Stream Morphology

Stream morphology varies naturally as streams pass across different landforms. Examples are: steep mountain slopes, glacial cirques, glacial troughlands, glacial outwash fans and terraces, alluvial fans, deltas, wide valleys, and landslides. Stream morphology on these different landforms can be described by individual parameters, such as bankfull width, bankfull depth, width/depth ratio, sinuosity, entrenchment, gradient, and size of bed material. Stream morphology parameters can be organized into logical groups by using a stream type classification system.

Stream morphology is periodically altered by natural processes such as floods, droughts, woody debris additions to streams (from wind storms, snow avalanches, and mortality from fire and insects), beaver and their dams, landslides, and the like. Stream morphology can also be altered by land management activities and infrastructure. Examples are: culverts, bridges, stream diversion structures, stream channel straightening, water withdrawals, stream flow augmentation, reservoirs, intense livestock grazing, dikes, and etc. All of these influences occur within the Powder River-Powder Valley Watershed Assessment area.

Stream Types

Hydrologists working for the WWNF believe that all the stream types described in the book Applied River Morphology (Rosgen and Silvey, 1990) may be found in the watershed. Type A streams occur on mountain slopes and valleys with slope gradients steeper than 4 percent. An example is Marble Creek. Type B streams occur in valleys with slope gradients between 2 and 10 percent. An example is Rock Creek near the Power Plant. Type C streams occur in low gradient valleys. They have many active bars indicating sediment movement. An example is the Powder River one-half mile upstream of its' crossing under Interstate 84. Type D streams (unstable braided channels) occur on backwater deltas of reservoirs, such as Thief Valley Reservoir. Type DA streams (stable braided channels) occur on backwater deltaic wetlands of lakes, such as Anthony Lakes. Type E streams (narrow and sinuous) occur in low-gradient meadows, such as lower Salmon Creek and the wetlands around Anthony Lakes. Type F (flat-bottomed vertical-banked) streams and Type G (v-shaped) streams often occur in downcut or altered stream channels. An example is Rock Creek as it passes through Haines and Wolf Creek or as it passes under Interstate Highway 84. The criteria for delineating stream types and examples of stream types within the watershed can be found in Appendix L.

WWNF Stream Surveys

The WWNF has collected stream morphology information along reference reaches of several streams in the Elkhorn Mountains as part of the agency's stream survey program. This information is summarized in WWNF 1999 (pp. 18-21), and is included in Appendix M). Note that all but a few of the stream types are A's.

ODFW Stream Surveys

Some information on stream morphology is also available from 1970's ODFW Fish Surveys (Appendix M) for Anthony Creek, North Fork Anthony Creek, Antone Creek, Antone Creek tributary, and the North Powder River. Stream morphology information in the tables is recorded under the Stream Width, Percent of Section in Pools, and Gradient columns.

Individual Stream Descriptions

Eleven (11) named streams empty into the Powder River in this assessment area. These streams are discussed in the following section beginning with the uppermost, and continuing downstream along the Powder River. Stream origins, lengths, and known channel modifications are discussed. Maps are found in Figures 45, 48, and 49.

<u>Salmon Creek and Tributaries</u>

Salmon Creek is the southernmost stream on the watershed. Its tributaries include Marble Creek, Mill Creek, Goodrich Creek, Spring Creek, and Pine Creek. Salmon Creek flows in a generally northeast direction for 6 miles, and then heads nearly due north for another 4½ miles to its mouth on the Powder River approximately 2½ miles southeast of Haines.

With a few short exceptions, Salmon Creek is in its original channel until it reaches Wingville Road. From that point to its mouth, Salmon Creek has been straightened. One of the exceptions is in a brushy, forested reach where the creek was reportedly diverted from its original channel for mining purposes (Baker County Bull Trout Response, 2003).

Of Salmon Creek's tributaries, only Pine Creek appears to be within its original channel. Pine Creek originates above Pine Creek Reservoir. Because of the rocky, porous alluvium over which Pine Creek flows, water from the stream never reaches the Powder River except during periods of high water.

Table 38. Description of Pine Creek

River Mile (RM)	*Description: PINE CREEK*
0 – 3.0	RM 0 is confluence with Salmon Creek. Intermittent stream with spring surge in May and June. Return flows, i.e. springs, other times of the year. Average grade is 1 percent. Mud and sand channel.
3.0 – 5.0	Dry mid-June to mid-May. Bottom is cobbles 6-10" in diameter. Average grade is 3 percent.
5.0 – 6.5	RM 6.5 is top of alluvial fan. Creek disappears in this reach most of the year. Bottom is cobbles up to 10" in diameter. Grade is 8 percent.
6.5 – 10.0	RM 10 is at reservoir. Year-long flow. Creek bottom is large granite boulders and cobbles with no spawning gravel. Average grade is 12 percent with extensive pitches over 20%.

Source: *Baker County Bull Trout Response*

Marble Creek, Mill Creek, Goodrich Creek, and Spring Creek all show evidence of having had some reaches straightened. Goodrich Creek has entirely lost its channel below Brown Road because its' flow never reaches that far. The flow of Goodrich Creek is used by Baker City for its municipal water supply.

Spring Creek was diverted into the Bowles Ditch when the Bowles Ditch was dug. The creek channel is dry from the Bowles Ditch to Brown Road, but then develops a significant flow from ground water below Brown Road.

Willow Creek and Tributaries

The next stream north of Pine Creek is Willow Creek. Willow Creek originates from a small, shallow lake below Maxwell Butte though it goes underground for several stretches (T. M. Kerns, written communication, 5/10/04). Maps show its tributaries as Hunt Creek and Marble Creek (not to be confused with the Marble Creek mentioned earlier). Both Hunt Creek and Marble

Creek are fairly insignificant streams. Hunt Creek has an ancient channel that reaches all the way to Willow Creek, but water from Hunt Creek almost never reaches Willow Creek even during spring runoff. Marble Creek is a 2-mile long spring that trickles into Willow Creek just after emerging from the forest.

Willow Creek has its mouth on the Powder River a mile and a half below the mouth of Salmon Creek and a mile south of Haines.

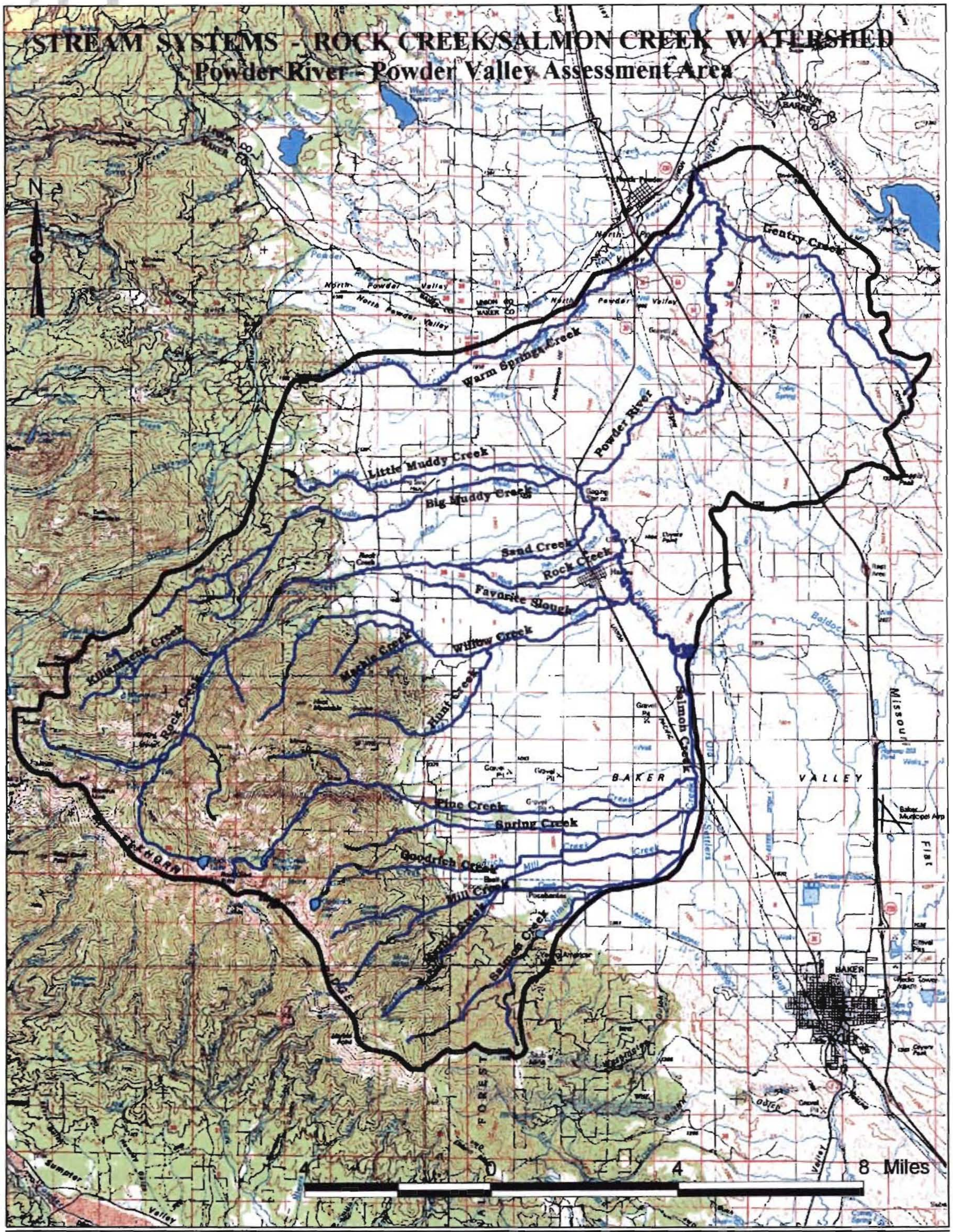
Willow Creek is largely within its original channel except for a 2¼-mile reach soon after it emerges from the forest. Before the early 1950's, Willow Creek, below Quail Road, meandered through the fields along a willow-lined channel. In order to make larger fields, the landowner, with government assistance, put the creek at the base of the alluvial fan and at the edge of the field. The relocated creek adjusted to its new location by cutting a gash 12-feet deep and 20-feet wide.

Plans were drafted in 1967 to install 21 grade stabilization structures made with grouted rock riprap to stabilize the stream. The estimated installation costs were $68,800 to improve 15,600 feet of the stream (Baker Valley SWCD, 1967). The plans were tied to plans for constructing the North Powder River dam and reservoir. When the North Powder River reservoir failed to sign up sufficient supporters, plans were dropped for that and for the other projects tied to it, including the plans to stabilize Willow Creek. The deep cut remains, but Willow Creek is no longer eroding as it did in the past. It has eroded through the fine material down to larger material that does not wash with the volume of water in the creek.

Rock Creek and Tributaries

Rock Creek originates high in the mountains at Rock Creek Lake. The outlet of Rock Creek Lake has been built up and dammed to make Rock Creek Lake a reservoir. Rock Creek flows approximately 8 miles from the lake before leaving the forest. It continues due east through the valley another six miles, through the city of Haines, and empties into the Powder River one-half mile east of Haines. The channel through Haines is greatly reduced and could not pass even the normal flows of Rock Creek above the power plant diversion. If the current channel through Haines is the original channel, it has been filled in to less than 10% of its original capacity. If it is not the original channel, then the true channel is one of several old channels to the north, including Sand Creek and Fish Creek. Stream information on the Haines USGS Quadrangle

Figure 48. Stream systems in the Rock Creek/Salmon Creek Watershed.



Source: NRCS

indicates that Rock Creek water can be delivered to the Powder River via six channels: Rock Creek, Fish Creek, Sand Creek and 3 other unnamed relic channels of Rock Creek. At this point in time, most Rock Creek water appears to be delivered to the Powder River via Sand Creek.

