

## Landslides Risk Assessment

*This plan is an update of the 2004 City of Redmond Hazard Mitigation Plan (HMP). Although it is an update, this document has been redesigned so that it looks, feels, and reads differently than the original. This is due to several factors: new hazard information has become available that drives new definitions of risk, the City has matured and new capabilities are now available, and the new format will allow readers to more easily understand the content. In addition, the 2004 HMP included several action items that have been completed, creating an opportunity for developing new mitigation strategies.*

### 8.1 Identify Landslide Hazards

A landslide is a movement of debris down a steep slope. The speed of the moving debris will vary from a slow creeping motion to a high-speed moving mass. Landslides are caused by a combination of factors, including geology, gravity, weather, and human activity. The steepness of a slope and the forces of gravity acting upon it are the main contributing forces of a landslide. For alluvial soils, on which much of Redmond sits, the angle of repose (the point at which a slope becomes unstable) is estimated to range from 30-35 degrees. Therefore, hillsides with a slope of greater than thirty degrees are landslide hazards.<sup>85</sup>

Landslides occur when the soil is saturated, causing instability on hillsides. Saturated steep slopes may give way and pose a threat to the area on and near the hillside. Landslides may also occur as a secondary hazard after an earthquake or a severe storm. An earthquake during an extended period of rain would likely cause landslides. A large landslide that falls into Lake Sammamish could cause a seiche.

Factors that increase the likelihood of a landslide:

- Undercutting of a stream into a hillside
- Soil erosion/makeup
- Improper drainage on hillside
- Earthquakes
- Fires
- Intense periods of precipitation
- Lack of vegetation
- Improper development and drainage practices
- Alternate freezing and thawing

Landslides vary in both speed and size. The moving mass may be as narrow as a few feet or as wide as a few miles. Trees, roads, bridges, and homes may be swept away in the slide.

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<sup>85</sup> Carson, M.A. and Kirkby, M.J., *Hillslope Form and Process*. West Nyack, New York, U.S.A. Cambridge University Press, 1972.

### Climate Change

Climate change will increase the risk of landslides by exacerbating some of the factors listed above, such as increased precipitation events or vegetation-destroying wildfires.

## 8.2 Profiling Landslide Hazard Events

### A. Location

Landslide hazard areas in Redmond are identified as slopes greater than thirty degrees and the areas within a fifty-foot buffer above and below such slopes. Steep slopes in Redmond are located primarily on the western and southeastern portion of Education Hill and along Redmond's northwestern border in the Willows/Rose Hill neighborhood.

Beyond the City limits there are several steep slopes surrounding Lake Sammamish and lining the Sammamish Plateau. A landslide on the slopes surrounding Lake Sammamish could result in a seiche. A seiche, sometimes called a lake tsunami, is an oscillating wave that occurs in an enclosed or semi-enclosed body of water.

**Map 27, City of Redmond Landslide Hazard Areas and Major Vegetation**, shows the hazard area along with the 50 foot buffer area. The King County Critical Areas Ordinance (CAO) designates critical slopes as hillsides with a slope of at least forty percent (approximated 21 degrees inclination) that are taller than ten feet. The CAO also includes a fifty-foot buffer (which can be waived for single family housing).<sup>86</sup>

### B. Timing and Duration

Soil saturation occurs primarily in the winter or spring, during Redmond's wettest months. Prolonged heavy rain will typically provide a few days warning prior to a slide. Signs of increased slope instability may indicate slopes that are most vulnerable during a particularly wet season. Irregular tree angles may present warning signs of past landslide occurrences. Close monitoring of structures built on or near the slopes may provide early indications of slides.

Slides can be slow, moving a couple of millimeters a year, or as fast as 200 miles per hour. Typical slides move at a rate of 30-50 miles per hour.<sup>87</sup> As a result of the fast movement, landslides are generally short in duration.

### C. Severity

The speed of landslides can cause damage to structures and injure people. Slopes that are protected by the CAO remain in a natural, vegetative state, providing some ground stability. However, development and habitat alteration above the slopes may change the natural drainage patterns of stormwater run-off. While few structures appear to be constructed mid-slope (construction prior to the 1990 CAO were grandfathered in<sup>88</sup>) on any of the steep hillsides in Redmond, some structures have

<sup>86</sup> King County Critical Areas Ordinance, "Chapter Two - Steep Slopes Hazard Area," King County, <http://your.kingcounty.gov/ddes/cao/Manual/II-SteepSlope.pdf>.

