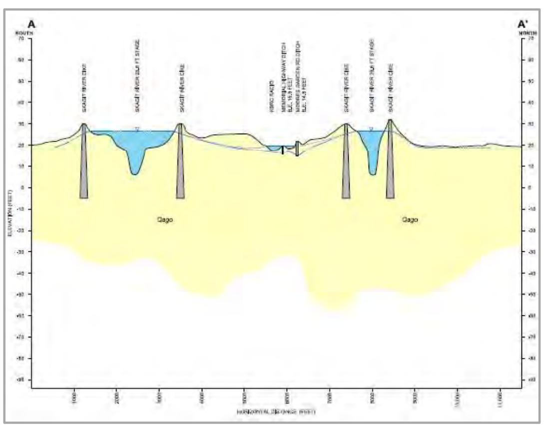
DUNBAR ROAD
STORMWATER MANAGEMENT PLAN

FINAL REPORT

Prepared for:

Skagit County Public Works
Mount Vernon, Washington



December 2016

NHC Ref. No. 20000985

northwest hydraulic consultants
water resource specialists

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Skagit County Public Works
Mt. Vernon, WA

Prepared by:

Northwest Hydraulic Consultants Inc.
Bellingham, Washington

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Prepared by:

Derek Stuart, P.E.
Associate

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CREDITS AND ACKNOWLEDGEMENTS

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Jay Chennault (AESI)
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EXECUTIVE SUMMARY

A stormwater management plan was developed for the Dunbar Road area in unincorporated Skagit County. The 0.42 square mile study area includes mixed residential, industrial, and commercial land uses along the Highway 536 corridor outside the Mount Vernon incorporated city limits. A review of drainage complaints and existing drainage information identified: a high groundwater table and seepage from the Skagit River, a lack of drainage infrastructure, and operational problems with an existing pump station at the intersection of Dunbar Road and Highway 536, as the primary deficiencies in the existing system. The plan provides recommendations for short term improvements as well as a plan for future build-out.

The future build-out stormwater plan proposes unique conceptual stormwater management approaches for four sub-areas of the planning area. The plan identifies how future development can be accommodated given the current infrastructure and regulatory requirements for each area. Since most of the project area has high groundwater concerns and poor drainage, direct discharge to the Skagit River via a manmade conveyance feature is recommended for any significant future development.

New water-level monitoring data were collected in well casings located along the Skagit River and two surface water depressions near Highway 536. When these data were compared to USGS water-level data in the Skagit River, a close relationship was found between the river, groundwater, and surface water depression water-levels. The data were used to calibrate a MODFLOW groundwater model of the study area that was used to estimate seepage rates that might be expected in a new conveyance system.

In addition to a groundwater model, a Hydrologic Simulation Program Fortran (HSPF) runoff model and a Stormwater Management Model (SWMM) of the proposed drainage conveyance system were also developed. Together these three modeling tools were used to size the future conveyance system and a new pump station. The pump station required for future build-out conditions would be much larger than the existing facility due both to the increased tributary service area and also increased land use density and impervious area. The required pump station capacity would be dependent on the amount of storage provided and on the amount of groundwater seepage that is captured or excluded from the new stormwater system. A pump station with a pumping capacity of 30 cfs would be needed if 3 acre-feet of storage were provided and assuming no exclusion of groundwater seepage from the drainage system.

An engineer's opinion of probable cost is provided for the core portion of the future stormwater system, including 3,200 feet of gravity main storm pipe along SR-536 and Dunbar Road, the new pump station and an 1,100-foot force main between SR-536 and the Skagit River. Construction costs, including 30% contingency adjustment, are estimated at 4.0 million dollars. In addition to the construction cost, the project should also plan an additional 2.1 million dollars for engineering, construction management, permitting and sales tax. The total project cost is estimated at 6.1 million dollars. It is also recommended that the County consider relocating the new pump station to the intersection of Moore's Garden Road and SR-536.

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1 INTRODUCTION

Skagit County (County) is developing a stormwater management plan that will result in upgraded stormwater conveyance and treatment for the Dunbar Road area in unincorporated Skagit County, located west of the City of Mount Vernon. This document provides the initial phase of that plan, including conceptual design of utility improvements. The final design will be included in a subsequent project phase.

The stormwater management plan study area includes 0.42 square miles (271 acres) of mixed residential, industrial, and commercial land uses including Dunbar Road, Cottonwood Lane, Sunset Lane, and areas adjoining Highway 536. The maximum potential service area to be covered by the plan is shown in Figure 1. Hydrologic and groundwater modeling performed as part of this study includes more than 0.77 square miles (496 acres), including additional areas both inside and outside of the Mt. Vernon incorporated city limits that are outside the study area limits.

Ponding of stormwater within the study area is common and relatively widespread in the winter months. Drainage problems are due to limited topographic relief, a high groundwater table (including seepage from the Skagit River at high river stages), and lack of drainage infrastructure. One pump station is located within the study area limits on Dunbar Road, but it only receives runoff from a small fraction of the total study area and it has experienced intermittent operating problems. The drainage infrastructure within the City of Mount Vernon city limits to the east of the study area is more developed and also includes a pump station on Behrens-Millett Road near Edgewater Park.

The primary objective of the proposed work is to develop conceptual level design for a stormwater collection system in the study area that is adequate to treat both existing and future development. The plan is being developed in two phases. The initial phase included in this document covers:

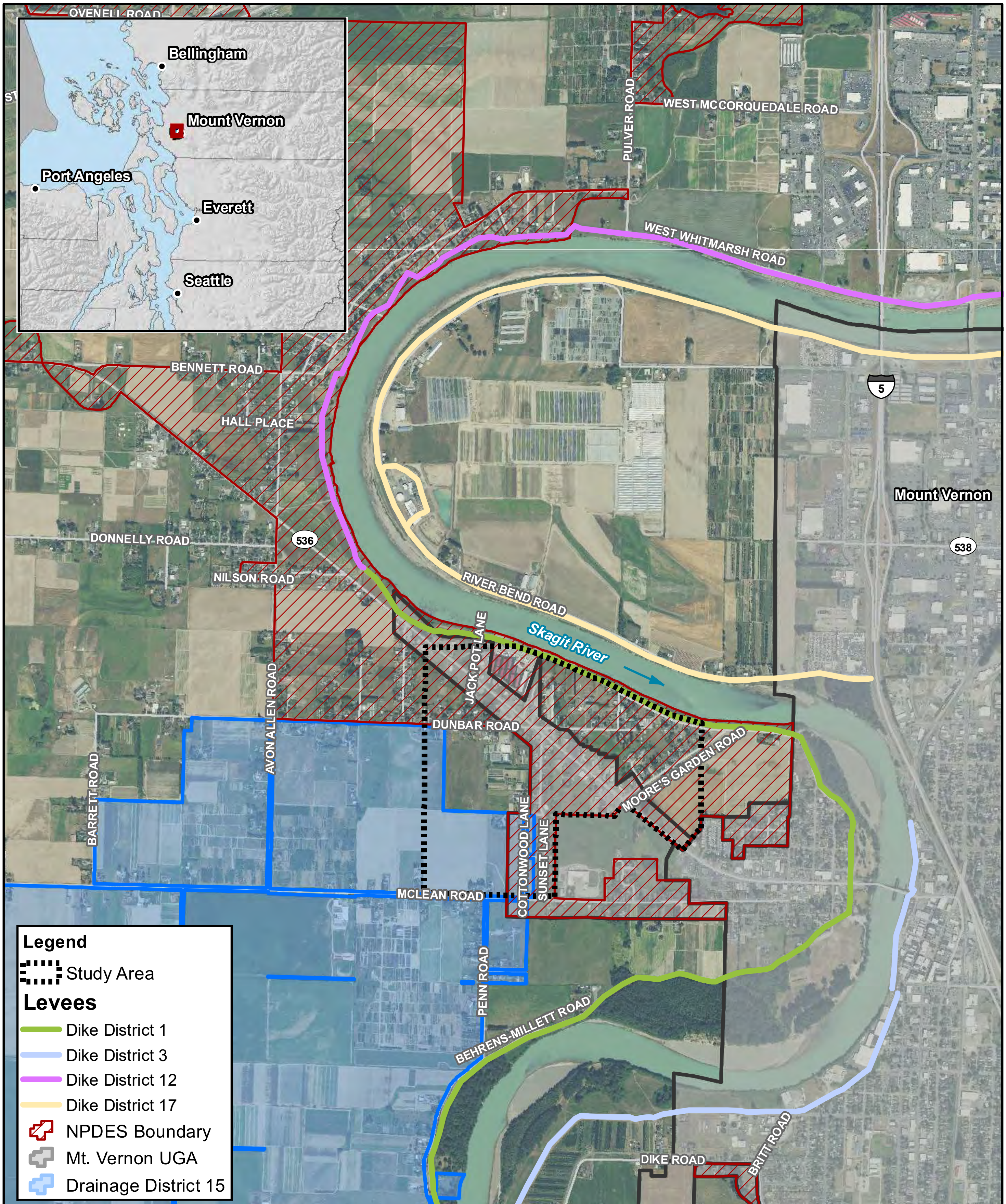
- Acquisition and review of available information
- Review of regulatory requirements and development of design standards
- Characterization of seepage from the Skagit River into the project area
- Development of conceptual design and a planning level cost opinion for a single alternative

2 BACKGROUND AND EXISTING SYSTEM

2.1 Prior Studies

Comprehensive Surface Water Management Plan, City of Mount Vernon

This 1995 plan prepared by the City of Mount Vernon provided a plan that was intended to solve current and future flooding throughout the City. The plan does not address the current study area but does address flooding issues in West Mount Vernon that are adjacent to the study area. The plan



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DUNBAR STORMWATER MANAGEMENT PLAN

Vicinity Map

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Coordinate System: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET

Job: 2000985 *Date: 30-Dec-2016*

FIGURE 1

Q:\2000985_Dunbar_Stormwater_Management_Plan\GIS\MXD\Figures\Dunbar_Vicinity.mxd recommended that:

- the West Mount Vernon conveyance system be upsized from 12-inches to 30-inches,
- additional catch basins be installed to drain areas affected by groundwater flooding,
- a flood notification system be installed, and,
- affected properties be bought out and regraded to a higher elevation. These improvements were estimated to cost just over $600,000 in 1995 dollars.

The current City of Mount Vernon drainage infrastructure inventory shows 30-inch diameter pipes along Wall Street south of SR-536 to the Mount Vernon pump station, but smaller along SR-536 and elsewhere. It could not be verified if these 30-inch pipes were installed after the 1995 report or if other recommended improvements have been implemented.

USGS Groundwater Studies

The U.S. Geological Survey (USGS) has conducted several groundwater studies in the general vicinity of the present study area, the most relevant of which is a study of shallow groundwater movement in the area between the lower Skagit River and Puget Sound[1]. This work was undertaken by the USGS to assist Skagit County and the Washington State Department of Ecology (WSDOE) with the identification of areas where water withdrawals from existing and new wells could adversely affect streamflow in the Skagit River.

The USGS study showed that flow in the shallow groundwater system generally moves in a southwesterly direction away from the Skagit River and toward the Swinomish Channel and Skagit Bay. The study also concluded that groundwater levels along the eastern margin of the USGS study area (which includes West Mount Vernon) are likely influenced by stages of the Skagit River.

The USGS study provided useful background information for the development of a MODFLOW groundwater model of the current study area. The MODFLOW model, described in Section 4.2 and Appendix C, was used to estimate groundwater seepage rates for drainage system design.

USACE Skagit River Flood Risk Management General Investigation

Flooding of the Skagit River delta (including the cities of Mount Vernon and Burlington) has been studied extensively over the past several decades in various efforts to reduce flood risk due to extreme Skagit River flows, the most recent study being the U.S. Army Corps of Engineers (USACE) Skagit River Flood Risk Management General Investigation (GI), with Skagit County as the local sponsor. The GI ended in 2015.

The primary flooding mechanism of concern in the GI — and most other major flood studies in the Skagit River delta — was breaching and/or overtopping of the Skagit River levees. No recent studies have

[1] Savoca, M.E., Johnson, K.H., and Fasser, E.T., 2009, Shallow groundwater movement in the Skagit River Delta Area, Skagit County, Washington: U.S. Geological Survey Scientific Investigations Report 2009–5208, 22 p.

addressed "local" flooding in the current study area due to high groundwater levels and locally generated storm water runoff.

The Tentatively Selected Plan (TSP) under the GI is the Comprehensive Urban Levee Improvement (CULI) alternative. While the TSP has not been accepted, it is anticipated that work to maintain and improve the reliability of the Skagit River levees will continue, (as envisaged under the CULI alternative), and that local diking districts will continue to participate in the USACE PL 84-99 program for levee rehabilitation and repair.

2.2 Skagit River Levees and Anecdotal Information about Seepage

The study area, located on the inside of a meander bend of the Skagit River, is bounded by levees on three sides. The levees around the study area are managed by Skagit County Diking District 1 (green line on Skagit River left bank in Figure 1). Neither design drawings nor construction notes for the levees were available to NHC for review, but some general background about the district's levees was obtained via personal communication with Jason Van Der Kooy from the district (November 18, 2015). Jason explained that the levees, which were constructed between 1905 and 1950, are approximately 30 to 35 feet deep. There is a key at the footing, but seepage passes underneath. The levees were constructed with local material (top soil, etc.) so a small amount of seepage through the levee is also expected. There is a seepage berm in place to keep top soil from mobilizing. The seepage rate varies with the elevation and duration of river stages and at times is visible at the ground surface on the landward side of the levee. A significant amount of seepage occurs when the Skagit River is higher than approximately 20 feet (unconfirmed vertical datum). The diking district does not try to limit seepage, but monitors and maintains the levees to ensure their structural integrity. There are certain areas that have more seepage than others; within the study area, it is believed that there is more seepage near Jack Pot Lane than there is further east near Mount Vernon.

2.3 Land Use

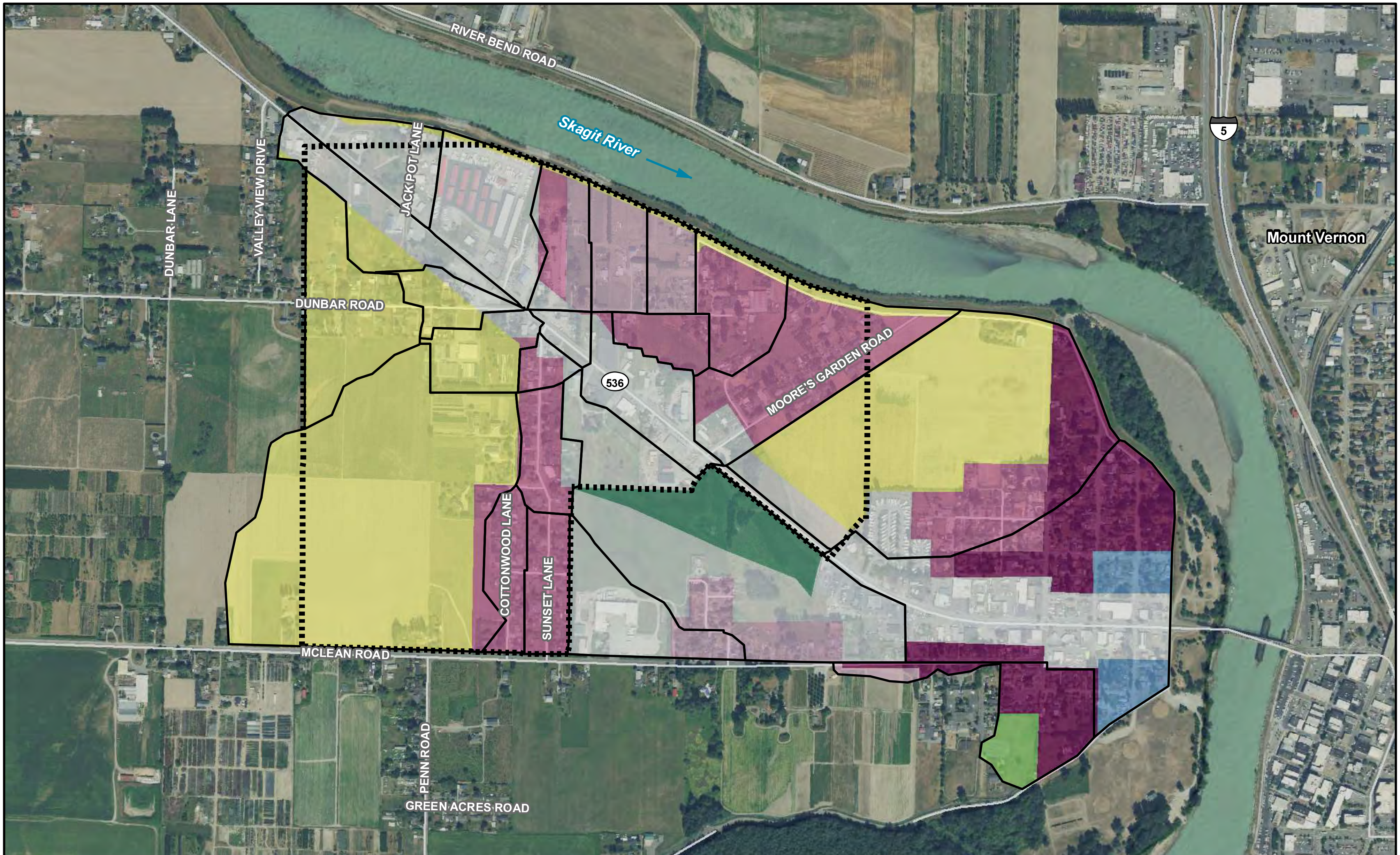
The study area is positioned at the interface between agricultural uses in the Skagit River floodplain and urban uses within the City of Mt. Vernon. The entire study area is located within the extents of the FEMA 100-year return period floodplain. While 69 percent of the project area is included within the County's National Pollutant Discharge Elimination System (NPDES) Permit service area (Skagit County, 2009), and more than 33 percent of the study area is within the City of Mount Vernon Urban Growth Area (UGA) (Mount Vernon, 2015), there is also 20% of the study area that lies within Drainage District 15. Generally drainage district service areas are exclusive of residential and commercial use areas served by the County's NPDES Permit service area, yet there are residential uses within Drainage District 15 (e.g. Cottonwood Lane). The mission of drainage districts is to facilitate drainage for agricultural uses. There are many areas within the study area where residential uses have been developed within the drainage districts and outside the NPDES service area.

County and Mount Vernon zoning within the project study area are summarized in Table 1 below. Outside of the Mt. Vernon UGA about 63 percent of the area is zoned agricultural (Ag-NRL) and the remaining area is Rural Reserve (RRv). The Rural Reserve zone allows a maximum residential density of one dwelling unit (DU) per 10 acres (0.1 DU/acre). Within the Mount Vernon UGA, County zoning includes one of two urban uses: either Urban Reserve Commercial Industrial [URC-I] or Urban Reserve Residential [URR]. The URR zone allows one DU per five acres (0.2 DU/acre). While County zoning is currently effective within the Mount Vernon UGA, the City's zoning is assumed to be predictive of ultimate build-out densities within the UGA. The City's zoning for non-commercial areas is Single Family – High Density [SF-HI], which is limited to 5.73 DU per acre. Existing densities within the study area are generally lower than those allowed by zoning; however there are some areas with non-conforming uses that are noted in Table 1. The table also includes a column of future land use that has been adjusted for the purposes of hydrologic modeling discussed later in this report and are mapped in Figure 2.