Table 39. Description of Rock Creek

River Mile (RM)	*Description: ROCK CREEK*
0 – 1.5	From the confluence at the Powder River back to RM 1.5, creek is normally dry from July to mid-May. Creek bottom is silt and sand. Stream grade is ½ percent.
1.5 – 2.5	Small amount of water year long. Creek bottom has larger material. Stream grade is ¾ percent.
2.5 – 3.5	Water year long from here to headwaters. Creek bottom is gravel. Stream grade is 1 ½ percent. Intersection of Sand Creek Channel where creek historically took either channel at will. Presently a control structure exists to channel water either way.
3.5 – 5.5	Creek bottom is cobble, i.e., ten-inch or smaller round granite rock. Stream grade is 2 ½ percent.
5.5 – 7.0	Creek bottom is cobble. There are boulders up to six feet in diameter. Stream grade is 5 percent. No spawning gravel exists.
7.0 – 9.0	Creek bottom is cobble and large boulders with no spawning gravel. Stream grade averages 10 percent with gradient to approximately 20 percent. Intersection of Killamacue Creek, which contributes significant water to Rock Creek. Killamacue Creek has an average grade above its mouth of 27 percent.
9.0 – 11.0	Creek bottom is cobble and gravel with woody material in channel. Grade is 5 ¾ percent.
11.0 – 14.0	Creek bottom is boulders. Average grade is 12 percent. At least one natural falls of approximately 25 feet. RM 14 is at reservoir.

Source: Baker County Bull Trout Response

Muddy Creek

Big Muddy Creek is the next stream north of Rock Creek. It is a 10-mile long stream running generally due east from its origin as a spring, to its mouth on the Powder River two miles north of Haines. Flowing parallel to Big Muddy Creek on its north is Little Muddy Creek. Little Muddy Creek also originates as a spring, and follows an 8-mile channel that lies between one mile and a quarter of a mile from the channel of Big Muddy Creek. The two creeks merge less than one half mile from the mouth of Muddy Creek on the Powder River.

The flow of Little Muddy Creek is augmented by the Mansfield Ditch. The Mansfield Ditch diverts water from the North Powder River, and dumps its water into Little Muddy Creek above Bulger Flat.

Big Muddy Creek has had its channel shifted due to placer mining that took place a century ago. The mining activities washed large amounts of sand down the creek. The sand filled a 3/4-mile long low area with four feet of sand. The affected area covered 15-20 acres, and caused the creek to find new channels. Some sand still washes down the creek from the old mining activities. It is likely that Muddy Creek got its name from turbidity caused by early miners.

Gentry Creek

Gentry Creek is the only named stream in the watershed having its mouth on the opposite side of Powder River. It originates two miles north of Magpie Peak, and flows six miles in a northwesterly direction through a dry, sagebrush-type environment. Its mouth on the Powder River is just east of the city of North Powder, and one-half mile south of the mouth of Warm Springs Creek.

Warm Springs Creek

Warm Springs Creek, or Hot Creek as it is sometimes called, arises at Fisher Hot Spring. The 600-gallon per minute spring comes from the side of a hill a thousand feet above Foothill Road. It flows east for six miles, nearly paralleling the North Powder River. The two streams range from ½ to 1½ miles apart. Warm Springs Creek has its mouth on the Powder River approximately one mile southeast of the city of North Powder. This stream is also discussed in the Hot Springs section.

North Powder River and Tributaries

The North Powder River originates from five small lakes high in the Elkhorn Range. The five lakes (Lost, Meadow, Little Summit, Summit, and Red Mountain) lie fairly close together, with the distance between the two most widely separated being not more than 2½ miles.

The North Powder River flows northeast for approximately 14 miles before emerging from the forest. It then makes a 10-mile long arc through the valley flowing southeast, then northeast, until it reaches its mouth on the Powder River one-half mile east of the city of North Powder.

The river's tributaries include Lawrence Creek, Dutch Flat Creek, Antone Creek, Anthony Creek and Pilcher Creek.

Lawrence Creek, a minor stream, originates as a spring. It is approximately three miles long. Its entire reach lies within the forest. Its mouth is on North Powder River approximately eight miles from the river's headwaters.

Dutch Flat Creek originates at Dutch Flat Lake. The creek is approximately nine miles long, never leaves the forest, and empties into North Powder River approximately 10 miles from the river's headwaters. Dutch Flat Creek has one tributary, a 1½-mile long creek coming from Van Patten Lake.

Antone Creek originates as a spring under Angell Peak. It flows nine miles before reaching its mouth on the North Powder River. One-half mile above its mouth, it is joined by Little Antone Creek, a three-mile long stream. Neither stream emerges from the forest before emptying into the North Powder River. The mouth of Antone Creek is approximately 11 miles from the headwaters of the North Powder River.

Anthony Creek has its headwaters at Anthony Lake and drains the Anthony Lakes Basin. Hoffer Lakes, Black Lake, and other small lakes contribute water to the stream.

Anthony Creek forms the boundary line between Baker and Union Counties. It flows in a generally northeast direction for ten miles, and then turns southeast for another three miles before reaching its mouth on the North Powder River. From this point onward, the county line follows the North Powder River to its confluence with the Powder River, and then follows the Powder River until the river exits the Powder River – Powder Valley Watershed.

Anthony Creek has several tributaries, the main ones being Indian Creek and North Fork Anthony Creek. Indian Creek lies south of Anthony Creek. It is a 3½-mile long stream lying entirely within the forest. Its mouth is approximately six miles from the headwaters of Anthony Creek. North Fork Anthony Creek is a 4-mile long stream, lying entirely within the forest, whose mouth is approximately 8½ miles below the headwaters of Anthony Creek. Of Anthony Creek's 13-mile length, all but the lower two miles lie within the forest. The lower two miles flow along the edge of the forest until the creek reaches its mouth on the Powder River. The mouth of Anthony Creek is approximately 14 miles from the headwaters of the North Powder River.

Pilcher Creek is a minor stream with a small drainage area. It is approximately six miles in length, and lies on the north side of North Powder River. Its mouth is about three miles below the mouth of Anthony Creek. It is significant because of its dam and reservoir that were constructed in 1983 to provide water to the Wolf Creek Reservoir. The Pilcher Reservoir is mostly filled with water diverted from Anthony Creek via the Shaw-Carnes Ditch.

North Powder River, from its confluence with Anthony Creek to its mouth on the Powder River, has had much of its original channel modified. The Army Corps of Engineers did extensive work in the 1930's to straighten the channel to eliminate its sinuosity that gave adjacent fields irregular, hard-to-work shapes. Riparian areas where channel modification took place now have large trees and stable streambanks.

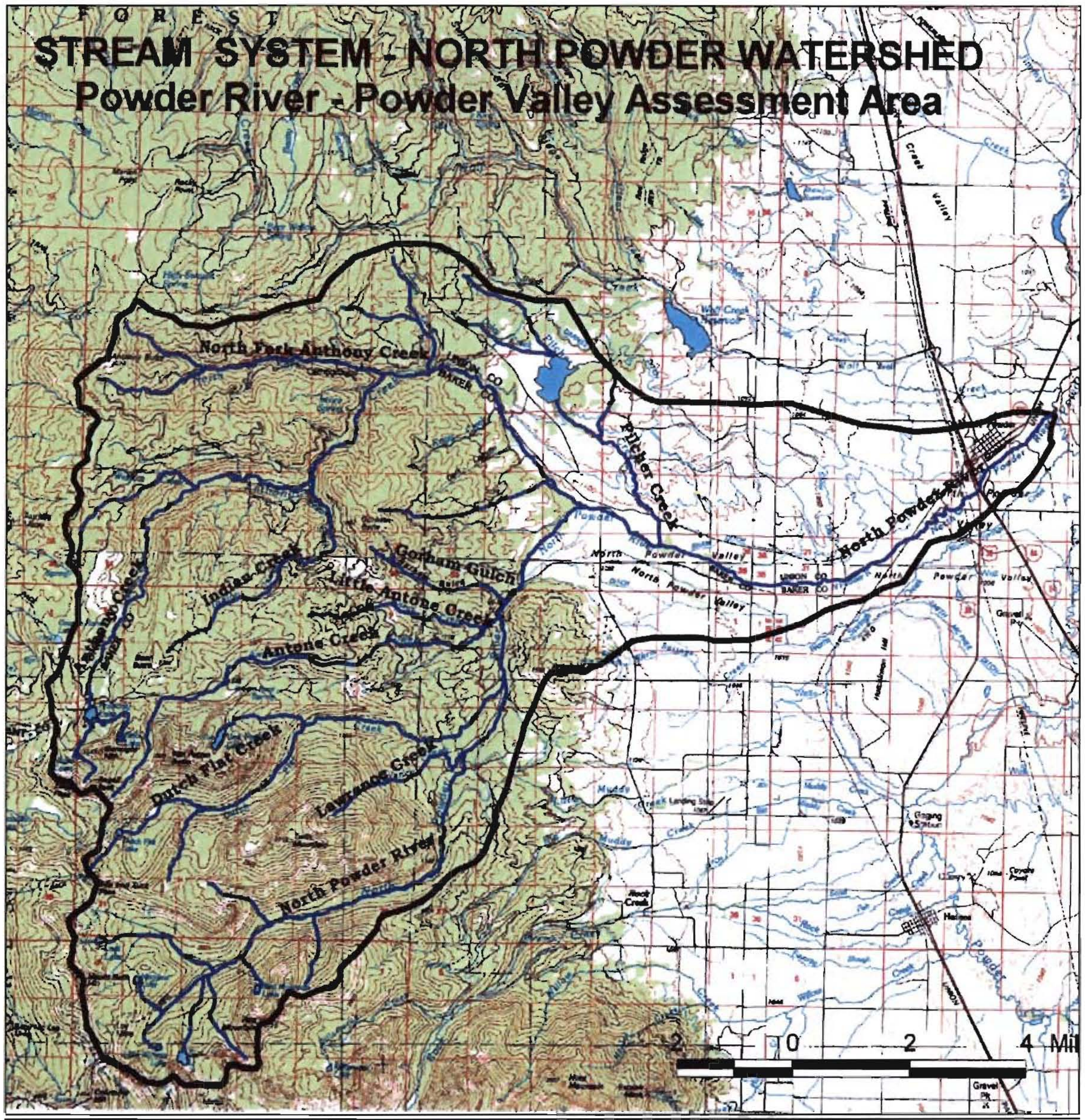
<u>Wolf Creek and Tributaries</u>

Wolf Creek has its headwaters at High Summit Spring, and flows 18 miles to its mouth on Powder River one mile northeast of the city of North Powder. From its headwaters it flows northeast for 6 1/2 miles where it is joined by a major tributary, North Fork Wolf Creek, a 3 1/2-mile long stream. It then flows southeast another 5 1/2 miles to Wolf Creek Reservoir Dam, and then flows in a general easterly direction to Powder River.

Two miles above the dam, Clear Creek, another major tributary, enters Wolf Creek from the north. Clear Creek is a 7-mile long stream. Clear Creek and North Fork Wolf Creek are entirely within forested areas.

Wolf Creek emerges from the forest as it enters Wolf Creek Reservoir. The creek is probably within its original channel throughout its entire reach, although an ancient channel can still be seen in fields south of its current channel.

Figure 49. Stream system in the North Powder River Watershed



Source: NRCS

Jimmy Creek and Tributaries

Jimmy Creek is a 7-mile long creek that originates as a spring on Craig Mountain. Craig Mountain is the mountain between I-84 and Highway 237. Jimmy Creek flows nearly due south, approximately equidistant between the two highways, to its mouth on Powder River 2½ miles below North Powder. Its mouth is on the bend of Powder River where the river turns due east toward Thief Valley Reservoir.

