

Seattle: Using vegetation to limit the hazard of landslides

Climate change impacts addressed	Ground instability
Spatial scale	Town or city
Response type	Regulations
Themes driving the initiative	Response to current climate Development need despite climate impacts Higher-level policy framework
Factors of success	Internal collaboration External collaboration Outsourcing research Sound evidence base Public engagement

Summary

Landslides are a widespread, frequent, and costly hazard in Seattle (Washington State, USA) due to the area's post-glacial geology, topography characterised by steep slopes, and climate with wet winters and frequent rain showers. Climate change is likely to increase ground instability in the area by exceeding the safe saturation levels of soil through more frequent and intense precipitation. After disastrous landslides in winters of 1995-96 and 1996-97, the City of Seattle in collaboration with the US Geological Survey and the State of Washington has carried out extensive research to identify the areas prone to landslides, and issued regulations on how landslide risk could be prevented. The regulations within the Seattle Municipal Code include detailed requirements on the maintenance and restoration of vegetation in areas prone to landslides. These regulations are also presented by the Department for Planning and Development to Seattle residents in form of user-friendly "Client Assistance Memos" and through public meetings.

Case study location

Seattle, Washington, is the northernmost major city in the United States, located on Puget Sound (a complex system of estuaries and marine basins; Figure 1). The city's population is approximately 600,000 within a metropolitan area of about 4 million. With the exception of coastal California, Seattle suffers more damage from landslides than most other large cities in the United States ⁽¹⁾. This is because Seattle's geology is characterised by glacial, alluvial and marine sediments ⁽²⁾. This type of ground, in combination with steep slopes, makes the Seattle area prone to landslides. These mainly occur following heavy rainfall or snowmelt ⁽³⁾, and predominantly during the winter season (October through April) ⁽²⁾. There is a clear correlation between the amount of rainfall and the incidence of landslides (Figure 2).

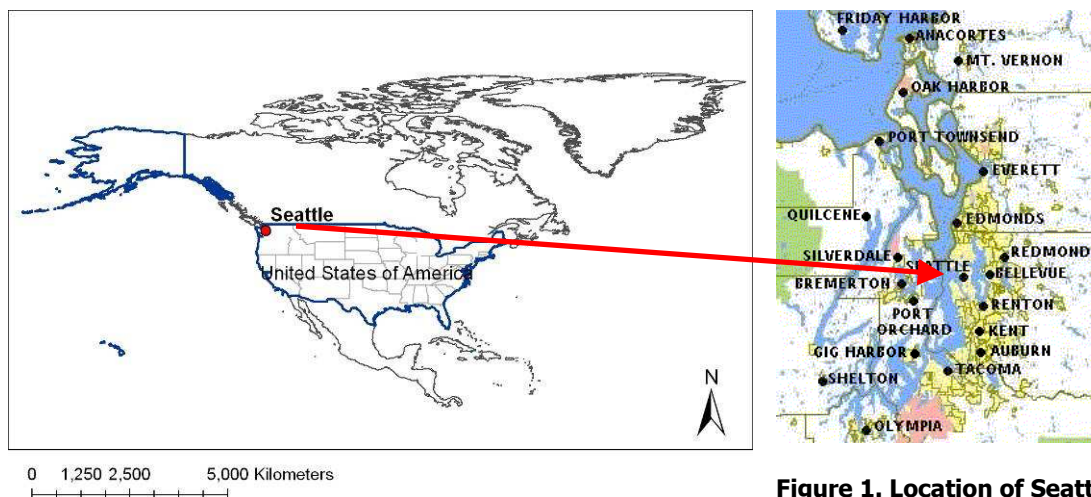


Figure 1. Location of Seattle.

