SKAGIT COUNTY
PUBLIC WORKS DEPARTMENT

BIG LAKE DRAINAGE MANAGEMENT PLAN

NOVEMBER 2007

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FINAL DRAFT - NOVEMBER 2007

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Executive Summary

This Big Lake Drainage Management Plan has been prepared to address stormwater management planning including facilities inventory, problems assessment, solutions development, capital improvements, and stormwater program needs within a 1.9 square mile study area surrounding and local to Big Lake, a developing urban fringe area near Mt Vernon, Skagit County, Washington. The location and extent of the study area and the Big Lake watershed are shown on Figure 1-1 (Chapter 1). This Executive Summary provides a brief synopsis of key findings of the plan. Details of the plan and its recommendations, methods of assessment, database, supporting analysis, assumptions, and results are documented in the various report chapters and appendices.

Big Lake, a 540-acre lake within a 18.6 square mile, mostly rural and primarily undeveloped watershed, is fed by Lake Creek (Upper Nookachamps Creek) to the south, with headwaters at Lake McMurray. It drains to Nookachamps Creek (a Skagit River tributary) to the north, with its outlet located near the Town of Big Lake. Being a recreational use lake, development and re-development activity is focused in close proximity to the lake, primarily within its perimeter road system that consists of SR 9 to the east and West Big Lake Boulevard to the west. The watershed is currently primarily forested, with portions of it undergoing active forest practices management. Other existing land uses include pasture, wetlands, and developed impervious and pervious areas. Future zoned land uses, in accordance with the County's Comprehensive Plan, could result in conversion of additional forest land (up to 22% estimated) to other uses through combined forest practices, pasture expansion, and other development-related effects. With those projected changes comes the need to effectively manage stormwater not only to correct existing drainage deficiencies, but more importantly, to plan for future stormwater system infrastructure consistent with those land use changes that will reduce flood hazards, improve water quality, and protect critical fish and wildlife habitat.

This plan provides maps and a documented inventory of the Big Lake study area local drainage systems and establishes Skagit County required actions necessary to improve drainage conditions and drainage management practices in the study area to achieve compliance with federal, state, and local stormwater programs and permits regulation. The major goals of the plan are to:

- Document study area topography and drainage system infrastructure
- Define drainage problems and solutions to reduce study area flood hazards
- Identify study area NPDES Phase II permit water quality program compliance needs
- Disseminate plan findings for coordinated use and public/resources benefits

A summary of the federal, state, and Skagit County regulatory framework as the basis for this planning effort is provided in Chapter 2 (Table 2-1). Mapping of the study area topography and an extensive inventory of drainage system infrastructure was conducted between March 2004 and October 2005 using aerial surveys, photogrammetric compilation methods, and ground survey as described in Chapters 3 and 4. The resulting aerial photography and inventoried major drainage systems are shown in Chapter 8 and Appendix A figures. Digital files of topographic mapping and facilities inventory products have been submitted separately to the County.

Characterization of the Big Lake watershed and study area including topography, drainage areas, climate, land use, soils, wetland, streams, and other critical areas is provided in Chapter 3.

Approximately 38 major drainage systems were identified and analyzed within the study area that convey stormwater runoff from the local drainage subbasins with outfall to Big Lake. Another 6 major drainage systems were reviewed that flow directly to Nookachamps Creek downstream of the Big Lake outlet. That area included a major development being constructed beyond the northeast corner of Big Lake. The drainage systems typically consist of roadside ditches that intercept upslope sheet and concentrated runoff, with culverts at perimeter road, local access roads, and driveway crossings. Those lateral drainage systems discharge to natural or altered drainage channels, some with sections of improved storm drain, that outfall to Big Lake or Nookachamps Creek.

For the study area drainage systems evaluated, existing stormwater-related problems are documented in Chapter 5 (Table 5-1) as determined by reviewed of County-recorded drainage complaints, discussions with property owners, and through field reconnaissance. Review of the drainage facilities inventory data suggests that many problems are related to damage of culvert end sections and to other obstruction due to sediment and debris accumulation. Of the over 600 drainage facility inlet and outlet locations inventoried, approximately 230 are partially to fully obstructed due to sediment or debris, and another approximate 35 locations are partially obstructed due to pipe end section damage. To restore target flow capacity of those drainage facilities, damaged culverts require repair or replacement, and other culverts obstructed by sediment or debris require more extensive periodic maintenance. If any of those systems are used by anadromous fish species that may be present, fish passage and habitat effects of culvert modifications or maintenance actions need to be considered.