Table 1: Study Area Zoning

Comprehensive Plan Zoning		Non-Conforming Use Sub Area	Area (acres)	Existing Residential Density (DU per Acre[1])	Future Land use Adjusted for Existing Non-Conforming Uses
Skagit County	**Mount Vernon**				
Outside Mt. Vernon UGA					
[Ag-NRL] Agricultural			115.1	0.3	Rural
[RRv] Rural Reserve		West of Dunbar Court	8.9	NA	Commercial
[RRv] Rural Reserve		Tax Parcels P21763 and P21764	4.3	NA	Commercial
[RRv] Rural Reserve		East of Tax Parcels P21763 and P21764 to Dunbar Road	17.9	0.9	Single Family Residential – Low
[RRv] Rural Reserve		Dunbar Road to Moore's Garden Road	34.0	2.0	Single Family Residential – Medium
Sub-Total			180.2		
Inside Mt. Vernon UGA					
[URC-I] Urban Reserve Commercial Industrial	[CL or GC] Commercial		62.1	NA	Commercial
[URR] Urban Reserve Residential	[SF-HI] Single Family - High Density		28.6	2.1	Single Family Residential – Medium
Sub-Total			90.7		
Total Study Area			271.0		

[1] Each parcel is assumed to have one dwelling unit



Study Area
Subcatchment

Future Land Use

- Commercial
- Grass
- Multi-Family Residential
- Pasture
- Rural
- SFR-Low
- SFR-Medium
- SFR-High

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DATE: 30-Dec-2016

DUNBAR STORMWATER MANAGEMENT PLAN

Future Land Use

FIGURE 2

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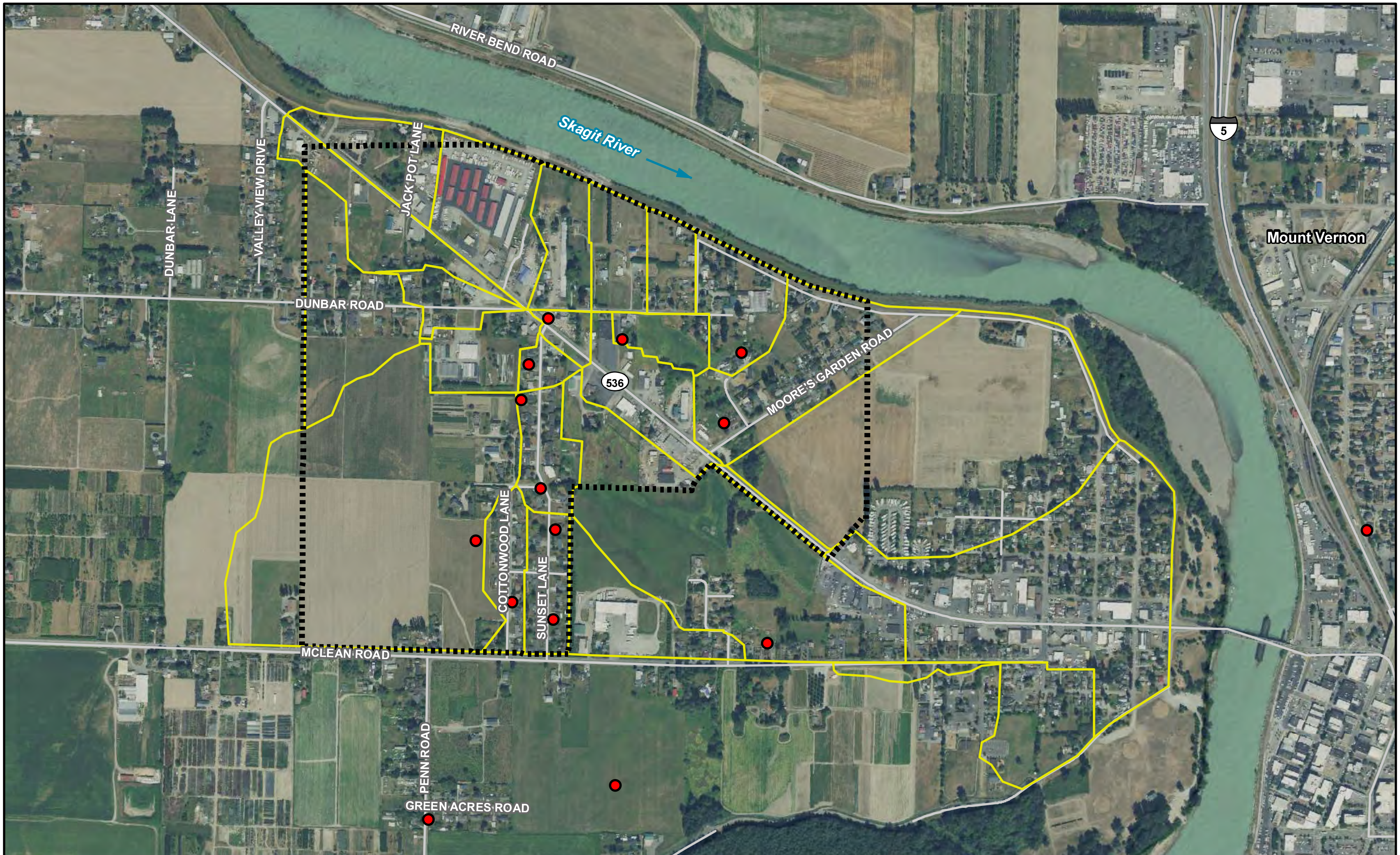
2.4 Drainage Complaints

Ponding of stormwater within the Dunbar Road study area is common and relatively widespread in the winter months. Drainage problems are due to limited topographic relief, a high groundwater table (including seepage from the Skagit River at high river stages), and lack of drainage infrastructure.

A review of the County's drainage complaint files shows 15 complaints within the study area in recent years. The large majority of complaints refer to standing water on residential properties or surrounding fields, and high ground water conditions. Additional problems include encroachment of flood waters into the Highway 536 (Memorial Highway) right of way and difficulty accessing the KBRC-AM radio station due to high water levels. Anecdotal reports consistently mention local ponding during periods of high water on the Skagit River regardless of local rainfall amounts. The locations of drainage complaints within the study area are shown on Figure 3.



Legend

- Drainage Complaint
- Study Area
- Subcatchment

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Coordinate System: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET

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DUNBAR STORMWATER MANAGEMENT PLAN

Drainage Complaint Locations

FIGURE 3

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2.5 Existing Drainage Infrastructure

Existing drainage infrastructure mapping shown on Figure 8 is based on drainage inventories from the County and WSDOT, a Closed Circuit Television (CCTV) pipe inspection, limited NHC survey, and field reconnaissance. The existing drainage inventory is not complete and there are several areas (including along Highway 536) where the locations of pipe and pipe connections are uncertain or unknown. The CCTV survey showed that several pipe segments are plugged or partially plugged with sediment. Solid lines in Figure 8 indicate pipe or ditch features and dashed lines indicate less defined overland flow connections.

2.5.1 Drainage Pathway Descriptions

In addition to showing existing stormwater infrastructure, Figure 8 also includes six regions of colored shading that each correspond to basin areas with different drainage pathways that pass through or are immediately adjacent to the study area. Each of the drainage pathways are described as follows.

- Basin 1 – Green – Includes the southwest corner of the study area. This area includes the southern portion of Sunset and Cottonwood Lanes. Currently there is no formal drainage system on this portion of Sunset Lane. And only a small southerly flowing 6" pipe conveyance system exists on Cottonwood Lane. Runoff from this area collects in a depression north of McLean Road and west of Cottonwood Lane that is noted in drainage complaint logs as frequently flooding. Some relief to this flooding is provided by an agricultural ditch (Figure 4 left) that conveys flows to a culvert that runs west along McLean Road (the culvert flows along the north side of the roadway flowing in the direction of the right photo shown in Figure 4). The outlet of that culvert could not be confirmed, but it appears that the flows combine with the system flowing north along Penn Road and together continue west along McLean Road.

Figure 4: Drainage Downstream of Cottonwood Lane (left, agricultural use; right, McLean Road ditch)

- Basin 2 – Red – Includes all areas tributary to two strings of natural depressions that converge near the KBRC-AM radio towers on the south side of Highway 536. The first string of depressions flows in a clockwise direction beginning in a depression on the south side of Dunbar

Road approximately 1000 feet east of the Dunbar Road pump station, crossing Moores Garden Road and Highway 536 via partially buried culverts. The second string of depressions is actually only a single pond located on the east side of Sunset Lane (shown at top left in Figure 5) that, based on topographic mapping, discharges east in the general direction of the radio tower, however a defined ditch or channel could not be identified to confirm that overland flow occurs. This pond receives runoff directly from a developed area which makes it function more like a formal stormwater pond than the other depressions in the study area. However, the drainage area currently routed to the pond is limited to the parcels immediately adjacent to the intersection of Cottonwood and Sunset Lanes (bottom left and bottom right photos in Figure 5). And the inlet to the pond shown at top right in Figure 5 was, until recently discovered by Skagit County, buried and unknown to the adjacent property owner. The inlet pipe passes underneath a shed on private property before upwelling into the inlet structure and then flowing overland into the pond.

Figure 5: Pond on East Side of Sunset Lane (upper left, pond; upper right, pond inlet; bottom left upstream end of inlet pipe; bottom right, exposed yard drains connected to pond inlet)

- Basin 3 – Orange – Includes the west portion of Dunbar Road that currently flows west away from the Dunbar Road pump station. There is currently no formal conveyance system along this section of Dunbar Road. Runoff disperses to the south and either infiltrates or flows overland through the Green Region and to McLean Road.
- Basin 4 – Blue with Black Hatching – This is the area that was originally delineated as the now-abolished Dunbar Sub-Flood Control Zone (SFCZ). The area is serviced by a small storm water pump station with a nominal discharge capacity of about 400 gpm (0.89 cfs), located just east of the intersection of Hwy 536 and Dunbar Road. The pump has a 3 HP motor (Figure 6, upper left) and discharges to the Skagit River via an 1,100-foot long, 6-inch diameter PVC pipe with a concrete collar (Figure 6, lower left). The pump is installed in a 72-inch diameter manhole (Figure 6, upper right) with an approximately 170-foot long, 2-foot diameter inlet line which together, serve as a sump. The design basis for the existing pump station is not known, but it appears that it was originally intended to service an area of roughly 12 acres along Hwy 536, Dunbar Road and Sunset Lane. The discharge line from the pump station north to the Skagit River lies within a 15-foot wide easement, which includes the condition:

  "…should the original drainage system be enlarged at a later date, to the extent that a larger conduit, using this easement would become necessary, this easement would be re-negotiated."

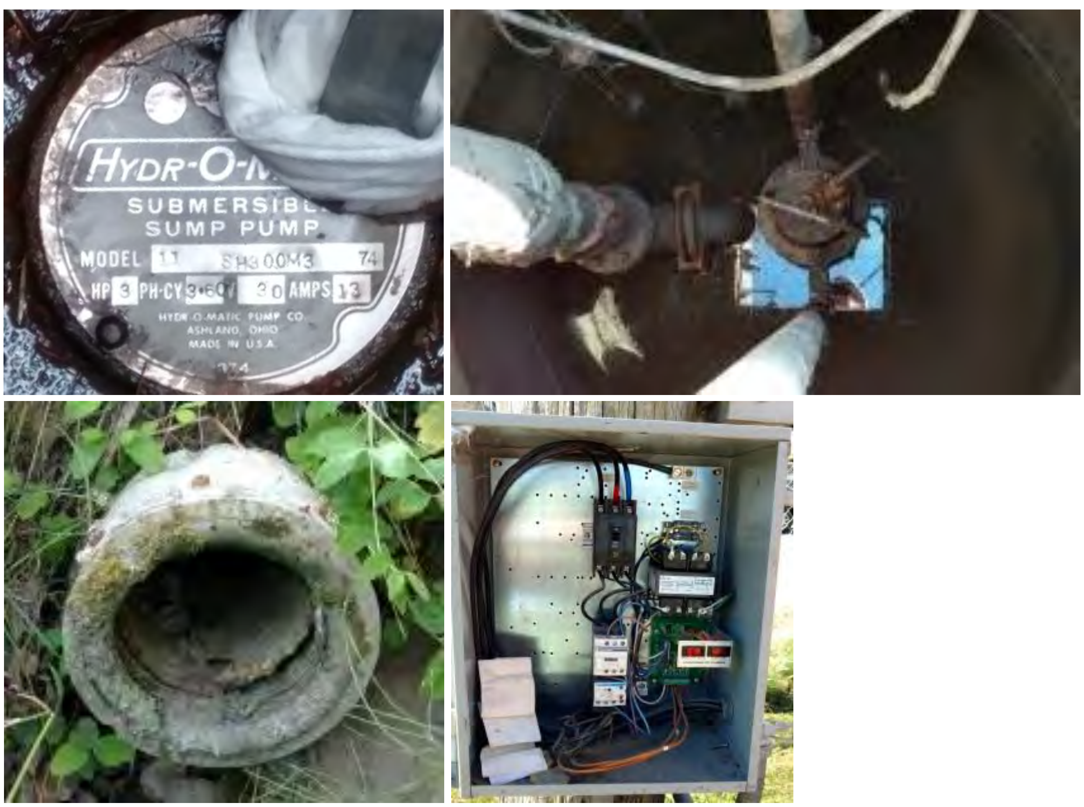


Figure 6: Dunbar Road Pump Station (upper left and top right, pump; lower left, outfall; lower right, controller)

- Basin 4 – Blue, no hatch – Includes areas that are topographically tributary to the Dunbar Road pump station but were not part of the Dunbar SFCZ and do not have a known connection to the Dunbar Road pump station. Runoff in this area infiltrates in local depressions along either side of Highway 536.
- Basin 5 – Yellow – Located immediately east of the study area. This area is routed to the City of Mount Vernon stormwater pump station located on Behrens Millett Road, due south beyond the southern end of North Wall Street. The City Engineer has stated that the conveyance system and pump station are both at capacity and could not receive additional inflows (Blain Chesterfield, personal communication). This portion of the study area is excluded from the stormwater plan.

2.5.2 Detailed Investigations

CCTV Inspection of Stormwater Pipes at Dunbar Road and Highway 536

The condition and layout of the pipe system in the Dunbar Road and Highway 536 vicinity was inspected by Innovac Vacuum Services using a CCTV equipped rover on January 26, 2016 and July 27, 2016. During the first inspection, Innovac encountered severe sediment accumulation and standing water (Figure 7, left and middle) and had to re-schedule the CCTV work. On February 2, 2016, WSDOT cleaned sediment out of some of the basins in and around the intersection but some could not be cleaned due to property access limitations. Innovac returned to complete the CCTV survey on July 27, 2016 under drier conditions and following WSDOT's attempt to clean the system. During this second inspection, they were able to inventory most of the Dunbar Road and Highway 536 intersection, but some restrictions (e.g. sediment blockage shown in Figure 7, right) remained and prevented collection of a full inventory. The CCTV inventory is reflected in the combined infrastructure map in Figure 8 and is provided in its original form in Appendix A.

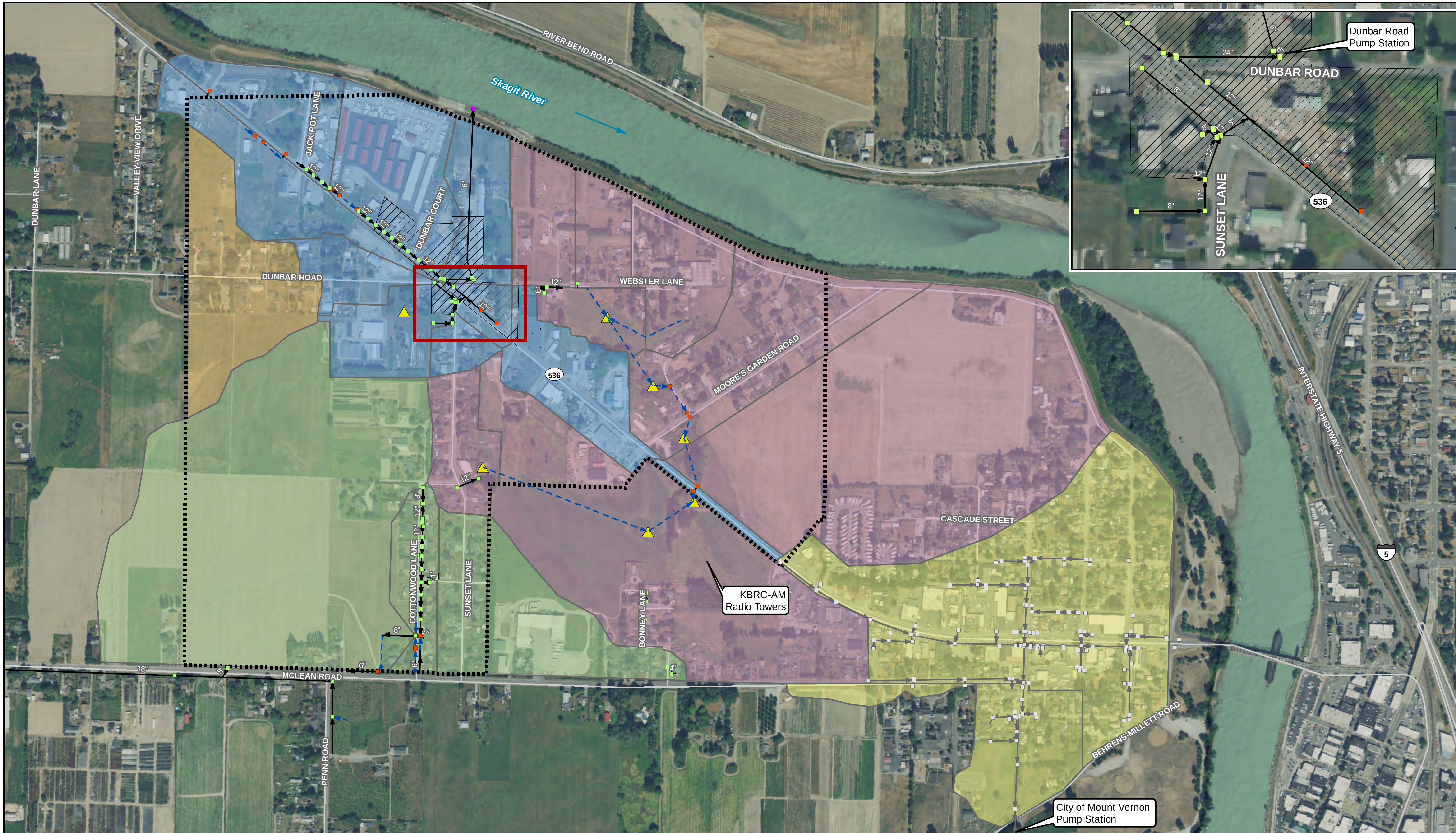
Figure 7: Sediment Plugged Pipes in Dunbar Road and Highway 536 Intersection (left and middle, January 26, 2016; right, July 27, 2016)

Pump Station Inspection and Servicing Recommendation

Several instances of the pump station tripping have occurred in recent years, resulting in flooding at the intersection of Dunbar Road and Highway 536. Skagit County requested that NHC investigate the cause of the pump station trips. On July 19, 2016, NHC's pump experts and Skagit County staff inspected the pump station. This inspection provided some new information about the circumstances, but key questions about the pump could not be answered without removing the pump from its wet well for detailed servicing and inspection. Based on files available from Skagit County, there is no record of recent pump servicing and it appears to be the original pump installed in the 1970's. The pump model number, SH300M3, is similar to other Hydr-O-Matic brand pumps, but unfortunately the local distributor, Pump Tech, could not locate the design performance curve (hydraulic head vs. pumping discharge) for the pump using the model number alone. Two theories regarding the reason for the pump station trips and two recommendations for future servicing actions were identified from the pump station inspection.

1. The pump has a leaky seal causing the mechanical seal leak sensor to trip, shutting down the pump. This could be corrected by pulling the pump and servicing its seals. NHC recommends this be done at the next available opportunity.

2. The pump control panel amperage does not match the pump. Skagit County records show that the pump power supply control panel was recently replaced; however, the power supply control panel is of a lower amperage than the 30 amps shown on the pump information plate. If the control panel is undersized, it could cause the pump to trip. NHC recommends that the installer verify that the control panel has the proper amperage when the pump is serviced.



