Council Meeting Date: March 26, 2012 **Agenda Item:** 9(a)

CITY COUNCIL AGENDA ITEM

CITY OF SHORELINE, WASHINGTON

AGENDA TITLE:	Storm Creek Basin Plan Update
DEPARTMENT:	Public Works
PRESENTED BY:	Mark Relph, Public Works Director Jesus Sanchez, Operations Manager Brian Landau, Surface Water and Environmental Service Manager
ACTION:	____ Ordinance ____ Resolution ____ Motion _X_ Discussion ____ Public Hearing

PROBLEM/ISSUE STATEMENT:

The adopted 2011 Surface Water Master Plan emphasized the role of basin planning to improve the management of the City's surface water and infrastructure. The City completed its first basin plan for the Thornton Creek basin in 2009. The City is currently conducting basin plans in the Storm Creek and Boeing Creek basins to assess the basin conditions including drainage, erosion, infrastructure condition, water quality, and aquatic habitat. The assessment includes identification of problems and programmatic management actions to address the problems. The programmatic management actions may include capital projects, repair and replacement of infrastructure, improved maintenance, outreach programs or other corrective actions. The programmatic management action plan for the Storm Creek and Boeing Creek basins is scheduled to be completed in April 2012.

Erosion has been an issue in the Storm Creek basin, particularly at the mouth of Storm Creek. The Storm Creek basin plan will specifically address erosion and other identified surface water issues through specific studies and will provide recommendations to address these problems. Erosion in the lower reach of Storm Creek has been part of the geologic changes that have accelerated in the past few decades, which is a cause for concern for local residents who have homes on the adjacent bluffs. The City of Shoreline and Ronald Wastewater are also interested in the erosion because of the public facilities (road and wastewater line) in the lower reach of Storm Creek.

RESOURCE/FINANCIAL IMPACT:

There is no resource or financial impact associated with this discussion. The programmatic management actions identified in the Storm Creek Basin Plan (to be completed in April 2012) will be prioritized with other management actions identified within the other surface water basin plans in the city and may be proposed in the City's Capital Improvement Plan (CIP) budget process. All operational and capital expenditures are funded through the Surface Water Utility Fund.

RECOMMENDATION

No action is required at this time. This item is for Council discussion. The basin plan recommended programmatic management actions and associated costs will be prioritized as part of the 2013 CIP process.

Approved By: City Manager - *JU* City Attorney - *IS*

INTRODUCTION

The City is currently conducting a Storm Creek Basin Plan to assess conditions in the basin including drainage, erosion, water quality, and habitat. The assessment includes identification of problems and programmatic management actions to address the problems. These programmatic management actions may include capital projects, repair and replacement of infrastructure, maintenance, monitoring, outreach programs, and other potential solutions.

BACKGROUND

The Storm Creek and Boeing Creek Basin Plan studies began in mid-September 2011. The scope of the basin plans is to assess surface water conditions in streams and within buried infrastructure (i.e. pipes and catch basins) so that comprehensive strategies that include maintenance, repair and replacement, capital, and outreach programs can be used to address problems. These problems and management strategies will be prioritized so they can be implemented over a period of time, according to need and resource availability. The basin plans includes specific studies on hydrology and drainage, erosion, water quality, infrastructure condition assessment, and aquatic habitat (i.e. streams and wetlands).

DISCUSSION

The following discussion provides an update on some of the initial findings of the basin plan, including hydrology, water quality, erosion and infrastructure condition assessment.

Basin Hydrologic Analysis

A hydrologic model was developed for Storm Creek as part of the basin planning effort; basin geology, topography, land cover (impervious surfaces and vegetation), and historic precipitation records were used as inputs to the model to simulate rainfall-runoff relationships under different sizes of rainfall events. The model will be used to identify stormwater management strategies to address specific local or basin-wide issues, including flooding, erosion and water quality treatment.

Based on a review of service requests for the past 10 years, Storm Creek basin does not have extensive flooding problems. Flood-related service calls have been primarily due to very localized problems, such as debris-clogged catch basins or culverts, rather than system-wide flooding caused by lack of capacity (streams or pipes) to contain large flows. The basin plan will provide a map that shows the extent of the 100-year floodplain, particularly upstream of 15th Ave NW.