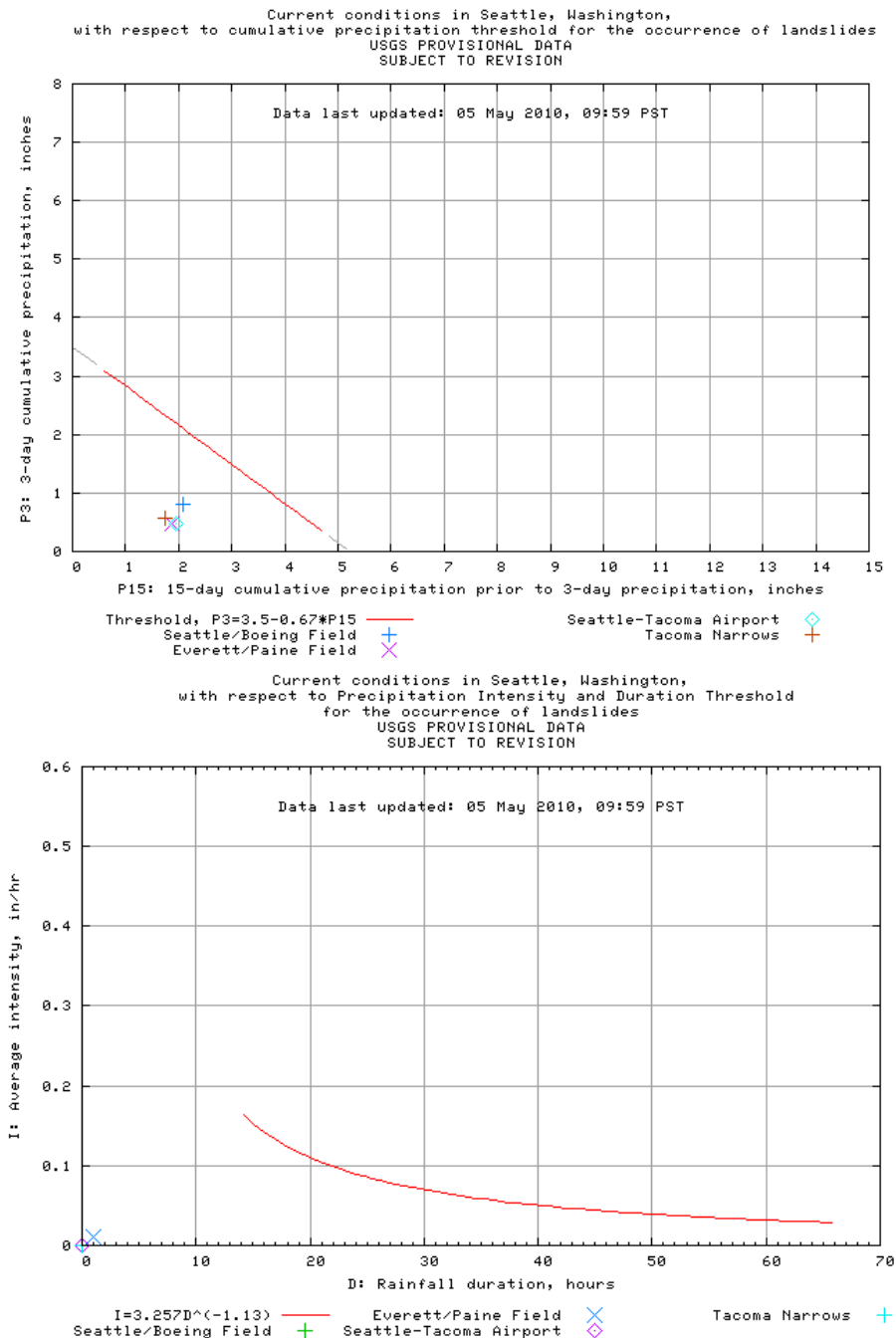


Figure 2. Cumulative precipitation threshold and rainfall intensity/duration threshold in Seattle (4)

Winter storms have triggered significant numbers of landslides in 1934, 1972, 1986, 1990, 1996, 1997, and 2001. Landslides in 1996 and 1997 caused major damage to private and public property and resulted in the deaths of four people. Although Seattle regulates development on steep hillsides, damage caused by landslides continues for several key reasons. They include pressure to build on or near landslide-prone areas to maintain economic growth and development; increased soil erosion caused by urban runoff which reduces slope stability locally; and as a result of ongoing damage to structures that were built in unstable areas before regulations existed (2).

