APPENDIX C.
KING COUNTY FLOOD RISK ASSESSMENT

INTRODUCTION

The King County Flood Risk Assessment is used to determine potential losses from a flood event in terms of life, property, economy and environment. The assessment required the systematic use of all available information to determine how each flood hazard may affect King County, how often flood events can occur and the potential severity of their consequence. The information in this risk assessment was used in development of the *2013 Flood Hazard Management Plan* to support the decision-making process. Three steps were used in generating this analysis:

- Identify the flood hazard
- Determine impacts of the flood hazard
- Analyze vulnerability.

The Disaster Mitigation Act of 2000 is federal legislation that emphasizes planning for disaster events before they occur. It addresses local and state mitigation planning and requires that plans be completed before Hazard Mitigation Grant Program funds are available to communities. This is intended to reduce the risk of repetitive disaster damage on communities and establish long-term solutions to impacts from disasters. The Disaster Mitigation Act requires a local government to assess its risk from natural hazards that may impact it. Creation of this risk assessment completes this task for the flood hazard.

Planning Context

The risk assessment is a key element of the overall planning process prescribed by programs such as the Disaster Mitigation Act, the Community Rating System, the Flood Mitigation Assistance Grant Program, and the Washington State Flood Control Account Assistance Program. This process provides a loss estimation that identifies the effects of the flood events in monetary terms. The loss estimation informs the public, policy-makers and decision-makers about the tangible effects of disaster events on communities. The risk assessment can identify specific issues that will help determine areas that should be focused on and provide information to aid policy makers in comparing benefits and costs of possible mitigation strategies and establishing priorities for those strategies. The information used in the preparation of this risk assessment was the best available at the time of this assessment.

Methodology

The risk assessment was developed with guidance provided in the Federal Emergency Management Agency's (FEMA's) local mitigation planning guide, *Understanding Your Risks, Identifying Hazards and Estimating Losses* and Section 510 of the 2007 Community Rating System Coordinator's Manual. The assessment augments information provided in the main body of the Plan to ensure that programmatic requirements prescribed under federal and state planning programs are met. Specifically, it addresses the following planning requirements:

- **Identify the flood hazard**—A detailed description of the extent and location of flooding by basin is presented in Chapter 5 of the Plan.
- **Profile the flood hazard**— The risk assessment performed for each basin is reach-based, segregating each basin into segments with similar flood-related characteristics, such as land use, geomorphology or hydrology. Profiling the flood hazard was determined with the following information:

- **Past Events**—This provides detailed information, where available, on past flood events, including dollar estimates of losses.
- **Flood Characteristics**—Flood characteristics are analyzed in two categories. Basin flow characteristics describe drainage, the 100-year flood flow at various gage stations and the flow for the flood of record. Basin flood characteristics describe land use, estimated depth of flooding, presence of channel migration zones as defined by King County and estimated warning time by reach. Land use by reach is evaluated in terms defined by the King County Comprehensive plan.

- **Vulnerability Analysis**—Vulnerability was determined using Geographic Information System (GIS) overlays of the King County floodplain and anecdotal information from County, state and other public sources. Vulnerability from flooding was analyzed based on impacts on life, safety and health, structures, natural and environmental areas, future development and economic areas.
  - **Public Health and Safety**—This is a discussion of how flooding affects public health and welfare. This is defined in terms of regulated floodplain area and length of unmapped floodplain.
  - **Critical Facilities**—This identifies the critical facilities and infrastructure that are vulnerable to flooding, using GIS overlays and anecdotal information.
  - **Land Use and Structures and estimated losses from a 100-year flood**—FEMA's HAZUS-MH GIS model together with King County data was used to determine the estimated number of exposed buildings, value of exposed buildings and the value of buildings contents. . The model also produced the value of the structure damage and content damage from a 100-year flood event.
  - **Environment**—An ecological review of each basin is presented in Chapter 5 of the Plan.
  - **Development Trends**—This is a description of likely development that will occur in the future.
  - **Economy—**This consists of a very brief discussion of what drives the economy in the basin and what is vulnerable to flooding. A more thorough analysis was completed in 2007 by ECONorthwest under contract by King County titled Economic Connections Between the King County Floodplains and the Greater King County Economy. For this risk assessment, an anecdotal approach was used to evaluate the economic impact of flooding in each basin. This evaluation was based primarily on historical flooding in the basin. The following classifications of potential impacts were assigned for planning purposes:
    - *Significant Impact*—Flooding in the basin would have a major countywide economic impact.
    - *Moderate Impact*—Flooding in the basin would have an economic impact on citizens in the basin, but not severely impact the countywide economy.
    - *Minimal Impact*—Flooding in the basin would not cause significant economic impact in the basin or countywide.
  - **Repetitive Loss**—This summarizes all properties in the basin that have repeatedly been flooded, as identified by FEMA.

Data Sources

The risk assessment was developed based on existing information from various sources, including several planning documents King County has developed. A large part of the analysis required the use of data

from King County's GIS system. Other technical information, including river flow data, was taken from data developed by the U.S. Geological Survey (USGS). The outputs generated for this risk assessment represent those generated from FEMA's HAZUS-MH loss estimation tools and planning guidance.

Insurance Analysis

A Countywide flood insurance policy analysis was performed to identify the geographic distribution of policies and to assist in locating areas with the most severe flood impacts. Geographic clusters of policies are a good indicator of the actual and perceived threat of flooding in a given area. Policy holders are scattered throughout King County in both floodplain and non-floodplain areas. Not surprisingly, clusters of policies are located in areas where severe flooding has been observed in the past. Areas of unincorporated King County show a higher density of policy holders than adjacent incorporated areas with similar flooding characteristics. Unincorporated King County policy holders are eligible for a 40% discount due to the County's participation in the CRS program. This discount is thought to provide a significant incentive to property owners to purchase a flood insurance policy.

Repetitive Loss Properties

Repetitive loss properties require special attention in terms of flood mitigation planning. A repetitive loss property as defined by FEMA is a property insured under the National Flood Insurance Program that, since 1978 and regardless of changes in ownership during that period, has experienced any of the following:

- Four or more paid losses in excess of $1,000
- Two paid losses in excess of $1,000 within any rolling 10-year period since 1978
- Three or more paid losses that equal or exceed the current value of the insured property.

The main identifiers for repetitive loss properties are the existence of flood insurance policies and claims paid by those policies. The Community Rating System program, which King County is a part of, requires that repetitive loss properties be identified. A repetitive loss area is the portion of a floodplain where buildings that meet FEMA's definition of repetitive loss properties are clustered together.

Repetitive loss data is compiled by Insurance Services Office, a private company under contract with FEMA that collects statistical data, promulgates rating information, develops standard policy forms, and files information with state regulators on behalf of insurance companies that purchase its services. Insurance Services Office provides data annually to communities on the number of repetitive loss properties located within their jurisdictions. Repetitive loss data is an indication of the severity of flooding within communities, but can also be misleading because it is based on properties that are covered by a flood insurance policy. For communities where levees are not recognized as sufficient to contain the 100-year flood, the areas behind the levees are mapped as floodplain and mandatory flood insurance purchase requirements apply. FEMA has been updating flood insurance rate maps that in some areas will not recognize many levees previously recognized as containing the 100-year flood, thus expanding the mapped floodplain and increasing the mandatory flood insurance purchase requirements. Consequently some of the communities with new mapping could see an increase in the number of repetitive loss properties over time. In addition, the threshold for classifying a property as a repetitive loss property is very low and even small flood insurance claims can quickly exceed the repetitive loss threshold. Table 1 shows the number of mitigated and unmitigated repetitive loss properties in King County.

TABLE 1.
REPETITIVE LOSS PROPERTIES IN KING COUNTY

Jurisdiction	Number of Repetitive Loss Properties
Bellevue	2
Burien	7
Issaquah	17
Kenmore	3
Kent	1
Unincorporated King County	171
Kirkland	1
Lake Forest Park	1
Mercer Island	1
Normandy Park	1
North Bend	4
Sammamish	1
Seattle	7
Shoreline	3
Skykomish	1
Snoqualmie	172
Total	**393**

Data provided by Insurance Services Office

How to Use This Risk Assessment

This risk assessment is organized by drainage basin within King County. This follows the approach the County uses in the management of its floodplains, and thus better enables this assessment to provide the degree of information necessary to augment the County's floodplain management activities. The risk assessment methodology was followed for each of the following basins:

- South Fork Skykomish River Basin
- Snoqualmie River Basin
- Sammamish River Basin
- Cedar River Basin
- Green River Basin
- White River Basin

Basin specific information is analyzed for each of these basins in the following sections.

SOUTH FORK SKYKOMISH RIVER BASIN PROFILE

The South Fork Skykomish River basin lies predominantly in the northeast portion of King County and is a part of Water Resource Inventory Area 7. The King County portion of the basin drains 234 square miles of mountainous terrain within the forest production zone and Alpine Lakes Wilderness Area. Major tributaries within King County include the Foss, Tye, Miller, and Beckler Rivers.

Hazard Profile

Past Events

Table 2 summarizes the history of flood events for the South Fork Skykomish River Basin since 1990. Peak flows are listed in cubic feet per second (cfs). The most severe recent flood event was the January 2011 flood. The flow data used is collected in the Snohomish County portion of the Skykomish River. Most of the data in Table 2 is from gage data collected in Snohomish County.