Legend

- Dunbar Sub-Flood Control Zone
- Subcatchment
- Study Area

Drainage Nodes

- Manhole or Catchbasin
- Ditch or System Inlet
- Outfall
- Mt. Vernon Nodes
- Storage

Drainage Lines

Type

- Pipe
- Ditch or other connection
- Mt. Vernon Lines

Existing Drainage

- City of Mt. Vernon Pump Station
- Dunbar Road Pump Station
- Dunbar Road West
- Radio Tower/Local Depressions
- Southwest Depression/McLean Road

nhc
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SCALE - 1:7,200

0 600 1,200 Feet

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Coordinate System: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET

Job: 2000985 Date: 30-Dec-2016

DUNBAR STORMWATER MANAGEMENT PLAN

Existing Drainage Inventory

FIGURE 8

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2.6 Regulatory Requirements

All applicable County, State, and Federal requirements that apply at the time the recommended stormwater plan alternatives are implemented will need to be met prior to the construction of the large capital improvement works/projects. Those requirements considered most important at guiding the conceptual stormwater management approach (i.e. County and NPDES stormwater code requirements) are summarized below. Other permit requirements, such as those pertaining to any new river outfall, will be addressed during Phase 2 of the project.

The current provisions of Skagit County Code Drainage Ordinance, Chapter 14.32, apply when new development and/or redevelopment occur. The proposed project does not include creation of new impervious surface, but the project will collect runoff from more than 5,000 square feet of existing development that currently disperses without formal stormwater treatment. In order to meet the intent of Chapter 14.32, "…To help protect adjacent landowners from downstream flooding, erosion, and pollution," stormwater treatment should be provided for the project area in order to prevent downstream impacts through treatment of the collected runoff as though it were new impervious surface.

Section 14.32.080 of the Skagit County Code, Stormwater Management, includes provisions for stormwater quantity and quality control and stormwater conveyance. In addition to these minimum requirements, there are additional stormwater requirements that apply: A) within the NPDES service area portion of the study area for equivalence with Appendix I of the 2013-2018 NPDES Phase II Municipal Stormwater Permit (Ecology, 2014), and B) to development within designated flood hazard areas as per the County's Flood Damage Prevention section of the Code (Section 14.34.150).

The County has peak flow control requirements for new development (Section 14.32.80 (3)), but these are only applicable within the study area in areas where stormwater conveyance does not discharge directly to the Skagit River. The Skagit River is listed as a major receiving water that can be exempt from flow control requirements under Appendix 1-E of the WSDOE Stormwater Management Manual for Western Washington (SWMMWW). Two key conditions that must be met to allow flow control exemption include:

1. Direct discharge to the exempt receiving water does not result in the diversion of drainage from any perennial stream or from any category I, II, or III wetland.
2. The project site must be drained by a conveyance system that is comprised entirely of manmade conveyance elements (e.g., pipes, ditches, outfall protection, etc.) and extends to the ordinary high water line of the exempt receiving water.

In addition to being exempt from flow control requirements, projects discharging to the Skagit River do not need to achieve the Low Impact Development (LID) performance standard, nor consider bioretention, rain gardens, permeable pavement, or full dispersion, all of which hare typically required to meet Ecology's SWMMWW Minimum Requirement #5, On-Site Stormwater Management. These projects must still implement best management practice (BMP) T5.13 (Soil Amendment); BMPs T5.10A, B, or C (Downspout Dispersion); BMP T5.11 (Concentrated Flow Dispersion); or T5.12 (Sheetflow Dispersion), if feasible.

In addition to the limited amount of LID that must be considered as per the SWMMWW On-Site Stormwater Management Requirements, the all areas within the flood hazard zone are required to construct LID BMPs "to the extent feasible" as per Section 14.34.150 of the County Flood Damage Prevention Code. A list of required "if feasible" LID BMPs is included in the County's "Low Impact Development in Special Flood Hazard Areas" checklist.

The last two requirements in the SWMMWW that apply to the study area are runoff water-quality treatment and wetland protection. Minimum Requirement #6, regarding runoff water-quality treatment, is required for pollution generating surfaces, regardless of flow control exemptions. The level of required treatment varies as a function of the volume of traffic at a site. Applicable thresholds include 7,500, 15,000, and 30,000 Annual Average Daily Traffic (AADT) counts per day depending on the location. Minimum Requirement #8 pertains to wetlands protection and requires that discharges to wetlands maintain the hydro-period and flows of existing site conditions to the extent necessary to protect the characteristic uses of the wetland.

3 GROUNDWATER AND SURFACE WATER STAGE MONITORING DATA

Two sets of monitoring data were used to characterize the interaction of ground and surface water as part of the stormwater plan. One set included legacy groundwater monitoring data and the other a set of new data collected as part of this project.

3.1 Recovered USACE GI Monitoring Well Data

In addition to evaluating riverine flood hazards as part of the USACE GI, the Corps also deployed groundwater monitoring instrumentation to monitor seepage in each of the diking districts in the Skagit River floodplain. Groundwater monitoring wells were installed at one or more locations in each diking district, and the monitors were operated in coordination with each diking district. In Diking District 1, which is included in the project study area, wells were installed and water levels loggers were deployed, but the data was never downloaded or processed. NHC recovered the data that had been collected at two locations on Jack Pot Road between November 2009 and May 2014. One of the recovered well monitors located in the levee top was labeled "Skagit River Riverbend3&4 levee" and the other, located approximately 115 feet landward on Jack Pot Road was labeled "Skagit River Jackpot 1 land." A second landward well on Jack Pot Road could not be accessed. Data held by the levee top logger had an obvious drift and was not usable. Data held by the landward levee provided useful characterization of groundwater stages over this four year period. These are plotted along with observed river stages from the USGS Skagit River near Mount Vernon monitoring gage in Figure 9. A time shift was discovered in the recovered groundwater stage data that was consistent with the time not having been set properly at the time of deployment. The error was corrected by adding 558 days to the time stamps corresponding to each observation in the recovered datafile. By adding this shift, the observed groundwater well water levels closely track the rise and fall of Skagit River stages shown in the observed USGS data.

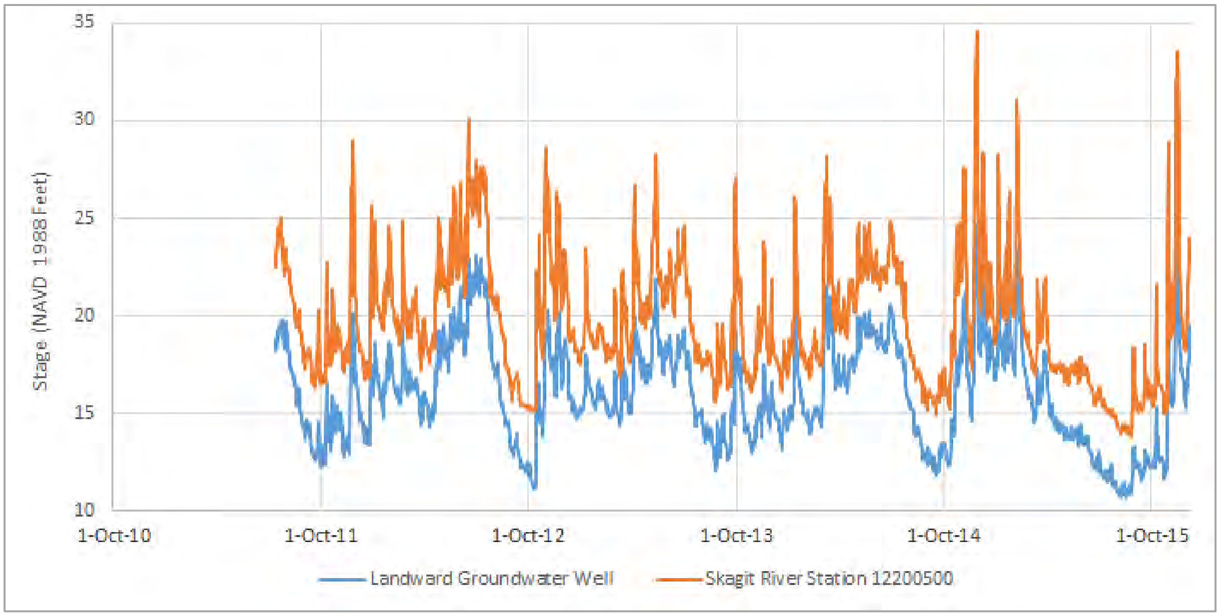


Figure 9: Groundwater Level Data Recovered from Corps Monitoring Well and USGS Reported Stages at Skagit River Station 12200500 (2009 - 2014)

3.2 New Groundwater and Surface Water Monitoring Data

In addition to recovering pre-project groundwater level data, NHC also deployed groundwater well level recorders in one of the landward groundwater wells on Jack Pot Road and deployed surface water level recorders in two surface water depressions along Highway 536. One of the surface water level recorders was installed on the north side of Highway 536 (east of the Net Drive-In) and a second on the south side of Highway 536 (northwest of the KBRC-AM radio towers). The loggers located in the landward groundwater well and the northern surface water depression (Figure 10, upper right) recorded data from December 15, 2015 through June 10, 2016. The logger located in the southern surface water depression (Figure 10, upper left) was only operated for approximately one month, from December 15, 2015 through January 20, 2016. The data collected during the project are plotted in Figure 11; all of the recorded stages are referenced to the NAVD 1988 vertical datum.

Figure 10: Photos of Monitoring Locations; (upper left, radio tower depression on south side of Highway 536; upper right, depression on north side of Highway 536; bottom left and bottom right, monitoring well on top of levee)

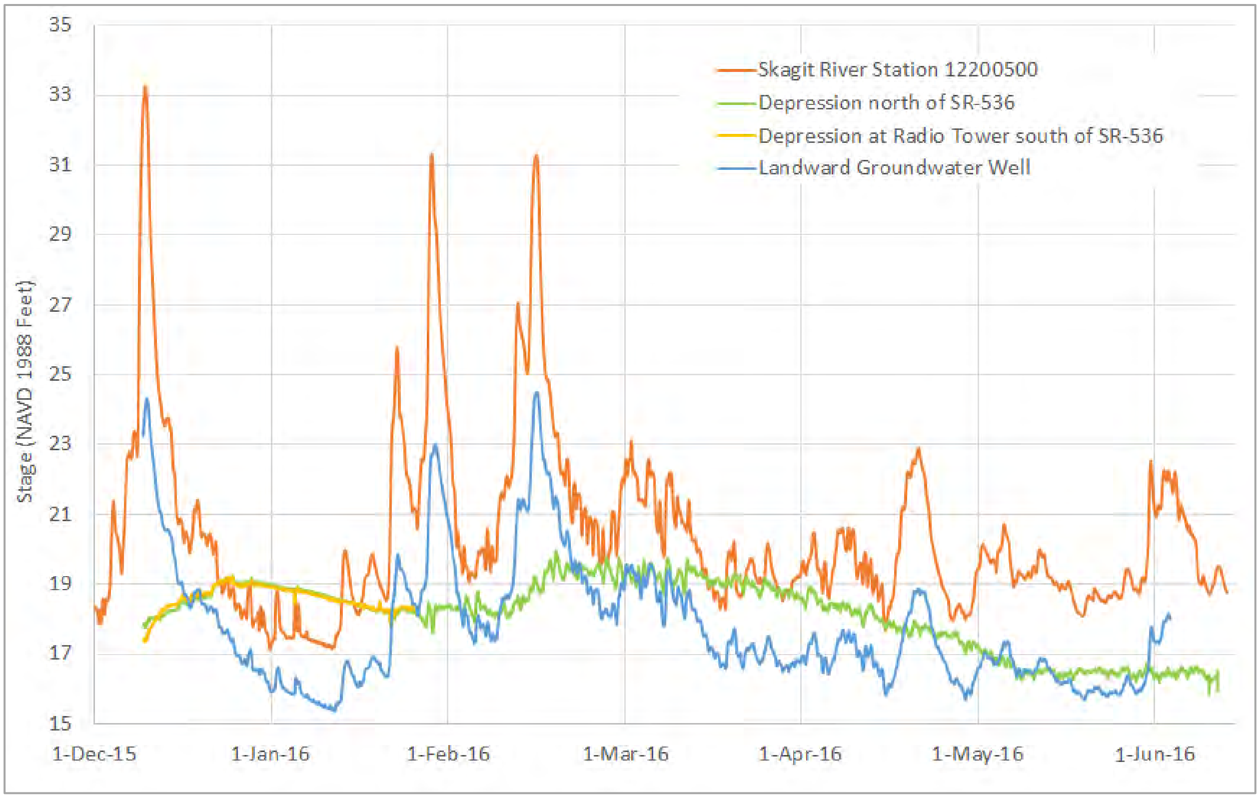


Figure 11: New Groundwater and Surface Water Monitoring Data Collected by NHC (2015 - 2016)

4 STORMWATER MODELING OF PROPOSED STORMWATER SYSTEM

The proposed Dunbar Road area storm drainage system was sized using a modeling suite consisting of the Hydrologic Simulation Program Fortran (HSPF) hydrology model, the MODFLOW groundwater model, and the Stormwater Management Model (SWMM) hydraulic model. HSPF is used to simulate runoff from the land surface, MODFLOW is used to simulate seepage from the groundwater into the stormwater system, and SWMM is used to simulate water levels and routing of flows through the proposed storm drainage system. All three programs are made available for public use by the US Federal Government: HSPF and SWMM by the USEPA, and MODFLOW by the USGS.

4.1 HSPF Hydrology Model

HSPF is a continuous hydrologic simulation model, which has been used extensively in recent years for stormwater management and basin planning applications, and is the standard for runoff modeling at the basin scale within the State of Washington. The objective of the HSPF application in the present study is to provide long-term time-series of simulated runoff into the proposed stormwater system, which is being modeled separately with SWMM. No in-basin flow data were available to calibrate the model, so runoff parameters were assigned using regionally accepted values based on land cover and soil type (Dinicola, 1990).

4.1.1 Precipitation and Evaporation Data

HSPF is a continuous hydrologic simulation model which requires long continuous time-series of hourly or sub-hourly precipitation data for input. Rainfall data are available from several stations in and around Mount Vernon, including from the WSU Mount Vernon Research and Extension Center, approximately 1.5 miles northwest of the study area. Unfortunately, a long gap-filled time-series of hourly data suitable for hydrologic modeling has not been developed for this station. In the absence of suitable local data, precipitation data for hydrologic modeling was taken from a long record of quality-controlled hourly rainfall data from Kayak Point, on the east side of Port Susan Bay, 7 miles south of Stanwood and approximately 20 miles south of Mount Vernon. (The Kayak Point record covers the 65-year period of water years 1950 through 2014) A check of precipitation data from Kayak Point against data from the WSU Mount Vernon Research and Extension Center shows that the Kayak Point record is reasonably representative of the rainfall regime in Mount Vernon with respect to long-term volumes. However, storm event totals from Kayak Point appear to be somewhat higher than indicated by the available records from Mount Vernon. This is contrary to the spatial patterns in storm rainfall amounts from PRISM mapping (for example, PRISM maps show 100-year 24-hour rainfall of 3.0 inches at Kayak Point compared to 3.7 inches at Mount Vernon). In view of the uncertainty in the records, rainfall data from Kayak Point were applied without adjustment to represent conditions in the study area.

Runoff simulations performed using HSPF also require a time-series of potential evapotranspiration. This time-series was estimated using daily pan evaporation data obtained from the Puyallup Experimental Station. Pan evaporation data were converted to potential evapotranspiration for use in HSPF by application of a pan coefficient of 0.70. Since hydrologic modelling of winter high flows is insensitive to uncertainty in potential evapotranspiration, the distance between the Puyallup station where pan evaporation data is recorded and the project site is not a significant concern.

4.1.2 Impervious Area

The total impervious area (TIA) and the % connectedness specified in the HSPF model input files were calculated based on the zoning-based land use categories listed in Appendix B (right column). The Appendix B land use tabulation is similar to Table 1 (presented previously in Section 2.3) except that it also includes a larger land area that covers the full extent of the HSPF model, not just the area within the study planning area boundary. The Skagit County code specifies TIA limits based on lot density, but these values tend to overestimate actual impervious area cover. The modeled TIA areas corresponding to each development density reflect regional development patterns. For this project, TIA areas from Snohomish County's hydrologic modeling protocols (Snohomish County, 2002) were utilized. Snohomish County (2002) also provides values of % connectedness for each land use density, which were applied to both the existing condition and future condition TIA values for each basin.

4.1.3 Soils

Soils within the study area were grouped into three categories: till, outwash, and saturated (wetland), each of which have corresponding calibrated HSPF runoff parameters documented in Dinicola (1990). The extents of each soil category was determined using mapping data available from the US Natural

Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) (NRCS, 2015) that include descriptions of the properties for each soil. The texture classifications within the study area and resulting model categories are:

Till Type

- Field silt loam
- Field silt loam, protected
- Sedrowoolley silt loam
- Skagit silt loam
- Urban land-Mt. Vernon-Field complex

Outwash Type

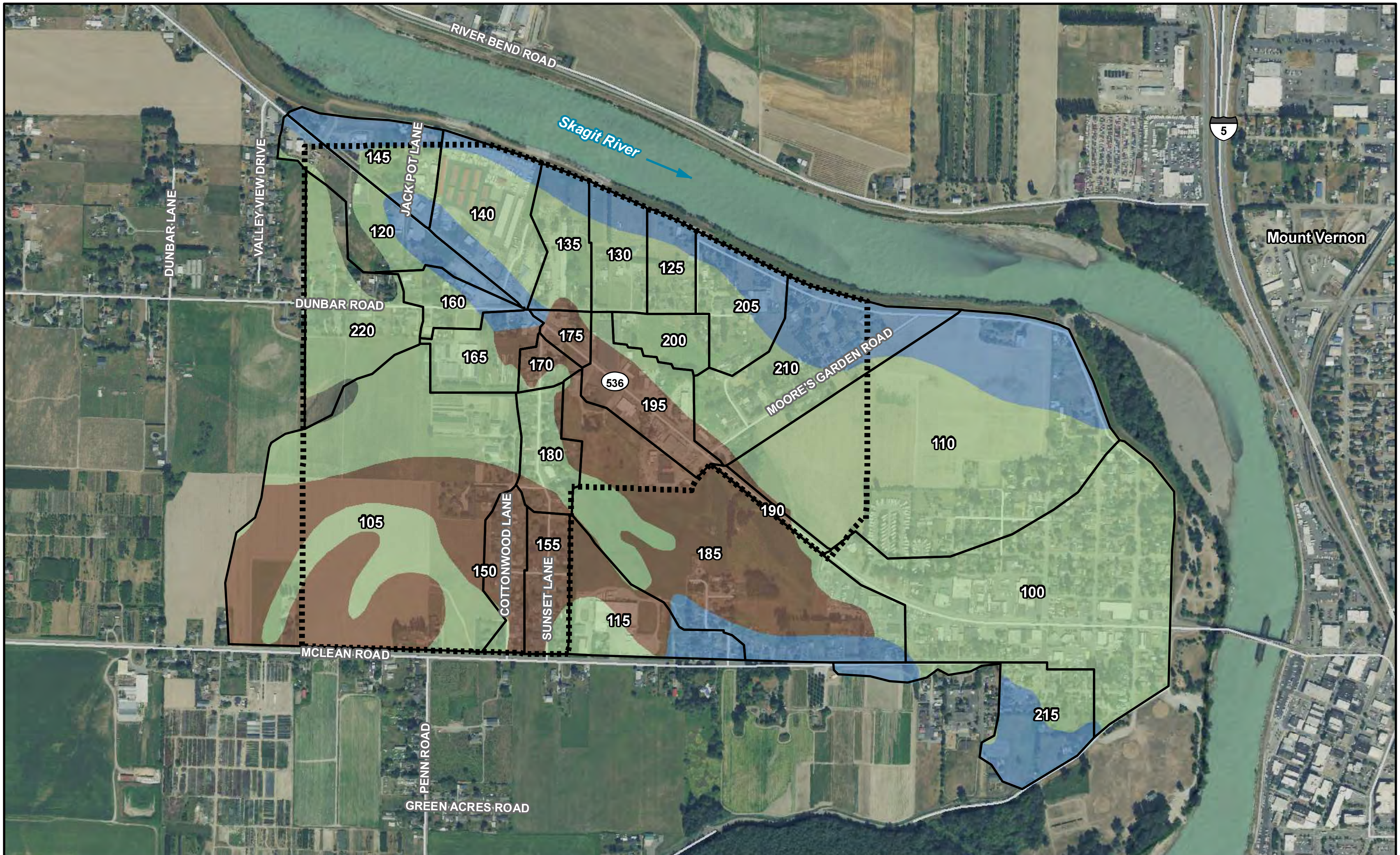
- Briscot fine sandy loam: Custer-Norma
- Mt. Vernon very fine sandy loam
- Pilchuck variant fine sandy loam

Saturated

- Sumas silt loam

4.1.4 Runoff Simulation

The HSPF model was run for a 65-year period beginning on October 1, 1949 and ending on January 13, 2015. Simulation output, time-series of runoff flow rates at 15-minute intervals, was saved for each of the 25 catchment areas shown in Figure 12. Runoff from these catchments was then further divided and routed into 83 individual stormwater system inlets represented by the SWMM model described in Section 4.3.