<sup>87</sup> United States Geological Survey, "Landslide Hazards Program," <http://landslides.usgs.gov/learning/faq/>.

<sup>88</sup> King County Critical Areas Ordinance, "Chapter Two - Steep Slopes Hazard," King County, <http://your.kingcounty.gov/ddes/cao/Manual/II-SteepSlope.pdf>.

been built on the edges above and below steep slopes, and are therefore susceptible to foundation damage and/or complete destruction of the structure by moving debris. **Map 27, City of Redmond Landslide Hazard Areas and Major Vegetation**, shows the steep slopes lacking vegetation.

#### D. Frequency

##### *Previous Occurrences*

Landslides have frequently caused disturbances in King County cities. The storms of 1996 and 1997 caused more than 100 landslides throughout the county. The 2001 Nisqually earthquake triggered a portion of road near Renton, WA to slide into the Cedar River.<sup>89</sup>

##### *Probability of Future Events*

Climate change forecasts warn of an increase in frequency and severity in precipitation; thus landslides in Redmond are likely to become more frequent. Increased and intensified development on the hillsides and surrounding areas will change the character of runoff. Increased runoff elevates the landslide threat. Proper drainage practices, hillside terracing, and increased vegetation can stabilize hillsides and reduce the probability of landslides.

### 8.3 Assessing Landslide Vulnerability

#### 8.3.1 Overview

In the United States, landslides cause 25-50 deaths and over \$1 billion in damages annually.<sup>90</sup> The built environment and drainage culverts are likely to be vulnerable during a landslide. Delicate fish and wildlife habitat will also be vulnerable to a landslide. Since landslides will happen in isolated areas, damage will be location specific.

#### 8.3.2 Profiling the Vulnerabilities

##### A. Man-made

Redmond's natural geologic slopes and development on or near steep slopes make the built environment vulnerable. Approximately 10% of the residential structures in Redmond are located in the landslide hazard zone. About 9.5% of the non-residential (commercial and public) buildings are also within the designated buffer. **Map 28, City of Redmond Buildings in Landslide Hazard Areas**, shows the prevalence and location of commercial and residential structures located on, or within, the 50-foot buffer of slopes that are greater than 30%.

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kingcounty.gov/ddes/cao/Manual/II-SteepSlope.pdf.

89 King County Office of Emergency Management, "Landslides," King County, [http://www.kingcounty.gov/safety/prepare/residents\\_business/Hazards\\_Disasters/Landslides.aspx](http://www.kingcounty.gov/safety/prepare/residents_business/Hazards_Disasters/Landslides.aspx)

90 United States Geological Survey, "Landslides Hazard Program," <http://landslides.usgs.gov/learning/ls101.php>.

**B. Natural**

A landslide may increase sedimentation and siltation in waterways, which may negatively impact fish and other wildlife habitat. A landslide may further destabilize a steep hillside and destroy trees and other vegetation, which may also impact wildlife habitat.

**C. Systems**

Roads and telecommunication networks may be vulnerable to a landslide. The location of the landslide will determine the impact. About 9.5% of the City's stormwater culverts are located within the 50-foot landslide buffer hazard zone. Damaged or blocked culverts may cause additional damage to the transportation system and provide subsequent obstacles for businesses (see **Map 29, City of Redmond Roads and Culverts in Landslide Hazard Areas**).

Slides, similar to earthquakes and other seismic activity, increase the vulnerability of telecommunication networks and infrastructure. Landslides generally impact all built forms and infrastructure within the affected area. Therefore, other utility infrastructure may also have increased exposure to risks if a landslide should take place in proximity to these systems.

Transportation systems are vulnerable to landslides. Damage may limit access for residents and employees in the City of Redmond. Emergency crew access could be limited by a landslide that makes roads unusable.

**D. Populations**

Refer to **Map 30, City of Redmond Populations Vulnerable to Landslides**, for the locations of vulnerable populations outlined below.

*Hazard Specific*

People who live or work near a steep slope are vulnerable in the event of a landslide. However, sufficient monitoring during periods of heavy rain may provide sufficient time for evacuation.

*Isolated Populations*

A landslide may isolate populations that live near a slide area. If a landslide impacts a road, and no alternate route exists, communities may become isolated. Specifically, Education Hill residents may become isolated in the event of a landslide that blocks roads.

*Disabled Persons*

In the case of a landslide, people with mobility constraints may have difficulty with a rapid evacuation.