TABLE 2.
SOUTH FORK SKYKOMISH BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Peak Flow (cfs)[a]	Type of Damage	Estimated Cost
11/26/1990	Yes/#883	102,000	Overbank flooding causing damage to both public and private property. Stream bank erosion.	$1.4 million for entire County
02/19/1995	No	44,100	Overbank flooding. No significant property damage reported	No information available
12/03/1995	Yes/#1079	79,600	Overbank flooding causing damage to both public and private property. Levee damage.	$ 1,141,498 in public property damage
02/10/1996	Yes/#1100	74,400	Overbank flooding causing damage to both public and private property. Stream bank erosion. Levee damage.	$215,142 in public property damage
10/20/2003	Yes/#1499	86,500	Private property damage only.	No information available
11/06/2006	Yes/#1671	129,000	Stream bank erosion. Levee/revetment damage.	$5,386,323 in public property damages county-wide
12/1/2007	Yes/#1734	N/A	No reported damages to river flood protection infrastructure	$5,123,841 in public property damages countywide
01/08/2009	Yes/#1817	74,000	No reported damages to river flood protection infrastructure	$16,444,775 in public property damages countywide
01/17/11	Yes/#1963	63,900	Miller River channel shift caused portion of Old Cascade Highway to washout, roadway remains impassable. Damage to river flood protection infrastructure.	No information available
1/14/2012	Yes/#4056	N/A	Information not yet available	No information available

a. Flow estimates based on USGS #12134500

Flood Characteristics

Tables 3 and 4 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Observed flooding depths for this basin vary

from less than 1 foot to 6 feet. King County considers the South Fork Skykomish River to have channel migration potential, and regulates this region under the channel migration zone provisions of the King County Critical Areas Ordinance.

King County does not have a four phase flood warning system on the South Fork Skykomish River System. Snohomish County operates a stage only gage located on the bridge in the Town of Skykomish that provides flood warning information for Snohomish County and a limited area within King County. The USGS's only available flow data is collected near the City of Goldbar in Snohomish County, which is significantly downstream from hazard areas in King County. The available data is not useful for providing flood warning to residents in these areas.

TABLE 3.
SOUTH FORK SKYKOMISH RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	USGS River Mile	Drainage Area (square miles)	100-Year Flood Flow (cfs)	Flood of Record, Date & Peak Flow (cfs)
Goldbar	12134500	43.0	535	119,300	11/06/2006; 129,000 cfs

TABLE 4.
SOUTH FORK SKYKOMISH RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
South Fork Skykomish	Clustered residential, National Forest.	0 - 6 Feet	No	No Warning Time

Vulnerability Analysis

Public Safety and Health

Flooding in the South Fork Skykomish River basin has a variety of potential impacts on life, safety and health. Very few lives have been lost, but damage and disruption caused by flooding have been significant. The South Fork Skykomish River is generally clean and free-flowing, with a very steep gradient and numerous rock cascades of white water in the King County portion. The steep gradient produces deep and high velocity flows that can be extremely dangerous for public health and safety. Several small communities have development within the floodplain, and deep flooding over State Route 2 has the potential to isolate these communities from the rest of the county.

There are many miles of small streams with unmapped floodplain within the South Fork Skykomish River basin. Since there is no mapped floodplain in these areas, the risk of flooding to the public may be more significant during severe events and may need to be monitored closely. This is especially true for communities having ingress and egress on only one road.

Critical Facilities

Critical facilities in the South Fork Skykomish River basin were identified using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a

flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 5 lists the critical facilities in the South Fork Skykomish River basin. All of these facilities are considered to be vulnerable to the impacts of flooding. The degree of vulnerability for the public health and safety facilities identified in Table 5 varies. King County has established policies in both its Regional Hazard Mitigation Plan and the *Flood Hazard Mitigation Plan* to proactively mitigate impacts on identified critical facilities when opportunities arise. Several of the facilities listed in Table 5 are not under County ownership. The County will work with all agencies involved to achieve this objective.

TABLE 5.
CRITICAL FACILITIES IN THE SOUTH FORK SKYKOMISH BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Infrastructure
Skykomish Police Substation	Town of Skykomish	16	X	
City Hall	City of Skykomish	16	X	
Skykomish K to 12 School	Skykomish School District	15.8	X	
Levee (Town of Skykomish left bank)[a]	King County	15.9		X
Fire Station 1	City of Skykomish	15.9	X	X
Railroad Line and Bridges	Burlington Northern	Length	X	
State Route 2 and bridges	Washington State	Full length		X

a. This is a training levee that protects the school

Land Use, Structures and Estimated Losses from a 100-Year Flood Event

The predominant land use in the South Fork Skykomish basin is forest use. Fifty percent of the basin is protected wilderness; 43 percent is zoned for forest production; 6 percent is in rural residential use; and approximately 1 percent is in urban use (King County 2002c). Development in the basin has been limited, but much of it has occurred in the floodplain. There are several developments in the Town of Skykomish, the unincorporated communities of Grotto and Baring and scattered residential subdivisions. During the November 1990 flood event, several riverfront homes were affected by severe bank erosion (King County 1993b).

A floodplain study of the South Fork Skykomish was completed in 1998. The total area of regulatory floodplain for the South Fork Skykomish River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. A channel migration study is in progress for portions of the South Fork Skykomish River. Approximately 94 percent of the South Fork Skykomish River basin regulatory floodplain is in unincorporated King County. Table 6 shows the area of regulatory floodplain.

Within the South Fork Skykomish River basin floodplain there are a total of 735 parcels. This is approximately 12 percent of the total number of parcels in King County floodplains (6,250). There are 407 structures at risk from flooding on these parcels.. The depth of flooding varies with location.

TABLE 6.
SOUTH FORK SKYKOMISH RIVER BASIN AREA OF REGULATORY FLOODPLAIN WITHIN KING COUNTY

	Area of Regulatory Floodplain (acres)
Unincorporated King County	1,856
Incorporated Areas	113
Total	**1,969**

Development Trends

The South Fork Skykomish River basin has maintained a rural land use environment. Significant development has not and likely will not occur in this area because a large portion of it is protected wilderness area and forest production area. Future land use is projected to be similar to current land use conditions. Only a small increase in households is projected for the 2001 through 2022 planning period (King County 2004). Table 7 summarizes estimated flood loss potential in the South Fork Skykomish River Basin's 100-year floodplain.

TABLE 7.
ESTIMATED LOSSES FROM A 100-YEAR FLOOD EVENT IN THE SOUTH FORK SKYKOMISH RIVER BASIN

Area of Floodplain (acres)	962
Buildings Exposed	304
Structure Value Exposed	$51,583037
Content Value Exposed	$36,457,868
Total Value Exposed (Structure & Contents)	**$88,040,904**
Structure Damage	$3,105,745
Content Damage	$5,837,718
Non-Residential Inventory Damage	$0
Total Damage (Structure, Contents & Inventory)	**$8,943,463**

Source: Hazards U.S. - Multi-Hazard (HAZUS-MH) Model for King County, WA (2012)

Economic Impact

Based on existing land use and past experience, flooding along the South Fork of the Skykomish River would have nominal economic impact within the basin, due primarily to the lack of significant population density within the basin. There are no major employment centers in this basin, but the loss of use of transportation corridors to major employment centers elsewhere in the County could have some economic impact within the basin. Due to the low population density, this potential impact is not considered significant. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be minimal.

Repetitive Loss Areas

There are eleven repetitive loss properties in the South Fork Skykomish River basin, three of which has been mitigated, as summarized in Table 8. Four of the unmitigated properties are located near Baring, Washington, and the remaining four are scattered along the length river. All of these parcels are single-family residences located in the floodway, and it is concluded that the cause of repetitive flooding for all of them is overbank riverine flooding, as reflected by the mapping for the basin.

TABLE 8.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE SOUTH FORK SKYKOMISH BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
8	1.98	$199,000	$566,000

SNOQUALMIE RIVER BASIN PROFILE

The Snoqualmie River basin covers northeast King County and drains to the Snohomish River and ultimately to Puget Sound. It is a part of Water Resource Inventory Area 7. The watershed includes the Tolt River, Raging River, Miller River, Tokul Creek, Griffin Creek, Harris Creek, Patterson Creek, and other tributaries.

Hazard Profile

To provide additional detail of the characteristics of flooding in Snoqualmie Basin, the analysis is separated into twelve reaches:

- North Fork headwaters to confluence
- Middle Fork headwaters to confluence
- South Fork headwaters to confluence
- Snoqualmie Forks confluence to Snoqualmie Falls
- Snoqualmie Falls to Fall City
- Snoqualmie at Fall City
- Patterson Creek to Tolt River
- Snoqualmie at Carnation
- Chinook Bend to County Line
- Tolt
- Raging
- Patterson Creek

Past Events

Table 9 summarizes the history of flood events for this basin since 1990. The most severe recent flooding event was the January 2009 flood. There has been millions of dollars worth of damage in the Snoqualmie River basin as result of flood events.

TABLE 9.
SNOQUALMIE RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/10/1990	Yes/#852	4/48,522	Overbank flooding causing damage to both public and private property. Channel avulsion.	$4.9 million for entire county
11/1990	Yes/#883	4/50,100	Overbank flooding causing damage to both public and private property. Channel avulsion.	$5.6 million for entire county
11/7/1995	Yes/#1079	4/49,350	Overbank flooding causing damage to both public and private property. Channel avulsion.	$ 683,612 in public property damage
01/1996	Yes/#1100	4/44,430	Overbank flooding causing damage to both public and private property. Channel avulsion.	$1,598,304 in public property damage
01/1997	Yes/#1159	3/>20,000	Overbank flooding causing damage to both public and private property. Channel avulsion.	No information available
03/1997	Yes/#1172	3/>20,000	Overbank flooding causing damage to both public and private property. Channel avulsion.	$647,005
10/1997	No	3/>20,000	No significant damage reported to public or private property.	No information available
11/1999	No	4/>38,000	Overbank flooding. No major damage to public or private property reported	No information available
12/2000	No	3/>20,000	No significant damage reported to public or private property.	No information available
01/2003	No	3/>20,000	No significant damage reported to public or private property.	No information available
03/2003	No	3/>20,000	No significant damage reported to public or private property.	No information available
10/21/2003	Yes/#1499	3/32,700	Overbank flooding causing damage to both public and private property. Channel avulsion.	Individual assistance only; approximately $68,748 countywide
11/06/2006	Yes/#1671	4/53,500	Overbank flooding causing damage to both public and private property. Channel avulsion.	$5,386,323 in public property damages county-wide
12/1/2007	Yes/#1734	N/A	No reported damages to river flood protection infrastructure	$5,123,841 in public property damages county-wide
1/07/2009	Yes/#1817	4/54,110	Overbank flooding causing damage to both public and private property. Channel avulsion.	$16,444,775 in public property damages county-wide
1/16/2011	Yes/#1963	3/34,740	Overbank flooding causing damage to both public and private property. Channel avulsion.	No information available
1/14/2012	Yes/#4056	N/A	Information not yet available	No information available

Flood severity is identified in terms of phases. Table 9 shows events that reached Phase 3 or above. Below are the phases of flooding for the Snoqualmie River.