Study Area
Subcatchment
Soils
Outwash
Saturated
Till

SCALE - 1:12,000
0 500 1,000 2,000 Feet
N

Coordinate System: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET

Job: 2000985

DATE: 30-Dec-2016

DUNBAR STORMWATER MANAGEMENT PLAN

HSPF Model Sub-Basins and Soils

FIGURE 12

nhc northwest hydraulic consultants

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4.2 MODFLOW Groundwater Model

As noted in Section 2.4, most of the drainage complaints within the study area concern standing water on residential and commercial properties, saturated ground, and high groundwater levels. Groundwater levels are closely linked to Skagit River water levels, with high Skagit River levels resulting in high groundwater levels in the study area independent of local rainfall. Standing water in certain locations, such as observed in the depression adjacent to the KBRC-AM radio tower, is believed to be a direct reflection of groundwater levels unrelated to storm water runoff.

Estimates of potential groundwater seepage rates for use in drainage system design were developed by Associated Earth Sciences Inc. (AESI) using a MODFLOW groundwater model. The model domain was defined by a 13,000-foot by 12,000-foot grid encompassing the study area and bounded on the north, east, and south by the Skagit River. The model was calibrated against observed water level data from a monitoring well on Jackpot Lane, adjacent to the Skagit River on the northern boundary of the study area, and from the radio tower depression previously presented in Figure 11. The MODFLOW groundwater model development and model results are described in more detail in Appendix C. Of particular interest is Figure 4 located at the rear of Appendix C, which shows the groundwater profile across the study area in section view. The view shows groundwater levels simulated with a relatively high Skagit River stage of 26.6 feet NAVD feet and includes depictions of the existing surface water depressions and hypothetical ditches discussed further below and in Section 5.

The MODFLOW model was used to simulate potential seepage rates at different locations within the study area by introducing into the model, hypothetical open ditches having alignments, depths and lengths comparable to those of possible future drainage systems. While pipes are proposed throughout most of the study area, open ditches represent the upper limit of expected seepage in any stormwater system. The seepage rages assigned as inputs to the SWMM model were set at constant inflow rates equal to the maximum simulated with MODFLOW for any given conveyance path. These peak simulated seepage rates ranged from 2.6 to 6.7 cfs per mile along the core SR-536 trunk line.

4.3 SWMM Conveyance System Model

The SWMM model representing the future stormwater system (discussed in Section 5) includes a network of closed conduit pipes, ditches, and storages that have been sized to convey flows in the future build-out condition. Elevations of catchbasins and manhole rim elevations are based on a combination of NHC survey and bare-earth LiDAR elevation data. Proposed pipe invert elevations are set to maintain three feet of cover below the overlying ground surface. Comparisons of NHC survey data and the bare-earth LiDAR data found that the LiDAR data are of a low accuracy relative to other datasets in the vicinity of Highway 536, with errors on the roadway surface on the order of one to two feet. Elevations elsewhere in the study area were deemed of a higher accuracy (~ 0.5 feet locally) and are more typical of LiDAR elevation data. Elevations should be updated following a ground survey as part of final design.

Stormwater system sizing was performed in three steps. First, inflows to the stormwater system were assigned time-series of HSPF model simulated runoff from a 10-year return period storm routed to the system and the maximum seepage rate simulated with the MODFLOW model. Next, the pipe and pump station capacities were adjusted until simulated water levels, determined via SWMM modeling, did not surcharge the proposed stormwater system. Then, once the system was sized to a 10-year storm, the capacity was checked by routing a larger 25-year storm to confirm that the proposed system did not result in major flooding.

The two historical storms used to represent the 10- and 25-year return period storms were May 31, 1958 and September 10, 1967. These two events were identified by evaluating output from a continuous simulation of the SWMM model using the full 65-year period of simulated HSPF runoff. The flood frequency curve shown in Figure 13 was performed by fitting 30-minute averages of total simulated inflows to the system (runoff and seepage) to the Log-Pearson Type III distribution. Curves were also fit to the 1-hour and 3-hour averages, which are all relatively short duration averages that are important for peak flow conveyance analysis. May 31, 1958 and September 10, 1967 were both identified as being close to 10- and 25-year return period events at the 30-minute, 1-hour, and 3-hour durations.

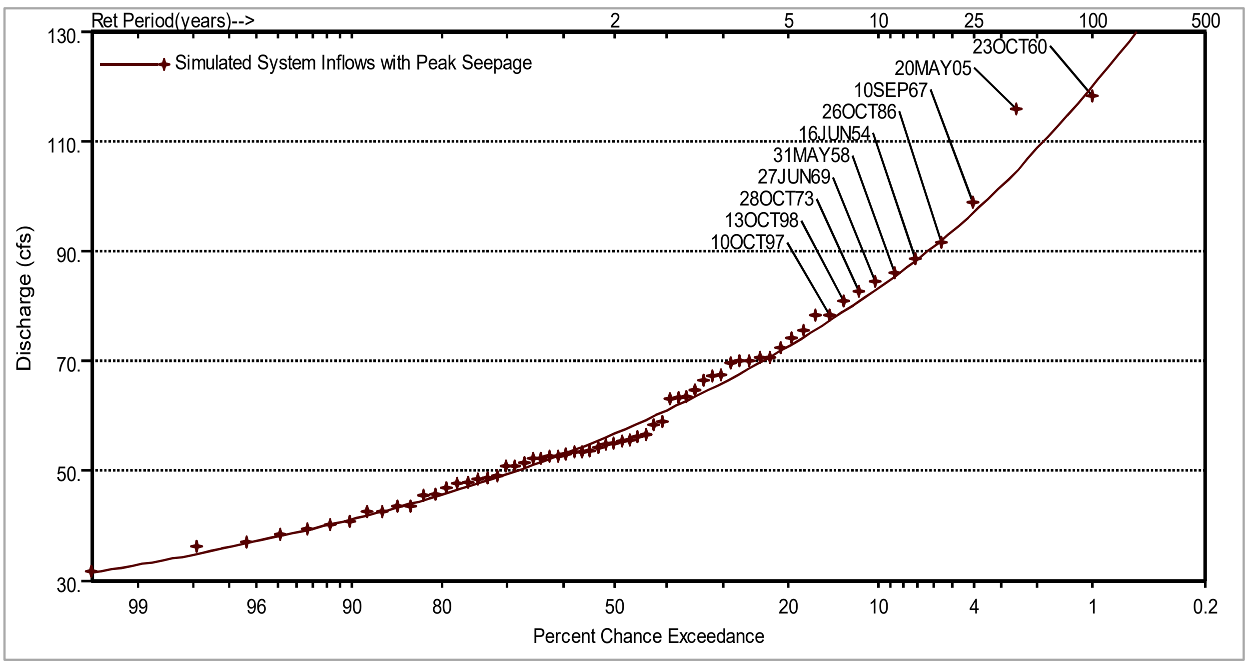


Figure 13: Flood Frequency Curves Fit to Annual Peaks of Simulated Total System Inflow

5 FUTURE SYSTEM PLAN

As discussed briefly in Section 1, this first phase of the stormwater management plan includes a conceptual design and a planning level cost opinion for a single alternative. As a subsequent phase, Skagit County will complete a final design that includes construction level detail and cost estimating. It is expected that the conceptual layout of the plan will evolve over time, based on development timeframes and patterns, and implementation requirements of other agencies (e.g. WSDOT). Ideally the core portion of the system described in Section 5.2 will be constructed first and then expand as development occurs. However, even if the core is not constructed in a single effort, the general concept of the plan will provide a guide for future improvements.

5.1 Conceptual Plan

The conceptual level stormwater plan addresses four main deficiencies of the current study area drainage system identified based on drainage complaints and anecdotal information described in Section 2.4. These deficiencies include:

- Functional issues with the Dunbar Road pump station
- Lack of surface water conveyance
- Flooding due to high groundwater
- Maintenance needs

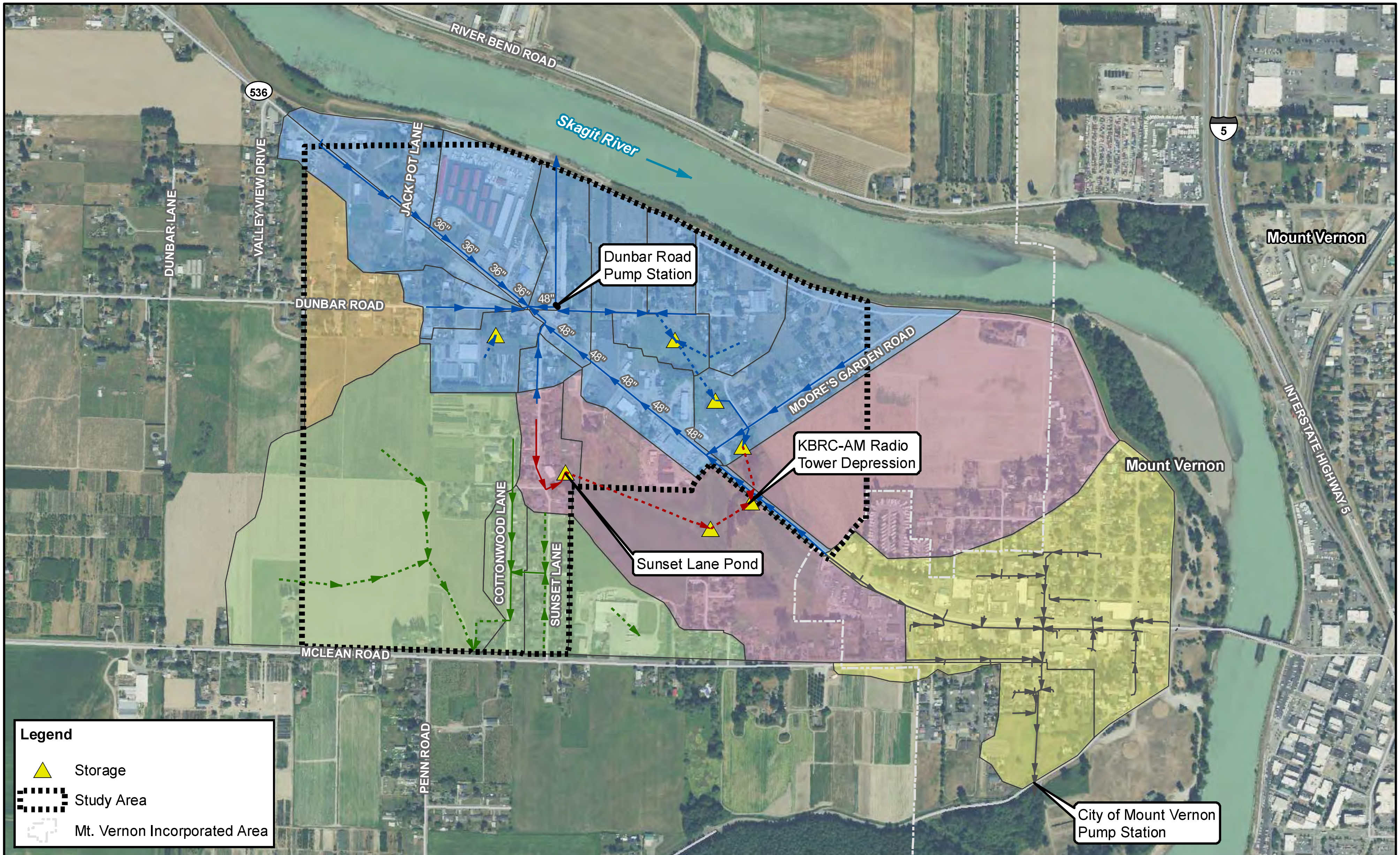
The future stormwater plan addresses these deficiencies by increasing the capacity of the Dunbar Road pump station and increasing the extent and capacity of the surface water conveyance system. Skagit County has other maintenance programs that are targeting some of the problems identified in this study area (e.g. clogged pipes and need for routine vactor truck cleaning).

5.1.1 System Plan Basins

A map of the plan shown in Figure 14 is very similar to the existing system inventory map in Figure 8 except the existing pipe infrastructure has been replaced by a new conveyance system and some of the colored drainage basins have be excluded and/or rerouted. The nodes identified as storage are existing depressions that currently collect stormwater. The system plan basins, which are truncated at the project area study limits, are described as follows.

- Basin 1 – Green – Includes southern portion of Sunset Land, Cottonwood Land, the southwest corner of the study area. Future development in this region cannot be allowed to increase the surface water runoff volume being conveyed to the depression on the west side of Cottonwood Lane. Given the limited potential for infiltration during high groundwater conditions within the study area, that would prohibit new development in this area unless runoff from this area is routed to the Skagit River via a manmade conveyance system. Options for a manmade conveyance system include improving the conveyance system flowing west along McLean Road or routing this area north to the Dunbar Road pump station. The McLean Road system is reportedly undersized for existing runoff and floods the near Penn Road. The costs associated with either of these improvements would be relatively high and there is relatively limited development potential in this area. As a result the recommended plan does not include routing of this basin to McLean Road or the Dunbar Road pump station. As a result, development will not be exempt from flow control requirements and future development would be limited as a result.

- Basin 2 – Red – Includes all areas tributary to the radio tower depression. This area is not clearly exempt from flow control requirements due to prohibition that flows by routed away from certain wetlands such as those in or adjacent to the radio tower depressions. Depending on the outcome of the recommended assessment of the vulnerability of the wetlands, some of this area could be bypassed to the Skagit River to allow flow control exemption for new or redevelopment. The recommended plan does not include re-routing of this basin, so future development would be limited as a result.
- Basin 3 – Orange – Includes the west portion of Dunbar Road that currently flows west away from the Dunbar Road pump station. Future development in this region cannot be allowed to increase the surface water runoff volume being conveyed to private property. There are no known drainage issues here, but given the limited potential for infiltration during high groundwater conditions, there would be few opportunities for new development in this area unless runoff from this area is routed to the Skagit River via a manmade conveyance system. This could be addressed by routing this area east to the Dunbar Road pump station, however there is relatively limited development potential relative to the cost to capture runoff from this area. The recommended plan does not include routing of this basin to the Dunbar Road pump station. As a result, development will not be exempt from flow control requirements and future development would be limited as a result.
- Basin 4 – Blue – Includes all areas that generally flow toward the Dunbar Road pump station, those areas that drain toward the pump station topographically but whose runoff is currently infiltrated in closed depressions, AND one additional area that has been diverted to the Dunbar Road pump station. Due to its proximity to the existing Dunbar Road pump station easement, this area is the most suited to increasing stormwater capacity to facilitate future development by increasing pumping capacity and improving conveyance infrastructure along Highway 536. The noted diversion, north and west of Moores Garden Road, is an area of 57.8 acres that was previously routed toward the radio tower depression, as indicated by red shading in the map of the existing drainage inventory (Figure 8). In the future stormwater plan (Figure 14), this area has been shaded blue indicating it will be rerouted northwest to the Dunbar Road pump station. The diversion, to be located at Moore's Garden Road, could either route all discharges to the pump station or only high flows. The type of bypass will be determined based on the outcome of an assessment of the hydrologic impacts of diverting flow away from the wetland located at the radio tower depression. As noted in Section 2.6, direct discharge to an exempt receiving water cannot result in the diversion of drainage from any perennial stream or from any category I, II, or III wetland. The interesting aspect of this wetland is that it is primarily fed by groundwater rather than surface water. The next phase of the stormwater plan should take a close look at these wetlands and determine if there would be any negative impacts associated with diverting all flows to the pump station.



northwest hydraulic consultants

Conduit	Link/Ditch		Drainage Area
→		City of Mt. Vernon Pump (existing)	
→	→	Dunbar Road Pump Station	
→	→	Radio Tower/Local Depressions	
→	→	Southwest Depression/McLean Road	
		Dunbar Road West	

SCALE - 1:12,000

0 500 1,000 2,000 Feet

N

Coordinate System: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET

Job: 2000985

DATE: 30-Dec-2016

DUNBAR STORMWATER MANAGEMENT PLAN

Future Stormwater Plan

FIGURE 14

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5.2 Proposed System

The primary stormwater infrastructure elements included in the recommended plan are new stormwater conveyance, water-quality treatment, and a new pump station. Replacement and expansion of the existing surface water conveyance system will provide much needed drainage improvement for low lying areas within the study area that currently are impacted by localized ponding, and will provide additional capacity to facilitate new development. The plan for the entire study area includes approximately 13,000 linear feet of conveyance pipe shown as solid lines shown in Figure 14, all sized as described in Section 4.3. However, only a core portion of the system included in the plan is expected to be constructed by the County. These core elements include the Dunbar Road pump station and the primary trunk of the conveyance system. Catch-basins for collection of local drainage are not included. Individual public or private construction projects will tie into stub-out connections provided at trunk system manholes (provided at approximately 250 feet intervals) as future development occurs. The County may also be able to pursue cost-in-lieu funding opportunities to share the cost of trunk system construction with future developers. The proposed trunk includes: 1) that portion of the system that flows southeast along SR-536 from Jack Pot Lane to Dunbar Road, 2) the portion that flows northwest from Moore's Garden Road, and 3) a short connection along Dunbar Road between SR-536 and the Dunbar Road pump station. Pipe sizes and lengths of these three sections of the trunk are summarized in Table 2. Reducing the pipes sizes further (to 24", 36", and 36" respectively) does not increase simulated flooding, but would bring water-levels within one foot (10-year) or six inches (25-year) of the ground surface. Additional detail should be added to the model before reducing the conveyance system to a size with such a small margin of error.

Table 2: Proposed System Pipe Sizes and Lengths for Trunk of Conveyance System

Pipe Size (inches)	Length (feet)
SR-536, Jack Pot Lane to Dunbar Road	
36"	1300
SR-536, Moore's Garden Road to Dunbar Road	
48"	1700
Dunbar Road, SR-536 to Pump Station	
48"	220

The pump station is expected to receive a peak discharge of greater than 53 cfs in the 10-year storm under full build-out conditions. This flow rate is a major increase compared with the estimated 0.89 cfs capacity of the existing pump. Additionally, an inflow rate of 53 cfs assumes that a water-tight conveyance system is installed that captures no seepage. A standard pipe system or fully ditched system would collect up to 7 cfs more. The cost associated with making the conveyance system water-tight is expected to add 15% to the total conveyance system cost but would be offset by reducing the pump station cost.

In addition to making the conveyance system water-tight, the pump station size could also be reduced by providing additional storage near the forebay of the pump station or elsewhere in the system. Four options for additional storage and the corresponding pump station pumping capacity requirements for three levels of seepage capture are listed in Table 3.

Table 3: Future Pump Station Forebay Storage vs. Required Pumping Capacity

Added Forebay Storage (acre-feet)	Required Pumping Capacity (cfs)		
	High Seepage Capture (equivalent to ditch)	50% Seepage Capture	No Seepage Captured
None	60	57	53
3	30	26	23
6	15	5	1
12	7	4	1

Any increase in the pump station size will also require that the County renegotiate the existing easement for the 1,100 foot long discharge pipe between the Dunbar Road pump station and the Skagit River. The existing easement is limited to a 6" line which is far too small for the pumping capacities required for full build out. The future discharge line may need to be 36-inches in diameter or larger with a 60-cfs pumping capacity.