Long-term solutions to reduce peak flows in a largely built-out watershed will require the implementation of retention or infiltrative stormwater management techniques in suitable parts of the upper watershed in city-owned rights-of-way. As part of the basin plan study, staff evaluated the effects of implementing stormwater infrastructure retrofits in the basin that would reduce the runoff into the creek. The reduced runoff for specific

storms would likely reduce erosion rates in Storm Creek. Preliminary analysis demonstrates that it would take approximately 29 acres of stormwater detention and/or infiltration in the basin to reduce flow rates in the creek to new Department of Ecology stormwater standards; the flow rate standard is the concept that stormwater runoff needs to be reduced to the runoff flows from a forested condition. Achieving a 29-acre capacity of detention/infiltration could be cumulatively accomplished through re-development and public works projects within the City's right-of-way. For example, flow reduction and water quality treatment projects in Thornton Creek watershed include the recently constructed Cromwell Park stormwater wetland detention facility and the grant funded North Fork Thornton Creek LID Stormwater Retrofit Project which will design and construct LID stormwater facilities within the City's ROW.

This preliminary analysis provides staff with a framework to assess the benefits and associated costs with proposing potential stormwater retrofit projects within the Storm Creek basin.

In the future, over many years, Storm Creek will experience a reduction in creek flows because all residential and commercial redevelopment will require stormwater facilities to reduce runoff to the drainage system, including Storm Creek. These facilities will include low impact development (LID) practices and infiltration and detention systems.

Infrastructure Condition Assessment

The Condition Assessment included inspection of 271 stormwater pipes with a total length of 27,400 feet within the Storm Creek Subbasin. The condition assessment included an overall conditions rating of the each pipe based on maintenance condition and structural condition. The initial findings indicate 18 of the 271 pipes are in very poor condition and will require replacement.

Water Quality

The City has been monitoring water quality at a single location in Storm Creek since 2007. The data indicate the water quality is fair to poor overall. This monitoring data indicates that actions should be taken to improve stream conditions. The primary constituents of concern in Storm Creek are fecal coliform, dissolved oxygen, pH, and nutrients (nitrogen and phosphorus).

Erosion

Storm Creek is considered the natural receiving waters as part of an overall drainage system. The erosion area of primary concern near the mouth of Storm Creek is primarily occurring on private property. The stream erosion is migrating east up the creek channel and may eventually reach the city's public facilities (roadway and City culverts). Currently, the public infrastructure is not at imminent risk of failure.

As part of the basin plan, a separate erosion study (Attachment A) was specifically conducted for Storm Creek, downstream of 17th Ave NW. The accelerated stream erosion is caused by a complex series of factors including geology, topography, stream

flow, loss of wetlands, and stormwater and vegetation management. The erosion is occurring on private property and may present a risk to public infrastructure in the future. The initial findings are highlighted below:

- The basin has been developed since the 1950's and 1960's, and is considered to be 90% fully developed, so flows in the basin have not likely changed significantly in recent years
- Stream bed and bluff erosion in the ravine have accelerated in the last 10 to 15 years (according to local residents).
- The slope instability and stream bed erosion is likely caused by a complex set of factors including geology, topography, stream flow, loss of wetlands, stormwater runoff, and vegetation management.

Programmatic Management Actions to Reduce Erosion**:**

The basin plan will identify potential management programmatic actions including monitoring, maintenance, and capital projects to improve watershed conditions, including erosion. As discussed earlier, potential infiltration or detention projects in the upper basin would reduce flows in Storm Creek. The costs for such projects will be estimated in the basin plan study to determine the economic feasibility of such actions. However, another management approach to directly address erosion is a project at the source of erosion.

Monitoring

As part of the basin plan, a preliminary management action recommendation regarding the stream erosion is the development of a stream erosion monitoring plan. The purpose of the monitoring plan is to track the stream erosion as it migrates upstream towards public infrastructure. The monitoring would allow the City to assess when a potential capital project may need to be initiated to address a risk to public infrastructure including the road, culvert, and sanitary sewer.

Future Capital Project based upon Monitoring Plan

As discussed previously, long-term solutions to reduce peak flows in a largely built-out watershed will require the implementation of retention or infiltrative stormwater management techniques in suitable parts of the upper watershed in city-owned rights-of-way. However, other options to reduce erosion such as "tightlining" in the stream should be analyzed and considered when public facilities may be severely affected by the stream erosion. Separating runoff from the channel via a "tightline" pipe is a widely used approach that has been successful under much lengthier and more challenging applications. This would require the use of high-density polyethylene pipe, likely laid along the ground surface either along the bottom of the ravine or above the sidewalls, with an intake near 17th Place NW and an outfall just upslope of the railroad tracks. Although Storm Creek was almost certainly never a fish-passable stream, the piping of the entire flow (both "natural" and urban-derived) would likely pose some permitting challenges without additional mitigation measures.