*Children*

Children may become isolated from family members in the case of a landslide that affects the transportation system. Five schools and daycares are located within a

landslide hazards zone.

#### *Elderly*

Three retirement homes are located on steep slopes and two are located within close proximity to a steep slope. These facilities may be vulnerable to a landslide.

#### *Limited English Language*

Residents that do not have access to landslide hazard information in a language that they understand may not be able to adequately mitigate or have access to emergency information.

#### *Low-income Residents*

People with limited resources may not have the means to update their homes or relocate if necessary.

### **8.3.3 Analyzing Development Trends**

The King County and City of Redmond Critical Area Ordinances (CAO) limit development on or near slopes that exceed a forty percent grade (approximately 21 degree incline) and are taller than ten feet. Although the Future Land Use Map of Redmond shows that much of the land in the landslide hazard zones are zoned residential and commercial, the CAO restricts potential development. However, development above and below steep hillsides (beyond the CAO fifty-foot buffer) may have a negative impact on the drainage and stability of the hillside. Development will alter the landslide hazard zone.

### **8.3.4 Redmond's Landslide History**

Redmond has dealt with two significant landslides in their history dating back to 1997. In January, 1997, a severe winter storm (Federal Disaster 1159-DR-WA) caused localized flooding and overwhelmed storm drains and culverts in several locations in the City. A substantial landslide occurred on the southwest side of town when a hillside gave way due to excessive water overflowing storm drains and culverts at the top of the hill. The subsequent slide caused a road to be washed out.

In December, 2001, a water line broke as a result of a private development project at the top of a hillside. The resulting water flow overwhelmed a culvert caused slippage on the adjacent hillside. This slide occurred on the south west side of town off of 24th Ave NE. (See Maps 27, 28). The slide actually occurred on private property.

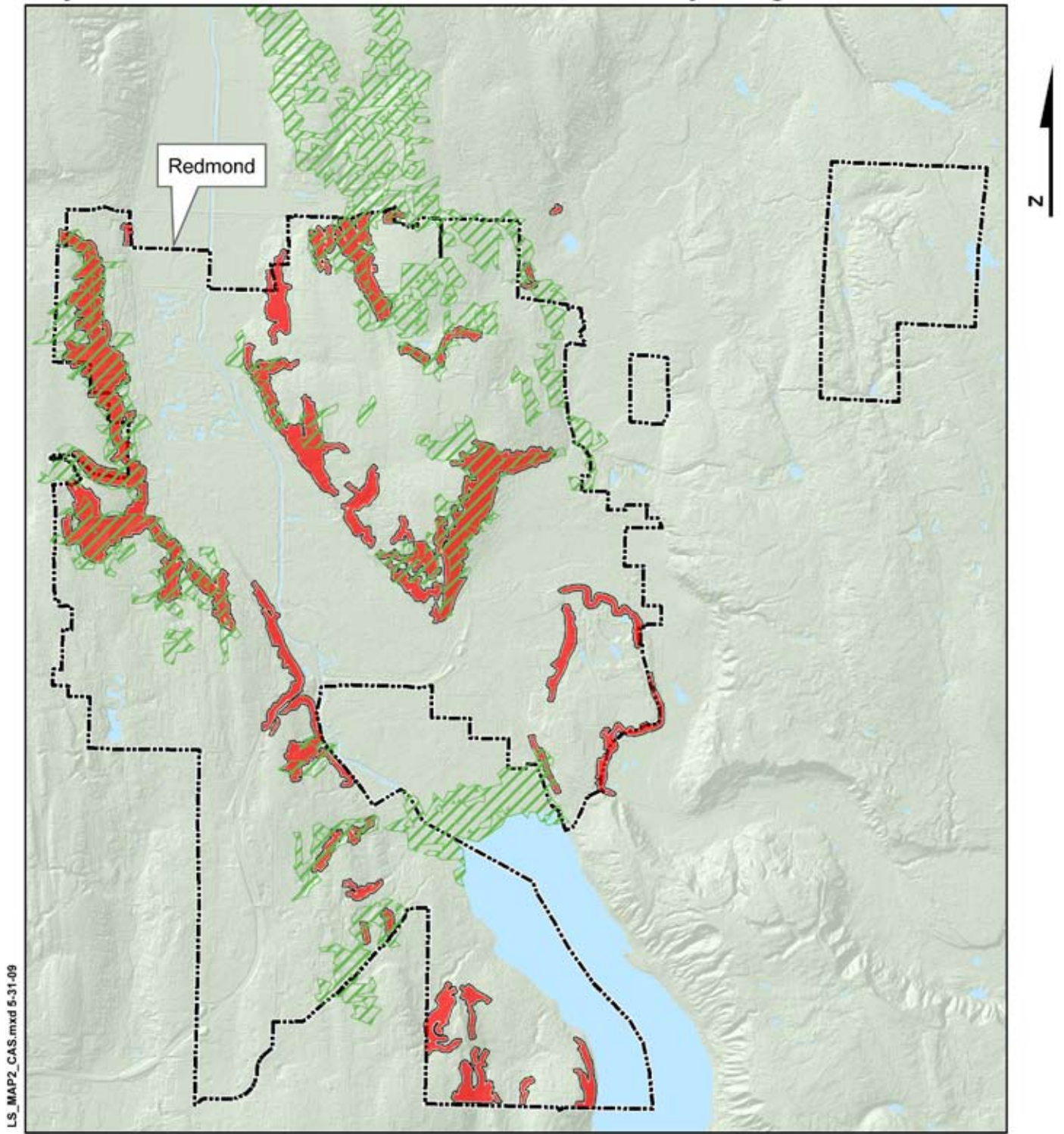
These two landslides listed above have led to a Public Works review of the storm drain capacity in Redmond and some changes to the development codes for residential and commercial development. In addition, Redmond conducted a review of its policy relating to regular street cleaning and storm drain clearing that ultimately included messaging to Redmond residents encouraging them to regularly check storm drains