Clover Creek is a tributary of Jimmy Creek. Clover Creek is a 6-mile long stream that originates as a spring at the extreme north end of Powder Valley. Peach Creek is a 7-mile long tributary of Clover Creek that originates on Shaw Mountain. Both of these small streams have had their channels straightened where they pass through agricultural lands.

There is a privately owned reservoir five miles from the headwaters of Jimmy Creek. Another privately owned reservoir, Shaw Reservoir, is located on Peach Creek below Shaw Mountain.

<u>Antelope Creek and Tributary</u>

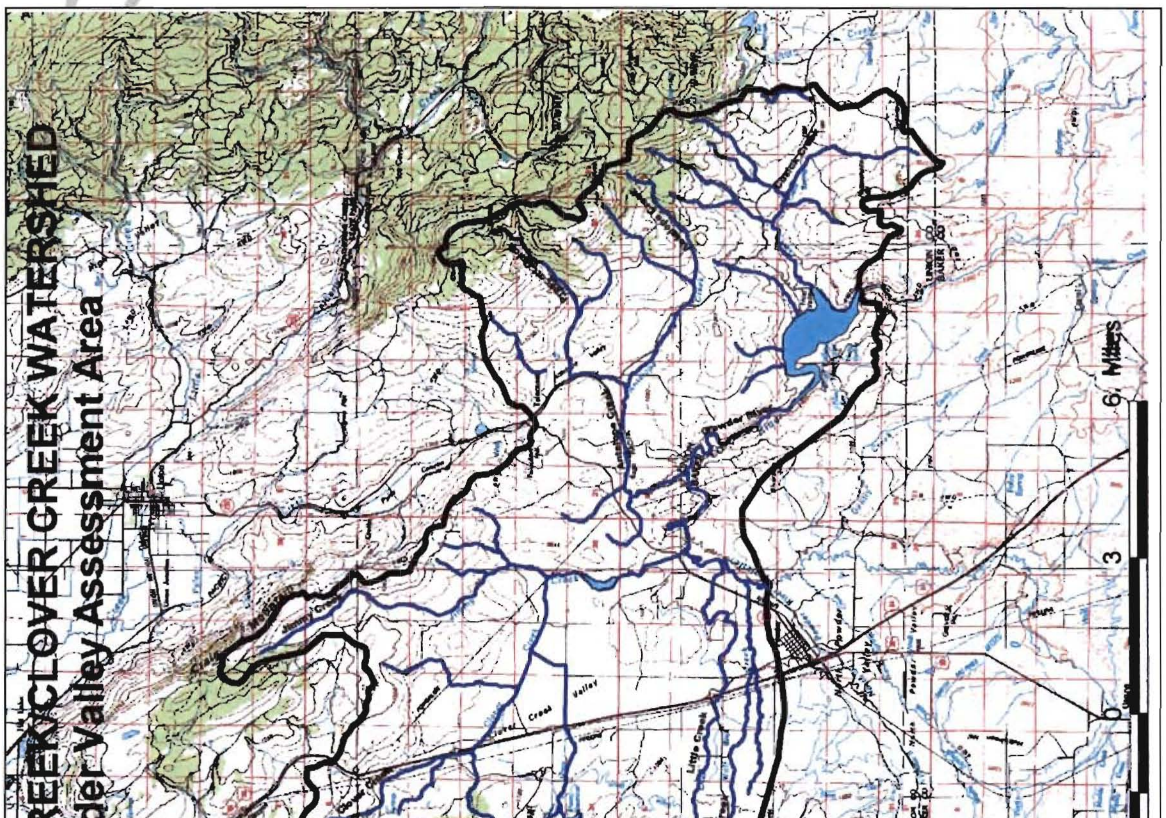
Antelope Creek is a 7-mile long creek that originates on the dry, non-forested side of Reeves Mountain northeast of Thief Valley Reservoir. It begins with two 2½-mile long branches that run parallel to each other in a southwesterly direction. At their juncture, the stream turns northwest, and flows through Antelope Valley toward the community of Telocaset. At its confluence with Prescott Gulch, the stream turns and flows due west for two miles, and then makes a sharp turn to the south to flow one more mile to its mouth on the Powder River. It joins the Powder River where the Powder River begins its turn to the southeast.

Prescott Gulch is a 5-mile long tributary of Antelope Creek, having its origins below Clark Mountain east of Telocaset. Both Antelope Creek and Prescott Gulch are mostly within a dry, sagebrush-type environment. Both streams are probably within their original channels. The Union Pacific Railroad follows Prescott Gulch in its lower 1½- mile reach, and then follows Antelope Creek in its lower 3-mile reach.

<u>Cusick Creek</u>

Cusick Creek is a small stream that empties directly into Thief Valley Reservoir on the reservoir's east side. It has its origins on Sugarloaf Mountain midway between the reservoir and the Pondosa/Medical Springs area. The 5-mile long stream lies entirely within a dry, sagebrush-type environment.

Figure 50. Stream systems in Wolf Creek/Clover Creek Subwatershed



Source: NRCS

Powder River (Salmon Creek to Thief Valley Reservoir Dam)

The Powder River originates in the town of Sumpter at the confluence of McCulley Fork and Cracker Creeks east of Baker City across the Elkhorn Mountains. The river flows southeasterly through Phillips Lake Reservoir, turns easterly, then northeasterly and finally northerly through Baker City. About six miles north of Baker City it turns northwesterly and flows into this assessment area. After entering the assessment area it continues northwesterly past the town of Haines a couple of miles. It then turns northeasterly until it flows under I-84 at which point it turns and flows northerly past the city of North Powder. About 3 miles north of North Powder it turns easterly into a canyon and then southeasterly into Thief Valley Reservoir. Within this assessment area it flows through parts of the Baker Valley and the Powder Valley.

WATER QUALITY

303(d) List

The 1972 Federal Clean Water Act (CWA) required states to develop a list of water bodies that do not meet water quality standards without application of additional pollution controls. The water quality standards include measurements of temperature, dissolved oxygen, bacteria, sedimentation, pH, chemicals, and nutrients. The nutrients usually measured are nitrates and phosphorus. These two nutrients promote the growth of algae that can remove dissolved oxygen from the water upon which other aquatic life depends.

Section 303(d) of the CWA is the section that requires states to develop lists of "water quality limited" water bodies. The 303(d) List must be updated every two years. That responsibility rests with the ODEQ. The first studies were done in Oregon in 1988. That original list was updated in 1994, 1996, 1998, and in the fall of 2002.

The 303(d) List is not regulatory. A Total Maximum Daily Load (TMDL) and a Water Quality Management Plan will succeed the 303(d) list in 2005-6. TMDL's will not be regulatory for private landowners, but Water Quality Management Plans will be. TMDL's are enforceable and regulatory for Federal Agencies. The goal is to be able to remove water bodies from the 303(d) List. (See Appendix O for a summary of water quality rules and laws).

The temperature standards were revised as of December 2003 and approved by the EPA on March 2, 2004. The revised ODEQ standards are based on recent research into temperature requirements of fish as a function of their life history. All life stages are of concern but the time when the fish are most likely to be stressed is during the summer months when stream temperatures are highest. Streams on the 303d list are currently undergoing a process of reevaluation based on the new temperature standards. A revised 303d list will be out sometime late 2004 (M. Simpson, DEQ, pers. com. March 2004).

Fish found within the assessment area that have DEQ temperature standards are redband trout (*Onchorhynchus mykiss*) and bull trout (*Salvelinus confluentus*). Redband trout is on the Regional Forester's sensitive species list in Region 6 as a Candidate 2 sensitive species and bull trout is a Federally threatened species. The new stream temperature standards are different for redband trout and bull trout and are shown in Table 39 along with the old ODEQ temperature standards.

All streams in the assessment area have been designated for redband trout and a number of streams have a designated fish use for bull trout spawning and juvenile rearing. Some of the streams listed by ODEQ under their August 2003 Draft Table 260b for bull trout include: Anthony Creek, Big Muddy Creek, Goodrich Creek, Indian Creek, Killamacue Creek, Marble Creek, Mill Creek, North Fork Anthony Creek, Rock Creek, Salmon Creek, and Wolf Creek. Four streams are currently on the 303(d) List in the assessment area. Those streams and their reasons for listing are as follows: (Also see map in Figure 51).

Table 40. Comparison of old and 2003-revised ODEQ stream temperature standards for redband trout and bull trout.

Life Stage	**Old Std for Bull Trout**	**Old Std for Redband Trout**	**2003-revised std Redband Trout**		**2003-revised std Bull Trout**	
	°F	°F	°F	Season applies	°F	Season applies
Rearing	/ 50	≤ 64	≤ 68	Year round	≤ 53.6	Year round
Spawning	/ 50	≤ 55				
Incubation		≤ 55				
Migration		≤ 64				

Source: ODEQ Web Page, www.deq.state.or.us/wq/standards

Table 41. Streams on 2003 303(d) List. The list is currently under revision based on the new standards.

Stream	Parameter	Criteria	Season	Source of Supporting Temperature Data
Anthony Creek	Temperature	Bull trout: 50 °F	Summer	USFS 1992 and 1993 data from 3 sites
Indian Creek	Temperature	Bull trout: 50 °F	Summer	USFS 1992 and 1993 data
North Powder River	Temperature	Rearing: ≤64 °F	Summer	USFS 1992 and 1993 data
Powder River	Temperature Dissolved Oxygen Fecal Coliform Bacteria	Rearing: ≤64 °F	Summer Summer Year-round	Baker Valley SWCD 1995 and 1996 data USBOR 1988 to 1995 data

Source: ODEQ webpage: www.deq.state.or.us/wq/303dlist/

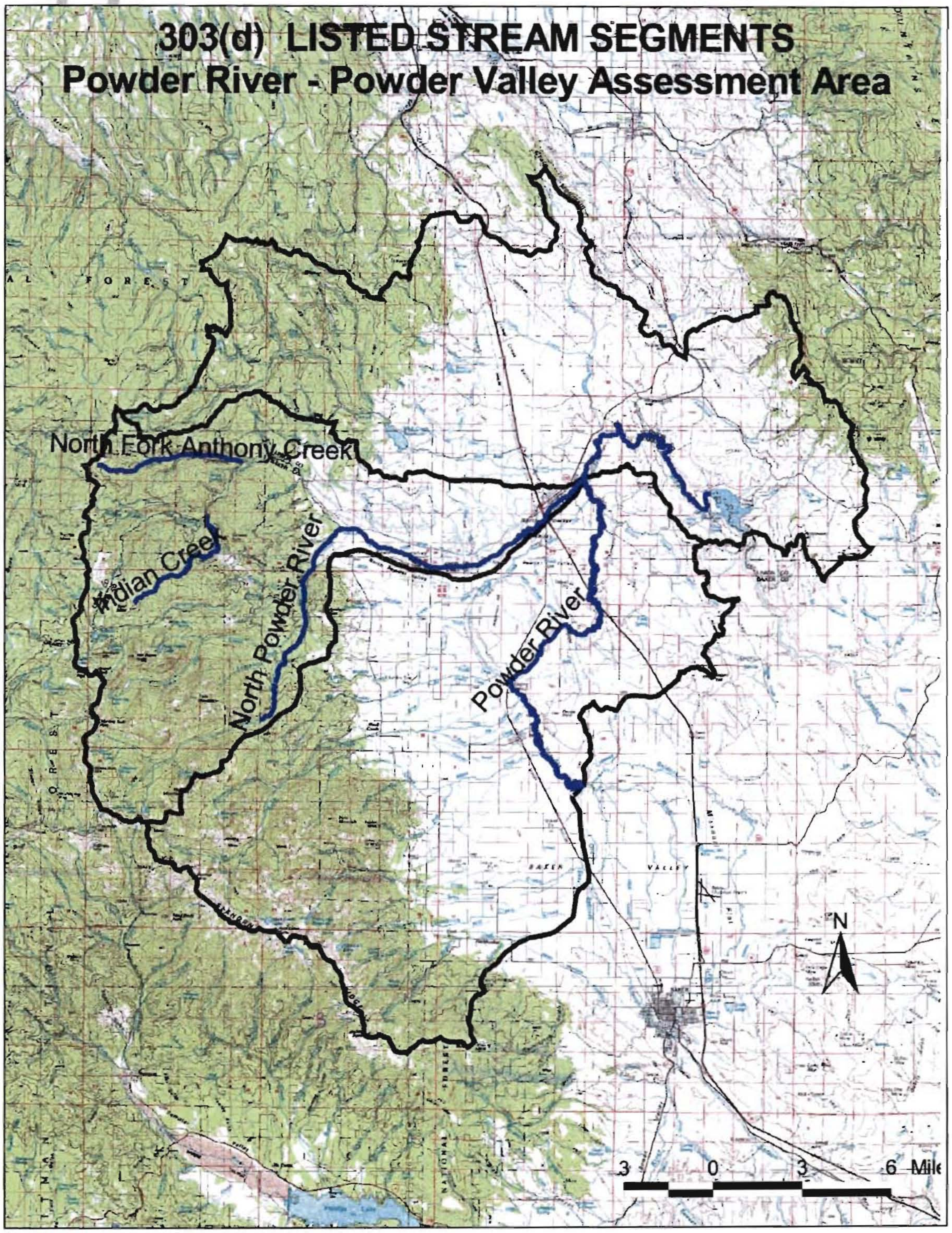
The 2003 revised stream temperature standard for Anthony Creek, Indian Creek and North Powder River is that stream temperatures cannot exceed 53.6 °F. These streams have a ODEQ fish use designation for bull trout spawning and juvenile rearing habitat. The revised 2003 temperature standard for Powder River is that stream temperatures cannot exceed 68 °F. This stream has an ODEQ fish use designation for redband trout.