A project such as this should only be considered and funded by the City if public facilities are in danger of being severely impacted. At this time there is no imminent danger to the City's public infrastructure. Because the stream erosion and associated slope instability is occurring on private property, a tightline pipe may be the answer to their private property concerns. In this case, the City may consider a joint project with the private property owners in the future, if and when, damage to public property is imminent.

-There are many complexities to any potential capital project in the stream. A tightline project would occur on private property, including Innis Arden Reserve, Burlington Northern, and potentially private residential property as well. As a result, the City would need to develop easements that legally protect the city. In addition, the approval of a permit from the Washington Department of Fish and Wildlife (WDFW) to construct a project in the creek may be difficult to obtain; if obtained there is a high likelihood that extensive mitigation may be required, which could be costly.

Summary of Preliminary Conclusions:

The stormwater runoff in Storm Creek will be reduced over time through (1) the redevelopment process which allows the current stormwater standards and regulations to start having a cumulative improvement on watershed conditions and (2) construction of low impact development retention/infiltration capital projects in the City right-of-way. The basin plan will provide recommendations to improve watershed conditions by prioritizing capital projects and other programmatic actions that can meet multiple objectives such as reducing flows and improving water quality and restoring habitat; such projects will include low-impact development type projects within City right-of-way. The stormwater condition assessment provides the information necessary to make critical repair and replacement investments in the city's aging stormwater infrastructure. In addition, the basin plan will allow the City to propose stormwater retrofit projects that allow for leveraging of grant funds to improve watershed conditions at reduced costs to the City.

In regards to the erosion at the mouth of Storm Creek, the basin plan will recommend a monitoring plan to assess the stream erosion as it moves towards public infrastructure on 17th Ave NW. Because the erosion is a problem on private property and is not currently **an imminent threat to** public infrastructure, a capital project is not proposed at this time.

STAKEHOLDER OUTREACH

The Open House for the Boeing and Storm Creek Basin Plan occurred on September 14, 2011 and was attended by 13 residents with interests in both drainage basins. The City presented the scope of the project and solicited public input on surface water problems and concerns in each of the respective basins. An open house to discuss the findings from the Storm Creek Basin plan is tentatively scheduled for late March/early April 2012. The basin plan is scheduled to be completed by the end of April 2012.

A public meeting on the findings of the Storm Creek Basin Plan is scheduled for early April 2012.

COUNCIL GOAL(S) ADDRESSED

The basin plan and its recommended projects support Council Goal # 2: Provide safe, efficient, and effective infrastructure to support our land use, transportation, and surface water plans

RESOURCE/FINANCIAL IMPACT

There is no resource or financial impact associated with this discussion. The programmatic management actions identified in the Storm Creek Basin Plan (to be completed April 2012) will be prioritized with other management actions identified within the other surface water basin plans in the city and may be proposed in the City's CIP budget process. All operational and capital expenditures are funded through the Surface Water Utility Fund.

RECOMMENDATION

No action is required at this time. This item is for Council discussion. The basin plan recommended programmatic management actions and associated costs will be prioritized as part of the 2013 CIP process.

ATTACHMENTS

Attachment A: Final Draft Memo – Erosion in Lower Storm Creek

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FINAL DRAFT MEMORANDUM

To: Brian Landau, PE, LEG, City of Shoreline

From: Erin Nelson, PE, LG, Windward Environmental LLC
Derek Booth PhD, PG, PE, Cambria Science and Communication

Subject: Erosion in Lower Storm Creek

Date: January 25, 2012

BACKGROUND AND PURPOSE

Erosion in the lower reach of Storm Creek has been part of the geologic changes that have accelerated in the past few decades, which is a cause for concern for local residents who have homes on the adjacent bluffs. The City of Shoreline and Ronald Wastewater are also interested in the erosion because of the public facilities (road and wastewater line) in the lower reach of Storm Creek This memorandum summarizes the results of an erosion assessment conducted at the mouth of Storm Creek and throughout the upstream watershed to identify potential causes of this erosion and possible solutions to reduce the erosion.

PAST AND EXISTING CONDITIONS

In the assessment of Storm Creek, several previous studies, investigations, photos, and maps were reviewed to better understand the historical conditions and potential causes of the erosion that is now being manifest. A list of these documents and their general findings are presented in Table 1. A timeline for various events relevant to the Storm Creek basin are identified in Figure 1.