- Phase 1—The flow is greater than 6,000 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase 2—The flow is greater than 12,000 cfs and lowland flooding will occur. Several roads will be overtopped or closed (Neal Road, SE Reinig Road, West Snoqualmie River Road NE, Snoqualmie Meadowbrook Road, and Mill Pond Road).
- Phase 3—This is considered moderate flooding and exhibits flows greater than 20,000 cfs. Flooding of varied depth will occur in the entire Snoqualmie area. Fall City-Carnation Road, Tolt Hill Road and Novelty Flats Road will be overtopped or closed.
- Phase 4—This is extreme flooding. Flow is greater than 38,000 cfs and some residential areas may experience dangerous high velocities and flooding of homes. Roads that may be overtopped or closed are Woodinville-Duvall Road, State Route 203 between Duvall and Carnation, Moon Valley Road, and South Fork Road.

Flood Characteristics

Tables 10 and 11 summarize observed flooding characteristics typical for this basin. These tables reflect the range of flood conditions by identifiable reach or stream for planning purposes only. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Flood depths in this basin can vary from less than 1 foot to 6 feet, with significant velocities depending on extent and location within the basin.

TABLE 10.
SNOQUALMIE RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	USGS River Mile	Drainage Area (square miles)	100-Year Flood Flow (cfs)	Flood of Record, Date & Peak Flow (cfs)
North Fork	12142000	9.2	64.0	18,000 *a*	01/07/2009; 17,000 cfs
Middle Fork	12141300	55.6	154.0	37,100 *a*	11/06/2006; 31,700 cfs
South Fork	12143400	17.3	41.6	11,000 *a*	11/06/2006; 8,910 cfs
Snoqualmie @ Snoqualmie	12144500	40.0	375	79,100 *b*	11/24/1990; 78,800 cfs
Snoqualmie @ Carnation	12149000	23	603.0	91,800 *b*	01/08/2009; 82,900 cfs
Raging @ Fall City	12145500	2.75	30.6	6,970	11/24/1990; 6,220 cfs
North Fork Tolt	12147500	11.7	39.9	11,200 *a*	12/15/1959; 9,560 cfs
South Fork Tolt	12148000	6.8	19.7	8,720 *a*	12/15/1959; 6,500 cfs
Tolt @ Carnation	12148500	8.7	81.4	18,800	12/15/1959; 17,400 cfs

a. Based on USGS data through 2007. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.
B. Flow estimates based on hydrologic analysis for the Lower Snoqualmie and Skykomish River Revised Flood Insurance Study (2007).

TABLE 11.
SNOQUALMIE RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
North Fork headwaters to confluence Middle Fork headwaters to confluence South Fork headwaters to confluence Snoqualmie Forks confluence to Snoqualmie Falls	Mixed land use. Commercial, Industrial, Residential. Urban area land uses from the Cities of North Bend and Snoqualmie. Upper areas of this reach predominately national forest.	6 feet or greater with measurable velocity	Yes	2-4 hours
Snoqualmie Falls to Fall City & Snoqualmie at Fall City	Urban residential, light commercial, agricultural	6 feet or greater with measurable velocity	No	4 hours
Raging River	Rural Residential, National Forrest	Shallow Flooding 0-6 feet, with measurable velocity	Yes	No Warning
Patterson Creek to Tolt River & Snoqualmie at Carnation	Mixed land use. High density residential, commercial, industrial and agricultural	Shallow Flooding 3-6 feet	No	12+ hours
Tolt River	Rural residential, agricultural, National Forrest	Shallow Flooding 0-6 feet, with measurable velocity	Yes	2 hours
Chinook Bend to County Line	Agricultural and open space uses	6 feet or greater with measurable velocity	No	24 hours

Vulnerability Analysis

Public Safety and Health

Flooding in the Snoqualmie River basin has a variety of potential impacts on life, safety and health. Very few lives have been lost, but damage and disruption caused by flooding have been a recurrent problem.

The Cities of Snoqualmie and North Bend have been urbanizing since 1980. Significant growth is expected throughout the basin. Between 1980 and 1999, the population in the basin went from approximately 20,000 to approximately 38,000 (King County 2002c). The Puget Sound Regional Council predicts that the population in the Snoqualmie basin will grow from its current estimated level of approximately 40,000 to over 70,000 residents by 2020 (King County 2001).

There are many miles of unmapped floodplain along small streams in the Snoqualmie River basin. The risk of flooding to the public may be more significant in these areas during severe event, requiring close monitoring.

Critical Facilities

Critical facilities in the Snoqualmie River basin were identified using GIS. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 12 lists the critical facilities in the Snoqualmie River basin. All of these facilities are considered to be vulnerable to the impacts of flooding. The degree of vulnerability for the public health and safety facilities identified in Table 12 varies. King County has established policies in both its Regional Hazard Mitigation Plan and the *Flood Hazard Management Plan* to proactively mitigate risks to identified critical facilities when opportunities arise. Several of the facilities listed in Table 12 are not under County ownership. The County will work with all agencies involved to achieve this objective.

Critical facilities can also include critical infrastructure, such as roads whose closure could cause isolation and evacuation problems during flood events. Isolation is a key issue for flood preparedness and response in this basin. King County has determined that the following major roadways and stream crossings (bridges or culverts) would be impassable during a 100-year flood event:

- Neal Road
- SE Reinig Road
- West Snoqualmie River Road NE (Walker Road)
- Snoqualmie Meadowbrook Road
- Mill Pond Road.
- Fall City-Carnation Road
- Tolt Hill Road.
- Novelty Flats Road.
- Woodinville-Duvall Road
- SR 203 between Duvall and Carnation
- Moon Valley Road, South Fork Road

Land Use, Structures and Estimated Losses from a 100-Year Flood Event

The major portion of the Snoqualmie River basin floodplain is in unincorporated King County, with small but significant portions in the cities of North Bend, Snoqualmie, Duvall and Carnation. Development throughout the incorporated portions of the Snoqualmie River floodplain is mainly commercial and residential. Agricultural and residential development predominates in unincorporated King County along the lower and upper portions of the river.

King County regulatory floodplain mapping shows 21,489 acres of mapped floodplain in the Snoqualmie River basin. This includes the Raging and Tolt River, the three Forks of the Snoqualmie River and the mainstem of the Snoqualmie River. A floodplain study of the mainstem of the Snoqualmie River was completed in 2006 and included in the FEMA Preliminary Digital Flood Insurance Rate Maps. Studies and new floodplain boundaries for the Forks and the Raging and Tolt Rivers were completed during the past 20 years.

Approximately 86 percent of the Snoqualmie River basin regulatory floodplain is in unincorporated King County. Table 13 shows the area of regulatory floodplain.

TABLE 12.
CRITICAL FACILITIES IN THE SNOQUALMIE RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Infrastructure
Snoqualmie City Hall	City of Snoqualmie	39.8	X	
North Bend City Hall	City of North Bend	South Fork—2.5	X	
North Bend Elementary	North Bend	South Fork—2.5	X	
Two Rivers High School	Snoqualmie Valley	South Fork—2.5	X	
Administration/Transportation (Snoqualmie Valley)	Snoqualmie Valley	39.7	X	
Mt. Si High School	Snoqualmie Valley	40.1	X	
Snoqualmie Elementary	Snoqualmie Valley	40.3	X	
Snoqualmie Middle School	Snoqualmie Valley	40.2	X	
Wastewater Treatment Plant	North Bend Treatment Plant	North Fork—2.4	X	
Wastewater Treatment Plant	Snoqualmie Treatment Plant	38.8	X	
Police Department	City of North Bend	South Fork—1.4	X	
State Patrol District 2 North Bend Detachment	City of North Bend	South Fork—2.5	X	
Fire Station 87	Fire District 38—North Bend	South Fork—2.5	X	
Snoqualmie Fire Department	Snoqualmie	39	X	
Tolt River Dam	City of Seattle	South Fork Tolt – 8.5	X	X
S. Fork Levee at N. Bend	King County	South Fork - 2.0-3.0		X
Tolt River levee @ Carnation	King County	Tolt– 0.0-1.0		X
Raging River Levee @ Fall City	King County	Raging – 0.0-1.0		X
Wastewater Treatment Plant	City of Carnation	23.2	X	

TABLE 13.
SNOQUALMIE RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	18,499
Incorporated Areas	2,990
Total	**21,489**

Approximately 75 percent of the Snoqualmie basin is in the forest production district. Most of the Snoqualmie River floodplain below Snoqualmie Falls is within the agricultural production district. As timber harvesting in the basin has decreased, the timber companies have been slowly selling off their land. Much of that land could be developed, but there have been some efforts to conserve it. The potential for high density development in incorporated areas is increased by the presence of vested lots and plats.

Within the Snoqualmie River basin floodplain there are a total of 2,415 parcels with structures. This is approximately 40 percent of the total number of parcels with structures in King County floodplains (6,250). The depth of flooding varies depending on location. Table 14 summarizes estimated flood loss potential. Of the 2,415 parcels with structures in the Snoqualmie River basin floodplain, 2,143 are residential structures and 272 are commercial or other designations.