Both Anthony Creek and Indian Creek lie almost entirely within forested areas. Whether their higher than desired temperatures is the best that can naturally be expected, or the lingering result of historic channel changes and/or the loss of shade due to the 1960 Anthony Lakes Burn is unknown at this time. The burned areas are now reforested, mostly by lodgepole pine.

A Biomonitoring project was carried out on Antone Creek in the summer of 2002. (Lovelace and Dougan, 2002) Antone Creek is a neighboring stream to Anthony Creek and Indian Creek. It flows through similar terrain. Findings include:

÷ The 7-day max/average water temperature was 60.5° F.
÷ There were 32 days over 55° F and 0 days over 64° F.
÷ Turbidity measurements ranged from 2.46 NTUs (June) to 0.32 NTUs (July). (Very little suspended sediment).
÷ Dissolved oxygen readings ranged from 9.82 to 9.75. (Above 10 is ideal).
÷ Nitrate readings were below the standard of 10 mg/I. (That's good).
÷ Phosphate readings were above the standard of 0.10mg/I. The high phosphate reading could be a normal background measurement from phosphates in rocks.
÷ pH readings ranged from 8.37 to 7.5. (Ideal range for fish is 6.5-8.0).

Figure 51. 303(d) listed stream segments.



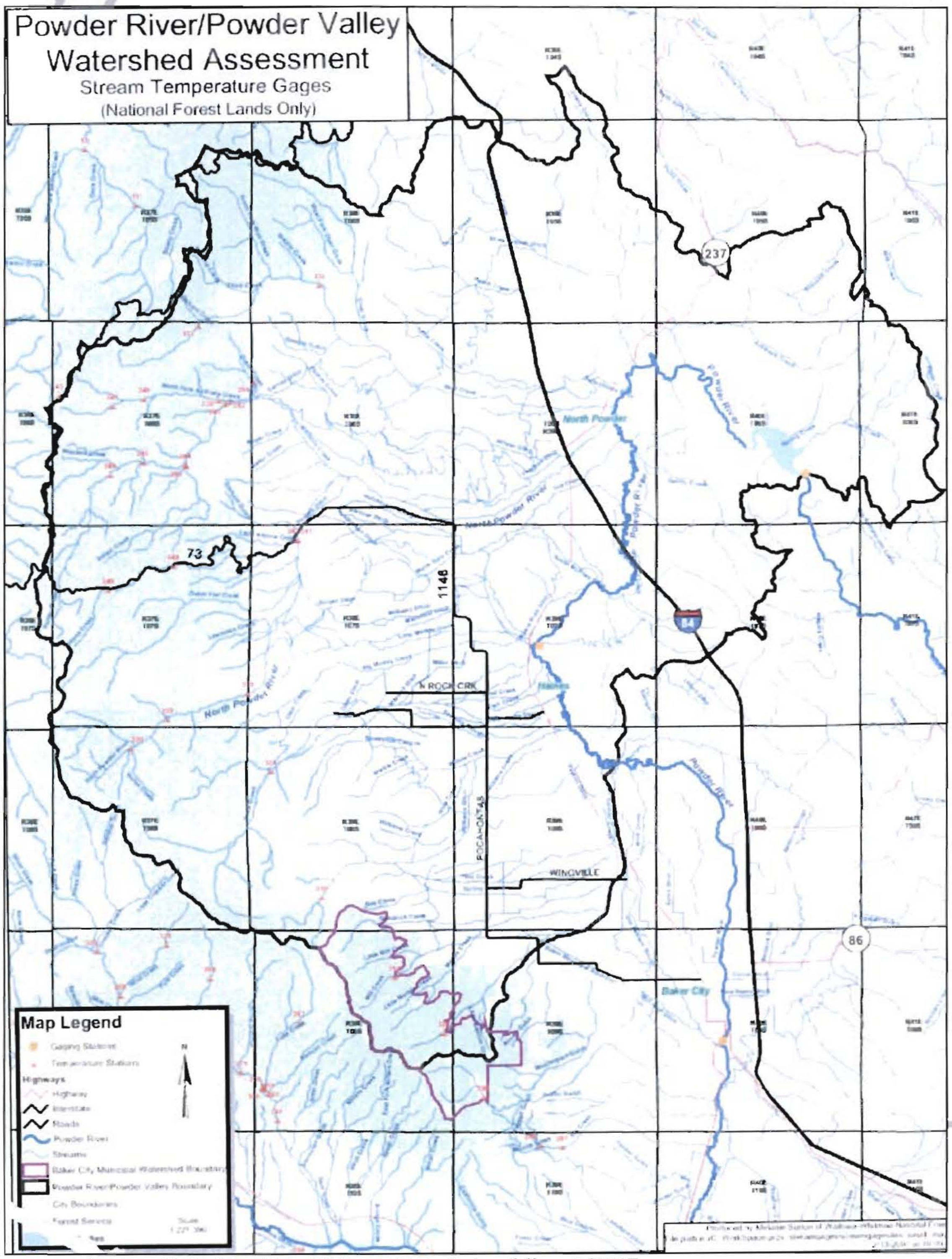
Source: ODEQ

Some stream temperatures, air temperatures and flow measurements taken in 1965-66 can be found in Hutchison and Fortune, 1967. Streams measured were Powder River, N. Fk. Powder River, Anthony Fk. Creek, N. Fk. Anthony Fk. Creek, Antone Creek, Dutch Flat Creek, Rock Creek, Wolf Creek and Clear Creek.

Additional stream temperature data have been collected in selected streams in the assessment area by the WWNF (Figure 52 and Table 44). Stream temperature gages have been installed from late June/early July to mid September/early October. The data were not analyzed in time for this assessment. However, time and budget permitting, the data will be analyzed in time for submission to DEQ for their 2005 303d list.

In many cases, stream temperature measurements are made in only one location. The data from that monitoring site are then applied to the entire stream. The result is a generalized assessment of current stream temperature conditions that makes it difficult to identify where to use limited resources. The analysis of WWNF data, when added to stream temperature data from BOR and the SWCD, will hopefully provide a more accurate picture of how stream temperature varies with location and elevation. A better understanding of how stream temperatures vary along a river will allow resources to be focused on those sections that have the greatest need. Various measurements have been made on several streams in the assessment area. See Appendix M for stream measurements in the assessment area.

Figure 52. Map showing the locations of the U.S. Forest Service stream temperature gages. Hobos are given a site number for ease of reading map. See Table 200 for the corresponding creek and hobo number.



Source: Hydrology files, Whitman Unit, Baker Office, WWNF

Table 42. Streams with temperature data collected by the WWNF and the years with data. X = years with temperature data.

			Years with Stream Temperatures							
Site	**Number**	**Map site number**	1993	1994	1995	1996	1997	1998	1999	2003
NFk Anthony	18G.1	239			X					
NFk Anthony	18G.2	240	X	X	X			X	X	X
NFk Anthony	18G.3	241	X	X	X					
Anthony	18F.05	242						X	X	X
Anthony	18H.1	243		X	X					
Anthony	18H.2	244		X	X					
Anthony	18H.2.5	245						X	X	X
Anthony	18H.3	246	X	X	X					
Antone	18J.1	247								
Antone	18J.2	248		X						
Antone	18J.3	249		X						
Dutch	18F.1	286			X					
Indian	18H.1	296		X				X	X	X
Mill	01H.1	312					X			
Pine	01G.1	316			X					
Powder N.	18L.2	317			X			X	X	
Powder N.	18L.3	318		X	X					
Powder N.	18L.4	319		X	X					
Powder N.	18L.5	320		X	X					
Rock	01D.1	321			X					
Salmon	01H.1	322					X			
Wolf	18C.1	332				X		X	X	X
Wolf	18C.3	333						X	X	X

Source: Hydrology files, Whitman Unit, Baker Office, WWNF

Factors influencing Stream Temperatures

Discussions regarding stream temperatures often get reduced to a debate of shade versus air temperature. However, streams are dynamic and complex systems. Therefore the factors controlling stream temperatures are complex, dynamic and interrelated. Air temperature influences the overall pattern of stream temperature changes (Figure 53) but air temperatures influence on the magnitude of those changes and in some cases the pattern of change is highly dependent on the other factors. Shade minimizes inputs of solar (short wave) radiation into the stream and keeps air temperatures lower than would occur in unshaded areas. A more complete list of factors influencing stream temperature is found below.

1. air temperature
2. shade
3. channel width
4. water depth
5. stream discharge volumes
6. stream velocity
7. subsurface groundwater return flow (volume and temperature)
8. stream orientation
9. water withdrawals via irrigation ditches
10. water additions via reservoir releases
11. elevation
12. aspect
13. topography
14. riparian vegetation type, density, height and continuity
15. amount of turbulence (mixing) in the stream
16. current land use
17. historic land use
18. hot springs

Historic land use is an important factor controlling current stream conditions that is often overlooked. The streams in the assessment area have undergone considerable change in the last 180 years in response to Euro-American land uses, beginning with beaver trapping in the early to late 1820s and continuing with channelization and irrigation withdrawals today. These land uses led to increased channel widths and depths, reduced riparian vegetation, decreased frequency of valley floor flooding, decreased stream flows during the summer and lowered valley water tables. All of these changes influence current stream temperatures. Examples of historic and current channel changes on the Powder River and many of its tributaries are found in Appendix H. Understanding how historic land uses have determined current conditions provides a broader perspective for interpreting current conditions and determining what types of restoration or temperature modifications are and are not physically possible.

An important aspect of the shade versus air temperature discussion, and one that helps explain the apparent contradiction in some of the research results, is the amount and type of radiation received by the stream. Duncan and Associates (2002) provide an excellent summary of the respective roles of long and short wave radiation on stream temperatures and the relative magnitude of influence on stream temperatures. A more detailed discussion is found in the original Burnt River Temperature study by Mangelson (2001). A paper by Larson and Larson (1996) and a conversation with Ken Mangelson of the BOR and author of the Burnt River study (3/31/04) add additional key information.