Table 1. Documents reviewed and general findings

Document	Date	Author(s)	Focus	Findings and Significance
Storm Creek Phase I Study (Foley 1993)	1993	Steve Foley, King County	flooding at Meadowbrook Apartments	No stormwater/erosion complaints in the vicinity of current erosion were documented by King County. Reference to "waterfall above the railroad tracks" indicates Storm Creek had not started downcutting at the mouth as of 1993. Alternatives that were evaluated acknowledged increased peak flows and erosion if these alternatives were implemented.
Storm Creek Drainage Improvements As-Built Plans (King County 1994)	1994	King County	flooding at Meadowbrook Apartments	Conveyance system in vicinity of Meadowbrook Apartments was modified with new, larger-capacity pipes and diversions to prevent apartment building flooding.
Storm Creek Ravine Preliminary Analysis (Otak 2009)	2009	Russ Gaston and Michelle Claassen, Otak	slope stability and erosion in lower reach of Storm Creek	The stream has "incised several vertical steps into the glacial till and is likely undergoing episodic headward erosion toward the road crossing…." Instability of ravine is "…due to fractures in the glacial till and oversteepening of the slope from stream erosion." Recommendations included further geotechnical investigation to determine if the ravine walls (private property) were stable, and then: • Repositioning existing debris to outside edges to protect toe of slope. from further erosion • Excavating a channel with step pools to keep water concentrated in the center, or filling ravine and creating a fishway
Preliminary Report on the Hydrology of the Storm Creek Basin (NHC 2010)	2010	Malcolm Leytham, NHC	hydrology of Storm Creek and causes of erosion	"The hydrologic regime has been significantly altered by land use change in the watershed." "Increased flows have resulted in serious erosion in the reach of Storm Creek downstream from 17th Place NW and have caused downcutting or incision of the channel…" "…runoff contribution from Innis Arden is …not a significant factor in the current serious erosional problems…."
Storm Creek Erosion with Photo Documentation (Harrington [undated])	2010?	Peter Harrington	ravine erosion in lower Storm Creek and safety issues	Significant erosion occurred between 2002 and 2010, as documented by photos. There is concern for the safety of trespassers who use the "cave" in the ravine for bonfires, drinking, and smoking on this section of private property "…25 years ago, the lower part of Eagle Reserve from 17th Place NW to almost the edge of the bluff was a shallow depression, ending in a 20-ft waterfall near the RR tracks."

Document	Date	Author(s)	Focus	Findings and Significance
Erosion Issues in the Lower Section of Eagle Reserve (Leary 2009a)	2009	T Richard Leary, Innis Arden Club	documentation of erosion in Eagle Reserve, including causes and consequences	"Within Innis Arden II a wetland existing prior to 1970…This wetland was filled…to create the soccer field and play area…." "A series of Gabions have been placed along the lower section of Storm Creek to help stabilize the erosion problems." Gabions near 17th Place NW were installed in 2003, after the road washed out. Gabions were installed by either King County or Ronald Waste Water to protect the sewer line. Photos show cracks in the surface on the south side of the bluff (Akers property), indicating instability and evidence of movement.
Statement of Compelling Environmental Benefit: Eagle Reserve (Leary 2009b)	2009	T Richard Leary, Innis Arden Club	stormwater and erosion issues from Storm Creek in Eagle Reserve	Upper end of the Eagle Reserve trail was washed out in the winter of 2007-2008, exposing an old sanitary sewer line that had run through the reserve and been replaced approximately 10 years earlier.
USGS Sno-King Composite Geologic Map (Booth et al. 2004)	2004	Booth et al.	geologic map	Glacial drift, a very compact, heterogeneous mixture of gravel, sand and silt is the geologic material that forms the bluff that is being eroded in the lower Storm Creek ravine. Detailed material properties were not specified in this reference.
King County i-Map parcel viewer (http://www.kingcounty.gov/operations/gis/proprese arch/parcelviewer, accessed Sept. 2011)	2011	King County	information on the age of development	Approximately 90% of the existing homes and businesses in the Storm Creek basin in Shoreline were constructed before 1980, and 70% were constructed before 1970. This does not include the portion of the basin in Edmonds.
GIS data layers	2011	City of Shoreline	stormwater and sanitary sewer infrastructure	Upstream of 15th Avenue NW, Storm Creek consists of short sections of open channel and pipes. Stormwater conveyance to the stream is mostly in ditches and pipes. Sanitary sewer lines in the vicinity of Storm Creek erosion were installed in 1970.
Aerial photographs	1936 1941 1970 1988 1995 2001 2007	Various sources (e.g., USGS, King County, Google® Earth)	historical imagery (land use changes)	Significant development occurred between 1941 and 1970 (area was mostly rural in 1941). Approximately 70% of the basin was developed prior to 1970 and 90% of the basin was developed before 1990. This does not include the portion of the basin in Edmonds.