Water-quality treatment should be provided for runoff from existing pollution generating impervious surfaces that is captured by the system. This area is estimated to be approximately 0.8 acres. The system plan calls for two storm filters near the intersection of SR-536 and Dunbar Road. One filter would treat flows from the north and the other would treat flows from the south. Bio-retention or other treatment technologies could also be used to treat this runoff.

Due to the dramatic increase in required pumping capacities at the site under built-out conditions, aside from some relatively minor permitting benefits associated with using an existing outfall to the Skagit River, the existing pump station infrastructure provides little practical benefit to the future stormwater plan. As an option the County should consider abandoning the existing Dunbar pump station and locating the replacement pump station more centrally within the area of expected development. One option for a new location is the intersection of SR-536 and Moore's Garden Road. This intersection, at a regional low-point topographically, is only 800 feet further from the Skagit River than the existing pump station location. There would be additional cost to construct a longer force main to the river (relative to the cost opinion provided for the existing pump station location in Section 5.2.1) but those costs would be at least partially offset by administrative and operational efficiencies gained by locating the force-main within the Moore's Garden Road public right-of-way instead of routing it across private property. Any decision regarding relocating the pump station should include a more detailed evaluation of increased permitting costs associated with adding a new outfall instead of continuing to discharge at the existing outfall location.

5.2.1 Engineers Opinion of Probable Cost

An engineer's opinion of probable cost (cost estimate) developed for the core stormwater trunk system, with a new pump station located the same location as the existing Dunbar Road pump station, has been provided for planning purposes only. Quantity and cost estimate details are provided in Appendix D. Construction costs, including a 30% contingency adjustment, are estimated at 4.0 million dollars for the option including construction of a pump station with 60 cfs of capacity. In addition to the construction cost, the project should also plan for an additional 2.1 million dollars for engineering, construction management, permitting, and sales tax. The total project cost is estimated at 6.1 million dollars.

6 CLOSURE

This initial phase of the Dunbar Road Stormwater Management Plan described herein provides the County with a better understanding of existing problems observed within the study area, recommendations for immediate improvements that can be made to improve the existing pump station and local conveyance system, and one recommended option for future stormwater management.

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USACE Skagit River Flood Risk Management General Investigation

Appendix A

Innovac CCTV Inventory

INNOVAC
INNOVATIVE VACUUM SERVICES

Innovac
20909 70th Ave W
Edmonds, WA 98026
Tel: 206-.783.3317
Fax: 206.783.9109
E-mail: service@innovac.com

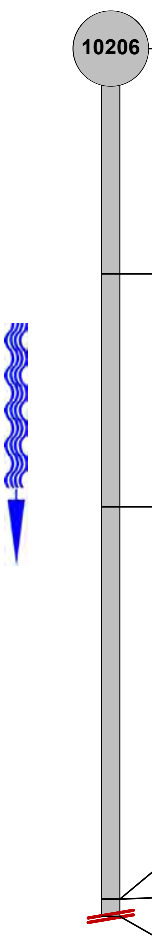
Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
1/26/2016			**Tim**	**-**	**1**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**10206**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**Unknown**
Loc. details		Flow Control		Dir. of Survey	**Downstream**
Location Code		Length surveyed	**79.13 ft**	Section Length	**79.13 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**24 inch**
Year Rehabilitated		Material	**Corrugated Metal Pipe**
Tape / Media No.		Lining Method	

Add. Information :



1:210	Position	Observation	Photo
	0.00	Catch Basin / 10206	
	20.55	General Observation / Depth 3'5"	
	41.74	General Observation / Depth 3'4"	
	77.49	General Observation / Tee connection	
	77.53	General Observation / Depth 4'2"	
	79.13	Survey Abandoned / Unable to drive further	-_26012016_091533.JPG, -_26012016_091547.JPG

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	**0000**	**0**	**0**	**0**	**0**	**0**	**0**

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Sunset Ln**		**-**	**1**

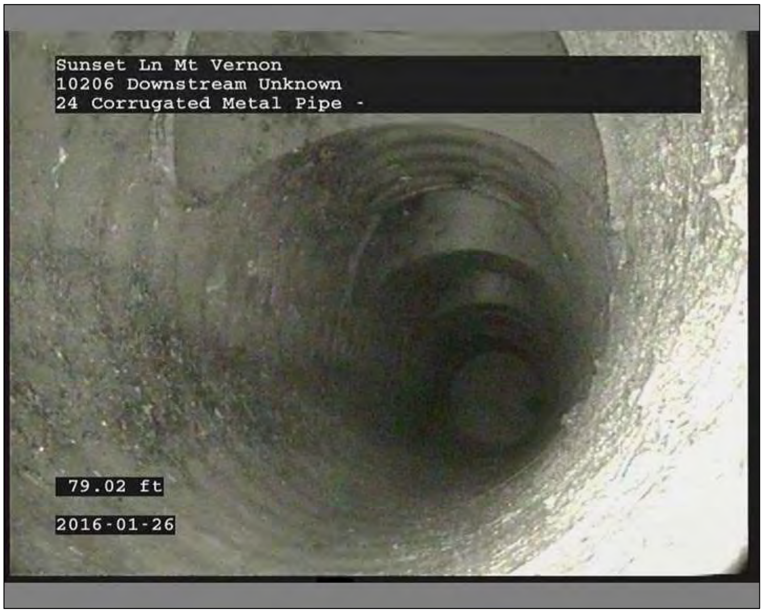

Photo: -_26012016_091533.JPG
79.13FT, Survey Abandoned

Photo: -_26012016_091547.JPG
79.13FT, Survey Abandoned

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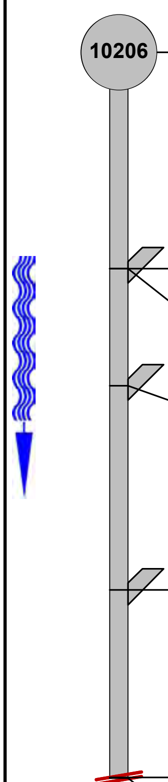
Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
1/26/2016		**Light Rain**	**Tim**	**-**	**2**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**10206**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**Unknown**
Loc. details		Flow Control		Dir. of Survey	**Downstream**
Location Code		Length surveyed	**15.74 ft**	Section Length	**15.74 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**24 inch**
Year Rehabilitated		Material	**Corrugated Metal Pipe**
Tape / Media No.		Lining Method	

Add. Information :



1:50	Position	Observation	Photo
	0.00	Catch Basin / 10206	
	4.68	Tap Factory Made, at 09 o'clock, -, within 8 inches of joint: NO, 24"	
	4.68	Material Change, Polyethylene	
	7.23	Tap Factory Made, at 09 o'clock, -, within 8 inches of joint: NO, 24"	
	11.66	Tap Factory Made, at 09 o'clock, -, within 8 inches of joint: NO, 24"	
	15.74	General Observation / Tee connection	
	15.74	Survey Abandoned / Unable to drive further	

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	0000	0	0	0	0	0	0

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Inspection Report

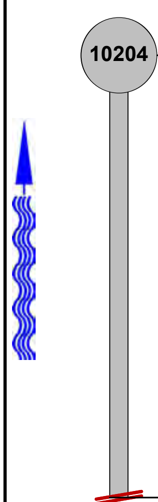
Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
1/26/2016		**Damp**	**Tim**	**-**	**3**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**Unknown**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10204**
Loc. details		Flow Control		Dir. of Survey	**Upstream**
Location Code		Length surveyed	**9.60 ft**	Section Length	**9.60 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**6 inch**
Year Rehabilitated		Material	**Polyvinyl Chloride**
Tape / Media No.		Lining Method	

Add. Information :

1:50	Position	Observation	Photo
	0.00	Manhole / 10204	
	9.60	Survey Abandoned / Debris	



QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	**0000**	**0**	**0**	**0**	**0**	**0**	**0**

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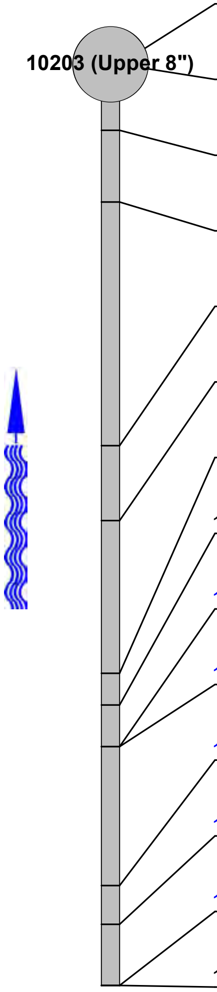
Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**4**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**Unknown (10207)**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10203 (Upper 8")**
Loc. details		Flow Control		Dir. of Survey	**Upstream**
Location Code		Length surveyed	**204.50 ft**	Section Length	**204.50 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**8 inch**
Year Rehabilitated		Material	**Polyethylene**
Tape / Media No.		Lining Method	

Add. Information :



1:360	Position		Observation	Photo
	0.00		Catch Basin / 10203	
	0.00		Water Level, 5 %of cross sectional area	
	10.24		General Observation / Depth 1'8"	
	21.45		Alignment Left, 45 % / Depth 1'10"	
	59.56		Water Level, Sag in pipe, 5 %of cross sectional area	
	71.23		Water Level, Sag in pipe, 5 %of cross sectional area	
	95.09	S1	Water Level, Sag in pipe, 10 %of cross sectional area, Start	
	100.06		General Observation / Depth 1'7"	
	106.50	F1	Water Level, Sag in pipe, 10 %of cross sectional area, Finish	
	106.50	S2	Water Level, Sag in pipe, 25 %of cross sectional area, Start	
	128.28	F2	Water Level, Sag in pipe, 25 %of cross sectional area, Finish	
	134.33	S3	Water Level, Sag in pipe, 25 %of cross sectional area, Start	
	143.82	S4	Water Level, Sag in pipe, 25 %of cross sectional area, Start	
	143.82		General Observation / Pump water from U/S CB	

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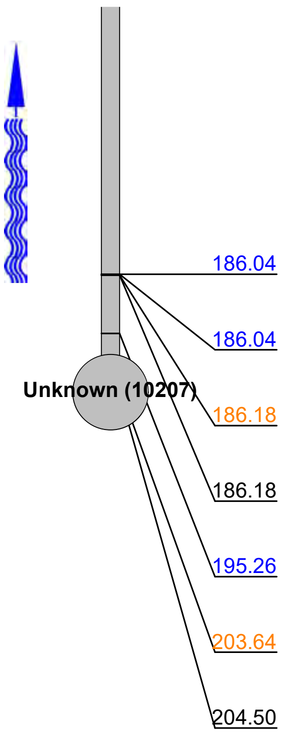
Inspection Report

Date :	Job number :	Weather :	Operator :	Counter :	Section name :
		Dry	**Tim**	**4**	
Present :	Vehicle :	Camera :	Preset :	Cleaned :	Rate :
				No Pre-Cleaning	

1:360	Position		Observation	Photo
	186.04	F4	Water Level, Sag in pipe, 25 %of cross sectional area, Finish	
	186.04	F3	Water Level, Sag in pipe, 25 %of cross sectional area, Finish	
	186.18	S5	Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Start	
	186.18		General Observation / Depth 1'4"	
	195.26		Alignment Left, 20 % / Depth 1'4"	
	203.64	F5	Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Finish	
	204.50		Catch Basin / 10207	



QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
2600	**4131**	**12**	**9**	**21**	**2**	**3**	**2.33**

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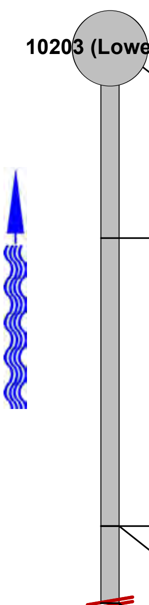
Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**5**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**Unknown**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10203 (Lower 8")**
Loc. details		Flow Control		Dir. of Survey	**Upstream**
Location Code		Length surveyed	**12.04 ft**	Section Length	**12.04 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**8 inch**
Year Rehabilitated		Material	**Polyethylene**
Tape / Media No.		Lining Method	

Add. Information :



1:50 Position		Observation	Photo
0.00		Catch Basin / 10203 (Lower 8")	
0.00		Water Level, 5 %of cross sectional area	
4.11	S1	Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Start	Unknown10203 (Lower 8)27072016_114017.JPG
10.36		Material Change, Concrete pipe (non-reinfored)	
10.36		Joint Angular Medium	Unknown10203 (Lower 8)27072016_114126.JPG
12.04	F1	Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Finish	
12.04		General Observation / Depth 3'	
12.04		Survey Abandoned / Unable to make bend	Unknown10203 (Lower 8)27072016_114849.JPG

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
1100	**3100**	**1**	**3**	**4**	**1**	**3**	**2**

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Sunset Ln**			**5**

Photo: Unknown10203 (Lower 8)27072016_114017.JPG
4.11FT, Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Start

Photo: Unknown10203 (Lower 8)27072016_114126.JPG
10.36FT, Joint Angular Medium

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Sunset Ln**			**5**

Photo: Unknown10203 (Lower 8)27072016_114849.JPG
12.04FT, Survey Abandoned

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Inspection Report

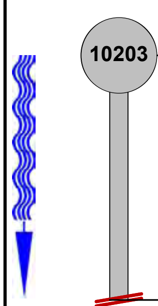
Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**6**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**10203**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**Unknown**
Loc. details		Flow Control		Dir. of Survey	**Downstream**
Location Code		Length surveyed	**5.31 ft**	Section Length	**5.31 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**12 inch**
Year Rehabilitated		Material	**Polyethylene**
Tape / Media No.		Lining Method	

Add. Information :

1:50	Position	Observation	Photo
	0.00	Catch Basin / 10203 (12" South)	
	5.30	Survey Abandoned / Deposits	



QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	**5100**	**0**	**5**	**5**	**0**	**5**	**5**

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Sunset Ln**			**6**

Photo: 10203Unknown27072016_120247.JPG
5.31FT, Deposits Settled Fine, 60 %of cross sectional area, from 03 to 09 o'clock, ,
within 8 inches of joint: NO

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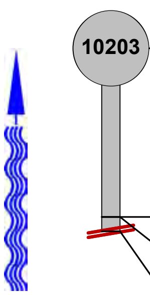
Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**7**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**10204**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10203**
Loc. details		Flow Control		Dir. of Survey	**Upstream**
Location Code		Length surveyed	**3.96 ft**	Section Length	**3.96 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**12 inch**
Year Rehabilitated		Material	**Polyethylene**
Tape / Media No.		Lining Method	

Add. Information :



1:50 Position	Observation	Photo
0.00	Catch Basin / 10203	
3.66	Alignment Right, 45 %	
3.66	Deposits Settled Fine, 30 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES	
3.96	Survey Abandoned / Deposits	102041020327072016_121958.JPG

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	**4200**	**0**	**8**	**8**	**0**	**4**	**4**

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Sunset Ln**			**7**

Photo: 102041020327072016_121958.JPG
3.96FT, Survey Abandoned

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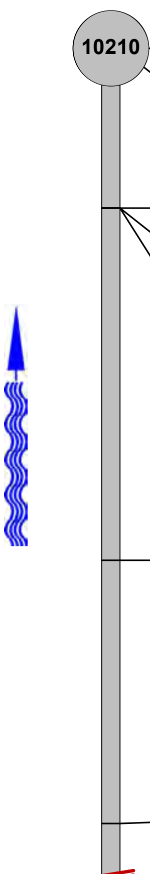
Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**8**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Sunset Ln**	Use of Sewer	**Stormwater**	Upstream MH	**Unknown**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10210**
Loc. details		Flow Control		Dir. of Survey	**Upstream**
Location Code		Length surveyed	**30.18 ft**	Section Length	**30.18 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**12 inch**
Year Rehabilitated		Material	**Concrete Pipe (non-reinforced)**
Tape / Media No.		Lining Method	

Add. Information :



1:84	Position		Observation	Photo
	0.00		Manhole / 10210	
	0.00	S1	Deposits Settled Fine, 25 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Start	
	5.82		General Observation / Dunbar Rd	
	5.82		Alignment Left, 20 %	
	5.82		Joint Angular Medium	
	18.67		Joint Separated Medium / Soil Visible	Unknown1021027072016_125738.JPG
	28.24		Joint Separated Medium / Soil Visible	Unknown1021027072016_125838.JPG
	30.18	F1	Deposits Settled Fine, 25 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Finish	
	30.18		Survey Abandoned / Offset/Deposits	

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
1300	4121	3	6	9	1	3	1.8

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Sunset Ln**			**8**

Photo: Unknown1021027072016_125738.JPG
18.67FT, Joint Separated Medium

Photo: Unknown1021027072016_125838.JPG
28.24FT, Joint Separated Medium

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Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**9**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Dunbar Rd**	Use of Sewer	**Stormwater**	Upstream MH	**10210**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10156**
Loc. details		Flow Control		Dir. of Survey	**Downstream**
Location Code		Length surveyed	**193.02 ft**	Section Length	**193.02 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**24 inch**
Year Rehabilitated		Material	**Corrugated Metal Pipe**
Tape / Media No.		Lining Method	

Add. Information :

1:490	Position	Observation	Photo
10210	0.00	Manhole / 10210	
	120.15	Tap Break-In Intruding, at 11 o'clock, -, -, within 8 inches of joint: NO, 8", 6" / Depth 3'9"	
10156	193.02	Manhole / 10156	

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	3100	0	3	3	0	3	3

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Inspection Report

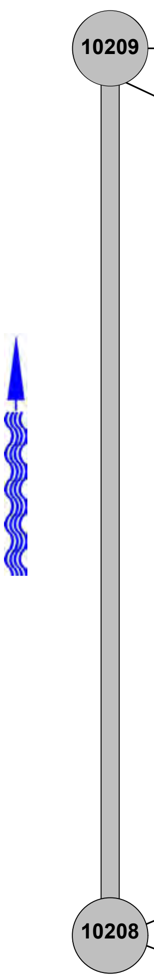
Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**10**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Dunbar Rd**	Use of Sewer	**Stormwater**	Upstream MH	**10208**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**10209**
Loc. details		Flow Control		Dir. of Survey	**Upstream**
Location Code		Length surveyed	**91.63 ft**	Section Length	**91.63 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**12 inch**
Year Rehabilitated		Material	**Concrete Pipe (non-reinforced)**
Tape / Media No.		Lining Method	

Add. Information :

1:238	Position		Observation	Photo
10209	0.00		Catch Basin / 10209	
	3.20	S1	Deposits Settled Fine, 25 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Start	
	91.63	F1	Deposits Settled Fine, 25 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Finish	
10208	91.63		Catch Basin / 10208	



QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	4100	0	4	4	0	4	4

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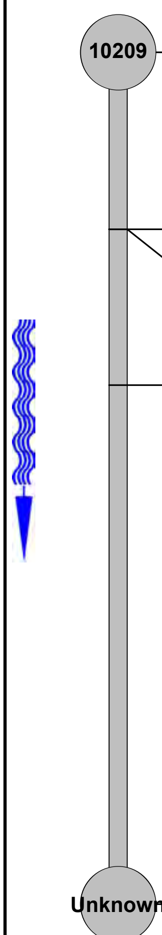
Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**11**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Dunbar Rd**	Use of Sewer	**Stormwater**	Upstream MH	**10209**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**Unknown**
Loc. details		Flow Control		Dir. of Survey	**Downstream**
Location Code		Length surveyed	**20.71 ft**	Section Length	**20.71 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**12 inch**
Year Rehabilitated		Material	**Concrete Pipe (non-reinforced)**
Tape / Media No.		Lining Method	

Add. Information :



1:56	Position	Observation	Photo
	0.00	Catch Basin / 10209	
	4.30	Joint Separated Medium / Soil Visible	10209Unknown27072016_143844.JPG
	4.30	Alignment Left, 20 %	
	8.08	Joint Separated Medium / Soil Visible	
	20.71	Manhole / 10210	

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
1200	2100	2	2	4	1	2	1.33

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Inspection photos

City :	Street :	Date :	Pipe Segment Reference :	Section No :
Mt Vernon	**Dunbar Rd**			**11**