Development Trends

Much of the urbanization of the watershed has been contained in high density incorporated areas. While urban areas constitute only about 3 percent of the total watershed area, they make up a significant portion of some subwatersheds including Coal Creek (50 percent), mainstem Snoqualmie (15 percent), Patterson Creek (10 percent), and Cherry Creek (6 percent). The potential for high density development is increased by the presence of vested lots and plats, particularly in the Patterson and Ames Creeks areas (King County 2002c).

Economic Impact

With the largest floodplain in King County, the Snoqualmie basin has experienced significant economic impact from flooding. Although this basin is not a major employment center although is a significant commercial agricultural community, flooding can have an economic impact on employment for the County because many of the basin's residents are not able to get to work due to road closures and isolation caused by flooding. Functional down time of roads is a major economic factor in this basin. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be significant.

It is the working assumption of this Plan that cities such as Snoqualmie and North Bend are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

The Snoqualmie River basin has 128 unmitigated repetitive loss properties. Table 15 summarizes the unmitigated repetitive loss properties in the basin. Of the 92 properties, all but 7 are single-family residential. All but 2 properties lies within a mapped 100-year floodplain, so it is concluded that the main cause of repetitive flooding for this basin is overbank riverine flooding reflected by the mapping for the basin.

TABLE 14.
ESTIMATED LOSSES FROM A 100-YEAR FLOOD EVENT IN THE SNOQUALMIE RIVER BASIN

	North Fork headwaters to confluence	Middle Fork headwaters to confluence	South Fork headwaters to confluence	Snoqualmie Forks confluence to Snoqualmie Falls	Snoqualmie Falls to Fall City	Snoqualmie at Fall City	Patterson Creek to Tolt River	Snoqualmie at Carnation	Chinook Bend to County Line	Tolt	Raging	Patterson Creek	Other areas outside identified subbasins	**Total**
Area of Floodplain (acres)	478	1102	2117	2228	238	2117	2101	2232	7493	638	244	446	55	**21,489**
Buildings Exposed	69	242	906	784	11	70	20	150	55	44	60	4	0	**2,415**
Structure Value Exposed	$13,680,260	$44,783,521	$292,935,946	$245,249,789	$3,581,207	$13,069,496	$4,167,399	$41,798,092	$10,954,349	$6,679,452	$9,981,635	$471,441	0	**$687,352,588**
Content Value Exposed	$6,840,130	$22,850,163	$224,707,347	$199,732,041	$1,790,604	$7,441,333	$2,457,891	$28,913,215	$6,343,098	$3,339,726	$5,088,478	$235,721	$0	**$509,739,747**
Total Value Exposed (Structure & Contents)	**$20,520,389**	**$67,633,684**	**$517,643,294**	**$444,981,831**	**$5,371,811**	**$20,510,829**	**$6,625,291**	**$70,711,307**	**$17,297,447**	**$10,019,178**	**$15,070,113**	**$707,162**	**$0**	**$1,197,092,335**
Structure Damage	503,127	$1,713,708	$20,867,127	$26,143,086	$491,247	$1,284,811	$570,181	$2,032,041	$1,903,097	$467,703	$370,202	$24,381	$0	**$56,370,711**
Content Damage	$226,247	$723,904	$27,310,007	$49,348,499	$260,060	$1,533,022	$851,216	$1,568,202	$1,408,337	$211,818	$160,496	$9,051	$0	**$83,610,859**
Non-Residential Inventory Damage	$0	$5,368	$10,865,481	$19,886,476	$0	$326,596	$0	$602,774	$378,300	$0	$6,559	$0	$0	**$32,071,554**
Total Damage (Structure, Contents & Inventory)	**$729,374**	**$2,442,980**	**$59,042,616**	**$95,378,060**	**$751,307**	**$3,144,429**	**$1,421,397**	**$4,203,017**	**$3,689,734**	**$679,521**	**$537,256**	**$33,432**	**$0**	**$172,053,123**

Source: Hazards U.S. - Multi-Hazard (HAZUS-MH) Model for King County, WA (2012)

TABLE 15.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE SNOQUALMIE RIVER BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
92	225.4	$9,816,900	$13,753,100

SAMMAMISH RIVER BASIN PROFILE

The Sammamish River originates at Lake Sammamish and drains a 240-square-mile watershed that includes 97 square miles of the Lake Sammamish basin, 50 square miles in the Bear Creek basin and 67 square miles of the combined Little Bear, North, and Swamp Creek basins.

Hazard Profile

To provide additional detail of the characteristics of flooding in the Sammamish River basin, the analysis of this basin is separated into the following reaches:

- Issaquah Creek Reach—Issaquah Creek headwaters to Lake Sammamish
- Upper Sammamish Reach—Lake Sammamish at Issaquah to River Mile 15.3
- Lower Sammamish Reach—River Mile 15.3 to Lake Washington
- Evans Creek Reach—Evans Creek headwaters to confluence with the Bear Creek in Redmond
- Bear Creek Reach—Bear Creek headwaters to confluence with Sammamish River in Redmond

Past Events

Table 16 summarizes the history of flood events for the Sammamish River basin. The data collected is mainly from Issaquah Creek.

Severity of historical floods is listed in terms of phases in Table 16. Below are the phases of flooding for Issaquah Creek based on the stage (height) of the Issaquah near Hobart gage.

- Phase 1—This is considered an internal alert, stage of 6.5 feet.
- Phase 2—Stage of 7.5 feet.
- Phase 3—This indicates a moderate flooding event, stage of 8.5 feet.
- Phase 4—This is considered extreme flooding, stage of 9.0 feet.

So far, no flood events have surpassing the 100-year flood flow at the Hobart gage.

Flood Characteristics

Tables 17 and 18 summarize observed flooding characteristics typical for this basin. These tables reflect the range of flood conditions by identifiable reach or stream for planning purposes only. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Table 17 shows events that reached above Phase 3 at the Hobart gage for Issaquah Creek unless otherwise indicated. Warning time estimates were not available for the Sammamish River basin. King County collects real-time gage information on Issaquah Creek. Observed depths of flooding in this basin range from less than 1 foot to 8.5 feet.

TABLE 16.
SAMMAMISH RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
12/1/1995	Yes/#1079	4/1,240	Overbank flooding causing both public and private property damage within the Issaquah Creek Basin.	$5.2 million for entire county
01/1997	No	4/1,240	Flooded farmland. No reports of significant public or private property damage.	No information available
11/06/2006	Yes/#1671	4/1,360	No reports of significant public or private property damage.	$5,386,323 in public property damages county-wide
12/1/2007	Yes/#1734	2/744	No reported damages to river flood protection infrastructure	$5,123,841 in public property damages county-wide
1/07/2009	Yes/#1817	3/1,290	No reports of significant public or private property damage.	$16,444,775 in public property damages county-wide
1/16/2011	Yes/#1963	N/A	No reported damages to river flood protection infrastructure	No information available
1/14/2012	Yes/#4056	N/A	Information not yet available	No information available

TABLE 17.
SAMMAMISH RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	USGS River Mile	Drainage Area (square miles)	100-year Flood Flow (cfs) *a, b*	Flood of Record, Date & Peak Flow (cfs)
Issaquah Creek @ Mouth	12121600	1.2	55.6	3,960	01/09/1990; 3,200 cfs

a. FEMA 2005.
b. Period of record of USGS gage data used to derive values in table may differ from period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

TABLE 18.
SAMMAMISH RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Issaquah Creek	Urban residential, rural residential, Commercial, agricultural	6-8.5 feet with measurable velocity	No	3-4 Hours[a]
Upper Sammamish	Urban Residential, light commercial	Shallow flooding 0-3 feet	No	No Warning
Lower Sammamish	Agricultural, Recreational/Open Space, Urban residential	Shallow flooding 0-3 feet	No	No Warning
Evans Creek	Rural Residential/Urban Residential	Shallow flooding 0-3 feet	No	No Warning
Bear Creek	Rural Residential/Urban Residential	Shallow flooding 0-3 feet	No	No Warning

a. Flood warning system on Issaquah Creek is operated by the City of Issaquah.

Vulnerability Analysis

Public Safety and Health

Flooding in the Sammamish River basin has a variety of potential impacts on life, safety and health. There are many miles of small streams with unmapped floodplain within the Sammamish River basin. . Since there is no mapped floodplain in these areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely.

Critical Facilities

Critical facilities in the Sammamish River basin were identified using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 19 shows the critical facilities in the Sammamish River basin. King County has established policies in both its Regional Hazard Mitigation Plan and the *Flood Hazard Management Plan* to proactively mitigate risks to identified critical facilities when opportunities arise. Several of the facilities listed in Table 19 are not under County ownership. The County will work with all agencies involved to achieve this objective.

Land Use, Structures and Estimated Losses from a 100-Year Flood Event

In recent decades, substantial development has occurred in the Sammamish River basin. Extensive commercial and residential developments have been constructed throughout the floodplain. There are also several parks and other recreational facilities. Land uses in the upper 10 miles are mainly recreational and agricultural as well as urban commercial, specifically in the Cities of Redmond and Woodinville. The lower 5 miles include significant residential and commercial developments as well as some open space areas.

TABLE 19.
CRITICAL FACILITIES IN THE SAMMAMISH RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Infrastructure
Flood Control Weir	Army Corps of Engineers	14.0		X
Redmond City Hall	City of Redmond	11.5	X	
Redmond Police Department	City of Redmond	11.5	X	
Support Service Center	Lake Washington School District	10.8	X	X
Metro Sewer Line[a]	Seattle Metro		X	
Hollywood Pump Station	King County	9.0		X

a. Considered a critical site due to its public health impacts

FEMA and King County floodplain mapping shows 9,524 acres of mapped floodplain in the Sammamish River basin, including Lake Sammamish. The total area of regulatory floodplain for the Sammamish River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. No channel migration area has been mapped in the Sammamish River basin. Approximately 40 percent of the Sammamish River basin regulatory floodplain is in unincorporated King County. Table 20 shows the area of regulatory floodplain.