in their neighborhoods. Redmond has also modified its procedures for monitoring construction during poor weather times to ensure that necessary precautions are taken to keep hillsides stable.

#### **8.4 Scenarios**

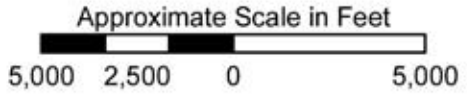
At 10 p.m. on November 5th, after several weeks of rain, a section of hillside in the Education Hill area gave way. Three homes slid fifty feet down the hillside, depositing debris in the backyards of several other homes, which were not damaged directly but lost landscaping and auxiliary structures, such as storage sheds. The residents and the City are cleaning up the large amounts of debris. Five people were injured, but there were no life-threatening injuries. Although neighboring homes are currently stable, monitoring will continue as the section that gave way continues to occasionally crumble. The road above the hill has been closed due to instability. The debris blocked a culvert at the bottom of the hill and caused two feet of flooding on sections of SR-202, Redmond-Woodinville Road. The road was closed for thirty-six hours before crews were able to restore normal traffic flow.




### City of Redmond Landslide Hazard Areas and Major Vegetation



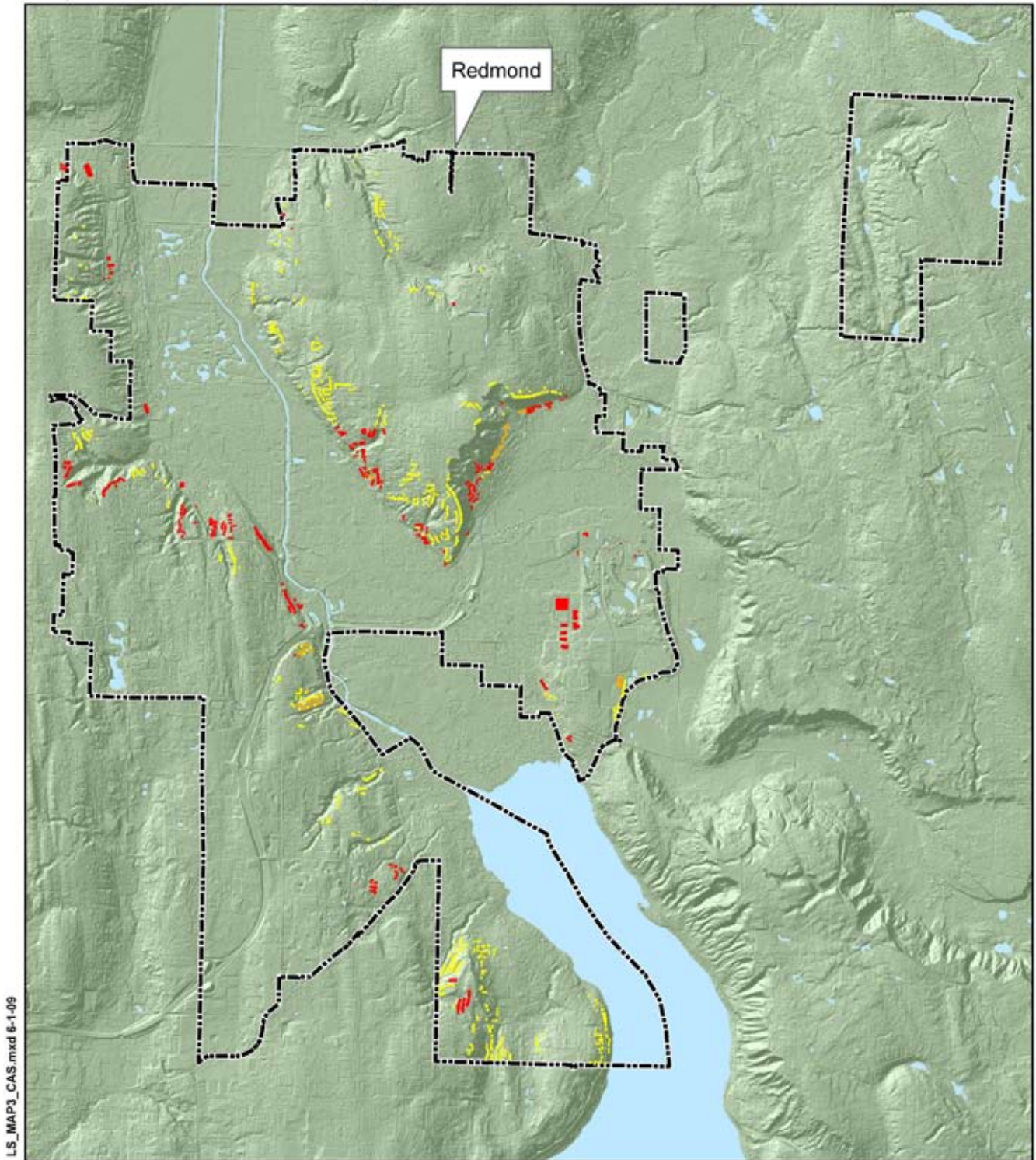
LS\_MAP2\_CAS.mxd 5-31-09

Source: King County






-  Major Vegetation
-  Landslide Hazard Area
-  50 Foot Buffer

### City of Redmond Buildings in Landslide Hazard Areas



LS\_MAP3\_CAS.mxd 6-1-09

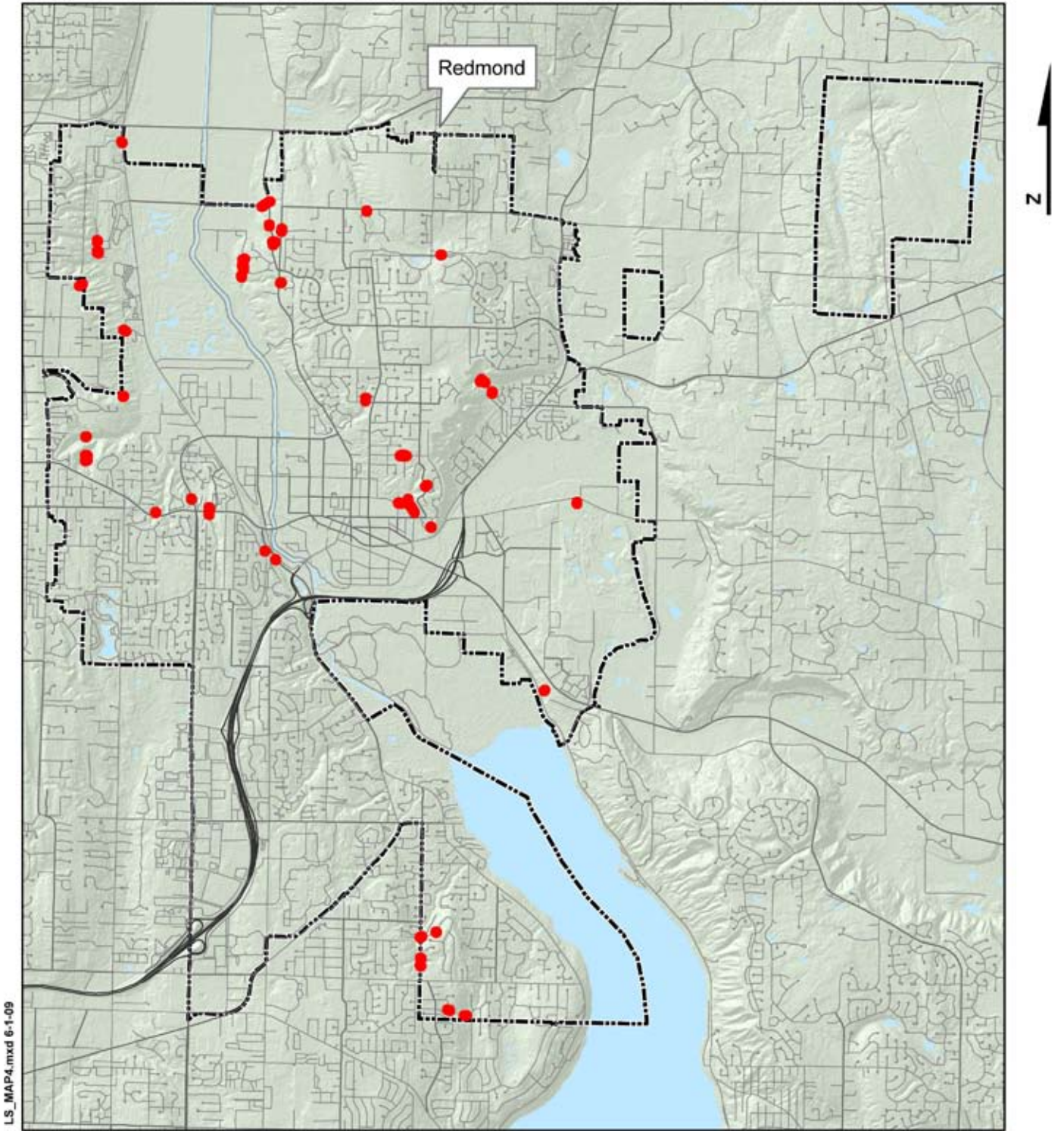
Source: King County

-  Multifamily Buildings
-  Single Family Buildings
-  Commercial Buildings

Approximate Scale in Feet  
5,000 2,500 0 5,000



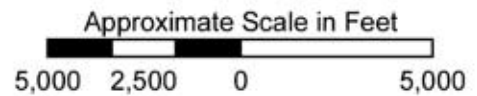
### City of Redmond Roads and Culverts in Landslide Hazard Areas