GIS – geographic information system
NHC – Northwest Hydraulic Consultants
USGS – US Geological Survey

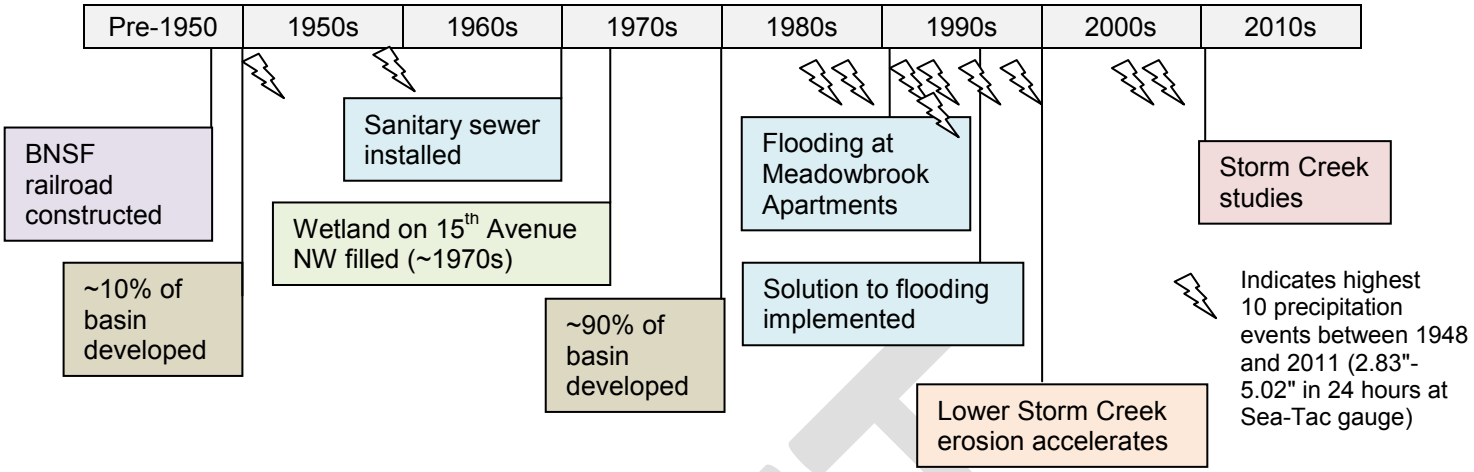


Figure 1. Timeline of events relevant to Storm Creek Basin

FIELD RECONNAISSANCE

Windward Environmental LLC (Windward) conducted a field reconnaissance on September 20, 2011, to observe current conditions and field-check information obtained from documents described detailed in Table 1. Windward staff walked along the Storm Creek stream channel from the mouth at the Burlington Northern Santa Fe (BNSF) railroad tracks to 15th Avenue NW in the Eagle Reserve (owned by the Innis Arden Club). For comparison purposes, staff also walked along the Heron Creek stream channel in the Heron Reserve (which is also owned by the Innis Arden Club). The Heron Creek basin is similar to Storm Creek basin in age of development, geologic setting, and topography, although it has a smaller drainage area.

ASSESSMENT OF EROSION FACTORS IN STORM CREEK

Erosion along the lowermost 300 ft of Storm Creek, from 17th Place NW to the BNSF railroad tracks, has been active for at least a decade. The form of the developing ravine is reminiscent of literally dozens of such features throughout King County and the entire Puget Sound lowlands, many of which were observed to form over a period of a few years in the immediate aftermath of upstream urban development in the early to mid-1980s (e.g., Booth 1989). What makes Storm Creek unusual in the context of the regional record is the long period of relative land-use stability, in that the vast majority of the contributing watershed was built out in the 1960s and has undergone little apparent change since that time. Although a few additional parcels have been infilled and/or developed since the 1990s after City incorporation, they appear to be quantitatively insufficient to serve as an obvious source of increased runoff. The only modification to drainage in the Storm Creek basin appears to be improvements constructed in 1994 at the Meadowbrook Apartments to alleviate flooding. These improvements are potential source of increased peak flows, although no hydrologic modeling has been conducted to confirm this. Nonetheless, any explanation for the

current conditions in Storm Creek (which, in turn, may lead to a potential alleviation of those conditions) could involve a variety of factors. These have been considered and are detailed below.

