Speed(mph)		56	46	53	36	29	38	23	23	29	37	35	60	60
-Year		1995	1993	1995	1993	1990	1992	1995	1990	1993	1992	1994	1995	DEC 1995
Peak Gust														
-Direction(!)	9	S	S	S	S	S	N	N	S		S	S	S	S
-Speed(mph)	9	70	64	74	47	54	60	36	46	44	66	58	85	85
-Date		1995	1993	1995	1995	1988	1992	1995	1987	1986	1989	1988	1995	DEC 1995

(a) - Length of Record in Years, although individual months may be missing.

0.* or * - The value is between 0.0 and 0.05.

Normals - Based on the 1961 - 1990 record period.

Extremes - Dates are the most recent occurrence.

Wind Dir.- Numerals show tens of degrees clockwise from true north. "00" indicates calm.

Resultant Directions are given to whole degrees.