Seattle's climate is usually described as temperate Oceanic or Marine west coast, with mild, damp winters and relatively dry and mild summers. Climate change projections suggest that the annual temperatures in the Pacific Northwest will be almost 2°C higher by the 2020s and almost 3°C higher by the 2040s, compared against 1970-1999 averages. Warmer temperatures means that more precipitation will fall as rain not snow, and that more snow will melt earlier in the spring (5).

Such conditions, and more frequent extreme weather events such as periods of intense rainfall, are likely to increase the likelihood of landslides through increased erosion and ground saturation.

It is also significant that 84% of landslides in Seattle are caused by reasons which include a human factor. These include improper drainage, broken or leaking pipes, excavation at the toe of a slope, fill placement at the top or side of a slope, imprudent cutting of vegetation, and the lack of maintenance of drainage facilities or vegetative cover. This suggests that countermeasures can be implemented by the City and private property owners to reduce the risk of damage to public and private properties resulting from landslides ⁽¹⁾.

Development of the initiative

Key aims

The collaborative research undertaken by the City of Seattle, the State of Washington and the US Geological Survey aimed to produce a detailed inventory of landslide-prone areas in Seattle and developing a better understanding of how to prevent landslides. Based on the findings of this research, the regulations issued by the City of Seattle now provide developers and land owners in the areas of risk with a regulatory framework and associated guidance on the provision, maintenance and restoration of vegetation. The goal of this approach is to contribute to stabilising slopes and removing excess water from the ground in areas of risk, therefore reducing landslide risk.

Themes driving the initiative

Frequent occurrence of landslides in the area

Shallow earth slides triggered by heavy rainfall are the most common type of landslide in the Seattle area, many of which transform into debris flows and cause significant property damage or disrupt transportation. The hundreds of landslides that occurred during the winters of 1995–96 and 1996–97 stimulated renewed interest in identifying landslide-prone areas and taking actions to reduce future landslide losses ⁽²⁾.

State legislation

The State of Washington, through Growth Management Act, requires that all local jurisdictions identify and delineate Environmentally Critical Areas (which, among others, include geologically hazardous areas), as well as adopt and implement zoning ordinances with development standards to protect these areas ⁽⁶⁾.

Previously existing data on landslides

The first database of landslides in the area was set up in the 1960s and has been updated periodically. As a result, prior to the 1995/96 and 1996/97 rainfall seasons, the City of Seattle had among the most comprehensive historical records of landslides in the US ^{(1), (7)}. This database provided an important resource that assisted the completion of the landscape study ⁽⁷⁾.

Role of vegetation in preventing landslides

Vegetative cover can contribute to improving the stability of steep slopes by reducing erosion, reducing direct infiltration from rainfall, and increasing the strength of the near-surface soil. Dense vegetation intercepts direct rainfall before raindrops impact the soil surface, thereby reducing or eliminating rainsplash erosion. With dense vegetative cover and thick forest litter, the overland flow is also reduced in intensity and speed, lessening surface erosion. Thick vegetation, forest litter, and organic soils retain moisture from direct precipitation, and evaporate the water back to the atmosphere. Root systems can increase the strength of the soil they penetrate, reducing the

likelihood of shallow landslides; and the deeper the roots, the better the protection in this respect. Native vegetation is best because it can be maintained without irrigation during the dry season. However, certain types of vegetation can have an adverse effect on slope stability, e.g. unstable trees can initiate a landslide if they are toppled during high wind conditions ⁽¹⁾.

Details of the initiative

In 1997, following the disastrous landslides of that year, the City of Seattle prepared a detailed policy and strategy document on landslide hazard mitigation. Legal mandate for related actions was established through resolutions. The first resolution established a framework for an integrated policy on landslide hazard mitigation. This emphasised the City as regulator, property owner, provider of utilities and services, and interdepartmental coordinator. Through a second resolution, the City defined principles to guide its goals and policy framework which included public safety, maintaining infrastructure and service standards; risk management to reduce losses to the city's own property. In 1998 a third resolution was adopted to guide development of programmes relating to reducing the risk of landslides ⁽⁷⁾.