Topography

The longitudinal profile of Storm Creek has a natural break in slope, approximately at the location of the 17th Place NW crossing. Above this point, the stream flows in a moderately confined upland channel at an average gradient of about 3 to 4%, which is typical for lowland streams in this general topography. Below the road crossing, the bed steepens abruptly, with an average gradient of almost 30%, and includes short reaches of near-vertical falls interspersed with short, relatively flat reaches (Figure 2). In general, such a slope is not stable over the long term and will continue to seek a lower course with a flatter gradient. This process is now occurring on an annual basis along the lower reach of Storm Creek. As the bottom of the channel has lowered, the canyon sidewalls have become progressively higher and steeper, and they, in turn, have begun to fail by landsliding, which serves to flatten their angle and regain a stable slope. This can only be accomplished through a widening of the canyon across its top, with attendant risk to developed upland properties on both sides of the canyon.

Figure 2. View of lower Storm Creek in the canyon reach, showing a portion of the steep reach about 100 ft upstream of the railroad tracks

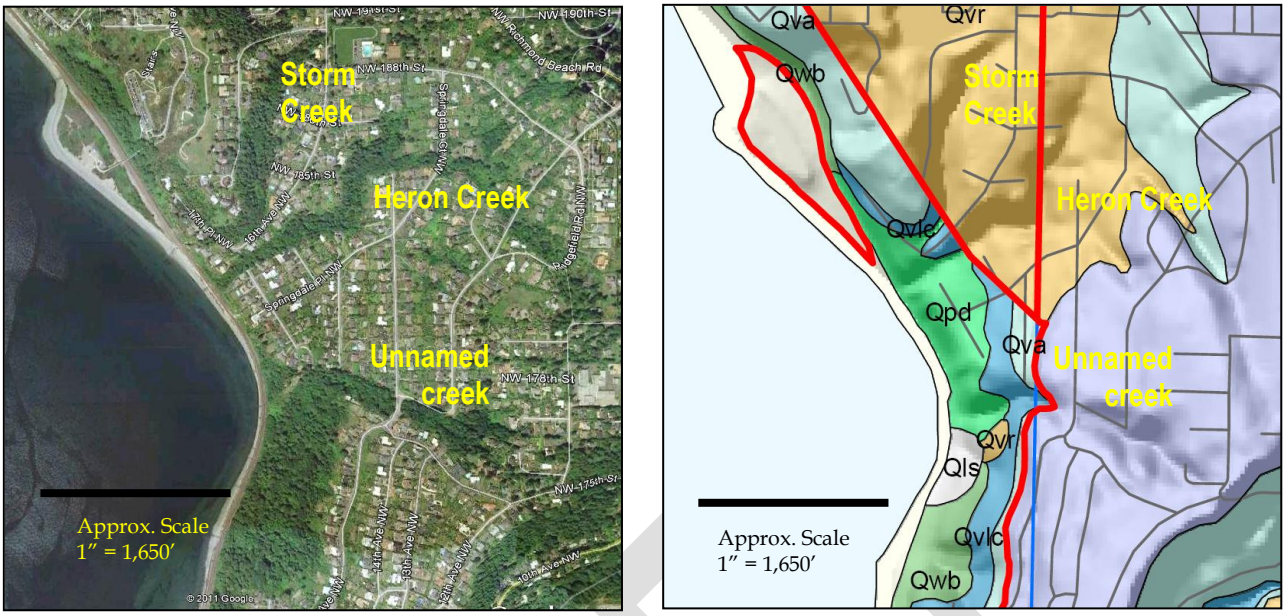
This process of channel downcutting and valley widening is an inevitable consequence of the coastal topography of Puget Sound, with an upland plateau that stands (in this area) anywhere from 80 to 200 ft above the coastline and is separated from the coastline by a steep coastal bluff. Over time, the downcutting of streams to "smooth" their course from upland to shoreline is inevitable, but there is no fixed rule for how long this process will take. An inspection of the drainages both north and south of Storm Creek,

most immediately at Heron Creek just south but also at nearby Boeing Creek and Pipers Creek, indicate that Storm Creek is anomalous—every other channel in the region has already created a relatively smooth grade down to Puget Sound, over a sufficient amount of time for mature trees to have become well-established in their valley bottoms (Figure 3). Such a differential cannot be obviously explained by "human" factors, such as the age of development (which is roughly the same throughout this portion of the coast) or direct channel modification, and so other explanations must be explored.