LS\_MAP4.mxd 6-1-09

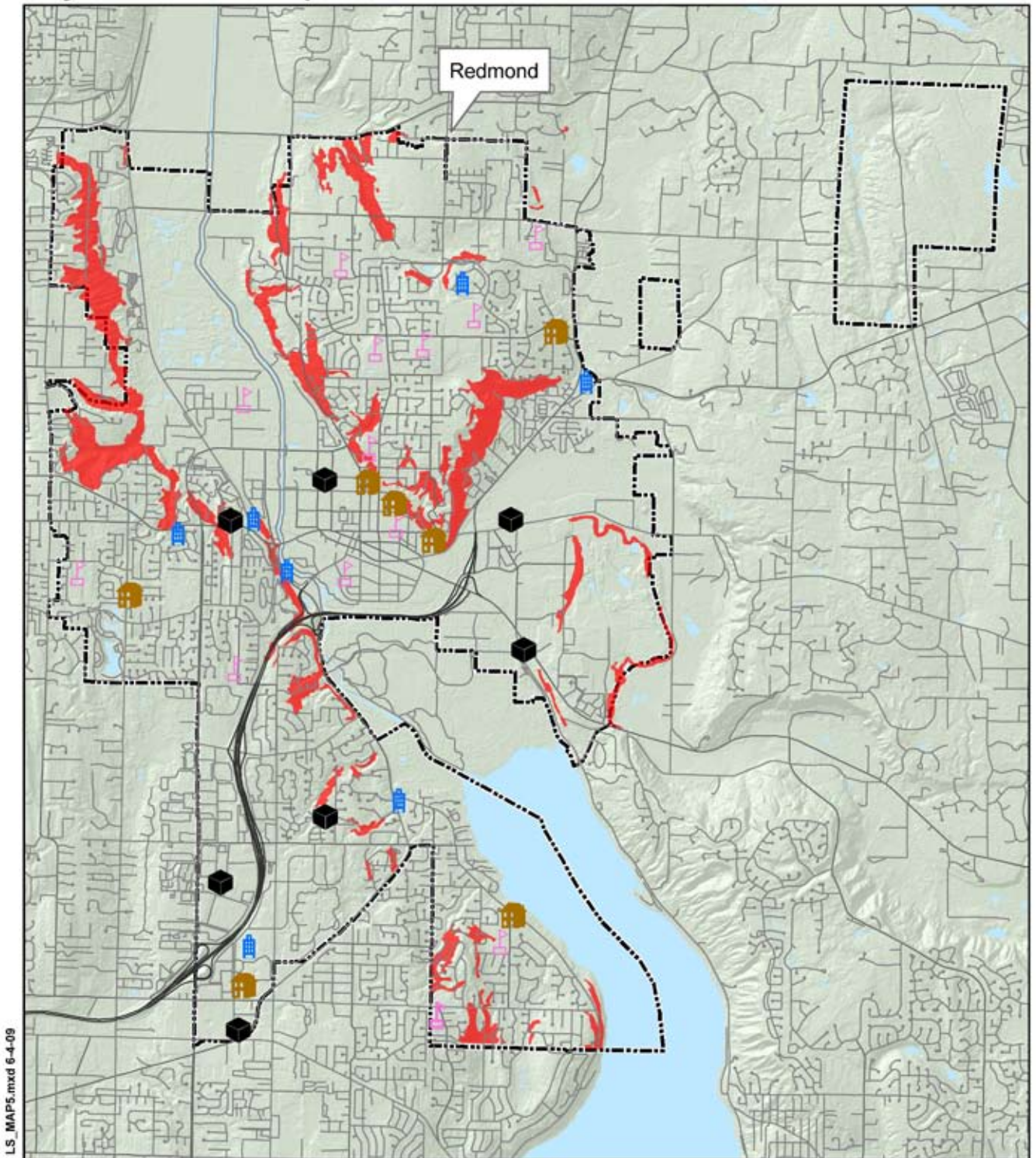
Source: King County

■ Culverts in Landslide Hazard Areas



Map 29: City of Redmond Roads and Culverts in Landslide Hazard Areas  
Hazard Identification and Risk Assessment

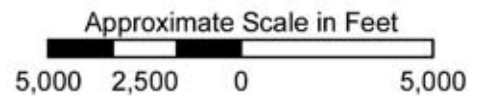
### City of Redmond Populations Vulnerable to Landslides