TABLE 20.
SAMMAMISH RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	3,777
Incorporated Areas	5,747
Total	**9,524**

Within the Sammamish River basin floodplain there are a total of 733 parcels with structures. This is approximately 12 percent of the total number of parcels in King County floodplains (6,250). The depth of flooding varies with location. Table 21 summarizes estimated flood loss potential. Of the 733 parcels with structures in the Sammamish River basin floodplain, 551 are residential and 182 are commercial or other designations.

Development Trends

The Sammamish River basin has been urbanizing rapidly since the 1950s. Future development is expected to continue throughout the Sammamish basin. Bellevue, Issaquah, Kirkland and Redmond have designated potential annexation areas, some of which are within the floodplain.

TABLE 21.
ESTIMATED LOSSES FROM A 100-YEAR FLOOD EVENT IN THE SAMMAMISH RIVER BASIN

	Bear Creek	Evans Creek	Issaquah Creek	Sammamish River	Other areas including Lake Sammamish and Phantom Lake	**Total**
Area of Floodplain (acres)	525	480	1196	2223	5100	**9,524**
Buildings Exposed	34	13	225	166	295	**733**
Structure Value Exposed	$83,464,237	$2,614,373	$138,913,975	$539,865,196	N/A	**$764,857,780**
Content Value Exposed	$70,969,956	$1,307,186	$119,299,933	$552,047,511	N/A	**$743,624,587**
Total Value Exposed (Structure & Contents)	**$154,434,193**	**$3,921,559**	**$258,213,908**	**$1,091,912,707**	**N/A**	**$1,508,482,366**
Structure Damage	$81,347	$84,202	$4,087,671	$20,332,427	N/A	**$24,585,646**
Content Damage	$33,497	$38,966	$4,880,925	$75,601,426	N/A	**$80,554,813**
Non-Residential Inventory Damage	$0	$0	$3,633,380	$71,172,211	N/A	**$74,805,591**
Total Damage (Structure, Contents & Inventory)	**$114,844**	**$123,168**	**$12,601,975**	**$167,106,064**	**N/A**	**$179,946,050**

Source: Hazards U.S. - Multi-Hazard (HAZUS-MH) Model for King County, WA (2012)

Economic Impact

Historically, flooding has caused significant public and private property in the City of Issaquah but not in other cities or in the unincorporated portions of the basin. The February 1996 and January 2009 floods were the most damaging in Issaquah's recent history, and were very similar. These floods impacted both commercial and residential areas, with total flood losses in the millions of dollars. This basin is fairly urbanized, with population centers in the Cities of Issaquah, Redmond, and Bothell. Within these population centers are businesses that employ many of the citizens of King County. However, past history shows that flooding in this basin has not shut down commerce for any prolonged period of time or had any measurable impact on tax base. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be moderate.

It is the working assumption of this Plan that cities such as Issaquah, Redmond and Bothell are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

Repetitive loss areas are not numerous in the Sammamish River basin. Table 22 summarizes the repetitive loss properties in the Sammamish River basin. All properties are residential. Two properties are located on Issaquah Creek, but they are not clustered together. One is located along Bear Creek and the other is outside the floodplain.

TABLE 22.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE SAMMAMISH RIVER BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
4	25.9	$ 828,000	$ 1,185,000

CEDAR RIVER BASIN PROFILE

The Cedar River flows west from the Cascade Mountains and then turns north to enter the south end of Lake Washington. The Cedar River is approximately 36 miles long from its mouth at Lake Washington in the City of Renton to Chester Morse Lake.

Hazard Profile

To provide additional detail of the characteristics of flooding in the Lower Cedar, the analysis of this basin is separated into five reaches:

- The Cedar River Reach—Headwaters to Landsburg diversion dam
- Lower Mainstem Reach— Landsburg diversion dam to Renton City Limits
- The Renton Reach—Renton City Limits to Interstate 405
- The Boeing Reach—Interstate 405 to Lake Washington
- Lake Washington Reach—The Lake Washington drainage basin, including May Creek

Past Events

Table 23 summarizes the history of flood events for the Cedar River basin since 1990. The most severe recent flooding events were the 1990, 1995 and 2009 federally declared disaster events. Severity is identified in terms of phases. Table 23 shows events that reached Phase 3 or above at the Landsburg gage. Below are the phases of flooding for the Cedar River:

- Phase 1—The flow is greater than 1,800 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase 2—The flow is greater than 2,800 cfs and Jones Rd near 156th Place SE may overtop and close.
- Phase 3—This is a moderate flooding event that exhibits flows greater than 4,200 cfs. Lower Dorre Don Way and Byers Rd SE may overtop and close. These roads provide access to several neighborhoods where residents may become trapped and require evacuation.
- Phase 4—This is considered extreme flooding and the flow is greater than 5,000 cfs. Additional roads may overtop and close including: Cedar Grove Rd SE, Maxwell Rd SE and SR-169 near the intersection with Cedar Grove Rd SE. Dead end streets may overtop and close including: Jan Rd SE (SE 197th St), SE 203rd St, SE 206th St, and SE 207th St. Fast and deep flows can create dangerous conditions throughout the floodplain.

TABLE 23.
CEDAR RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/09/1990	No	4/5,308	Landslides and road damage due to flooding on small streams	Information not available
11/22/1990	Yes/#883	4/10,800	Overbank flooding causing damage to both public and private property. Levee failure	$1.4 million for entire County
11/30/1995	Yes/#1079	4/6,750	Overbank flooding causing damage to both public and private property.	$882,965 public property damage ($5.2 million for entire county
02/10/1996	Yes/#1100	4/5,510	Overbank flooding causing damage to both public and private property. Levee failure	$1,385,193 in public property damage ($7.4 million for entire county
11/06/2006	Yes/#1671	3/4,670	Channel shifting causing undercutting, oversteepened banks. Bank slumping, erosion, and scour adjacent to trail and private property	$5,386,323 in public property damages county-wide
12/1/2007	Yes/#1734		No reported damages to river flood protection infrastructure	$5,123,841 in public property damages county-wide
1/07/2009	Yes/#1817	4/7,870	Levee and revetment damage	$16,444,775 in public property damages county-wide
1/16/2011	Yes/#1963	3/4,710	Levee and revetment damage	No information available
1/14/2012	Yes/#4056	N/A	Information not yet available	No information available

Flood Characteristics

Tables 24 and 25 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Table 25 also shows warning time in terms approximate amount of lead time county officials have to initiate warning procedures within the reach. These warning times are estimates based on the length of travel time from gage to gage where available and practical experience based on observed conditions.

Vulnerability Analysis

Public Safety and Health

Flooding in the Cedar River basin has a variety of potential impacts on life, safety and health. The mainstem Cedar upstream of the City of Renton is relatively narrow and steep. Flow velocities are generally high, and at many locations, the river approaches the steep valley walls at sharp angles, eroding the bases of several tall cliffs and at times, inducing landslides. The river's slope flattens in the city, reducing both its flow velocity and its sediment carrying capacity.

TABLE 24.
CEDAR RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	USGS River Mile	Drainage Area (square miles)	100-year Flood Flow (cfs) [a]	Flood of Record, Date & Peak Flow (cfs)
Cedar Falls	12116500	33.2	84.2	8,930	11/24/1990; 12,300
Landsburg	12117500	23.4	121.0	10,300	11/18/1911; 14,200
Renton	12119000	1.6	184.0	12,000	11/24/1990; 10,600

a. Final Flood Frequency Analysis Curve For Year 2000 Floodplain Mapping on the Lower Cedar River march 2000 include with King county's submittal to FEMA for a revised Flood Insurance Study for the Cedar River. Period of record of USGS gage data used to derive values in table may differ from period of record currently available. See Chapter 4, Section 4.1 for further discussion on derivation of flood frequencies.

TABLE 25.
CEDAR RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Cedar River	Open Space, Agricultural, Forest	1-6 feet	No	No Warning
Lower Mainstem	Rural Residential	1-6 feet	No	1.5 to 6 hours
Renton	Residential, Commercial, Some Open Space	3-6 feet	No	6 hours
Boeing	High density, Industrial, Commercial	1-3 feet	No	6 hours
Lake Washington	Forest, Rural Residential	3-6 Feet	No	0.5 to 1.5 Hours

Due to the valley's steep gradient, flood flows are generally very fast along the Cedar River. Given the heavy residential use of the valley bottom, these high velocities represent significant threats to health and safety. Flows can be made even more hazardous by the significant amount of logs and debris, generally carried by floods (King County 1993b). In one neighborhood during the November 1990 flood, floodwaters carried several trees out of the channel and piled them in two large jams on the riverbank, nearby crushing a garage and a residential structure.

The Renton reach of the mainstem Cedar has a wider floodplain and gentler channel gradient. These characteristics contribute to sediment deposition and repeated flooding. Between River Miles 1 and 3, channel capacity had been restricted by the encroachment of fill that was placed through the years by adjacent commercial operations (King County 1993b).

There are many miles of small streams with unmapped floodplain within the Cedar River basin. Since mapping is not available in these floodplain areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely. The lower Cedar River is highly urbanized and parts of the upper Cedar are beginning to urbanize. As more areas begin to urbanize the need for accurate floodplain mapping in unmapped areas becomes essential to minimize effects on public safety and health. King County has adopted comprehensive regulations to deal with the impacts of new

development in the floodplain (see Appendix B of this Flood Hazard Management Plan). The impact of this regulatory program should hold in check the possible increase in vulnerability due to new development in this basin.

Critical Facilities

Critical facilities in the Cedar River basin were identified by anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 26 lists the critical facilities in the Cedar River basin. In Renton there are several roads and bridges in the floodplain as well as public facilities such as City Hall, a public library and the Renton Airport. However, since the Cedar River dredging project was implemented in the City of Renton, the area near the Renton Airport is generally considered at less risk from flooding. As long as there is periodic dredging of the channel, this is expected to remain so. Severe flood damage was experienced during the November 1990 floods, in which damage to river facilities totaled $1.2 million. Other than the public facilities in the City of Renton, there are no other identified critical facilities within the currently mapped Cedar river floodplain.