> "...most of the heat transfer to and from a stream results from radiation. There are two forms – long-wave (infrared) and short wave (visible and ultraviolet). Long-wave radiation transmits heat to the stream from the atmosphere, from riparian vegetation, and from topographic features such as canyon walls. Solar radiation [short wave] transmits heat from the sun to the stream, either directly or from reflections off clouds. [In turn] the stream surface emits long-wave radiation, cooling the stream while heating the surrounding environment (Duncan and Associates 2002, p. 5)."

Long and short wave radiation penetrate the water column to different depths. This helps clarify the role of stream depth on stream temperature sensitivity to air temperature. Water absorbs about 90% of the incoming long wave radiation in the top ½ inch of a water column and 100% within the top 4 inches. The absorption of long wave radiation warms the top 4 inches of the water column without directly warming the water at greater depths (Larson and Larson 1996, p. 149). The depth short wave radiation can penetrate the water column varies depending on if the water is clear or muddy. If the water is muddy short wave radiation may penetrate less than 2 feet and warm only that portion. If the water is clear short wave radiation may penetrate much deeper with the amount of warming decreasing with depth as the short-wave radiation is absorbed (Mangelson, BOR, pers. com. 3/31/04). If streams are muddy and greater than 2 feet deep, the total water column is warmed as the water is mixed. Stream waters mix as they flow downstream. That is explains why stream temperatures can be uniform throughout a water column even though short and long-range radiation do not reach to bottom of the stream.

Table 43. Example of long and short wave (solar) radiation influences on relative stream temperatures as a function of water depth, shade, and clarity.

Stream Condition	Stream depth	Long wave input	Short wave input	Turbulence	Water column
Unshaded, water clear	≤ 4 inches	Upper 4 inches	Upper 4 inches	Yes	Mixing very warm with very warm
	3 feet	Upper 4 inches	Entire 3 feet	Yes	Mixing very warm top with less warm
Unshaded, water muddy	≤ 4 inches	Upper 4 inches	Upper 4 inches	Yes	Mixing very warm with very warm
	3 feet	Upper 4 inches	Upper 2 feet	Yes	Mixing very warm top with warm and cool waters
Shaded, clear	≤ 4 inches	Upper 4 inches	No inputs	Yes	Mixing warm with warm
	3 feet	Upper 4 inches	No inputs	Yes	Mixing warm with cool
Shaded, turbid	≤ 4 inches	Upper 4 inches	No inputs	Yes	Mixing warm with warm
	3 feet	Upper 4 inches	No inputs	Yes	Mixing warm with cool

Source: Based on information found in Larson and Larson 1996 and Personal Communication with Mangleson, March 2003.

The ability of water to emit long wave radiation means that under shaded conditions, when short wave radiation is blocked, incoming and outgoing long wave radiation is somewhat balanced. Thus the contribution of shade becomes clear. "Shade does not produce cooling, but rather prevents heating by direct solar radiation (Larson and Larson 1996, p. 150)." The removal of shade increases the amount of short-wave radiation into the stream. The greater amount of radiation eventually exceeds the amount of radiation emitted by the stream and stream temperatures increase.

Table 43 and information regarding depths that long and short wave radiation can penetrate a water column help explain why shallow streams are so responsive to air temperature even under shaded conditions. In shallow, shaded streams (≤ 4 inches) the entire water column is warmed by long wave radiation emitted from the atmosphere, riparian vegetation and topography (Duncan and Associates 2002). Even if there is turbulence in the stream, it is warm water mixing with warm water. In contrast, in deeper, fast-moving, shaded streams, the top 4 inches is warmed by long wave radiation alone and then mixed with the cooler water. The result is a dampened stream temperature response to air temperature. With the removal of shade, the water column is warmed by inputs of both short (solar) and long wave radiation. The upper 4 inches captures the incoming long wave radiation and a portion of the short wave radiation. The remaining short wave radiation passes deeper and helps warm the water below 4 inches. Warming in the upper 4 inches is increased because more energy is being added to the upper 4 inches at the same time that water below 4 inches is warmed by the short wave radiation. The net impact is that the water column is warmer as it moves downstream.

The ability of water to absorb long wave radiation within its upper 4 inches underscores the seriousness of channel widening. As the channel width increases, water depth decreases for a given flow. The net result is that a greater percentage of the water column becomes heated and responsive to air temperature. As Carr et al. (2003) found, even when much of a stream reach was shaded, there remained strong correlations with air temperature when the streams are shallow.

The shade factor does not exist in a vacuum. As multiple researchers have noted (Larson and Larson 1996, 1997; Beschta 1997; Duncan and Associates 2002) channel width determines the amount of stream surface area that is exposed to short-wave radiation. As channel width increases so does the required height of the vegetation if a similar amount of shade is to be maintained. The role of channel width and tree height and distance from the stream edge was presented in Larson and Larson (1996). In their example, the channel was 40 feet wide and tree heights were 20 and 50 feet. As expected, these tree heights provided minimal shade to the stream because of the width of the stream. The 40 foot channel width, however, is an example used to illustrate a point and not representative of streams in Eastern Oregon. Over 90% of the 38 subwatersheds comprising the Upper Grande River Basins have average wetted widths of 10 feet or less (Beschta 1997). A similar situation exists for many of the streams in the Powder River/Powder Valley assessment area (Appendix H). Therefore, historic and current land uses combined with high flow events that increase channel width also decrease the effectiveness of local vegetation in providing shade.

Mangelson (2001) provides an excellent case study documenting the different factors influencing stream temperature and the complex interactions between those factors. The study on the Burnt River addressed 15 of the 18 factors either directly or indirectly. The study only addresses current stream conditions. It does not discuss current and historic land uses and their impact on the 1) channel size, 2) stream flows (except reservoir releases), 3) riparian vegetation and 4) stream temperature values (except reservoir releases). However, early beaver trapping in the Burnt River drainage (Williams et al. 1971), settlement, grazing, agriculture, surface water diversions, building of reservoirs and ditches have altered stream channel widths and depths, stream flows, riparian vegetation, frequency of valley floor flooding and groundwater recharge.

Larson and Larson (1996) also identify multiple factors influencing stream temperatures. "The capacity of a stream to buffer against temperature increase is directly influenced by water volume and the size of the surface area that is exposed to the energy source. This capacity can be modified directly through the addition of snowmelt and interflow (p. 151)." To the above list, Larson and Larson (1997) added the additional factors of initial temperature at sunrise and how long the stream is exposed to the sun, air and soil. Factors that influence how long the stream is exposed include stream velocity and distance traveled (Meays et al. 2003). Water depth is an important control on stream velocity. As water depth increases, stream velocity increases because the influence of friction generated by the stream banks and channel bed decreases (Knighton 1998).

Research on stream temperatures underscores the complexity of the stream temperature controls. Meays et al. (2003) studied three tributaries to the South Fork Burnt River. The average water depth varied from 3 to 7 inches deep. Their study found that while shallow streams are highly sensitive to air temperatures and changes in elevation, the rate of stream temperature increase was decreased by 1) inputs of cool subsurface water and 2) higher stream velocities. The rate of increase in stream temperatures slowed because higher discharges and greater stream velocities decreased thermal exposure time. Meays et al. (2003) study was high in the watershed and inputs of cool subsurface waters were from natural groundwater return flows.

Other studies have examined how irrigation influences subsurface return flows and therefore stream temperatures lower in the watershed. Taylor et al (2003) studied a first-order stream near Steens Mountain to determine the impact of irrigation on stream temperatures. They noted that historic management activities have altered the natural groundwater flow pattern of the meadow and needed to be considered when interpreting their data. The study found that stream temperatures in the section of stream that flowed through an irrigated field became cooler than upstream temperatures in a non-irrigated section over the course of the irrigation season as the increased subsurface flow in the irrigated fields reached the stream. The magnitude of heating as the stream flowed downstream was partly controlled by the timing of the input of cooler, temperature-constant groundwater into the stream. A time lag of as much as a month was observed between the start of irrigation and when return flows began reaching the creek. The time lag varied as a function of pre-irrigation soil moisture conditions. The later the irrigating began, the drier the initial soil conditions and longer it took before irrigation-generated return flows reached the stream (Taylor et al. 2003).

Stringham et al. (1998) studied a third-order stream in south-central Grant County. They also found cooler daily maximum stream temperatures in the irrigated versus non-irrigated section of the meadow stream. Irrigation began in March and continued through late July and then resumed in September. By mid June discharges were greater in the irrigated portion than in the upstream non-irrigated portion (48.6 cfs vs. 31.1 cfs) indicating groundwater return flows were entering the irrigated section. However, differences in stream temperatures did not show up until mid-July. After mid-July, the portion of the stream that flowed through the irrigated section was 1.8 to 5.4 °F colder than in the non-irrigated section. The difference between pre- and post mid July is attributed to the end of the spring runoff. After the end of spring runoff the cooler groundwater flows became a larger percentage of the channel flow and their temperature influence increased. With the cessation of irrigation, the water table dropped in the wells closest to the ditch indicating the influence of irrigation on groundwater flow.

Beschta and Taylor (1988) documented stream temperature increases in response to land uses that reduced canopy cover. Other studies and data have documented the influence of reservoir releases (Duncan and Associates 2003) and water diversions (Fouty 2003b; WWNF, Whitman Unit, Baker Office Hydrology files) on stream temperatures. Stream temperature changes were opposite the expected relationships of warmer stream temperatures with decreasing elevation and warmer air temperatures. In these cases, stream temperatures were in large part controlled by the temperature of the water added or withheld from a section of stream.

The studies by Taylor et al (2003), Stringham et al. (1998) and Meays et al. (2003) highlight the importance of subsurface return flows in minimizing stream temperature changes. In the case of the Taylor et al. (2003) and Stringham et al. (1998) studies, field irrigation is mimicking what widespread spring flooding of the valley floors used to do only at a different time. In the case of the Burnt River study, field irrigation in the Burnt River valley may be mimicking and even extending the spring flood event (K. Mangelson, pers. com., 3/31/2004).

The change from spring flooding to irrigation flooding as a method of groundwater recharge and creation of subsurface return flows to streams is not a direct substitution of process. Irrigation's effectiveness at supplying subsurface return flows will vary depending on location, timing and type of irrigation, and the amount of area and length of time an area is irrigated. In some cases a local section of river may become cooler due to enhanced irrigation-generated subsurface return flow (Stringham et al. 1998; Taylor et al. 2003) while the removal of that water from the stream dewaters or reduces stream flows and contributes to an increase in its temperatures further upstream.