Hydrologic and hydraulic analyses that were conducted within the Big Lake watershed and study area for plan development are documented in Chapter 6. This included a watershed-scale evaluation of hydrologic response using the continuous simulation HSPF model to define estimated Big Lake inflow and outflow characteristics including flood flows, flow-duration statistics, and lake water level fluctuations. Key findings from that analysis are that Big Lake (combined with Lake McMurray upstream) has a major effect in regulating flood flows to the downstream Nookachamps Creek due to its large active storage volume (approximately 1,950 acre-feet at 100-year lake level). Peak 100-year flood flows for existing land use are reduced approximately 50 percent between the Big Lake inlet and outlet (from approximately 1,100 cfs to 550 cfs). Under assumed future land use consistent with the County’s Comprehensive Plan and considering other modeling assumptions, increases in flood flows at the lake outlet are projected to increase by only about 2 percent (less than 10 cfs). High lake levels were established that varied between elevation 88.3 and 89.9 (NAVD 88, project datum) for the 2-year through 100-year flood frequencies, respectively. This compares to a low lake level elevation of 86.3 under conditions of no outflow. For future land use conditions, the modeled increase in 100-year lake flood level is only 0.04 ft. The computed 100-year lake elevation is shown on the Appendix A figures. Review of those maps suggests that seven structures may be affected by 100-year lake flooding, although finished floor elevations of those structures are needed to confirm that flooding potential.

Analysis of the local drainage systems expected flood flows and hydraulic capacity is also described in Chapter 6. Over 60 drainage subbasins and subareas tributary to the 44 total outfalls to Big Lake and Nookachamps Creek were evaluated for estimation of peak flood flows (2-year through 100-year events). For that analysis, the HEC-HMS model was used to evaluate design storm event (Type 1A, 24-hour) runoff based on tributary subarea topography, land cover, soils, and the drainage system network. Findings from that analysis (peak flood flows) are included in Table 6-7. To assess the drainage facilities in need of capacity upgrades, the hydraulic capacities of the major drainage system facilities were computed and compared with the estimated peak flood flows for the 25-year design event (existing conditions). Only three culverts or storm drains along the major drainage system were shown to be deficient assuming unobstructed flow conditions. However, many other lateral drainage systems have drainage facilities that are insufficient due to damage and sediment/debris obstruction as noted previously.

Chapter 7 identifies the stormwater program needs to achieve compliance with the forthcoming National Pollutant Discharge Elimination System (NPDES) Phase II permit requirements (effective permit date February 17, 2007) and associated U.S. EPA rules (under the Federal Clean Water Act legislation). This program is being administered by the Washington State Department of Ecology (Ecology). Big Lake is part of the “automatically designated” census-defined Mt Vernon urban fringe area, and as such, will need to achieve compliance with this program. These regulations will require will require the County to develop and implement a stormwater management plan with six major elements. Those elements include Public Education and Outreach, Public Involvement, and Participation, Illicit Discharge Detection and Elimination, Controlling Runoff from New Development, Re-development, and Construction Sites, and Pollution Prevention and Operations/Maintenance for County Operations. In addition, monitoring plan (and future implementation) requirements apply along with annual reporting and record keeping (initial annual report required in March 2008). Details of the required actions and target schedule timelines based on the Phase II NPDES stormwater permit are summarized in Table 7-1.

Potential drainage improvements in the study area were assessed in consideration of drainage complaints and drainage facilities shown to have inadequate hydraulic capacity due to either size or the need for repair or replacement due to damage. A total of seven capital improvement projects are recommended to address problems on the major drainage systems. On lateral (minor) drainage systems, culverts and storm drains in need of repair or replacement due to damage were grouped as high, medium, or low priority based on the degree of obstruction and associated capacity limitations. Table ES-1 summarizes the resulting recommended CIP drainage improvement projects along with their planning-level estimated implementation costs (November 2007). A suggested priority of recommended capital improvements projects implementation is provided in Table 8-3. Table ES-2 provides a preliminary estimate of annual stormwater program costs associated with the NPDES Phase II permit program as described above.