Photo: 10209Unknown27072016_143844.JPG
4.3FT, Joint Separated Medium

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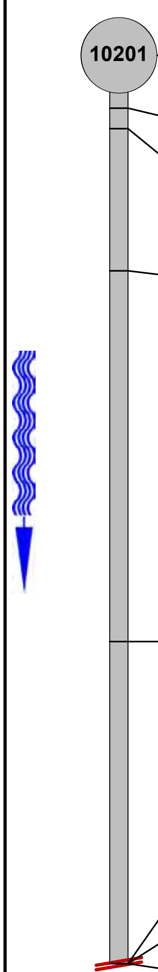
Inspection Report

Date	P/O. No.	Weather	Surveyor's Name	Pipe Segment Reference	Section No.
7/27/2016		**Dry**	**Tim**		**12**
Certificate No.	Survey Customer	System Owner	Date Cleaned	Pre-Cleaning	Sewer Category
U-1208-7919				**No Pre-Cleaning**	

Street123	**Dunbar Rd**	Use of Sewer	**Stormwater**	Upstream MH	**10201**
City	**Mt Vernon**	Drainage Area		Dowstream MH	**Unknown**
Loc. details		Flow Control		Dir. of Survey	**Downstream**
Location Code		Length surveyed	**55.17 ft**	Section Length	**55.17 ft**

Purpose of Survey	**Maintenance Related**	Joint Length	
Year Laid		Dia./Height	**12 inch**
Year Rehabilitated		Material	**Polyethylene**
Tape / Media No.		Lining Method	

Add. Information :



1:140 Position		Observation	Photo
0.00		Catch Basin / 10201	
3.20	S1	Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Start	
4.46		Alignment Right, 25 %	
13.09		Alignment Right, 25 %	
35.58		Alignment Right, 15 %	
55.16	F1	Deposits Settled Fine, 15 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES, Finish	
55.16		Deposits Settled Fine, 25 %of cross sectional area, from 04 to 08 o'clock, , within 8 inches of joint: YES / Depth 4'	
55.17		Survey Abandoned / Deposits	

QSR	QMR	SPR	MPR	OPR	SPRI	MPRI	OPRI
0000	4331	0	17	17	0	3.4	3.4

Appendix B

HSPF Model Land Use, Including Area Outside Study Area

Table B1: Model Domain Land Use

Comprehensive Plan Zoning		Non-Conforming Use Sub Area	Area (acres)	Existing Residential Density (DU per Acre[1])	Future Landuse Adjusted for Non-Conforming Uses
Skagit County	Mount Vernon				
Outside Mt. Vernon UGA					
[Ag-NRL] Agricultural			168.2	0.3	Rural
[RRv] Rural Reserve		West of Dunbar Court	9.1	NA	Commercial
[RRv] Rural Reserve		Tax Parcels P21763 and P21764	4.3	NA	Commercial
[RRv] Rural Reserve		East of Tax Parcels P21763 and P21764 to Dunbar Road	17.9	0.9	Single Family Residential – Low
[RRv] Rural Reserve		Dunbar Road to Moore's Garden Road	37.1	2.0	Single Family Residential – Medium
Inside Mt. Vernon UGA					
[URC-I] Urban Reserve Commercial Industrial	[CL or GC] Commercial		70.0	NA	Commercial
[URR] Urban Reserve Residential	[SF-HI] Single Family - High Density		54.6	2.5	Single Family Residential – Medium
Mt. Vernon Incorporated Area					
Incorporated	[CL or GC] Commercial		66.1	NA	Commercial
Incorporated	[CL or GC] Commercial	Radio Tower Depressions	13.0	NA	Pasture
Incorporated	Multi Family - High Density		9.0	4.3	Multi-Family Residential
Incorporated	Single Family - High Density		42.9	3.0	Single Family – High
Incorporated	Park		4.2	NA	Grass
Total Model Domain			490.3		

[1] Each parcel is assumed to have one dwelling unit

Appendix C

AESI Groundwater Seepage Analysis Memorandum, Dated November 30, 2016

associated earth sciences incorporated

November 30, 2016
Project No. EH140673A

Northwest Hydraulic Consultants
16300 Christiansen Road, Suite 350
Seattle, Washington 98188

Attention: Mr. Derek Stuart

Subject: Ground Water Seepage Analysis
Dunbar Road Drainage Improvements
Skagit County, Washington

INTRODUCTION

This report presents the results of Associated Earth Sciences, Inc. (AESI) analysis of potential ground water seepage into proposed drainage improvements designed by Northwest Hydraulic Consultants (NHC) in the Dunbar Road area of Skagit County, Washington. The project area is located west of the City of Mount Vernon, in unincorporated Skagit County, as shown on the *"Vicinity Map"*, Figure 1. The project area generally experiences various amounts of nuisance flooding as a result of stormwater runoff and elevated ground water (seepage) in low-lying areas. Skagit County has contracted with NHC to design proposed drainage improvements to help alleviate the flooding and accommodate future development. The proposed drainage improvements may include a network of open ditches as presented on the *"Site Map"*, Figure 2. NHC sub-contracted to AESI to help evaluate the quantity and timing of ground water seepage into the proposed drainage system improvements if open ditches are used.

PURPOSE AND SCOPE

The purpose of our work was to assist NHC with the design of the drainage system in the project area by estimating the rates of potential ground water seepage into the proposed drainage improvements. Specifically, our scope of work included:

1. A review of available information regarding the subsurface soil and ground water characteristics of the project area, including:
   a. Studies by the U.S. Geological Survey (USGS - SIR 2009-5208, SIR 2009-5270, SIR 2010-5184).

b. Anecdotal information of drainage issues from the Washington State Department of Transportation (WSDOT), Skagit County, and Dike District 01 (Personal communication, 2015a, 2015b, 2015c).

c. Water level data collected by NHC in a ground water monitoring well near Jackpot Lane and in surface water depression near the KBRC radio towers on Memorial Highway (Figure 2).

2. Participation in an on-site field meeting with NHC and WSDOT to discuss the drainage concerns, and the concepts, goals, and limitations of the potential drainage improvements in the project area.

3. Preparation of a MODFLOW numerical ground water flow model to estimate the quantity and timing of ground water seepage into the proposed improved drainage system in the project area. The MODFLOW model was calibrated based on information from the USGS (Savoca, et al., 2009a; Savoca, et al., 2009b) and observations from ground water levels collected by NHC.

SUBSURFACE SOIL AND GROUND WATER CONDITIONS

The project area is generally located in what is referred to as the Skagit River Delta Area, west of Mount Vernon, in Skagit County (Figure 1). The Skagit River Delta Area is bounded by the Skagit River to the east and south, and the Swinomish Channel, Padilla Bay (all parts of Puget Sound) to the West (Savoca, et al., 2009a). The USGS has recently conducted numerous studies on the subsurface geologic and ground water conditions in the Skagit River Basin, including Savoca, et al. (2009a), Savoca, et al. (2009b), Frasser and Julich (2009), and Johnson and Savoca, (2010). A brief summary of the subsurface geologic and ground water conditions presented in those studies for the project area are outlined below:

- The project area is predominantly underlain by both alluvium (Qa) and lahar runout deposits (Qvl) (Savoca et al., 2009a, 2009b).
- Alluvium (Qa) consists of active or abandoned channel and overbank deposits associated with the present and ancient Skagit River. Channel deposits typically are coarse grained and consist of loose sand and gravel. Overbank deposits consist mostly of soft to stiff, stratified sand, silt, and clay (Savoca et al., 2009a).
- Lahar runout deposits (Qvl) consist of loose, well-sorted massive to normally graded medium to fine grained volcanic sand originated from Glacier Peak eruptive events (Savoca et al., 2009a).
- Ground water is present at shallow depths within the Qa and Qvl deposits beneath the

project area. Ground water is generally unconfined where it is not fully saturated or exposed at the land surface (Savoca et al., 2009b).

- Ground water beneath the project area occurs in what has been generalized as the Alluvial and Recessional Outwash (Qago) Aquifer by the USGS (Savoca et al., 2009a). The median horizontal hydraulic conductivity for the Qago Aquifer was estimated at 47 feet per day (ft/d) (Savoca et al., 2009a).
- Ground water level monitoring data collected by the USGS (Savoca et al., 2009b) indicate shallow ground water flows beneath the project area generally to the west at a gradient of approximately 0.0005 to 0.0006 feet per foot (ft/ft) (2.5 to 3 feet per mile [ft/mi]). The seasonal fluctuation in ground water levels beneath the project area are approximately 4 feet. The overall flow direction remains generally east to west throughout the year.
- Ground water levels in wells along the eastern boundary of the project area are influenced by the stage of the Skagit River (Savoca et al., 2009b).
- Ground water level data collected by NHC in a monitoring well along Jackpot Lane, including stage data from the USGS streamflow gaging station on the Skagit River at Mount Vernon is presented in the "Ground Water Level and River Stage Hydrograph" – Figure 3 The data demonstrates a strong correlation between ground water levels and river stage, as described in Savoca et al. (2009b).
- Observations by Dike District 01 indicate that ground water seepage is prevalent in certain locations within the project area in response to elevated Skagit River stages. The area around Jackpot Lane is known to have significant ground water seepage when the Skagit River is at a stage above approximately 20 feet NVGD 88 (Personal communication, 2015a).

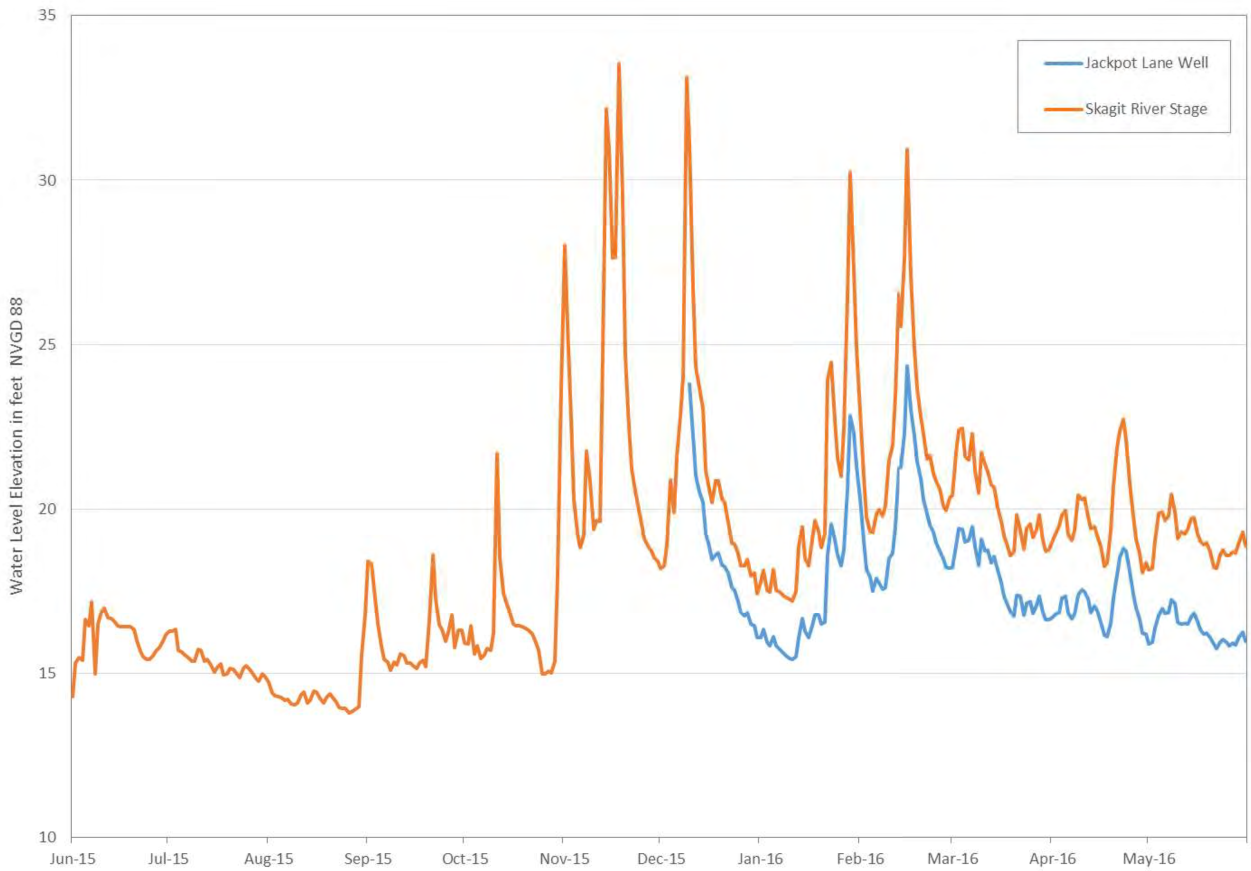


Figure 3. Ground Water Level and River Stage Hydrograph, June 2015 – May 2016

SEEPAGE EVALUATION METHOD

General

As discussed previously, NHC has been contracted by Skagit County to evaluate the current drainage system in the project area and to design proposed improvements to the system to alleviate seasonal nuisance flooding. NHC is designing drainage improvements to accommodate seepage resulting from seasonally high ground water. Stormwater runoff and seepage intercepted by the drainage system improvements will be conveyed to a pump station that will pump the water to the Skagit River. AESI developed a numerical ground water flow model (MODFLOW) to simulate ground water conditions in the project area and estimate the rate and timing of ground water seepage into the proposed drainage system.

MODFLOW Setup

The MODFLOW computer software program was used to model ground water flow within the project area and ground water seepage rates into the drainage system. MODFLOW solves a system of linear ground water flow equations using a finite difference methodology. Visual MODFLOW, developed by Waterloo Hydrogeologic, Inc., was used as a graphic interface to facilitate input and analyze output from MODFLOW. The finite-difference method solves a set of differential-flow equations to find the distribution of ground water elevations (or "head") for the model domain. This is accomplished by placing a network of grid cells over the flow system of the model domain and calculating the heads at each node.

As discussed above, the ground water system beneath the project area occurs within alluvial and lahar runout deposits in what is generally referred to as the Alluvial and Recessional Outwash Aquifer (Qago). The following is a brief discussion of the design/construction and input parameters in the MODFLOW model constructed for this project. Figures depicting the model domain and boundary conditions are provided in Attachment A. MODFLOW input and output files are available digitally as Attachment B.

<u>Domain and Grid</u>
The MODFLOW model domain was defined as a 13,000 foot by 12,000 foot grid with cell sizes of 100 feet by 100 feet. The model domain and grid is presented in Attachment A in the *"MODFLOW Model Domain"* - Figure A-1 and *"MODFLOW Model Domain and Grid"* - Figure A-2.

<u>Layers</u>
The model developed for the project included two layers to represent the general subsurface conditions at the site. Although the subsurface conditions beneath the site only includes the Qago Aquifer, utilizing two layers allows for the distinction of the Skagit River dike to be incorporated into the model. The ground surface elevation of the project area was determined by Light Detecting and Ranging (LiDAR) data and indicate the ground surface in the project area

range from approximately 30 NGVD88 at the top of the Skagit River Dike to approximately 15 feet NGVD88 at the south west corner of the model domain. The base of the model was set at an elevation of -100 feet NGVD88.

Layer 1 – Dike/Qago: The uppermost layer in the model includes cells down to an elevation of -5 feet to represent the Skagit River Dike, which is reportedly up to 35 feet thick (Personal Communication, 2015a). The area outside the dike includes the Qago sediments and aquifer.

Layer 2 – Qago: Layer 2 in the model also represents the Qago Aquifer, down to a depth of -100 feet NGVD88.

Boundary Conditions

In MODFLOW, boundary conditions are used to represent the exchange of flow between the model domain (grid) and the external system (inactive cells). The model for this project included constant head cells, river cells, drain cells, and recharge cells as described below.

Constant Head Boundary Cells

We used constant head boundary cells along the west edge of the model domain for Layer 1, set at an elevation of 12 feet during the initial calibration of the model, described below. The constant head cells are presented on the *"MODFLOW Layer 1 Boundary Cells"* (Figure A-3).

River Cells

River cells were assigned to Layer 1 to simulate the interaction between the Skagit River and the Qago Aquifer. River cells were assigned an elevation near the ground surface at each cell and riverbed conductance were assigned values of 10,000 feet^2/day to represent a high degree of hydraulic conductivity between the river and aquifer. The head values for the river cells were based on the average Skagit River stage for steady-state simulations and the Skagit River stage between June 1, 2015 and May 31, 2016 for transient simulations. River stages were measured by the USGS at Mount Vernon (USGS station 12202500). The river cells are presented on the *"MODFLOW Layer 1 Boundary Cells"* (Figure A-3).

Drain Cells

Drain cells were assigned to Layer 1 to simulate the ground water discharge from the Qago Aquifer into a hypothetical ditch drainage network. The locations of the drain cells were assigned to individual cells in the model to represent the linear drainage ditch network and lengths provided by NHC. The elevations of the drain cells were based on the designed bottom of ditch elevations, as provided by NHC, and were assigned conductance values of 10,000 feet^2/day to represent the high degree of hydraulic continuity between the aquifer and the drainage system. A summary of the hypothetical ditch network segments modeled as drains is provided in Table 1. The locations of the drain cells are presented on the *"MODFLOW Layer 1 Boundary Cells"* (Figure A-3).

Table 1
Summary of Drainage Ditch (Drain) Network

Ditch (Drain)	Bottom Elevation Start (ft NGVD88)	Bottom Elevation End (ft NGVD88)	Total Length (ft)
Drain 0	19.09	15.07	1,950
Drain 1	16.26	14.90	2,900
Drain 2	21.97	16.26	1,300
Drain 3	19.38	16.26	750
Drain 4	16.44	12.34	875
Drain 5	16.50	13.89	800
Drain 6	16.69	14.79	500
Drain 7	17.51	15.66	750
Drain 8	15.65	14.63	475
Drain 9	22.00	15.16	1,450

Recharge Cells

Recharge cells were assigned to Layer 1 to simulate the natural ground water recharge through the infiltration of direct precipitation to the model domain. Daily ground water recharge was assigned to the model domain during transient simulations as 50% of the daily precipitation measured at the Mount Vernon 3.4W climate station (ID: GHCND:US1WASG0023) for the period between June 1, 2015 and May 31, 2016. A 50% recharge rate is consistent with the recharge rate applied to the project area by the USGS in previous studies (Johnson and Savoca, 2010).

Aquifer Properties

Hydraulic conductivities and storage values for the Qago Aquifer were estimated based on data from the USGS (Savoca et al., 2009a; Johnson and Savoca, 2010). Those studies estimate the hydraulic conductivity of the Qago ranges from 0.04 to 1,322 ft/day with a median value of 47 ft/day. The hydraulic conductivity for the Qago Aquifer and dike material were initially set at 50 and 10 ft/day, respectively and adjusted during the calibration process.

Initial Heads

The initial heads (ground water elevations) for the Qago Aquifer were set at 14 feet. During the calibration process, the initial heads were adjusted to approximate the observed ground water gradient for the start of the transient simulations, as described below.

MODFLOW Calibration

Once the model setup was complete, it was run under steady-state conditions without any drains and the constant head boundary cells were adjusted to simulate a hydraulic gradient of approximately 0.0005 ft/ft from east to west across the model domain, and ground water elevations that fit observations in the Jackpot Lane well and the KBRC Radio surface water depression (Figure 2).

After this initial calibration, the simulated ground water elevations were exported to use as initial heads in the transient simulations. For the transient simulations, the head of the Skagit River cells fluctuated based on observed river stage values at the USGS gage at Mount Vernon (Station #12200500). The transient simulations were completed without the drains for the stormwater network to represent the existing site conditions. The hydraulic conductivity values of both the Qago Aquifer and dike were adjusted to calibrate the model to observed water levels NHC collected from a monitoring well at Jackpot Lane (Figure 2). Surface water elevation data collected by NHC from the KBRC Radio depression (Figure 2) are believed to reflect ground water levels and also used as a calibration point. The final calibrated horizontal hydraulic conductivity values for the Qago Aquifer and dike were 150 and 75 ft/day, respectively. Vertical hydraulic conductivity values were set at $1/10^{th}$ of the horizontal values.