Under the first resolution the City of Seattle established the Interdepartmental Landslide Team to work on protecting public infrastructure in landslide-prone areas. The Team consisted of representatives from Seattle Public Utilities, Seattle Department of Transportation, Seattle Department of Parks and Recreation and the Department of Design, Construction and Land Use (now Department of Planning and Development - DPD) ⁽⁸⁾. The main tasks of the team included development of new policies and public outreach.

In parallel (1996) the US Geological Survey (USGS) started a project to examine earthquake, flood, landslide, and volcano hazards in the five counties bordering on Puget Sound. In 1998, the Federal Emergency Management Agency (FEMA) launched a hazard mitigation program known as Project Impact, and selected Seattle as one of its pilot cities ⁽²⁾. This recommended that the City cooperate with the USGS. Consequently, the City of Seattle, the City's contractor, Shannon & Wilson consultancy, the USGS, and the University of Washington began cooperative efforts in 1998 to create a detailed three-dimensional geologic model and database of landslides utilising tens of thousands of existing geotechnical subsurface explorations.

As a result of the collaboration, a scientific base was developed to take action to respond to the problems associated with landslides. This enhanced knowledge base included the landslide map of Seattle, a report and map showing landslide susceptibility, a map showing density of landslide occurrence, 3D modelling of slope stability in coastal areas, rainfall thresholds for forecasting landslides, and an extensive database of 1,400 landslides that have occurred in the City of Seattle over the last 100 years.

The knowledge base is now integrated into decision making in Seattle, and provides a scientific basis for review and prioritisation of public projects ⁽⁷⁾. The Environmentally Critical Areas were delineated to indicate landslide risk areas and the Interdepartmental Landslide Team has developed policies for these, to enhance uniform administration, building codes and utility standards promoting slope stability ⁽⁸⁾. These policies are included as regulations in the Seattle Municipal Code (a compilation of the general and permanent ordinances of the City of Seattle) ⁽⁹⁾. The Code is divided into titles, chapters and sections. The most relevant to the use of vegetation as a preventive measure for landslides is Title 25. This relates to Environmental Protection and Historic Preservation and includes those provisions of the Code which relate to protection of the environment, historical areas and landmarks. The following sections in Chapter 25.09 – Regulations for Environmentally Critical Areas specify the use of vegetation in landslide areas:

Seattle Municipal Code 25.09.180 - Development Standards for Steep Slope Areas, which applies to parcels containing a steep slope area or buffer. It reads that techniques used in

construction should keep the disruption of existing topography and vegetation to a minimum. Also, if removal of trees or vegetation in a steep slope area and its buffer is authorized as part of approved development, it shall be kept to a minimum, and shall be carried out pursuant to a tree and revegetation plan described in section 25.09.320. Other removal of, clearing or any action detrimental to trees or vegetation in a steep slope area or buffer is prohibited, except as provided in Section 25.09.320 (see below for further details). In addition to complying with Section 25.09.320, any replanting that occurs shall consist of native vegetation.

Seattle Municipal Code 25.09.320 - Trees and Vegetation

This code states that within landslide-prone areas, removing, clearing, or any action detrimental to habitat, vegetation or trees (such as topping, or removal of parts of branches to reduce the canopy) is prohibited, with exception specified further in the text. The actions which are permitted include:

- Normal and routine pruning and maintenance of: trees and vegetative cover (in some cases limited to 70 m²), lawns and landscaping, and steep slopes;
- Removing trees or vegetation as part of an issued building or grading permit consistent with a tree and revegetation plan, provided that the work has been filed with DPD. If the area exceeds 140m², the plan needs to be approved by the Director of DPD, and the work needs to be carried out under the direction of approved professional.
- Restoring or improving vegetation and trees, including removing non-native vegetation or invasive plants and noxious weeds by hand, to promote maintenance or creation of a naturally functioning condition that prevents erosion, when the restoration or improvement is a condition to obtaining a permit or approval from the Director; or when appropriate permits have been achieved (if the area exceeds 140 m², calculated cumulatively over 3 years, or if the removal of invasive plants or noxious weeds is done by machine or chemicals, the plan must be approved by the Director of the DPD, and the work must be carried out under direction of a qualified professional).
- Removing trees or vegetation when the Director determines the tree or vegetation is a threat to health or safety based on a report prepared by a qualified professional and the removal is performed by or under the direction of a qualified professional.