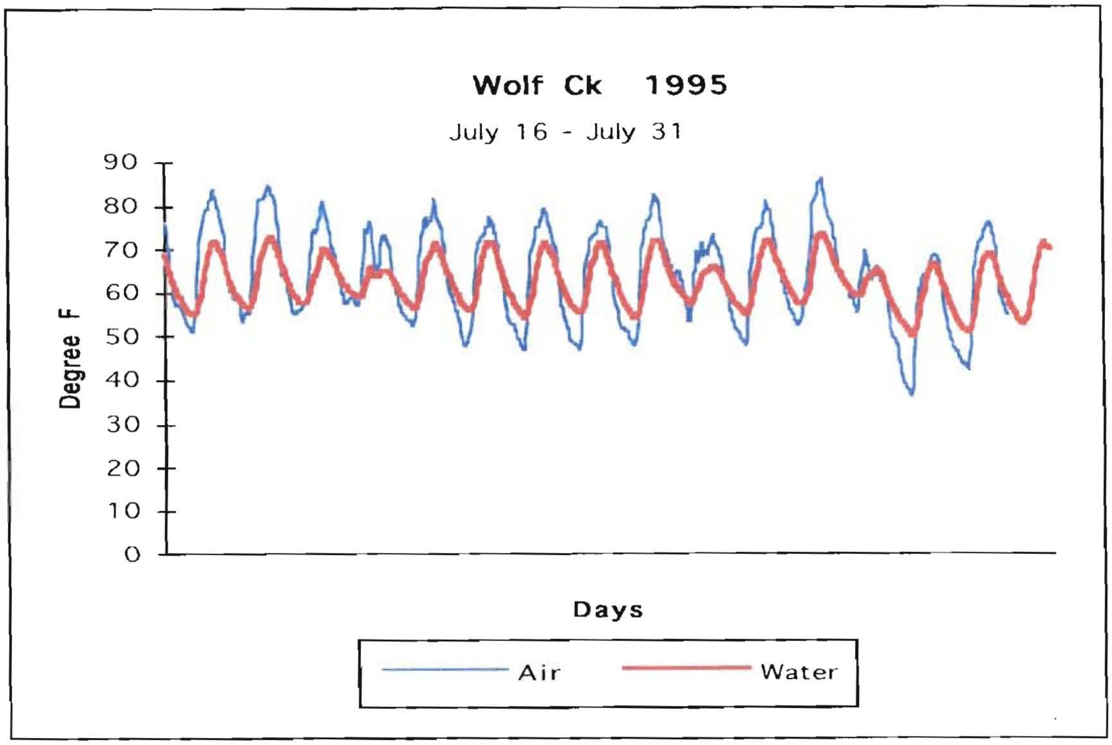
In contrast, during spring flooding the stream and the area flooded are adjacent. Flooding begins at the edge of the stream bank and extends outwards away from the stream. Therefore the areas closest to the stream were recharged first and most frequently. Water tables remain high near the stream and contribute cooler subsurface waters along its entire length during the low flow season, rather than just in local areas. This spotty contribution of subsurface irrigation return flows has been noted along the Powder River and Spring Creek (see the Hydrology section). In contrast, there is no consistent link between the stream location and the area undergoing flood irrigation. Some irrigated fields are adjacent to the stream, while other fields are more distant. As irrigation efficiencies and distance to a stream increase, the irrigation contribution to return subsurface flow and cooler stream temperatures decreases.

The timing of spring flooding is different than irrigation flooding, though the extent of the difference varies from place to place (compare Mangelson 2001 and Taylor et al. 2003). Spring flooding is more synchronous in time across an area and occurs during a time of water abundance in the watershed rather than water scarcity. Finally, the time lag noted by Taylor et al. (2003) between initial irrigation and subsurface return flows into the stream is another difference between current irrigation practices and spring flooding. In systems that have frequent valley floor flooding, the lag does not occur because soil moisture content and the water table remains high and connected to the stream. In areas that are irrigated late in the season, dry soil moisture conditions delay the timing of return flow. If irrigation is started early in April, the subsurface return flow could be more closely aligned with natural conditions (See Table 21, p. 16).

In summary, there are multiple factors influencing stream temperatures. Some of those factors are outside the control of humans (i.e. elevation, aspect, topography). Others can be controlled by humans (i.e. shade, channel widths, water depths, timing of water withdrawals and reservoir releases). Understanding of how various factors influence stream temperatures and their interrelationships allows landowners and land managers to focus their efforts and achieve the highest return for their resource input.

Water and air temperature data were collected at 6 sites on Powder River between Phillips Reservoir and North Powder, Oregon in a study spanning 8 years. The Baker County Association of Conservation Districts contracted a report. The report is titled "A Summary and Analysis of the Powder River Watershed Water Quality Monitoring Program 1999 through 2003." J. Ronald Miner wrote the report. The report was released to the public on April 13, 2004 and therefore could not be reviewed in time to include the results in this draft.

Figure 53. Water Temperatures as a Function of Air Temperatures.



Source: Water Quality Analysis Report, 1995-2002. The Wolf Creek average maximum water temperature was 73° F and the minimum average was 52° for the period displayed above. The average maximum air temperature at the site was 79°, and the average minimum was 48°. The average air and water temperatures were 64° and 63° respectively.

Water and air temperatures were measured during July 1995 on Wolf Creek at a site located just above the Reservoir. Figure 52 shows how water temperatures at the site followed air temperatures.

Baker County's Herbicide and Insecticide Use

Herbicides and insecticides (pesticides) are commonly used in the United States and in Baker County. As pesticides are designed to kill species, it is critical that individuals using these products be well aware of the potential health risks to themselves, their children and pets, their neighbors and neighbors' pets, and the birds, fish, plant, and insect life that provide many benefits free of charge. Many of these chemicals volatize or go into solution and therefore their impact can extend far beyond their point of initial application.

Several of the most common herbicides and insecticides used in Baker County are listed in Table 46. A very brief summary of some of the currently understood impacts on humans, water, soil, plant productivity, fish, wild life, and aquatic insects of these pesticides are found in Appendix Q. A review of the summarized information shows that many of the commonly used pesticides in Baker County affect birds, fish, and humans. The source of the information is listed at the end of each write-up. Appendix Q is not intended to be a complete list. Its goal is to summarize some of the impacts of a given pesticide to the community and allow individuals a means to find additional information. The full documents referenced in Appendix Q can be downloaded from Northwest Coalition for Alternatives website under their Pesticide Fact Sheet section: www.pesticide.org. Another good source of pesticide information can be found at EPA's website under Pesticide Fact Sheets: www.epa.gov/pesticides.

The type and the extent of use vary. For example, Baker County's agricultural community only occasionally uses insecticides. Insecticides are used on potatoes (though the use of fungicides is more common) and on particular insect problems such as the cereal leaf beetle and the alfalfa weevil (J. Carr, Baker County extension agent, 4/13/04). Homeowners, by comparison, use insecticides frequently and can be quite liberal in their use of lawn care products that contain pesticides. For example, systemic rose-care products are the most toxic rose-care products available to home gardeners, and are dangerous to dogs, cats and humans. The frequently bought weed-and-feed type products used on lawns cover the entire lawn with an herbicide even though the weeds are spotty (M. Robson, 2/26/03).

Table 44. Some of the common herbicides and insecticides used in Baker County and the user group. For information on their impacts see Appendix Q.

Common name	Active ingredient	Users	Category	Source
Round up	Glyphosate	Homeowners, Forest Service	Herbicide	Janice Cowan, OSU Extension Service; Steve Gibson, Forest Service
2,4-D	2,4-D	Homeowners	Herbicide	Janice Cowan, OSU Extension Service
Tordon *(restricted use)*	Picloran	Ranchers, agriculture, Forest Service, BLM	Herbicide	Arnie Grammon, Baker County Weed Control; Steve Gibson, Forest Service; Kevin McCoy, BLM; Jay Carr, Baker County Extension Service
Curtail	2,4-D and Clopyralid	Ranchers, agriculture	Herbicide	Arnie Grammon, Baker County Weed Control
Weedmaster	2,4-D and Dicamba	Ranchers, agriculture	Herbicide	Arnie Grammon, Baker County Weed Control
Diazinon	Diazinon	Homeowners, ranchers, agriculture	Insecticide	Janice Cowan, OSU Extension Service
Sevin	Carbaryl	Homeowners, ranchers, agriculture	Insecticide	Janice Cowan, OSU Extension Service
2,4-D/Banval	2,4-D	BLM	Herbicide	Kevin McCoy, BLM

Pesticide testing in the Powder River is limited. Herbicides were tested in August 1989 (Schwind, DEQ, 5/29/03) and one day in 1992 (M. Wolgamott, DEQ, email, 4/16/04). The 1989 samples were collected from groundwater, soil and surface water and appear to be restricted to agricultural areas. The 1989 values were below detections except for Picloram, which was observed at 0.00015 mg/L. The 1992 samples were collected in the Powder River from fish tissue because many pesticides are seldom found in surface water in concentrations that can be measured, at least not at the equipment limits that were available in 1992, but do bio-accumulate in fish. Almost all of the results were below 1992 detection limits with the exception of lindane and DDT metabolites. However, these two were also low. The source of the lindane and DDT metabolites would be application of herbicide and insecticides, though some may be residuals from applications made many years ago. The DDT metabolites are one example. It has been banned for years but it still shows up (M. Wolgamott, DEQ, email, 4/16/04). No other testing has been identified to date. No testing appears to exist to determine pesticide concentrations around homes or schools in North Powder, Haines or Baker City. This is an information need because as noted above, homeowners can be quite liberal in their use of pesticides.

Fecal Coliform Bacteria Standards

The sources of fecal coliform bacteria in the Powder River have yet to be determined. This should be done before TMDL's and a Water Quality Management Plan are put in place.

AFO/CAFO

The EPA and the ODA have regulatory responsibilities over Animal Feeding Operations (AFO), and Confined Animal Feeding Operations (CAFO). New definitions and regulations have recently been adopted by EPA and ODA. The new definitions and regulations are much more complex than in the past. These are regulated under "point source" pollution rules. ODA's rules can be found on their website, www.oda.state.or.us. They are also listed in OAR Chapter 603 Division 074. Following is the new ODA definition of a CAFO:

"(3)"Confined animal feeding operation" means

(a) The concentrated confined feeding or holding of animals or poultry, including but not limited to horse, cattle, sheep, or swine feeding areas, dairy confinement areas, slaughterhouse or shipping terminal holding pens, poultry and egg production facilities and fur farms;

(A) In buildings or in pens or lots where the surface has been prepared with concrete, rock or fibrous material to support animals in wet weather; or

(B) That have wastewater treatment works; or

(C) That discharge any wastes into waters of the state; or

(b) An animal feeding operation that is subject to regulation as a concentrated animal feeding operation pursuant to 40 CFR ψ122.23."

Several years ago EPA began inspections to see if wintering cattle and calves were watering out of creeks, or if runoff from confined feedsites was running off into creeks. County Extension Agents were forewarned that inspections would be coming. Extension Agents talked to operators that might be out of compliance. Solutions to local problems were usually as simple as shutting a gate. No inspections resulted in a fine in this watershed (J. Carr, pers. com., 2002). ODA has issued one CAFO permit in this watershed: a permit to SSI feedlot for 2000 head of beef cattle on Culley Lane near North Powder.

Operations that do not qualify as an AFO or CAFO are regulated under the "non-point" source pollution found in Section 208 and 319 of the Clean Water Act. Sections 208 and 319 provide incentives and grant programs to mitigate and correct non-point source problems.

Dr. Mansour Samadpour, Professor of Environmental Health Science at the University of Washington developed a technique for tracking the sources of fecal coliform bacteria using DNA "fingerprinting." The technique identifies the individual species from which a bacterial sample comes (Ferry County SWCD, 2002).

A similar study on the Powder River would be a valuable planning tool. If agriculture or humans are the major contributors to bacterial pollution of the river, steps can be taken to correct the problem. If wildlife is found to be the major contributor, lowering bacterial pollution becomes much more complicated. Two recent studies in neighboring states indicate the complexity that efforts to make Powder River meet water quality standards might face:

÷ A study of three tributaries of the Kettle River on the 303(d) List in Washington determined that "deer and elk accounted for the majority of fecal coliform bacteria sources at every sample site" (Ferry County SWCD, 2002).
÷ Another study on the lower Boise River, a 40-mile 303(d) List reach from Lucky Peak Dam to the river's confluence with Snake River, concluded that "resident geese and ducks were to blame for 70 percent of the E. coli samples found." Land use along this reach of the Boise River varies from urban and suburban uses (260,000 people) to agricultural farmland including 350,000 irrigated acres (Lower Boise River Water Quality Plan, March 2002).