Figure 3. View of lower Heron Creek, showing trees of sufficient maturity to suggest that the broader, deeper canyon here has existed in its present form for at least several decades (and possibly much longer)

Geology

The geologic materials that underlie this part of the lowland are, in part, quite uncommon (Figure 4). They include a sedimentary deposit from a regional ice advance about 60,000 years ago, which was named the "Possession Drift" (its deposits are denoted as "Qpd" on geologic maps of the region). In the exposed ravines of both Storm and Heron Creeks, the deposit is primarily till, a very compact, heterogeneous mixture of gravel, sand, and silt reminiscent of concrete (Figure 5, Photo A). However, it has abundant zones of nearly pure sand and a variety of transecting fractures, which provide avenues of weakness for the action of stream or wave erosion (Figure 5, Photo B).



Sources: Google® Earth 2011; Booth et al. (2004)

Note: Each image shows an area that is approximately 1 mile wide. The two creeks (and a smaller unnamed channel just south) drain across a localized body of unit Qpd, a deposit composed of glacial sediment correlated to the second-to-last glacial advance across the region (locally named the "Possession" glacial advance).

Figure 4. Aerial photograph and preliminary geologic map of the Shoreline coastal area in the vicinity of Storm and Heron Creeks

Photo A **Photo B**

Note: Photo A is the intact coherent material, with sufficient strength to stand in vertical (and locally overhanging) walls for many years without failure. Photo B shows the same geologic deposit in an adjacent area where sandier zones have permitted rapid hollowing out by natural and human agents of erosion.

Figure 5. Glacial till of the Possession age exposed in the lower canyon of Storm Creek

The local strength of the Possession till belies its ultimate weakness in the face of erosive agents acting for long periods of time. Indeed, the two other drainages that cut through this deposit (Heron Creek and the unnamed creek about 1,000 ft south) have long ago

established a smooth longitudinal profile. Only Storm Creek apparantly maintained a waterfall, dropping over a particularly resistant shelf of the Possession till, up until the last one or two decades. This condition is quite unusual across the entire region—suggesting that the appropriate question is not "Why has Storm Creek begun to erode?" but rather "Why was Storm Creek so slow in initiating that erosion?" The outcome, of course, is the same with respect to upslope developed properties, regardless of whether Storm Creek is "anamolously erosive" or "anamolously stable," but this distinction should help identify the cause of the erosion and suggest solutions that are likely to succeed.

Stormwater Runoff

The science of stormwater management, as well as the history of urban development in the Puget Sound lowland, strongly suggests that flows have increased dramatically in every urban stream since development began in earnest in this region. In the nearby Boeing Creek watershed, for example, a single commercial development (the Sears shopping center at N 160th Street) in the 1970s initiated channel downcutting and landsliding in a very non-resistant geologic deposit within a few years, leading to a long series of mostly ineffective capital projects to address the condition.

We have every reason to assume that a similar runoff response accompanied development in the Storm Creek watershed in the 1960s and 1970s. Stormwater management of that era was well-intentioned but, as is now widely recognized, ineffective at reducing downstream impacts such as flooding and stream erosion. Similar to the rest of the drainages in the region, Storm Creek has been receiving discharges well in excess of its "natural"rates. What is unusual here is that the canyon of Storm Creek is substantially narrower than those of its neighboring creeks, so much so that, for example, in the 1960s, the two houses that flank the mouth of Heron Creek were constructed 110 ft apart, but those that flank Storm Creek are only 70 ft apart (Figure 6; distances approximate as measured in Google® Earth). Although Storm Creek is a larger channel that drains a larger watershed, it had not incised nearly as deeply when the residential structures were built, and so it required (at the time) significantly less setback of structures from a significantly shallower ravine.

Note: The arrows show the spacing of houses on opposite sides of the two creeks; yellow = 70 ft across Storm Creek; orange = 110 ft across Heron Creek, undoubtedly reflecting the relative depth and width of the two ravines when this area was first developed.