As a minimum, plans for removal, maintenance and restoration of vegetation need to be consistent with the Department's standard tree and vegetation plans. For areas over 70 m² the plan needs to be approved by a geotechnical engineer or geologist licensed in the State of Washington with experience in analyzing geological hazards related to slope stability and vegetation removal on landslide prone areas. For the largest areas (over 140 m²) plans shall be prepared by a qualified professional with experience related to the type of environmentally critical area or buffer where work will occur. All plans need to be consistent with best management practices.

Implementing the initiative

Department of Planning and Development assists in the City's preparedness efforts for possible landslides by providing Seattle residents with information to help homes and businesses prepare for a potential landslide; by inspecting residences and businesses to make sure these structures meet City codes and regulations upon approval of a DPD permit; and by providing rapid evaluations and expedited emergency repair permits for structures damaged by a landslide⁽¹⁰⁾.

Building the evidence base

The scientific approach to data collection and processing was essential to the development of landslide hazard reduction policies and initiatives in Seattle. This emphasis on a scientific approach is partly due to the State regulations. The Revised Code of Washington (RCW) stipulates: In designating and protecting critical areas under this chapter, counties and cities "shall include the

best available science” in developing policies and development regulations to protect the functions and values of critical areas ⁽⁷⁾. This approach aids the landslide policy decisions taken by City officials, and increases public knowledge of landslides in the City ⁽⁷⁾. The development of the landslide database, which allowed identification of the environmentally critical areas in Seattle, was based on research processing a vast amount of information including consideration of geology, topography and climate data. One of the most important meteorological characteristics is the amount of rainfall, and its intensity, that is likely to result in landslides in the areas identified as being at risk (Figure 2). Such data allows projections of the threat of landslides to be made under future climate scenarios.

Monitoring and evaluation

In 2007, the USGS enlisted the help of a local planning firm, Planwest Partners, Inc., to help evaluate how research on landslide hazards in the Seattle area, conducted by USGS, was used. This was undertaken using the following methods:

- the review of the research by USGS, the City of Seattle, and its contractor, Shannon & Wilson, Inc., concerning landslide hazards of the region;
- interviews with numerous Seattle public officials and others who were instrumental in landslide hazard reduction policy;
- two roundtable discussions, the first with the representatives of agencies who were involved in setting landslide hazard reduction policies, and the second with USGS scientists who conducted research in the Seattle area;
- review of Washington State and Seattle regulations and laws that encouraged passage and enforcement of landslide hazard reduction policies ⁽⁷⁾.

Sources of funding

In 1998 FEMA provided a \$1 million grant to Project Impact to stimulate additional funding in Seattle ⁽²⁾. Within the City structures, establishment of the Interdepartmental Landslide Team enabled creation of a dedicated funding stream associated with activities of all departments involved in related work. The City’s cooperative approach allowed departments to leverage funds for landslide hazard reduction from multiple funding sources. The Interdepartmental Landslide Team contributed funding for the University of Washington and USGS to develop GIS soils layers, and it provided funding for educational workshops for the public (see public engagement section below) ⁽⁸⁾. Seattle also established a new funding mechanism, which authorized the collection of drainage management fees, and gave the City of Seattle a new revenue source to implement landslide hazard mitigation initiatives ⁽⁷⁾.

Stakeholder engagement

Collaboration with key stakeholders

The lead authority on the initiative is the City of Seattle. The implementation by the City of policies on the use of vegetation in areas prone to landslides is enforced through the Seattle Municipal Code under the lead of the Department of Planning and Development. However, compilation of the geological and climate information necessary to identify areas of hazard and effective measures of preventing landslides was only possible through cooperation between governments at local, state and national level, alongside involvement of research institutes and consultancies. Land use and development decisions are usually made at the local level. State governments enact general requirements that facilitate the development and implementation of local policies. At the national level, federal government agencies such as the USGS have a minimal role in land-use planning and enforcement but do provide information that may be of use to local governments as they

implement land use and hazard reduction policies. In the Seattle area, it is clear that each level of government brought different capabilities to the task of reducing the City's exposure to future damage from landslides ⁽⁷⁾.