A ground water elevation profile through the project area is presented in the *"Ground Water Elevation Profile"*, Figure 4. The schematic profile demonstrates the simulated ground water elevation from the calibrated MODFLOW model with a Skagit River stage of 26.6 feet NVGD88, the 7-day average peak stage observed during the calibration period from February 13 - 19, 2016. Note that the profile depicts the Skagit River dikes extending to an elevation of -5 feet NGVD88. The actual depth of the dikes is somewhat uncertain, although they are believed to be approximately 35 feet thick (Personal Communication, 2015a).

A relatively good correlation was obtained between observed and calculated head values under the transient simulations indicating a reasonable degree of calibration for the model. A calibration plot is presented in the *"Calibration Plot of Calculated vs. Observed Ground Water Elevations – Jackpot Lane"*, Figure 5 and the *"Calibration Plot of Calculated vs. Observed Ground Water Elevations – KBRC Radio"*, Figure 6.

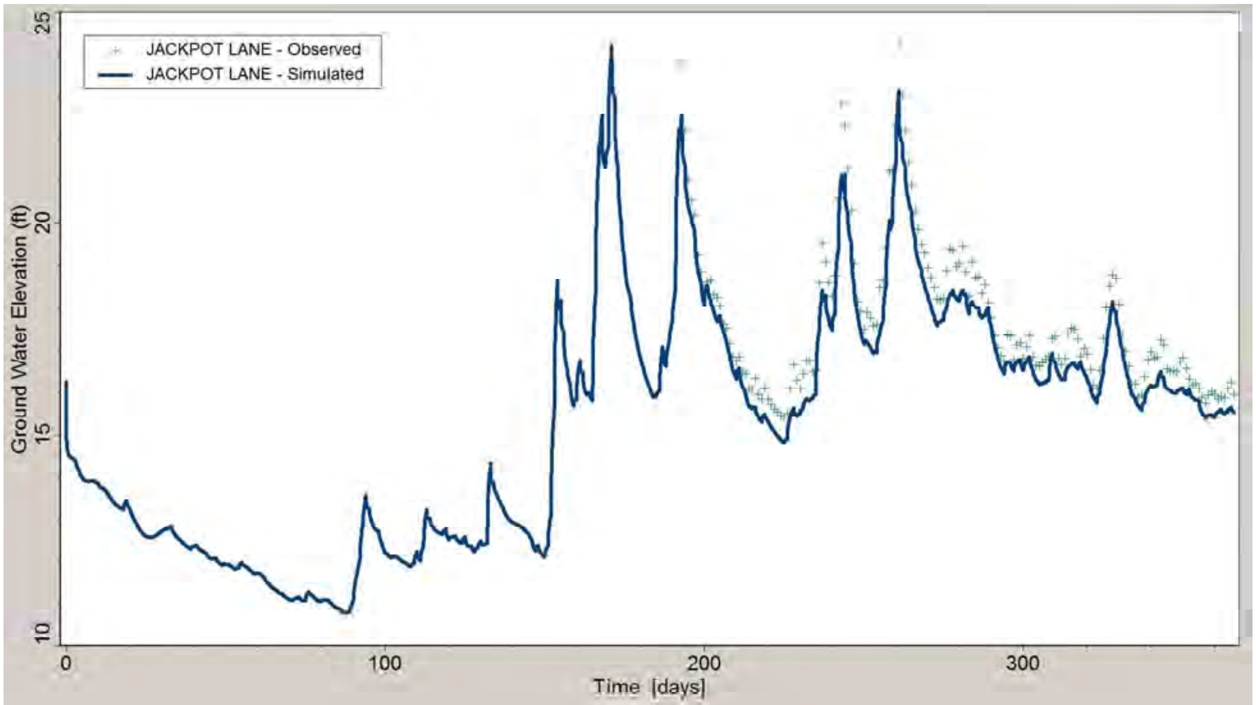


Figure 5. Calibration Plot of Calculated vs. Observed Ground Water Elevations – Jackpot Lane

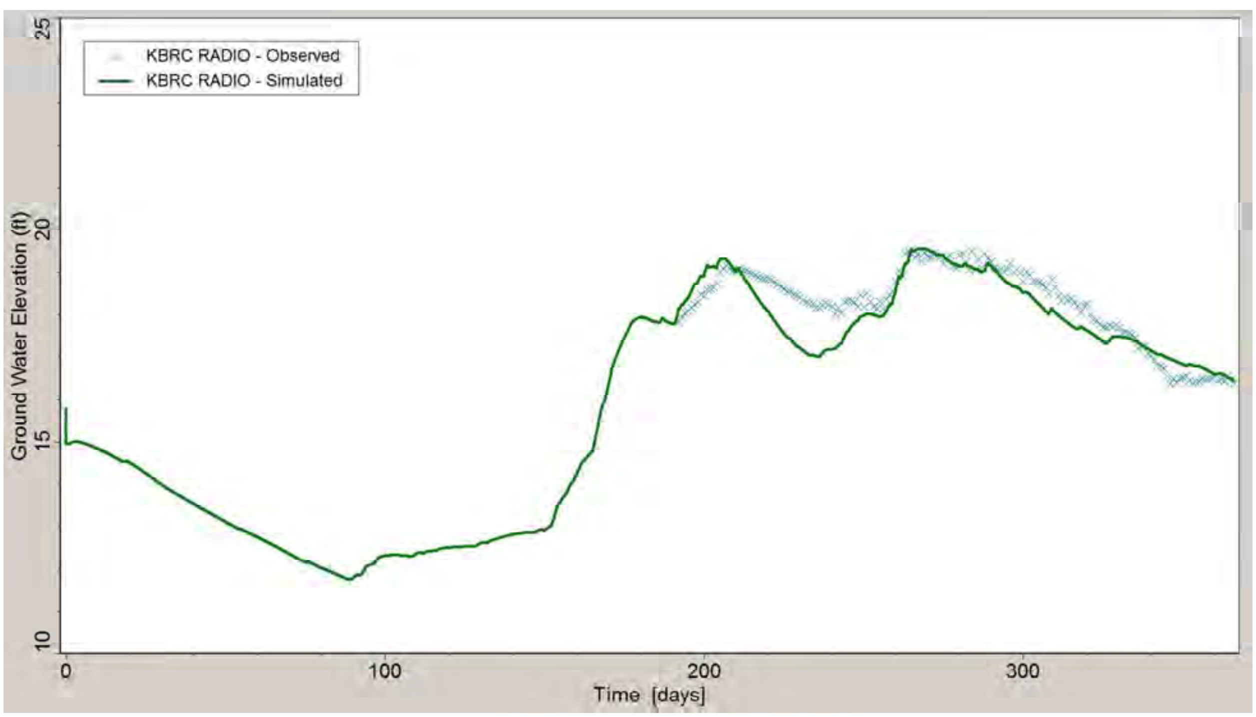


Figure 6. Calibration Plot of Calculated vs. Observed Ground Water Elevations – KBRC Radio

MODFLOW Results

The calculated ground water seepage rates into each segment of the proposed drainage improvements (labeled Drain 0 through Drain 9, Figure A-3) are presented in the *"Ground Water Seepage Rates in CFS",* Figure 7. The average monthly seepage rates are presented in Table 2. The seepage rates are based on stream stage values recorded at the USGS Mount Vernon gage between June 1, 2015 and May 31, 2016. The seepage rates vary seasonally as ground water levels fluctuate in response to seasonal precipitation and the stage of the Skagit River.

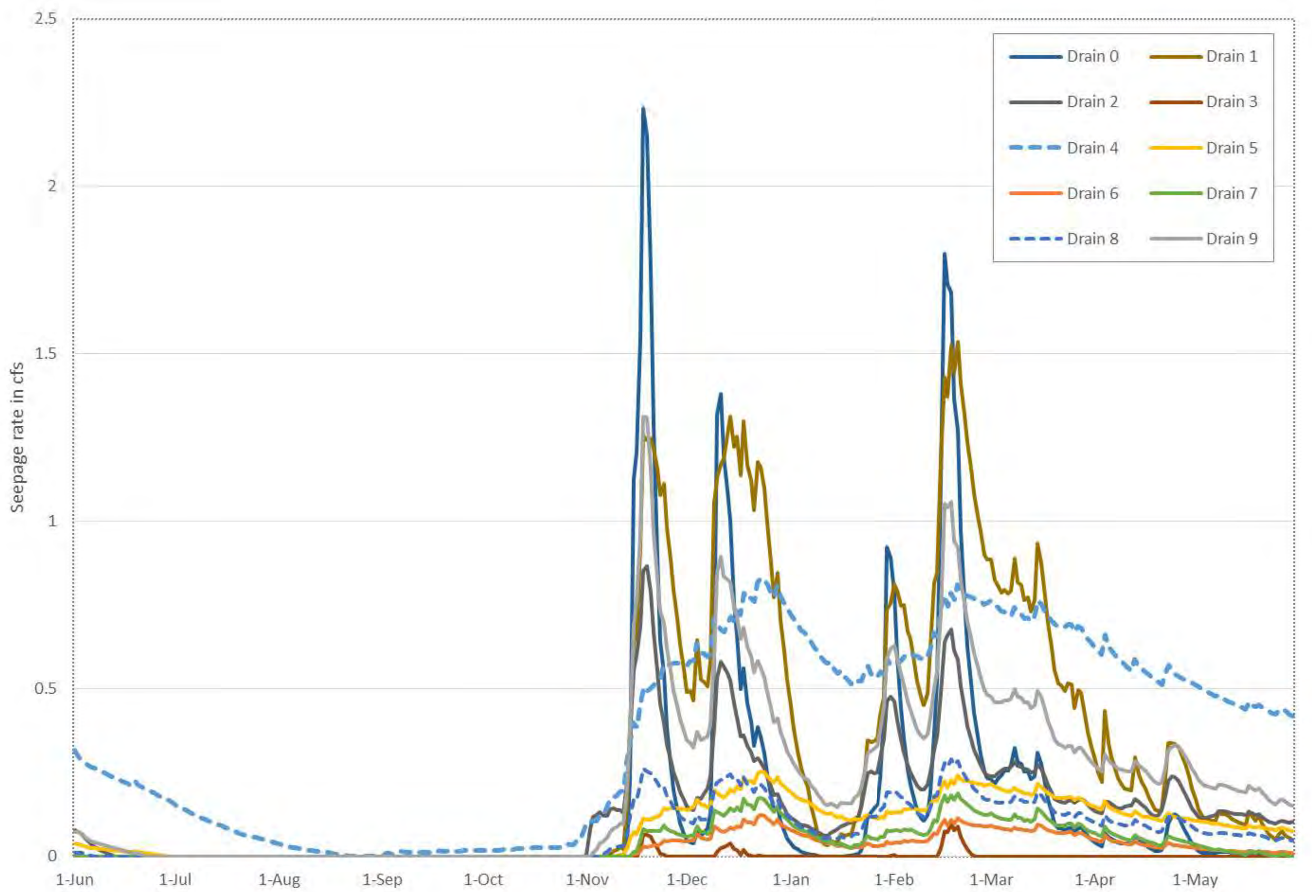


Figure 7. Ground Water Seepage Rates in CFS – June 1 – May 31, 2016

Table 2
Summary of Ground Water Seepage Rates

Month	Average Ground Water Seepage Rate in CFS									
	Drain 0	Drain 1	Drain 2	Drain 3	Drain 4	Drain 5	Drain 6	Drain 7	Drain 8	Drain 9
January	0.10	0.23	0.15	0	0.59	0.13	0.04	0.06	0.09	0.25
February	0.61	0.96	0.37	0.02	0.69	0.18	0.07	0.12	0.20	0.62
March	0.18	0.67	0.22	0	0.71	0.19	0.08	0.11	0.15	0.40
April	0.05	0.25	0.16	0	0.57	0.13	0.04	0.05	0.10	0.27
May	0.01	0.10	0.11	0	0.44	0.09	0.02	0.01	0.06	0.19
June	0	0	0.02	0	0.23	0.02	0	0	0	0.02
July	0	0	0	0	0.09	0	0	0	0	0
August	0	0	0	0	0.01	0	0	0	0	0
September	0	0	0	0	0.01	0	0	0	0	0
October	0	0	0	0	0.03	0	0	0	0	0
November	0.49	0.52	0.33	0.01	0.36	0.07	0.02	0.04	0.11	0.45
December	0.41	0.91	0.30	0	0.71	0.20	0.08	0.12	0.18	0.54

As demonstrated in Figure 7 and Tables 1 and 2, the ground water seepage rates are predictably higher in drainage system elements that are lowest in elevation (e.g. Drain 4) or elements that are longest or closest to the river (e.g. Drains 0, 1, 2, and 9).

The simulated ground water drawdown that results from the drainage ditches are also presented schematically on Figure 4. The simulated ground water elevation from the MODFLOW model with the drainage ditches is approximately 3 to 4 feet lower than the model without the ditches near Memorial Highway and Moores Garden Road. The river stage and ground water elevations depicted on Figure 4 represent the 7-day average water levels from February 13 – 19, 2016, which was generally the period of highest ground water seepage into the drainage system.

CONCLUSIONS

The ground water seepage rates presented above were estimated based on the proposed drainage system alignments and elevations provided by NHC, assuming a network of open ditches, and a calibrated numerical ground water flow model (MODFLOW). The MOFLOW simulations were based on inputs of both ground water recharge and river stages for the period of June 1, 2015 through May 31, 2016. We consider these estimates to be appropriate for design calculations for the drainage system improvements. We also consider these estimates to be conservatively high for the following reasons:

- The time period used for simulations (June 1, 2015 through May 31, 2016) was slightly wetter than average conditions for the project area. The precipitation that fell during that time period (39.4 inches) was slightly higher than the average annual precipitation for the project area (33 inches). The average monthly river stage for the Skagit River during the simulation period was also consistently higher than average during the winter months (November through April). Additionally, many daily peak stages during the simulated period were above the 90^{th} percentile for the period of record for the Skagit River gage. These peak stages are commonly associated with ground water seepage in the project area.

- The MODFLOW model was calibrated based primarily on ground water level observations from a monitoring well at Jackpot Lane. The Jackpot Lane area is one known to experience significant ground water seepage, indicating that preferential ground water flow pathways (e.g. areas of higher hydraulic conductivity) may be present in that vicinity. Because our primary calibration point was in an area of potentially higher hydraulic conductivity, the MODFLOW model would over predict ground water seepage rates in areas that may have lower hydraulic conductivities.

LMITATIONS

We prepared this letter report for use by NHC regarding the proposed drainage system improvements west of Mount Vernon, in Skagit County Washington. The information presented in this letter report is based on the above-described research and limited reconnaissance. It should be noted that subsurface conditions, particularly hydrogeologic characteristics, can vary widely over very short distances.

Within the limitations of scope, schedule, and budget, AESI attempted to execute these services in accordance with generally accepted professional principles in the field of hydrogeology at the time this letter report was prepared. No warranty, express or implied, is made.

If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Everett, Washington

State of Washington
Hydrogeologist
2556
Licensed Geologist
Jay W. Chennault

11/30/16

Jay W. Chennault, L.G., L.Hg., P.E.
Senior Hydrogeologist/Engineer

Charles S. Lindsay, L.G., L.E.G., L.Hg.
Senior Principal Geologist/Hydrogeologist

Attachments: Figure 1: Vicinity Map
Figure 2: Site Map
Figure 4: Ground Water Elevation Profile
Attachment A: MODFLOW Figures
Attachment B: Digital MODFLOW Files

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Dike District 01, 2015a, Personal communication with Jason Van Der Kooy, November 18, 2015.

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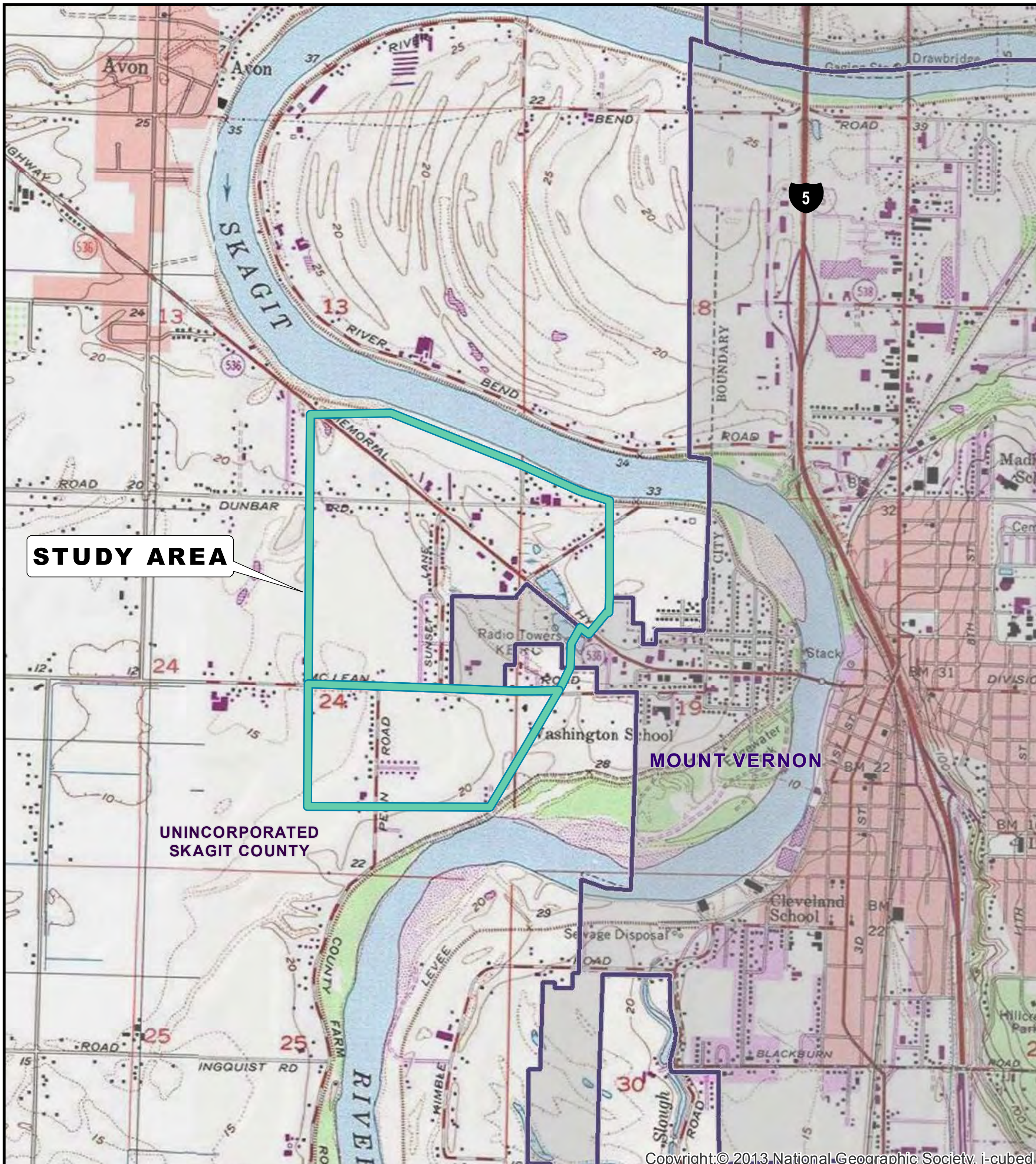