Figure 6. Aerial view of the mouths of Storm Creek (upper left) and Heron Creek (lower right)

As previously noted, there are no visible indications of recent, significant changes in watershed land cover or stormwater management that would explain a "triggering" of the erosion of Storm Creek during the past decade or so. As such, it is concluded that the channel is undergoing a belated, but no less expected, response to upstream development in its watershed over the past half-century. The delay is likely a consequence of the material properties of the geologic deposit through which it must erode; the fact that it shares the same substrate with Heron Creek while following a somewhat delayed history can only be ascribed, albeit speculatively, to the heterogeneity of the deposit—more resistant across the path of Storm Creek and less resistant across the path of Heron Creek. However, without mitigation, the same final outcome is virtually assured: a relatively well-graded channel profile that rises steeply but smoothly from the coast up to the (presumably) non-eroding culvert at 17th Place NW, with a ravine whose sidewalls eventually erode back by landsliding to a stable angle of repose and a top width that is substantially wider than it is today.

RECOMMENDED ACTIONS

Wherever channel erosion occurs in an area of previous development, the potential consequences of unmitigated events can be severe. In the case of Storm Creek, the greatest threat to public infrastructure involves the potential undermining of a sewer lift station at 17th Place NW, likely only after many additional years because of the slow

pace of headward expansion. Of much greater potential public concern is the health and safety of visitors to Richmond Beach Park who are inclined to explore the adjacent coastline, complete with crumbling bluffs and overhanging caverns (Figure 7). Lastly, the catastrophic collapse of a portion of the ravine sidewalls (or the rapid flushing of previously eroded sediment during a storm) could easily clog the culvert under the railroad tracks and potentially block the tracks should sufficient material become involved.

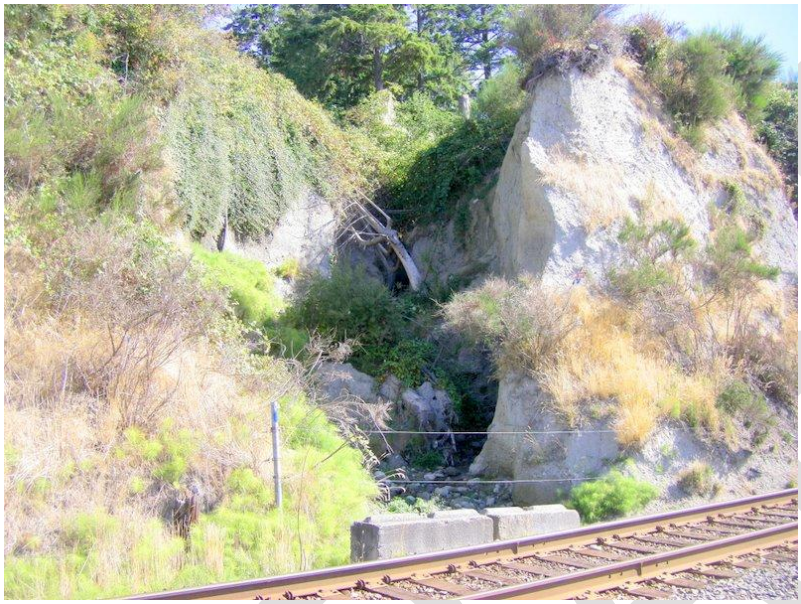


Figure 7. View of the mouth of Storm Creek, from the railroad embankment just above the southern extent of the beach at Richmond Beach Park

Potential solutions that would be effective in the short term (i.e., immediately upon implementation) require that either the channel be hardened to the effects of runoff or the runoff be separated from the channel itself. Based on existing conditions in the ravine, the first alternative (channel hardening) does not appear to be feasible—there are far too many opportunities for obstructions or armoring to be undermined, flanked, or simply swept away. The region has a long history of such efforts; and unless the entire refilling and reconstruction of the ravine bottom is contemplated, this alternative should be abandoned.

In contrast, separating runoff from the channel via a tightline is a widely used approach that has been successful under much lengthier and more challenging applications. This would require the use of high-density polyethylene pipe, likely laid along the ground surface either along the bottom of the ravine or above the sidewalls, with an intake near 17th Place NW and an outfall just upslope of the railroad tracks. Although Storm Creek was almost certainly never a fish-passable stream, the piping of the entire flow (both "natural" and urban-derived) would likely pose some permitting challenges without additional mitigation measures.

However, the alleviation of further erosion at the base of the ravine walls will not immediately halt the risk to adjacent private property. Although addressing those concerns is beyond the scope of this memorandum, the need to manage ongoing slope adjustments to the erosion that has already occurred is likely to continue for many years into the future, even if no further downcutting is allowed to occur.

Long-term solutions to reduce peak flows in a largely built-out watershed will almost certainly require the implementation of retention or infiltrative stormwater management techniques in suitable parts of the upper watershed in city-owned rights-of-way.

REFERENCES

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