The State of Washington contributed to the success of the adoption of landslide hazard reduction policies through the Growth Management Act (GMA) that requires all local jurisdictions, such as Seattle, to identify and regulate geologically hazardous areas ⁽⁶⁾. While Seattle selected Shannon and Wilson, Inc., to compile a digital database of city-wide landslide information dating from 1890 to the present, this landslide and topographic data was made freely available to the USGS for use in its studies. In return, USGS landslide techniques were used to identify geologically hazardous areas and the City departments were given information about how the USGS developed these techniques and how to use them in practice ⁽⁷⁾. More recently, cooperation between county, state, and federal agencies has resulted in the acquisition of high-resolution topographic data by LIDAR for most of the Puget Sound region, including the city of Seattle ⁽²⁾.

Engaging the public

Alongside the gathering of scientific data, public outreach was undertaken at the early stages of the development of City of Seattle policies for the prevention of and better response to landslides. During 1997-1998, citizen comments on the approach were collected during a series of five public meetings ⁽¹⁾.

Scientific studies completed within the USGS Seattle Landslide Project were made available to the public and communities interested in the implementation of landslide reduction approaches. These documents are freely available on the City of Seattle website ⁽¹¹⁾.

Regular educational workshops on landslide hazards and mitigation approaches are organised for the Seattle residents. Between 1997 and 2004, 12 such workshops were attended by 950 members of the public. The meetings are still happening. Indeed, in 2009 the City of Seattle set up two free public landslide awareness meetings, which included a discussion on the causes of landslides, proper drainage for sloping sites, and vegetation maintenance on slopes. This was followed by a question and answer session and time for one-on-one discussions with professionals in the field, including the City of Seattle, The American Society for Civil Engineers, The Association of Engineering Geologists, The International Society of Arboriculture, and Associated Building Contractors (Figure 3).

In addition, the Department of Planning and Development produces a series of Client Assistance Memos (CAMs) that typically summarise the regulations affecting property owners and developers in Seattle and provide advice on permits that need to be obtained to perform given actions relating to the development and use of land.


CAM 324 "Reducing landslide and stormwater erosion damage: what you can do" ⁽¹²⁾ suggests stabilising slopes with the use of vegetation: *"Improve your soil's ability to resist erosion by stabilizing slopes with mulching and any of a number of plantings, including grass, ground covers, and trees. However, stable native vegetated slopes should not be disturbed and a grading/building permit may be required if any filling or excavation is performed."*

The requirements of Seattle Municipal Code 25.09.320 were included in CAM 331 "Environmentally Critical Areas: Tree and Vegetation overview" ⁽¹³⁾, which explains to land owners and developers which planting, pruning and vegetation removal actions are allowed in areas under risk of landslides.

Free Landslide Awareness Meetings

Learn how to protect yourself and your property at one of two free landslide awareness meetings this fall, sponsored by the City of Seattle.

Presentations will include a discussion of the causes of landslides and proper drainage and vegetation for sloping sites. These will be followed by a question and answer session and time for one-on-one discussions. Both meetings will have the same format and information.



Landslide Awareness Meetings:

Nov. 7, 2009
South Seattle Community College
6000 16th Ave. SW
Judge Warren & Nobie Chan Education Center near the Arboretum (park in the northeast lot)
10 a.m. - noon

Nov. 21, 2009
Northgate Community Center
10510 5th Ave. NE
Multipurpose Room
(across from the Northgate Mall)
10 a.m. - noon

More Information:
Department of Planning and Development (DPD)
(206) 684-8443
www.seattle.gov/dpd/Emergency/Landslides

*Please RSVP by contacting Tyson Lin at (206) 684-8443 or tyson.lin@seattle.gov.