Critical facilities can also include critical infrastructure such as roads that could cause isolation and evacuation problems during flood events. King County has determined that the following major roadways and stream crossings (bridges or culverts) would be impassable during a 100-year flood event:

- Dorre Don Road
- Arcadia Road

TABLE 26.
CRITICAL FACILITIES IN THE CEDAR RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Infrastructure
Levees and Revetments[a]	King County	NA		X
Landsburg Dam	City of Seattle	21.7		X
Cedar Falls Powerhouse	City of Seattle	33.7		X
Masonry Dam	Seattle Public Utilities	35.7		X
Leachate Line[b]	King County	At Rainbow	X	

a. There are several critical levees and revetments along the length of the Cedar River that overtop or could be subject to failure.
b. Considered a critical site due to its public health impacts.

Land Use, Structures and Estimated Losses from a 100-Year Flood Event

Land use in the Cedar River basin is dominated by forest uses (60.6 percent). The other main uses are residential; 21.3 percent can be classified as low-density development, 7.7 percent as medium and 0.9 percent as high density development. High-density development is located primarily in the Cities of

Renton and Maple Valley. Damage in the City of Renton during the November 1990 flood was estimated to be $5 million.

The total area of regulatory floodplain for the Cedar River basin includes all portions of the FEMA flood zones and King County's regulatory floodplain and floodway map, which includes most current floodplain studies. A channel migration study is currently being completed for the Cedar River but it is not included in the area of regulatory floodplain because it has yet to be finalized. Approximately 86 percent of the Cedar River basin regulatory floodplain is in unincorporated King County. The area of regulatory floodplain in the Cedar River basin is reflected in Table 27.

TABLE 27.
CEDAR RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	1,272
Incorporated Areas	207
Total	**1,479**

Within the Cedar River basin floodplain there are a total of 268 parcels with structures. This is approximately 4 percent of the total number of parcels in King County floodplains (6,250). The depth of flooding varies with location. Table 28 summarizes estimated flood loss potential. All of the 268 structures in the Cedar River basin floodplain are residential.

TABLE 28.
ESTIMATED LOSSES FROM A 100-YEAR FLOOD EVENT IN THE CEDAR RIVER BASIN

	Renton	Elliott	Upper	**Total**
Area of Floodplain (acres)	39	170	1,270	**1,479**
Buildings Exposed	0	52	216	**268**
Structure Value Exposed	$0	$8,021,055	$33,531,081	**$41,552,136**
Content Value Exposed	$0	$4,010,528	$16,765,541	**$20,776,068**
Total Value Exposed (Structure & Contents)	**$0**	**$12,031,583**	**$50,296,622**	**$62,328,204**
Structure Damage	$0	$112,072	$2,021,877	**$2,133,949**
Content Damage	$0	$43,121	$1,033,413	**$1,076,534**
Non-Residential Inventory Damage	$0	$0	$0	**$0**
Total Damage (Structure, Contents & Inventory)	**$0**	**$155,192**	**$3,055,290**	**$3,210,483**

Source: Hazards U.S. - Multi-Hazard (HAZUS-MH) Model for King County, WA (2012)

Development Trends

The greater part of the Cedar River floodplain is in unincorporated King County, with a smaller portion in the City of Renton. There is commercial, industrial and residential development throughout the incorporated areas of the Cedar River floodplain. Residential development has also occurred in unincorporated King County along the upper floodplain, which is likely due to its proximity to Renton.

Renton is expected to annex portions of the land along the Cedar River. There is expected to be a significant amount of growth in Renton during the 2001 to 2022 planning period (King County 2005).

King County and City of Renton regulations currently in effect strive to limit the impact of new development on the floodplain and the impact of flooding on new development.

Economic Impact

Based on existing land use and past experience, flooding along the Boeing and Renton reaches of the Cedar River would have the most severe economic impact within the basin. Both of these reaches contain the major population centers in the basin, and the Boeing reach contains areas of major employment for the entire County. The functional down time associated with the flooding typical for this basin could have a significant financial impact on the region. No detailed analysis of this potential impact was performed under this risk assessment. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be significant.

It is the working assumption of this Plan that cities such as Renton are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

There are 8 unmitigated repetitive loss properties in the Cedar River basin. Table 29 summarizes the unmitigated repetitive loss properties in the Cedar River basin. The properties are located in no consistent location in the basin and all are single-family residential properties. They all lie within a mapped 100-year floodplain, so it is concluded that the cause of repetitive flooding for this basin is overbank riverine flooding reflected by the mapping for the basin.

TABLE 29.
UNMITIGATED REPETITIVE LOSS PROPERTIES IN THE CEDAR RIVER BASIN

Number of Parcels	Total Area (acres)	Total Land Value	Total Improvement Value
8	7.1	$641,000	$652,000

GREEN RIVER BASIN PROFILE

The Green/Duwamish River is a 93-mile long river system that originates in the Cascade Mountains at an approximate elevation of 4,500 feet. The headwaters are in the vicinity of Blowout Mountain and Snowshoe Butte, about 30 miles northeast of Mount Rainier (King County 2002b). The river basin is part of Watershed Resource Inventory Area 9.

Hazard Profile

For the purposes of this risk assessment, the Green River basin can be divided into five reaches:

- The Upper Green River reach —Headwaters to the Howard Hanson Dam at River Mile 64.5
- The Gorge Reach—Howard Hanson Dam to Flaming Geyser park at River Mile 45.2

- The Middle Green River reach—Flaming Geyser Park at River Mile 45.2 to Auburn city limit at River Mile 31.8
- The Lower Green River reach—Auburn city limit at River Mile 31.8 to confluence with the Black River at River Mile 11.
- The Mill Creek reach—Mill Creek headwaters to confluence at Tukwila

Past Events

Historically, there have been several severe flooding events in the Green River basin, with records dating back to 1933. Table 30 summarizes the history of flood events for this basin since 1990. The most severe recent flooding event was the January 2011 flood.

Severity is identified in terms of phases. Table 30 shows events that reached Phase 3 or above at the Auburn gage. Below are the phases of flooding for the Green River based on the actual or expected flow at the Auburn gage

- Phase 1—The flow is greater than 5,000 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase 2—The flow is greater than 7,000 cfs and minor flooding is expected in rural lowland areas upstream of Auburn. This river level is not a major flood threat to the urban areas of the Green River valley.
- Phase 3—This is a moderate flooding, flow is greater than 9,000 cfs. At phase 3 moderate flooding is expected in rural lowland areas both upstream and downstream of Auburn, Urban areas of the Green River valley are generally protected from Phase 3 floods by the levee system. Flood conditions can change rapidly in levee-protected areas.
- Phase 4—The flow is greater than 12,000 cfs. At phase 4 major flooding may occur. Critical flood control levees may weaken from saturation. Sudden changes in flood conditions are possible, especially in levee-protected areas. These changes may include rapidly rising water, widespread inundation, road closures, and utility disruptions.

Flood Characteristics

Tables 31 and 32 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach. Table 31 also shows the calculated 1 percent chance annual flood flow for each gage. Table 32 also shows warning time in terms of length of time from gage to gage where available. This is shown as the time that it takes peak flows to travel downstream from one gage to the next.

TABLE 30.
GREEN RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/09/1990	No	3/10,800	No significant public or private property damage reported for this event	Information not available
11/09/1990	Yes/#883	3/10,200	Overbank flooding. Property damage to both public and private property. Levee damage.	$5.6 million for entire county
11/22/1990	Yes/#896	3/11,500	Overbank flooding. Property damage to both public and private property. Levee damage.	$1.4 million for entire county
02/19/1991	No	3/10,300	No significant public or private property damage reported for this event	Information not available
02/19/1995	No	3/9,450	No significant public or private property damage reported for this event	Information not available
12/01/1995	Yes/#1079	3/11,700	Overbank flooding. Property damage to both public and private property. Levee damage.	$2,402,374 in damage to public property
02/10/1996	Yes/#1100	4/12,400	Overbank flooding. Property damage to both public and private property. Levee damage.	$1,728,704 in damage to public property
03/20/1997	Yes/#1172	3/9,290	No significant public or private property damage reported for this event	Information not available
11/26/1999	No	3/9,200	No significant public or private property damage reported for this event	Information not available
12/16/1999	No	3/9,130	No significant public or private property damage reported for this event	Information not available
11/06/2006	Yes/#1671	4/12,200	Damage to levees and revetments	$5,386,323 in public property damages county-wide
12/1/2007	Yes/#1734	N/A	No reported damages to river flood protection infrastructure	$5,123,841 in public property damages county-wide
1/07/2009	Yes/#1817	3/11,100	Overtopping, damage to flood protection infrastructure and to residential property	$16,444,775 in public property damages county-wide
1/16/2011	Yes/#1963	3/10,400	Damage to levees and revetments	No information available
1/14/2012	Yes/#4056	N/A	Information not yet available	No information available

TABLE 31.
GREEN RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	USGS River Mile	Drainage Area (square miles)	100-year Flood Flow (cfs)[a,b]	Flood of Record, Date & Peak Flow (cfs)
Howard Hanson Dam	12105900	63.8	221.0	Maximum flow release to meet target of 12,000 cfs at Auburn	12/21/1960; 12,200 (pre-dam)
Auburn	12113000	32.0	399.0	12,000 (as regulated by Howard Hanson Dam)	11/23/1959; 28,100 (pre-dam)
Tukwila	12113350	NA	440.0	12,400	01/31/1965; 12,100

a. FEMA (2005)
b. Affected by regulation at the Howard Hanson Dam

TABLE 32.
GREEN RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Mapped Channel Migration Zone (yes/no)	Approximate Warning Time
Middle Green	Forestry, Open Space/Recreation, Agricultural, Rural Residential	Up to 20 feet with measurable velocity contained in gorge channel. Shallow Flooding; 1 – 3 feet in agricultural areas.	Yes	8 hours
Reddington/ Green River Road, Horseshoe Bend/Russell, Midway/Johnson, Briscoe, Duwamish West, Duwamish East	Urban Residential, Commercial, Light Industrial	1 – 6 feet	No	12 hours
Mill Creek/Mullen Slough	Some agricultural, mixed rural and urban residential	Up to 12 feet in Johnson Creek vicinity, 1 – 6 feet everywhere else	No	No warning

Vulnerability Analysis

Public Safety and Health

Flooding in the Green River basin has a variety of potential impacts on life, safety and health. Very few lives have been lost, but damage and disruption caused by flooding have been significant. The river's historical floodplain on the Lower and Middle Green River includes the Southcenter commercial area and much of the region's industrial and warehouse capacity. The Middle Green River is a broad valley. The Middle and Lower Green River areas are protected by the Howard Hanson Dam and extensive flood containment levees and pumps. The Upper Green River is steep with high velocity flows.