Underground Fuel Tanks

The federal government established rules governing underground fuel tanks in 1986. The Oregon legislature adopted the federal tank rules in 1988. The rules state that tanks larger than 1,100 gallons must be reported to ODEQ and are subject to regulation. All regulated tanks must meet stringent requirements concerning spills, overfill, corrosion protection for tanks and piping, and monitoring for release detection.

Four facilities in Haines, and six facilities in North Powder, had a total of 21 tanks that fell under the rules for regulation. All but four have either been decommissioned or removed. The four remaining tanks are under permit, and are operated by Co-op Supply at the Cenex gas station in North Powder. The ODEQ is unaware of any underground fuel tanks which are causing any pollution to ground water in the Powder River-Powder Valley Watershed.

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REFERENCES

Baker City Herald. 13 February 2003.

Baker County Bull Trout Response, Critical Habitat, Recovery and Economic Impact Analysis. 2003. NRCS, Baker City, Oregon.

Baker County Comprehensive Land Use Plan. Published by Baker county Planning Commission. Adopted March 9, 1983. Acknowledged April 24, 1986 by Oregon Land Conservation and Development Commission (LCDC).

Baker County Historical Society. 1986. *The History of Baker County Oregon.* Portland, Oregon: Taylor Publishing Company.

Baker County Extension Service, no date provided.

Baker Ranger District. September 1999. Baker Ranger District, Wallowa – Whitman National Forest, Region 6 Watershed Analysis for Section 7 Subbasins.

Baker Ranger District. November 2001. Anthony Lakes Mountain Resort Final Environmental Impact Statement and Record of Decision. USDA Forest Service, Wallowa- Whitman National Forest.

Baker Valley Soil and Water Control District and Powder Valley Water Control District. June 1967. Watershed Work Plan North Powder River Watershed. Baker County, Oregon.

Behnke, Robert J. 1992. *Native Trout of Western North America.* Bethesda, Maryland: American Fisheries Society.

Bestcha, R. L. (1997). Riparian shade and stream temperature: An alternative perspective. Rangelands: 19(2), 25 – 28.

Beschta, R. L. and Taylor, R. L. (1988). Stream temperature increases and land use in a forested Oregon watershed. Water Resources Bulletin 24(1): 19-25.

Bjornn, T.C. 1957. A survey of the fishery resources of Priest lakes and their tributaries, Idaho. Idaho Department of Fish and Game, Federal Aid to Fish and Wildlife Restoration Report F-24-R, Boise

Blatchford, Jim. 2003. Farmer. Personal interview.

Bliss, Timothy. 2003. Soil scientist/hydrologist with Wallowa – Whitman National Forest; member of Powder Basin Watershed Council and Assessment Committee Chair. Personal interviews.

Bowler, Dennis. 2000. Sacramento River Watershed Program Coordinator. "Seeking a Healthy Watershed," in What is a Healthy Watershed Workshop, January 2000, Chico, CA.

Bridges, Andrew. November 22, 2002. AP Science Writer, as quoted in Baker City Herald article, pg. 1B.

Browning, Ralph. 1996. *Aquatic Inventory Program Summary, 1989-95.* Wallowa-Whitman N.F.

Bryan, K. (1927). "Channel erosion of the Rio Salado, Socorro County, New Mexico." U.S. Geological Survey Bulletin 790: 17-19.

Bryan, K. (1928a). "Historic evidence on changes in the channel of Rio Puerco, a tributary of the Rio Grande in New Mexico." Journal of Geology 36: 265-282.

Bryan, K. (1928b). "Change in plant associations by change in ground water level." Ecology 9: 474-478.

Buchanan, David V., et. al. October 1997. Status of Oregon's Bull Trout. Oregon Department of Fish and Wildlife, Portland, Oregon.

Burkham, D. E. (1972). "Channel changes of the Gila River in Safford Valley, Arizona 1846 - 1970." U. S. Geological Survey Professional Paper 655 - G: 1-24.

Button, Clair. Feb. 24, 2003. Personal correspondence from Clair Button@or.blm.gov.

Campbell, K. L., Kumar, S., and Johnson, H. P. 1972. "Stream straightening effects on flood-runoff characteristics." American Society of Agricultural Engineering Transactions 15: 94-98.

Carr, Jay. 2002. Baker County Extension Agent. Personal interview.

Carr, Jay (2004). Baker County Extension Service, personal communication, April 13, 2004.

Carr, C., Strangham, T., and Thomas, D. (2003). The influence of environmental and physical factors on the thermal patterns of headwater streams *In* 2003 Range Field Day Progress Report on Environmental and Management Impact on Stream Temperature, July 1, 2003, Unity, Oregon. pp. 35-50.

Cooke, R. U. and R. W. Reeves (1976). Arroyos and environmental change in the American Southwest. Oxford, Clarendon Press.

Colton, Fred and Chris. 2002. Personal interviews.

Cottam, W. P. and G. Stewart (1940). "Plant succession as a result of grazing and of meadow desiccation by erosion since settlement in 1862." Journal of Forestry 38: 613-626.

Cowan, Janice (2004). Baker County Extension Service, personal communication, March 31, 2004.

Crowe, Elizabeth A. and Clausnitzer, Rodrick R. Wetland Plant Associations of the Malheur, Umatilla and Wallowa-Whitman National Forests. USDA Forest Service, Pacific NW Region, Wallowa-Whitman N. F. R6-NR-ECOL-TP-22-97. 1997.

Dade, Gary. 2002. Union County Director of Vegetation Management. Personal interview.

Department of Environmental Quality. 2002. Oregon's Final 2002 303(d) List. http://www.deq.state.or.us/wq/WQLData/View303dList02.asp

Dielman, Gary. January 16, 2003. Article in Baker City Herald.

Dielman, Gary. April 21, 2003. Personal interview.

Dobyns, H. F., 1981. From Fire to Flood: Historic human destruction of Sonoran Desert riverine oases, Ballena Press.

Dougan, Jackie. 2002 and 2003. Fish biologist, Bureau of Land Management. Personal interview.

Draft Baker County Study on Water Quality. 1995. Powder Basin Watershed Council.

Driscoll, F. G., 1986. Groundwater and Wells. Johnson Division. St. Paul. Second Edition.

Ducret, G. L. Jr. and Anderson, D. B. March 1965. Records of Wells, Water levels and Chemical Quality of Water in Baker Valley, Baker County, Oregon. Prepared in Cooperation with the United States Department of the Interior Geological Survey.

Duncan, David and Associates. April 2002. Burnt River Water Temperature Study, Steering Committee Final Report. Boise, Idaho.

Dunne, T. and Leopold, L., 1978. Water in Environmental Planning. W. H. Freeman and Company, New York.

D. Dyke, Bureau of Reclamation, Personal interview, 2004.

Elle, S., R. Thurow and T. Lamanski. 1994. Rapid River bull trout movement and mortality. studies. Idaho Department of Fish and Game, Boise, ID., Job performance report F.-73-R-16.

Ely, Craig. 2004. Oregon Department of Fish and Wildlife, Special Project Coordinator for the Wolf Management Plan , email 5/10/04.

Ensminger, Lloyd. An article dated January 27, 1927, found in his Book of Remembrance, in possession of the Haines Museum, Haines, Oregon.

EO 11988. 1977. Floodplain Management. Executive Order 11988 was signed by the President of the United States on May 24, 1977.

EO 11990. 1977. Protection of Wetlands. Executive Order 11990 was signed by the President of the United States on May 24, 1977.

Evans, John W. 1991. Powerful Rockey, The Blue Mountains and the Oregon Trail. La Grande, Oregon: Eastern Oregon State College.

Federal Register. May 26, 1999. Vol. 64. Rules and Regulations.

Ferns, Mark. 2002. District Geologist for State of Oregon. Personal interview.

Ferry County SWCD. 2002. Kettle Tri-Watershed Project. Ferry County Soil and Water Conservation District. Republic, WA.

Fish Commission of Oregon. June 1960. Environmental Survey Report Pertaining to Salmon and Steelhead in Certain Rivers of Eastern Oregon and the Willamette River and its Tributaries, Part 1: Survey Reports of Eastern Oregon Rivers. Fish Commission of Oregon Research Division, Clackamas, Oregon.

Fisher, George A. "The History of Rock Creek, Oregon." Unpublished article in possession of Haines Museum, Haines, Oregon.

Fleming, Dick. 2002. Public Works Director for Baker City. Personal interview.

Fouty, S. C., 2003a. Analysis of current watershed condition in the proposed Barnard vegetation management project. Wallowa Whitman National Forest, Baker Office.

Fouty, S. C., 2003b. Current and historic stream channel response to changes in cattle and elk grazing pressure and beaver activity. Ph.D. dissertation. University of Oregon, Department of Geography.

Gerig, Allen. 2002. General soils map and related soil map unit legend.

Gibson, Steve (2004). Range Conservationist, Wallowa Whitman National Forest, Whitman Unit, personal communication, April 2004.

Gildemeister, Jerry. April 1992. Bull Trout, Walking Grouse and Buffalo Bones, Oral Histories of Northeast Oregon Fish and Wildlife. Oregon Department of Fish and Wildlife. La Grande, Oregon.

Grammon, Arnie. 2002. Baker County Weed Supervisor. Personal interview.

Grammon, Arnie (2004). Baker County Weed Control, personal communication, April 2004.

Gregory, H. E. (1917). "Geology of the Navajo Country: A reconnaissance of Parts of Arizona, New Mexico, and Utah." U.S. Geological Survey Professional Paper 93.

Helgerson, Ken. 2002. Baker County Road Supervisor. Personal interview.

Henner, Wilma. 2002. Personal interview with centenarian.

Hiatt, Isaac. 1893. Thirty-one years in Baker County, A History of the County from 1861 to 1893. Abbott & Foster, Book and Job Printers, Baker City, Oregon. Reprinted 1997, Eloise Dielman, editor. Baker County Historical Society, Baker City, Oregon.

Hill, Elmer. 2002. Farmer. Personal interview.

Holman, Ken. 2003. Owner, Oregon Trail Mountain Spring Water. Personal interview.

Hooker, Cindy. 2002. Office clerk, weighmaster. Personal interview.

Hudson, Wreatha. 1983. Baker County with Sheep on a Thousand Hills. Hudson Printing, Baker, Oregon.

Hutchison, James M. and Fortune, John D. Jr. August, 1967. The Fish and Wildlife Resources of the Powder Basin and Their Water Requirements. Oregon State Game Commission, Portland, Oregon.

Ingram, Stan. 1971. Anthony, A Tale of Two Skis.

Johnson, Charles Grier, and Clausnitzer, Rodrick R. 1991. Plant Associations of the Blue and Ochoco Mountains. U.S. Forest Service, Wallowa-Whitman National Forest.

Jones, Ron. 2003. Livestock Water Quality Specialist, Oregon Department of Agriculture. Personal interview.

Keister, George. 1997. Letter to Baker County Board of Commissioners Nov. 25,1997

Keister, George, Baker District Wildlife Biologist, Oregon Department of Fish and Wildlife. 2002. Personal interviews.

Kerns, Tom Mac. 2002. Personal interview.

Kerns, Mac. 2004. Personal communication. See March 3, 2004 Council minutes.

Kerns, Tom Mac. 5/10/04. Written comments on Draft 3.

Knighton, D. (1998). Fluvial forms and processes: A new perspective. John Wiley and Sons Inc., New York.

Larson, L. L. and Larson, S. L (1996). Riparian shade and stream temperature: A perspective. Rangelands 18 (4): 149 – 152.

Larson, L. L. and Larson, P. A. (1997). The natural heating and cooling of water. Rangelands 19(6): 6-8.

Leggett, Deryl. 2002. Personal interview.

Lovelace, William and Dougan, Jackie. 2002. The Antone Creek WSEP Biomonitoring Project 2002. Powder Basin Watershed Council, Baker City, Oregon.