Joining City of Seattle Staff:
The American Society for Civil Engineers
The Association of Engineering Geologists
The International Society of Arboriculture
Associated Building Contractors



City of Seattle

Figure 3. An example of a leaflet inviting Seattle residents to public meetings

CAM 331a "Environmentally Critical Areas: Vegetation Restoration" ⁽¹⁴⁾ emphasises that vegetation restoration projects in areas prone to landslides can play a critical role in improving the health and function of these areas. It provides step-by-step instructions to designing and implementation of a vegetation restoration project (assessment of location, preparation of a plan, choosing the plants, preparation of the site, carrying out the planting, monitoring and maintenance), as well as links to additional information. CAM 331a reads that: *"Restoration should result in a densely vegetated area with a significant diversity of native trees, shrubs and groundcover."*

CAM 331a offers a list of recommended native tree, shrub and groundcover plants and specifies the conditions they grow best in, including those that can grow on steep slopes, and consequently stabilise them without the risk of the tree falling over (Figure 4). It is emphasised that in assessing the effectiveness of restoration actions, it is important to consider the ecological function of existing mature trees and avoid removing existing tree canopy cover when possible ⁽¹⁴⁾.

Recommended Native Plant List						
LIGHT NEEDS		SITE PREFERENCE				
○ = Full Sun ◐ = Partial Sun / Partial Shade ● = Full Shade		🌊 Water's Edge = Edge of stream, wetland or freshwater shoreline 🌳 Wet = Soils that usually hold water or are very near water table 🏠 Standard = General condition of soil in Seattle (may hold water) ⚡ Steep = Also appropriate for Steep Slopes				
Trees						
Quantity	Common Name	Scientific Name	Average Ht. (ft.)	Light Needs	Site Preference	Comments
	Cascara	<i>Rhamnus purshiana</i>	25	◐ ●	🌳 🏠 ⚡	Good for riparian
	Douglas fir	<i>Pseudotsuga menziesii</i>	200	○	🌳 🏠 ⚡	Fast grower
	Oregon Ash	<i>Fraxinus latifolia</i>	70	○ ◐	🌳 🏠 ⚡	
	Pacific willow	<i>Salix lasiandra</i>	40	○ ◐ ●	🌊 🌳 🏠 ⚡	Prefers riparian
	Shore pine	<i>Pinus contorta</i>	40	○ ◐ ●	🌳 🏠 ⚡	Tolerates poor soil
	Sitka willow	<i>Salix sitchensis</i>	25	○ ◐ ●	🌊 🌳 🏠 ⚡	
	Vine maple	<i>Acer circinatum</i>	15	●	🌳 🏠 ⚡	Slow grower
	Western Hemlock	<i>Tsuga heterophylla</i>	150	○ ◐ ●	🌳 🏠 ⚡	Not drought-tolerant
	Western Red Cedar	<i>Thuja plicata</i>	150	◐ ●	🌳 🏠 ⚡	

Figure 4. Recommended native plant species (excerpt) ⁽¹⁴⁾

Can it have an impact?

The collection of extensive information about landslides, and developing a database of historical recorded events, helped to systematically build knowledge about the areas prone to landslides. This has in turn allowed the delineation of zones (the Environmentally Critical Areas) where policies should be applied to manage landslide risk. The review of the Seattle Landslides Project by an independent company has helped to ensure that the process is meeting criteria of both scientific rigour and appropriate conduct of a public body.

Extensive public outreach and translation of policies in the Seattle Municipal Code into publically accessible Client Assistance Memos, supplemented by the awareness-raising meetings, has helped to ensure that the residents of Seattle are familiar with the City's policies on managing the risk of landslides and are therefore more likely to follow them.

The use of vegetation in mitigating landslides is emphasised by many policies. However, it is also acknowledged that vegetation is only one of many measures that could be applied to help stabilise slopes. The role of vegetation is not overestimated, and the expectations of what can be achieved by greening steep slopes are therefore realistic and proportionate.

Key messages

- Extensive scientific research has provided a sound scientific base for decision-making in relation to landslides.
- Scientific research results were also used to increase levels of awareness of general public of landslide issues through a programme of meetings and educational brochures.
- Involvement of government departments at different levels, alongside subcontracting work to private companies, allowed the use of the best available information, competences and skills across a range of different organisations.
- Inter-departmental collaboration was important in tackling the problem of landslides in Seattle, and also enabled tapping into different funding sources that would otherwise be off limits to this kind of initiative.
- The evaluation of the process leading to establishment of the evidence base, carried out by an external company increased its reliability and justified spending of public money on the development of an approach to manage landslide risk.

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