During the January 2009 flood, the abutment to Howard Hanson Dam exhibited higher than expected rates of seepage and turbidity. Until a solution was in place, the dam operated using a limited capacity which greatly increased the odds of severe flooding. During this time extensive flood preparedness measures were enacted by government agencies, businesses and the public. Construction occurred to install a grout curtain on a significant portion of the abutment along with additional drainage wells. By the Fall of 2011 the U.S. Army Corps of Engineers began to operate the dam as it had in the past. The incident has increased awareness of the vulnerability associated with areas protected by the dam.

There are many miles of small streams with unmapped floodplain within the Green River basin. Since there is no mapped floodplain in these areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely. There are significant amounts of development throughout the Green River valley. It is home to several commercial and industrial centers and has a growing residential population. With this growth, it is likely that public health and welfare will be at risk from flooding. The population in the Green River basin, estimated to be 564,000 in the 2000 census, is mostly concentrated in the lower end of the basin, but the fastest rate of population increase is in the suburban cities and nearby unincorporated areas east of Seattle (King County 2002b).

Critical Facilities

Critical Facilities in the Green River basin were identified using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.).

Table 33 lists the critical facilities in the Green River basin. King County has established policies in both its Regional Hazard Mitigation Plan and the Flood Hazard reduction Plan to proactively mitigate risks to identified critical facilities when opportunities arise. Several of the facilities listed in Table 33 are not under County ownership. The County will work with all agencies involved to achieve this objective.

TABLE 33.
CRITICAL FACILITIES IN THE GREEN RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Infrastructure
Kent Junior High	Kent School District	10.0	X	
Fire Station 14	City of Renton	1.0	X	
Neely O'Brien Elementary	Kent School District	20.0	X	
Tukwila Fire Station	City of Tukwila	13.0	X	
Pipeline #5 (Water Supply)	King County		X	
Levees[a]	King County and private property owners			X
Howard Hanson Dam	Army Corps of Engineers	64.5		X
Black River Pump Station	King County	11.0		X

a. Various levees along the Green River are in need of repair. Projects and recommended priorities are located in Chapter 5 and Appendix G.

Highways, arterial roadways and additional pipelines are critical facilities located throughout the floodplain.

Land Use, Structures and Estimated Losses from a 100-Year Flood Event

Land use in the Green River basin varies significantly among the lower, middle and upper portions. The land in the Upper Green River is primarily forestland. The Middle Green River is primarily farmland and a mix of urban and rural residential. The major land uses are residential (50 percent), forestry (27 percent) and agriculture (12 percent) (King County 2005). Several large state and county parks abut the river in this segment. The Lower Green River contains less farmland and is mainly urban. Except for occasional stretches of parkland, a mixture of residential, commercial and industrial land uses are the main land uses. Residential development (50 percent), industrial development (17 percent), and commercial development (10 percent) are the primary uses along the Lower Green River.

King County floodplain mapping shows 12,340 acres of mapped floodplain in the Green River basin. A floodplain study of the Lower and Middle Green River was submitted to FEMA in 2008 and will be used to update the floodplain and floodway data in future Flood Insurance Rate Maps.

The total area of regulatory floodplain for the Green River basin includes King County's regulatory floodplain and floodway map that include most current floodplain studies. A channel migration study is completed for portions of the Green River; the results are not included in the area of regulatory floodplain. The area of regulatory floodplain is shown in Table 34. Approximately 42 percent of the Green River regulatory floodplain is in unincorporated King County.

TABLE 34.
GREEN RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	5,225
Incorporated Areas	7,115
Total	**12,340**

Within the mainstem Green River and Mill Creek basin floodplain (not including other areas within the basin) there are a total of 1,175 parcels with structures. This is approximately 19 percent of the total number of parcels in King County floodplains (6,250). Of these, 312 are residential structures and 184 are commercial. The depth of flooding varies with location. Table 35 summarizes estimated flood loss potential.

Development Trends

Urbanization of the Green River floodplain began in 1962, with rapid annexation of the valley floor by the valley cities as soon as the dam became operational. In the 1990s, Black Diamond, Enumclaw and Covington experienced rapid growth. Land development estimates indicate that the largest areas of future development will be in the Lower and Middle Green River areas.

TABLE 35.
ESTIMATED LOSSES FROM A 100-YEAR FLOOD EVENT IN THE GREEN RIVER BASIN

	Middle Green	Reddington/ Green River Road	Mill Creek/Mullen Slough	Horseshoe Bend/Russell	Midway/ Johnson	Briscoe	Duwamish West	Duwamish East	Other areas	**Total**
Area of Floodplain (acres)	1,753	482	2,349	2,170	584	1,602	482	260	2,658	**12,340**
Buildings Exposed	29	41	157	508	25	249	162	4	N/A	**1175**
Structure Value Exposed	$7,592,471	$42,751,692	$420,723,973	$1,623,256,048	$67,363,286	$1,393,477,676	$107,021,158	$941,358	N/A	**$3,663,127,662**
Content Value Exposed	$5,416,051	$26,088,658	$429,260,766	$1,581,047,600	$33,681,643	$1,413,554,072	$138,746,934	$537,541	N/A	**$3,628,333,265**
Total Value Exposed (Structure & Contents)	**$13,008,522**	**$68,840,350**	**$849,984,739**	**$3,204,303,648**	**$101,044,929**	**$2,807,031,748**	**$245,768,092**	**$1,478,900**	**N/A**	**$7,291,460,927**
Structure Damage	$139,528	$5,740,780	$2,208,205	$98,134,353	$537,893	$104,716,553	$971,539	$15,218	N/A	**$212,464,070**
Content Damage	$334,386	$4,793,482	$7,368,271	$313,654,941	$315,024	$346,151,961	$1,145,728	$26,581	N/A	**$673,790,375**
Non-Residential Inventory Damage	$378,200	$669,041	$6,792,385	$347,167,103	$0	$379,849,429	$1,404,333	$29,492	N/A	**$736,289,984**
Total Damage (Structure, Contents & Inventory)	**$852,115**	**$11,203,304**	**$16,368,862**	**$758,956,398**	**$852,917**	**$830,717,944**	**$3,521,600**	**$71,291**	**N/A**	**$1,622,544,429**

Source: Hazards U.S. - Multi-Hazard (HAZUS-MH) Model for King County, WA (2012)

Economic Impact

Based on existing land use and past experience, flooding along the middle and lower reaches of the Green River would have the most severe economic impact in the basin. Theses reaches contain the major population/employment centers in the basin and in the county. The river flows in the lower reaches of the Green River are contained by levee systems, and costs associated with flood fighting and levee repair have been the highest of all basins in King County. Such costs can have an impact on the tax base in the long run. The functional down time associated with the flooding typical for this basin could have a significant financial impact on the region. No detailed analysis of this potential impact was performed for this risk assessment although a risk analysis on levees was performed in 2007. For planning purposes, King County considers the possible economic impact of typical flooding in this basin to be significant.

It is the working assumption of this Plan that cities such as Auburn, Kent, Renton and Tukwila are carefully addressing significant flood-related hazards through coordinated planning efforts. This coordination at a minimum should involve consultations with King County, the Washington Department of Ecology, FEMA, the U.S. Army Corps of Engineers, and other agencies with expertise and responsibility for addressing flooding concerns. It should be carried out in a manner that fully meets state standards for city consistency with County flood hazard planning, as set forth in Chapter 86.12 RCW.

Repetitive Loss Areas

Based on the County's review of repetitive loss data provided by FEMA, there are two unmitigated repetitive loss properties in the Green River basin. These properties are single-family residential. One property is currently not mapped in the 100-year floodplain which means that the flooding was likely due to storm water drainage problems.

WHITE RIVER BASIN PROFILE

The White River is a glacially-fed river system that originates on the northeast face of Mount Rainier and is a part of Water Resource Inventory Area 10. The White River flows in northwest from its headwaters and then turns south to join with the Puyallup River near the City of Sumner. The Puyallup River flows for 10 miles through the Cities of Puyallup and Tacoma to Commencement Bay in south Puget Sound. The White River drains an area of approximately 494 square miles (King County 2002d).

Hazard Profile

The analysis of this basin is separated into five reaches:

- Upper White/Greenwater Reach—Basin divide to Mud Mountain Dam
- Boise Creek Reach—Boise Creek headwaters to confluence with the White River
- Dams Reach—Mud Mountain Dam to SR 410
- Natural Reach—SR 410 to upper end of levee protected channel
- Lower White—Upper end of levee protected channel to King County/Pierce County line

Past Events

Historically, there have been several severe flooding events in the White River basin. Table 36 summarizes the history of flood events for this basin since 1990.

Severity is identified in terms of phases. Table 36 shows events that reached Phase 3 or above at the Buckley gage, unless otherwise indicated. Below are the phases of flooding for the White River:

- Phase 1—The flow is greater than 2,500 cfs and is considered an internal alert to the King County Flood Warning Center.
- Phase 2—The flow is greater than 6,000 cfs and Red Creek area residents may experience overtopped roads and high water.
- Phase 3—This is moderate flooding and exhibits flows greater than 8,000 cfs. Red Creek area residents may experience dangerous, high velocities, debris flow, and residential flooding.
- Phase 4—This is considered extreme flooding. The flow is greater than 12,000 cfs and there is likely to be significant overbank flooding, possibly inundating areas of State Route 410 and Sumner. Area residents may experience dangerous high velocities and debris flows.