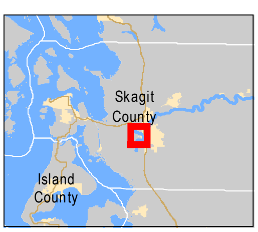

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FEET

DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
SKAGIT CO: STREETS, PARCELS, CITY BOUNDARY 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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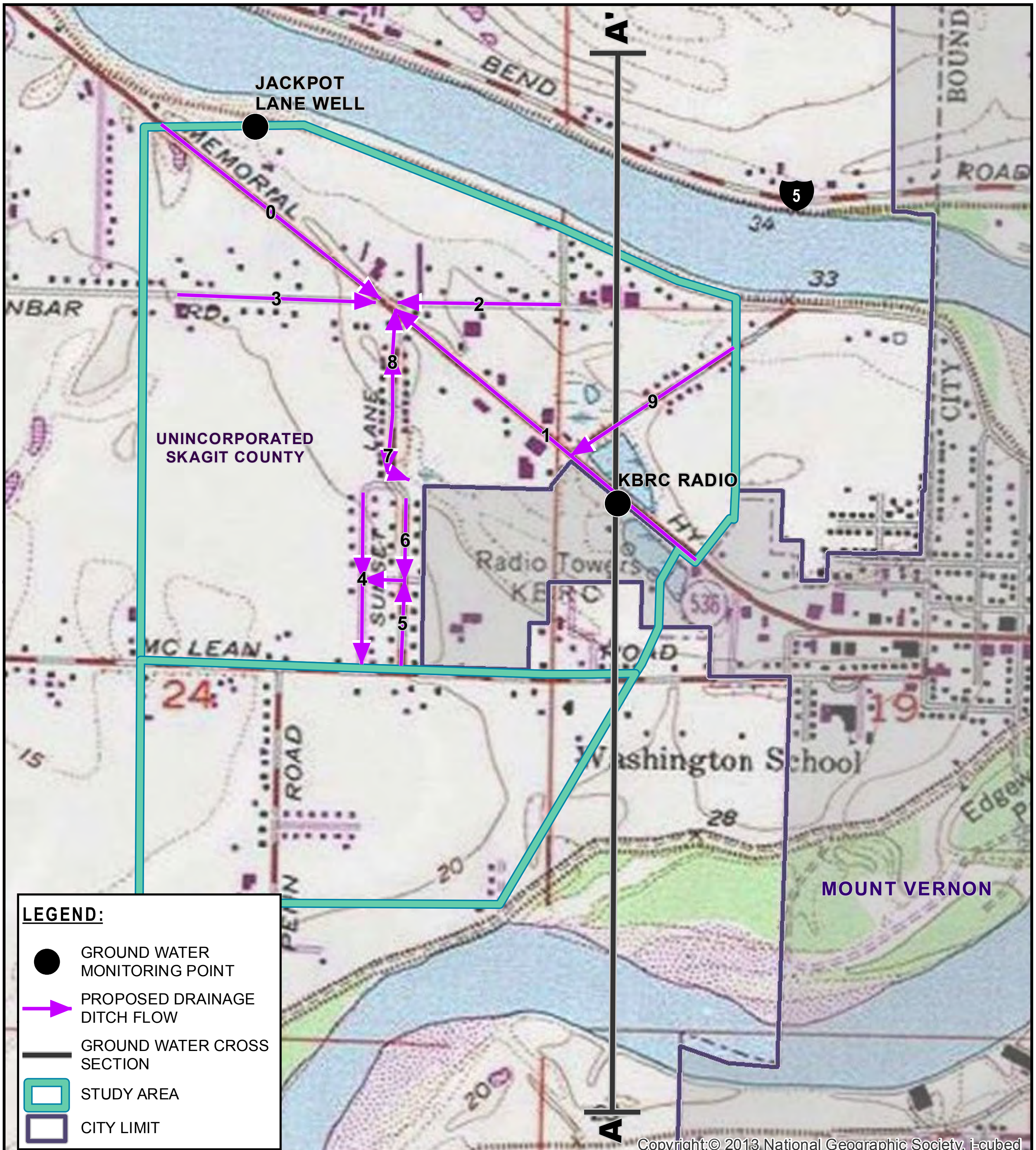
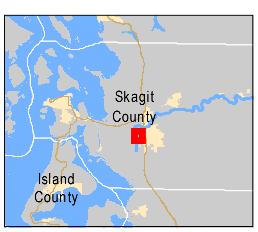
VICINITY MAP

GROUND WATER SEEPAGE ANALYSIS,
DUNBAR ROAD DRAINAGE IMPROVEMENTS
SKAGIT COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
EH140673A	11/16	1

Document Path: G:\GIS_Projects\aY14post0716\140673 GW Seepage\mxd\140673 Fig1 ProjectVicinity_Skagit.mxd





DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
SKAGIT CO: STREETS, PARCELS, CITY BOUNDARY 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

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0 500 1000
FEET

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SITE MAP

GROUND WATER SEEPAGE ANALYSIS,
DUNBAR ROAD DRAINAGE IMPROVEMENTS
SKAGIT COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
EH140673A	11/16	2

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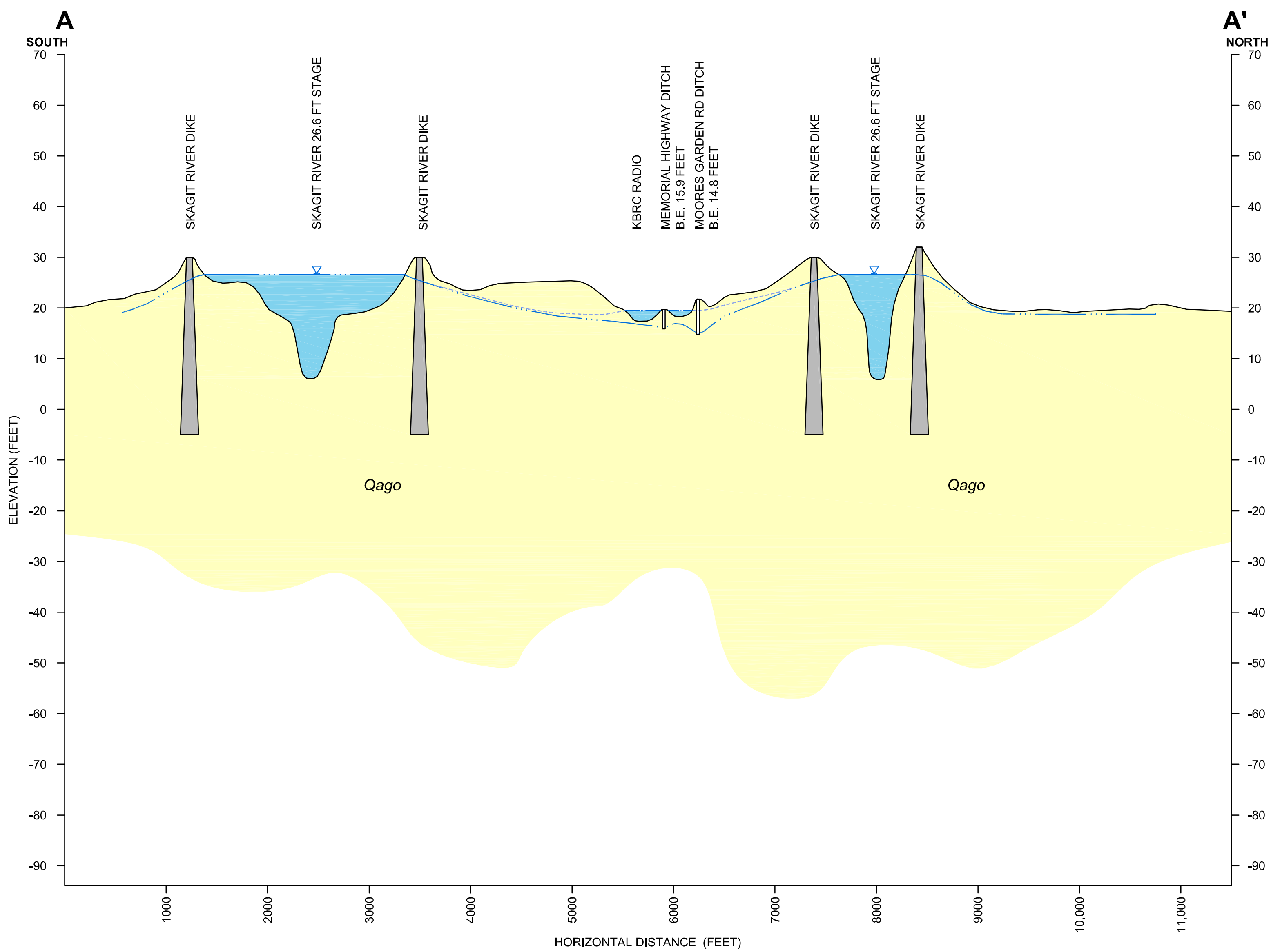

LEGEND:

Qago	SKAGIT RIVER ALLUVIAL AND RECESSIONAL OUTWASH
	SKAGIT RIVER DIKE FILL
	GROUND WATER ELEVATION WITHOUT DRAINAGE DITCHES
	GROUND WATER ELEVATION WITH DRAINAGE DITCHES
▽	SKAGIT RIVER WATER LEVEL = 26.6 FT

VERTICAL EXAGGERATION = 50X

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE

NOTES:
1. THE SUBSURFACE CONDITIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION ARE BASED ON AN INTERPRETATION OF CONDITIONS ENCOUNTERED IN WIDELY SPACED EXPLORATIONS COMPLETED AT THE SUBJECT SITE AND RELEVANT SITE INFORMATION DEVELOPED AND PROVIDED BY OTHERS. THE SUBSURFACE INTERPRETATIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION SHOULD NOT BE CONSTRUED AS A WARRANTY OF ACTUAL SUBSURFACE CONDITIONS AT THE SITE. OUR EXPERIENCE HAS SHOWN THAT SOIL AND GROUND WATER CONDITIONS CAN VARY SIGNIFICANTLY OVER SMALL DISTANCES.

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

associated earth sciences incorporated

CROSS-SECTION A - A'
GROUND WATER PROFILE
GROUND WATER SEEPAGE ANALYSIS
SKAGIT COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
EH140673A	11/16	4

140673 GW Seep \ 140673 GeoSects.dwg LAYOUT: F4 Sect A-A

ATTACHMENT A

MODFLOW FIGURES

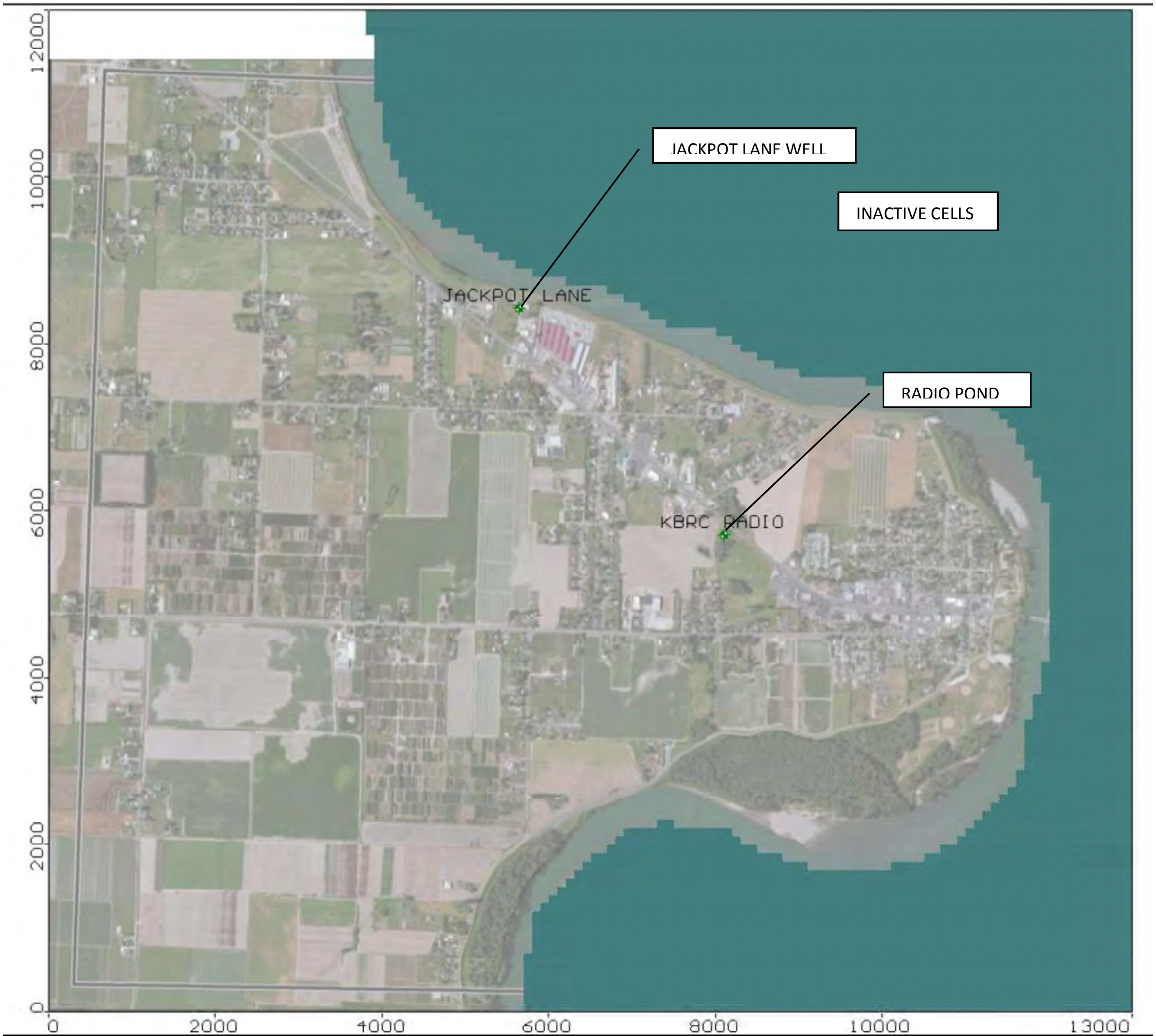

Figure A-1. MODFLOW Model Domain

Figure A-2. MODFLOW Model Domain and Grid

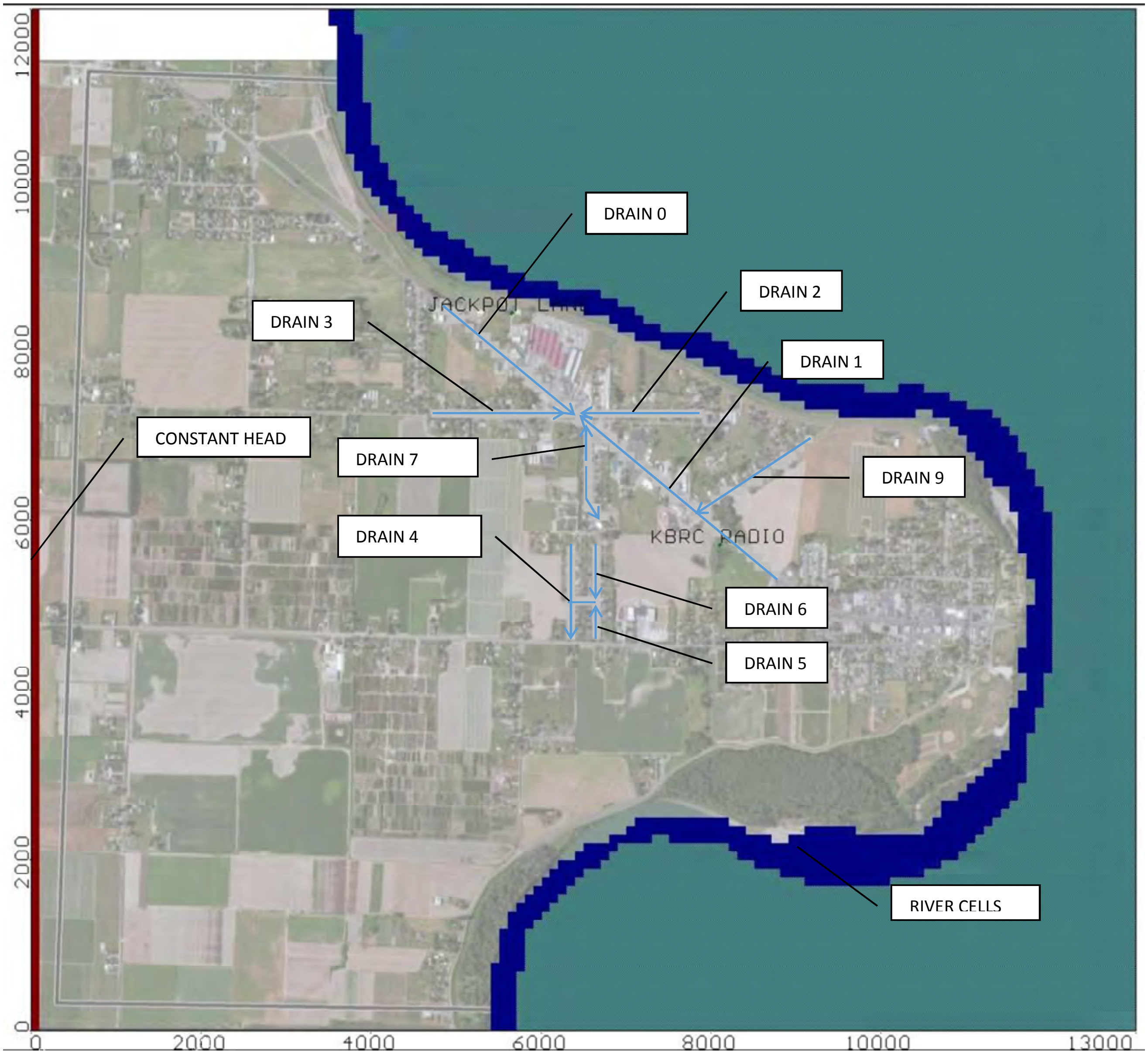

Figure A-3. MODFLOW Layer 1 Boundary Cells

Appendix D

Planning Level Construction Cost Opinion

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT:	**Dunbar Road Stormwater Management Plan**	**CHECKED BY:**	**KML**
BY:	**DLS**	**DATE:**	**12/30/2016**

ITEM NO.	BID ITEM[1]	QUANTITY	UNIT COST (Incl. O&P)	UNIT PRICE	AMOUNT
1	36" Conc, Reinforced, with gaskets[2]	1300	$ 132.00	LF	$ 171,600
2	48" Conc, Reinforced, with gaskets[2]	1820	$ 186.00	LF	$ 338,520
3	Trenching, Common Earth, 6' wide w/ trench box, no slope, 8' deep[2]	2400	$ 31.80	LF	$ 76,320
4	Trenching, Common Earth, 8' wide w/ trench box, no slope, 8' deep[2]	1820	$ 41.79	LF	$ 76,061
5	Pipe Bedding 36" (6' wide) [2]	2400	$ 25.65	LF	$ 61,560
6	Pipe Bedding 48" (7' wide) [2]	1820	$ 40.85	LF	$ 74,347
7	Pavement demolition and removal[2]	2831	$ 9.60	SY	$ 27,179
8	New Pavement[2]	2831	$ 61.50	SY	$ 174,113
9	Pressurized Line[2]	1100	$ 275.00	LF	$ 302,500
10	Manhole, Pre-Cast, 5' I.D., 8' deep[2,5]	31	$ 6,950.00	EA	$ 215,450
11	Pump Station (60 cfs capacity)[3]	1	$ 614,680.00	LS	$ 614,680
12	Flap Gate (36")[2]	1	$ 6,575.00	EA	$ 6,575
13	StormFilter[4]	2	$ 122,210.00	EA	$ 244,420
				Subtotal	$2,383,325
	UTILITY RELOCATE	2%			$ 47,666
	DEWATERING	5%			$ 119,166
	EROSION & SEDIMENTATION CONTROL	5%			$ 119,166
	TRAFFIC CONTROL	8%			$ 190,666
				Subtotal	$2,859,990
	MOBILIZATION (GENERAL REQ)	10%			$ 285,999
	CONTINGENCY	30%			$ 857,997
	Construction Subtotal (Rounded)				$4,004,000
	STATE SALES TAX	8.6%			$ 344,344
	ENGINEERING/LEGAL/ADMIN	25%			$1,001,000
	CONSTRUCTION MANAGEMENT	15%			$ 600,600
	PERMITTING	5%			$ 200,200
	Total Estimated Project Cost (Rounded)				**$6,150,000**

[1] Costs for right-of-way acquisition are not included in the cost estimate.
[2] Costs from 2015 RSMeans Heavy Construction Cost Data Catalog (Sections 33 41, G10, G30, and others)
[3] Cost scaled on discharge from Douglas Creek Pump Station cost estimate (NHC, 2014)
[4] Cost from Snohomish County bid tab.
[5] Only large diameter manholes are included in core conveyance system plan. Catch-basins for local drainage will be added as part of subsequent development or redevelopment projects.