Lower Boise River Water Quality Plan. March 2002. Revised Draft Summary Report, Coliform Bacteria DNA Testing.

Lusk, Rick. 2002, 5/12/04. Baker County Watermaster. Personal interview.

Lusch, Ed. 1985. *Comprehensive Guide to Western Gamefish.* Portland, Oregon: Frank Amato Publications.

Lystrom, et. al. 1967. Ground Water of Baker Valley, Baker County, Oregon.

Geohydrologic Map and Water-Quality Map, prepared in cooperation with the Oregon State Engineer. United States Geological Survey.

Malheur County Weed Board. "Selected Noxious Weeds of Eastern Oregon." Tri-County Weed Management Area, Vale District BLM, National Fish & Wildlife Foundation.

Mangelson, Kenneth (2001). Burnt River Basin water temperature modeling study. U.S. Department of the Interior, Bureau of Reclamation, Water Quality and Land Suitability Group, Denver, CO.

Mangelson, Kenneth, U.S. Department of Interior, Bureau of Reclamation, pers. com. March 31, 2004.

Maynard, Bob. 2003. Well Specialist, Baker County Watermaster's Office. Personal interview.

McCoy, Kevin (2004). Bureau of Land Management, Baker Office, personal communication, April 2004.

McPhail, J. D. and C. B. Murray 1979. The early life history and ecology of Dolly Varden (*Salvenlinus Malma*) in the upper Arrow Lakes. Report to B. C. Hydro and Power Authority and Kootenay Region Fish and Wildlife, Nelson British Columbia, 113pp.

Meays, C. L., Borman, M. M., and Larson, L. L., 2003. Elevation, thermal environment, and stream temperatures on headwater streams in northeastern Oregon. 2003 Range Field Day Progress Report on Environmental and Management Impact on Stream Temperature, July 1, 2003, Unity, Oregon. pp. 51-65.

Miles, Myron. 2002. Personal interview.

Naiman, R. J., Johnston, C. A., and Kelley, J. C., 1988. Alteration of North American streams by beaver. BioSciences 38 (11): 753-762.

Oliphant, J. O., 1968. On the Cattle Ranges of the Oregon Country. University of Washington Press, Seattle.

Olsen, Mike. 2002. Owner. Personal interview.

Oregon Blue Book, 2001-2002. Published by Bill Bradbury, Secretary of State, 2001, Salem, Oregon. www.bluebook.state.or.us

Oregon Department of Fish and Wildlife. 1980. Fish and wildlife Habitat Protection Plan for Baker County. A Report of the Oregon Department of Fish and Wildlife to the Baker County Division of Planning and Development 1980.

Oregon Department of Fish and Wildlife. 1995. Aquatic Inventory Project, Fish Surveys, 1990-1995. Burnt River Basin, Pine Creek Basin, Powder River Basin, Snake River (Brownlee).

Oregon Department of Fish and Wildlife. December 1995. 1995 Biennial Report on the Status of Wild fish in Oregon. Portland, Oregon.

Oregon Department of Fish and Wildlife 1997. Status of Oregon's bull trout.

Oregon Department of Fish and Wildlife. 2001. 2001 Big Game Statistics Oregon Department of Fish and Wildlife, Salem OR.

Oregon Department of Forestry. 1998. Color aerial photography. Approx. 4" = 1 Mile.

Orr, Kathy. 2002. Personal interview.

OWHP. 1995. Guidelines for Watershed Councils. Final report to the Legislature, Volume 2. Oregon Watershed Health Program. August 1995.

Northwest Coalition for Alternatives to Pesticides website. www.pesticide.org

Powder Basin Watershed Council. 1996. Preliminary Watershed Assessment. Powder Basin Watershed Council, Baker City, OR

Powder Basin Watershed Council. August 2000. Pine Creek Watershed Assessment. Baker City, Oregon.

Powder Basin Watershed Council . 2000. Pine Creek Watershed Assessment. Powder Basin Watershed Council, Baker City, OR.

Powder/Brownlee Agricultural Water Quality Management Area Plan. 1 April 2003. Powder/BrownleeLocal Advisory Committee with assistance from Oregon Department of Agriculture and Baker Valley and Eagle Valley Soil and Water Conservation Districts.

Prather, Timothy S., et. al. 2002. Idaho's Noxious Weeds. Department of Plant, Soil and Entomological Sciences, College of Agricultural and Life Sciences, University of Idaho, Moscow, Idaho, in cooperation with the Idaho Weed Coordinating Committee, Idaho Department of Agriculture, Boise, Idaho.

Pratt,K. L. 1992. A review of bull trout life history, p. 5 – 9 *In* P.J. Howell and D. V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.

Ratliff, Donald E. and Howell, Philip J. 1992. "The Status of Bull Trout Populations in Oregon." Proceedings of the Gearhart Mountain Bull Trout Workshop Oregon Chapter of the American fisheries Society.

Rieman, B. E. and J. D. McIntyre. 1993. Demographic and habitat requirements for the conservation of bull trout *Salvelinus confluentus.* U.S. Forest Service Intermountain Research Station, General Technical Report INT-302, Ogden, Utah.

Robson, Mary (2003). "Love the weeds you're with" *In* The Seattle Times, Feb 26, 2003. (Washington State University/King County Cooperative Extension horticulture agent).

Rosgen, Dave and Hilton Lee Silvey. 1996. Applied River Morphology. Media Companies, Minneapolis, MN.

Rudolph, Tom. 2002. Baker County Deputy Watermaster. Personal interview.

Schaffer, P. W. (1941). Beaver on trial, Soil Conservation Service

Schoenfeld, Eric. 2002. Personal interview.

Schommer, Tim. 2003. Forest Wildlife Biologist, Wallowa – Whitman National Forest. Personal interview.

Schumm, S. A. and R. W. Lichty, 1963. "Channel widening and flood-plain construction along Cimarron River in southwestern Kansas." U. S. Geological Survey Professional Paper 352 - D: 71 - 88.

Shankman, D. and T. B. Pugh, 1992. "Discharge response to channelization of a coastal plain stream." Wetlands 12(3): 157-162.

Shepard, B. B., S. A. Leathe, T. M. Weaver, and M. D. Ink., 1984. Monitoring levels of fine sediments within tributaries of Flathead Lake and impacts of fine sedimentson bull trout recruitment. Proceedings of the Wild Trout III symposium, Yellowstone NP, Wyoming

Smith, D. G., 1976. Effect of vegetation on lateral migration of anastomosed channels of a glacier meltwater river. Geological Society of America Bulletin 87: 857-860.

Stevens, Jack. 2002. Owner, Radium Hot Springs. Personal interview.

Stringham, T. K, Buckhouse, J. C. and Krueger, W. C. (1998). Stream temperatures as related to subsurface waterflows originating from irrigation. Journal of Range Management 51: 88-90

Taylor, G. I., Stringham, T. K., and Krueger, W.C., 2003. Irrigation as a tool for stream temperature management. 2003 Range Field Day Progress Report on Environmental and Management Impact on Stream Temperature, July 1, 2003, Unity, Oregon. pp. 1- 12.

The Research Group. 1991. Oregon Angler Survey and Economic Study.

Thee, Dan. 2003. Personal interview.

Umpleby, Lyle. 2002 and 2003. Manager, Powder Valley Water Control District. Personal interviews.

USACE. 1987. Corps of Engineers Wetlands Delineation Manual. Environmental Laboratory. Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi. Reproduced by US Department of Commerce. National Technical Information Service, Springfield, VA.

USDA Forest Service. 1998. Forest Service Manual 2521 R-6 Supplement 2500-98-1. Watershed Condition Assessment; Soil Quality Standards.

USDA Forest Service. 2000. Interior Columbia Basin Ecosystem Management Project.

USDA Natural Resource Conservation Service. 1997. Soil Survey of Baker County Area, Oregon. US Government Printing Office.

USDA Soil Conservation Service. 1985. Soil Survey of Union County Area, Oregon. US Government Printing Office.

USDI Bureau of Land Management, Vale District, Baker Resource Area. April, 1994. Powder River, Final Management Plan/Environmental Assessment.

USDI Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census. 1996. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

USDHUD. 1978a. US Department of Housing and Urban Development, Federal Insurance Administration. Flood Hazard Boundary Maps. 1:24,000 scale. Baker County, Oregon, Unincorporated Area.

USDHUD. 1978b. US Department of Housing and Urban Development, Federal Insurance Administration. Flood Hazard Boundary Maps. 1:24,000 scale. Union County, Oregon, Unincorporated Area.

USDI Fish and Wildlife Service. 1979. Classification of Wetlands and Deepwater Habitats of the United States. USDI Fish and Wildlife Service. Washington, D. C.

USDI Fish and Wildlife Service. 2001. Net Economic Values for Wildlife-Related Recreation in 2001, Addendum to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Fish and Wildlife Service.

USDI Fish & Wildlife Service. June 2002. Recovery Plan for the Howell's Spectacular Thelypody (*Thelypodium howellii ssp. spectabillis*). Portland, Oregon.

USDI BLM. 1994. Riparian Area Management. Process for Assessing Proper Functioning Condition for Lentic Riparian-Wetland Areas. TR 1737-11 1994. USDI Bureau of Land Management. Denver, CO. p. 1.

US Environmental Protection Agency. 1980. An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook). Environmental Research Laboratory, Office of Research and Development, Athens, GA. EPA-600/8-80-012. Chapter 4, Surface Soil Loss.

Vanderwall, Bert. 2003. Personal interview.

Walker, G. W. and McLeod, N. S. 1991. USGS Geologic Map of Oregon. U. S. Department of the Interior, Geological Suirvey.

Wallowa-Whitman National Forest: Baker Ranger District. 1999. Powder River Haines (01) and North Powder River Wolf Creek (18) Watershed Analysis.

Wallowa-Whitman National Forest, Baker, Pine, and Unity Ranger Districts. 1996. Fish Sampling report.

Wallowa-Whitman National Forest. 2003. Progressive ecological unit inventory of the Wallowa-Whitman National Forest.

Water Quality Analysis Report for Baker Valley District. 1995-2002.

Watershed Professionals Network. 1999. Oregon Watershed Assessment Manual. June 1999. Prepared for the Governor's Watershed Enhancement Board, Salem, Oregon.

Wiens, K. C. (2001). The effects of headcutting on the bottomland hardwood wetlands of the Wolf River near Memphis, Tennessee. Biology. Cookeville, TN, Tennessee Technological University: 92.

Willamette National Forest. 1989. Biology of the Bull Trout, *Salvelinus confluentus*, a Literature Review. Eugene, Oregon.

Williams, G., Miller, D. E., and Miller, D. H., editors, 1971. Peter Skene Ogden's Snake Country Journals: 1827-28 and 1828-29. The Hudson's Bay Record Society, London.

Wilson, John. 2002. Partner, Wilson Cattle Company. Personal interview.

Whitsen, T.D., L.C. Burrill, S.A. Dewey, D.W. Cudney, B.E. Nelson, R.D. Lee, and R. Parker, Editors. 2002. Weeds of the West. Western Society of Weed Science.

Wolgamott, Mitch (2004). Department of Environmental Quality, email, 4/16/04

Womack, W. R. and S. A. Schumm (1977). "Terraces of Douglas Creek, northwestern Colorado: An example of episodic erosion." Geology 5: 72-76.

Yates, Gene. 2003. Forest Botanist, Wallowa – Whitman National Forest. Personal interview.

Young, William H. 1990. Surface Water Records for Oregon---Deschutes, Grande Ronde, Hood and Powder Basins. 1979-1989. Water Resources Department, Salem, Oregon.

Zakel, Jeff. 2002 and 2003. Fish Biologist, Oregon Department of Fish and Wildlife. Personal interview.

Zdanowicz, 1999. (need rest of reference)

APPENDICES

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APPENDIX A

HISTORIC INFORMATION