TABLE 36.
WHITE RIVER BASIN FLOOD EVENT HISTORY

Date of Flood	Declaration (yes/no) #	Flood Phase/ Peak Flow (cfs)	Type of Damage	Estimated Cost
01/11/1990	No	4/13,000	No significant public or private property damage reported for this event	No information available
12/02/1995	Yes/#1079	4/15,000 @ Auburn	Overbank flooding. Property damage to both public and private property.	$304,054 in damage to public facilities
02/10/1996	Yes/#1100	3/10,600	Overbank flooding. Property damage to both public and private property.	$20,213 in damage to public facilities
12/30/1996	No	3/>8,000	No significant public or private property damage reported for this event	No information available
11/06/2006	Yes/#1671	4/14,700	No reports of significant public or private property damage.	$5,386,323 in public property damages county-wide
12/1/2007	Yes/#1734		No reported damages to river flood protection infrastructure	$5,123,841 in public property damages county-wide
1/07/2009	Yes/#1817	3/11,800	Erosion and scour, damage to concrete revetment	$16,444,775 in public property damages county-wide
1/16/2011	Yes/#1963	1/7,410	No reported damages to river flood protection infrastructure	No information available
1/14/2012	Yes/#4056		Information not yet available	No information available

Flood Characteristics

Tables 37 and 38 summarize observed flooding characteristics typical for this basin. Understanding the potential flood conditions for a specific area enables the County to identify mitigation alternatives appropriate for the level of risk for that stream or reach.

TABLE 37.
WHITE RIVER BASIN FLOW CHARACTERISTICS

Gage Location	USGS Station Number	River Mile	Drainage Area (square miles)	100-Year Flood Flow (cfs)	Flood of Record, Date & Peak Flow (cfs)
Buckley	12098500	27.9	401.0	12,350 *a*	12/01/1933; 28,000 (pre-dam)
Auburn	12100496	6.30	464.0	15,500 *a*	02/10/1996; 15,000
Greenwater	12097500	1.10	73.5	6,780 *b*	12/02/1977; 10,500

a. Based on 2008 flood study.
b. Based on USGS data through 2007

TABLE 38.
WHITE RIVER BASIN FLOOD CHARACTERISTICS

Reach	Land Uses Surrounding the Reach	Depth of Flooding	Channel Migration Zone (yes/no)	Approximate Warning Time
Above Mud Mountain Dam – Greenwater River & Greenwater River	Low density Residential, Forestry	Shallow Flooding, 0-3 feet	No	No warning
Boise Creek	Low density Residential, Agricultural	Shallow Flooding, 0-3 feet	No	No warning
SR 410 – Mud Mountain Dam	Low density Residential, Agricultural	6 feet or greater with measurable velocities	No	2-4 hours
River Mile 10 – SR 410	APD, recreational-open space, Agricultural	Shallow flooding 0-6 feet with some measurable velocity	No	2-4 hours
8th Street – RM 10	Mixed Use: Urban residential, commercial, industrial	Shallow flooding,0-6 feet with some measurable velocity	No	4-5 hours

Vulnerability Analysis

Public Safety and Health

Flooding in the White River basin has a variety of potential impacts on life, safety and health. The large amount of sediment carried by the White River affects its drainage pattern and can cause flooding in the valley lands near the cities of Auburn and Pacific. In this area, the gradient lessens, the velocity slows and the sediments and debris tend to settle out onto the floodplain (King County 1993b).

There are many miles of small streams with unmapped floodplain within the White River basin. Since there is no mapped floodplain in these areas, risk of flooding to the public may be more significant during severe events and may need to be monitored closely. This is more of a concern in areas that are becoming more urbanized, such as the lower White River near Auburn and Pacific.

Critical Facilities

Critical Facilities in the White River basin were identified by using GIS and anecdotal information. For purposes of this document, critical facilities are identified in two categories: 1) facilities and infrastructure that are critical to public health and welfare that are especially important following a flood event; and 2) facilities and infrastructure that are critical to King County for floodplain management (roads, dams, etc.). Table 39 lists the critical facilities in the White River basin.

TABLE 39.
CRITICAL FACILITIES IN THE WHITE RIVER BASIN

Facility or Infrastructure	Owner	Location (River Mile)	Public Health & Safety	Flood Protection Infrastructure
Pump Station	King County—Wastewater Treatment Division	6.5	X	
Natural Gas Pipeline[a]	Williams	10.8	X	
Water Supply Pipeline #1[b]	Tacoma Public Utilities	23.3	X	
Water supply well-field[c]	City of Auburn	Approximately 9.0	X	
Auburn Wall[d]	King County—Water and Land Resources Division	8.1		X
Riverside High School[e]	Riverside High School	6.5	X	
Mount Baker Middle School[f]	Mount Baker Middle School	7.0	X	
Abandoned Land Fill[g]	King County	6.0	X	

a. Pipeline exposed in 1995 flood. In 2003, Williams replaced crossing with new pipeline well-below expected scour depth.
b. In 2003, TPU replaced crossing with the new pipeline well-below expected scour depth.
c. Only a major avulsion would affect the well-field
d. This facility protects the City of Auburn from any potential avulsion into the historic White River channel.
e. This is on the left bank and is built on fill and will likely be in a moderate channel migration zone.
f. This is on the right bank and is built on fill and will likely be in a moderate channel migration zone.
g. Considered a critical site due to its potential public health impacts.

Land Use, Structures and Estimated Losses from a 100-Year Flood Event

Approximately 175 square miles in the White River basin is owned and managed by the Mount Baker-Snoqualmie National Forest. Another 90 square miles of the basin is part of Mount Rainier National Park. In this upper portion, the basin is mainly undeveloped but includes some scattered residential and commercial property around Greenwater (King County 1993b). In the lower areas of the basin, there are

some agricultural lands and a mix of residential, commercial and industrial uses closer to and in the cities. Upstream of the Muckleshoot Indian Reservation, the river is unconstrained and the valley is mostly undeveloped (King County 1993b).

King County floodplain mapping shows 4,171 acres of mapped floodplain in the White River basin. One of the major risks in the White River basin is that there are significant channel migration hazards related to the river's significant sediment load and debris local, especially in the upper basin.

A channel migration study will be completed on the White River but is not currently included in the area of regulatory floodplain. About 85 percent of the regulatory floodplain in the basin is in unincorporated King County. Table 40 shows the area of regulatory floodplain.

TABLE 40.
WHITE RIVER BASIN AREA OF REGULATORY FLOODPLAIN

	Area of Regulatory Floodplain (acres)
Unincorporated King County	3,568
Incorporated Areas	603
Total	**4,171**

Within the White River basin floodplain there are a total of 211 parcels with structures. This is approximately 3 percent of the total number of parcels in King County floodplains (6,250). The depth of flooding varies depending on location. Table 41 summarizes estimated flood loss potential. Of the 211 identified structures in the White River basin floodplain, 205 are residential structures and 6 are commercial or other designations.

Development Trends

The majority of the White River basin is in unincorporated King County, with a smaller portion in the cities and the Muckleshoot Indian Tribe Reservation. There is commercial, industrial and residential development throughout the incorporated areas of the White River floodplain. The majority of development is along the White River in the Auburn and Pacific area. This area has significant potential for new residential, commercial and industrial development.

Economic Impact

The economic impact for this basin is based on a review of historical flooding, the inventory of structures at risk, and current land use in the basin. The current land use is predominantly open space, forestry and agricultural in the upper reaches, and the urbanized lower reaches are channelized and protected by flood control infrastructure. The safety provided by flood control infrastructure is dependent on the functionality and integrity of the flood protection infrastructure at the time of a flood event. Failure of a flood control Infrastructure in this basin could have a measurable economic impact within the basin due to functional downtime, flood fighting costs and flood protection infrastructure repair. Costs have been significant during past events; King County considers the possible economic impact of typical flooding in this basin to be moderate.

TABLE 41.
ESTIMATED LOSSES FROM A 100-YEAR FLOOD EVENT IN THE WHITE RIVER BASIN

	Above Mud Mountain Dam-Greenwater River	SR 410 – Mud Mountain Dam	Boise Creek Reach	River Mile 10 – SR 410	8th Street – RM 10	Other areas	**Total**
Area of Floodplain (acres)	782	846	529	1,311	285	418	**4,171**
Buildings Exposed	16	4	38	0	138	15	**211**
Structure Value Exposed	$1,595,083	$611,936	$7,983,129	$0	$26,202,049	N/A	**$36,392,197**
Content Value Exposed	$797,542	$305,968	$3,991,564	$0	$13,375,570	N/A	**$18,470,644**
Total Value Exposed (Structure & Contents)	**$2,392,625**	**$917,904**	**$11,974,693**	**$0**	**$39,577,619**	**N/A**	**$54,862,841**
Structure Damage	$161,862	$69,959	$1,353,501	$0	$2,031,236	N/A	**$3,616,557**
Content Damage	$99,431	$49,245	$643,907	$0	$968,093	N/A	**$1,760,676**
Non-Residential Inventory Damage	$0	$0	$0	$0	$201,156	N/A	**$201,156**
Total Damage (Structure, Contents & Inventory)	**$261,292**	**$119,203**	**$1,997,407**	**$0**	**$3,200,486**	**N/A**	**$5,578,389**

Source: Hazards U.S. - Multi-Hazard (HAZUS-MH) Model for King County, WA (2012)

Repetitive Loss areas

There currently are no unmitigated repetitive loss properties in this basin. However, at one time, this basin included a single property with the most flood insurance claims of any property in the County. This property was located along the Boise Creek reach of this basin, and was mitigated through a property acquisition by King County in 2000.