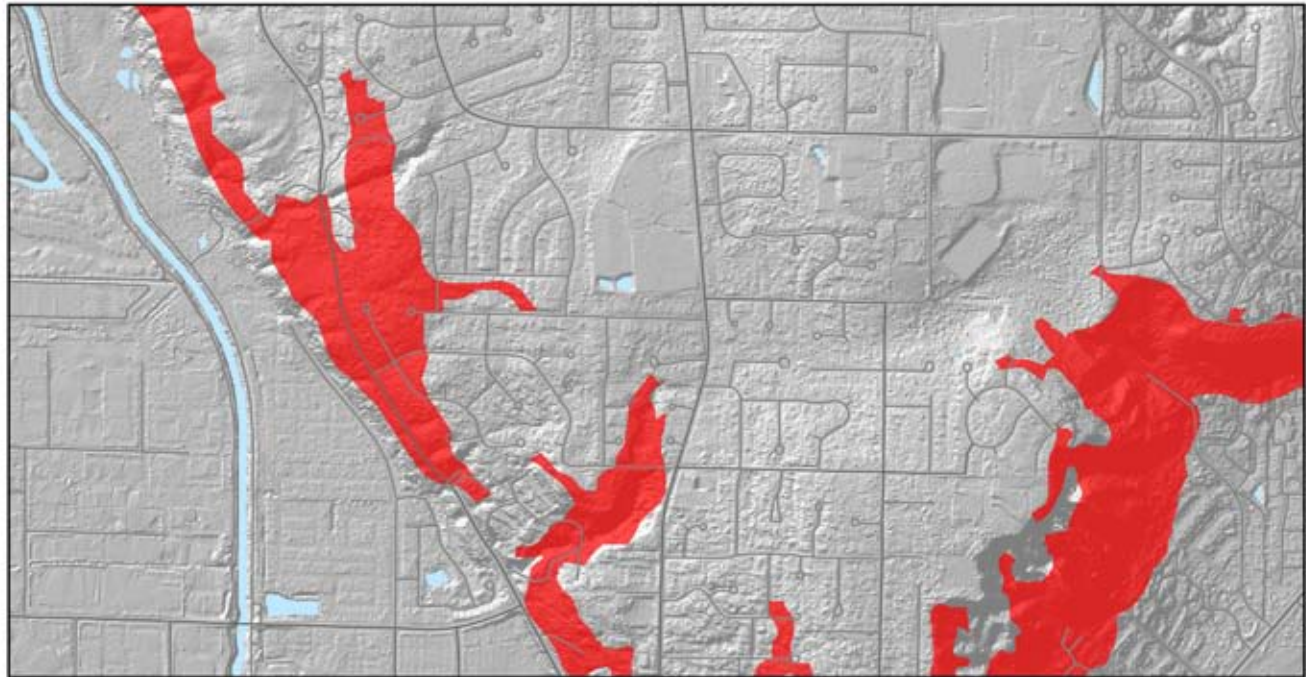
LS\_MAP5.mxd 6-4-09

Source: King County

- Daycare
- Affordable Housing
- School
- Retirement Home
- Landslide Hazard Area

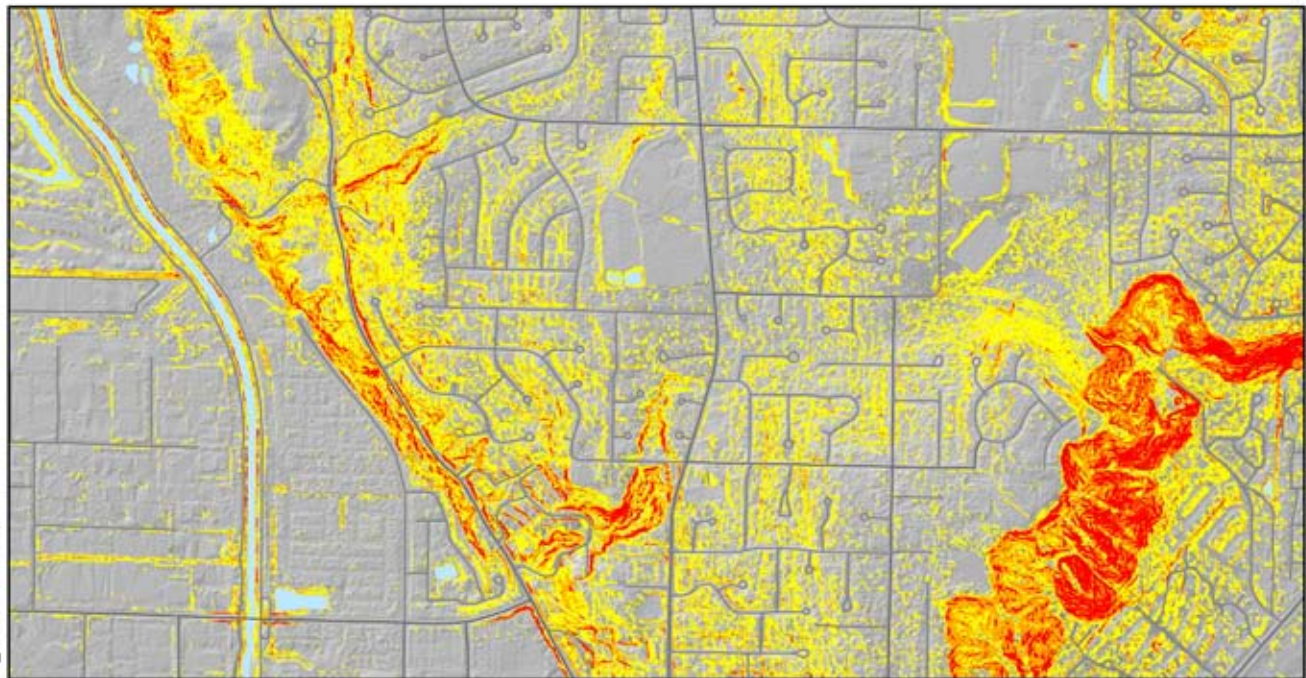


**Differences Between Current County Data and KC LiDAR Data**






 Landslide Hazard Area

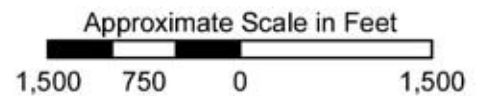
**Current County Data**



**KC LiDAR Data**

Source: King County

-  10 - 20 Degree Slope
-  20 - 30 Degree Slope
-  >30 Degree Slope



LS\_MAP6.mxd 6-4-09

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