Table ES-1. Recommended CIP Drainage Improvements and Estimated Implementation Costs

Recommended CIP Drainage Improvements – Big Lake Study Area				
Outfall No.	**CIP No.**	**Drainage Complaint Nos. Addressed**	**Proposed Improvement**	**Estimated Project Implementation Cost**
Major Drainage System Improvements				
BL3	01-BL3	193, 410, 415, 654	Lake Terrace Ln. Drainage Collection Improvement	$56,900
BL6	02-BL6	625	Storm Drain/Outfall Replacement (Enlargement)	$90,600
BL25	03-BL25	None	SR 9 Parallel & Cross Culvert Replacements	$51,500
BL27	04-BL27	533, 624	New Storm Drain and Interceptor Drain Replacement	$221,100
BL28	05-BL28	3, 61, 466	New/Replacement Storm Drain System	$365,200
BL31	06-BL31	566, 583	New/Replacement Storm Drain System and Rock Lined Channel	$326,200
NC2b	07-NC2b	599, 647	New Overflow Storm Drain and Culvert	$95,100
			Subtotal Major Drainage System CIP Costs	**$1,206,600**
Minor Drainage System Improvements				
High Priority	08-CR-HP	Various	6 – 12 inch and 1 – 18 inch damaged culverts repair or replacement	$92,900
Medium Priority	08-CR-MP	Various	2 – 12 inch and 1 - 18-inch damaged culverts repair or replacement	$44,700
Low Priority	08-CR-LP	Various	11 – 12 inch, 3 – 18 inch, and 4 – 24 inch damaged culverts repair or replacement	$305,000
			Subtotal Minor Drainage System CIP Costs	**$442,600**
			Total Recommended Drainage System CIP Estimated Costs	**$1,649,200**

Table ES-2. NPDES Phase II Program Elements and Estimated Annual Costs

NPDES Phase II Permit Program Element	Estimate Annual Cost
Element S5.1, 5.2 - Public Education and Outreach (PEO), Involvement, and Participation	20,000
Element S5.3 - Illicit Discharge Detection and Elimination (IDDE)	$30,000
Element S5.4, 5.5 - Controlling Runoff from New Development, Re-development, and Construction Sites	$60,000
Element S5.6 - Pollution Prevention and Operations/Maintenance for County Operations	$60,000
Element S8 - Monitoring	$25,000
Element S9 - Annual Reporting	$25,000
Total Estimated NPDES Phase II Permit Annual Program Costs	**$220,000** (1)

(1) Based on initial Phase II permit cycle, will depend on allocation of similar costs to the entire Mt. Vernon regulated area; many activities are multi-year; this represents only a preliminary estimate for initial years of program as pertains to Big Lake.

Preparation of the Big Lake Drainage Management Plan has been completed by Montgomery Water Group (MWG) in association with Skagit Surveyors and Engineers (SSE), Walker and Associates (WA), and MGS Engineering Consultants (MGS) under Contract No. C20040173 (Phase 1) and No. A20050055 (Phase 2) with the Skagit County Department of Public Works (County).

Prepared under the supervision of:

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1.0 Chapter 1 – Introduction

1.1 Introduction

This Big Lake Drainage Management Plan (DMP) has been prepared to serve as a comprehensive guide to storm drainage management within an urbanizing 1.9 square mile study area surrounding Big Lake, Skagit County, Washington. Skagit County Department of Public Works is responsible for surface water management within unincorporated areas of Skagit County. This includes Big Lake and its rural tributary watershed areas east of Mount Vernon. Figure 1-1 shows the location of the Big Lake study area and watershed within unincorporated Skagit County.

Figure 1-1. Big Lake Regional Location Map

The DMP documents the existing drainage system infrastructure and condition, addresses improvements needed to respond to drainage complaints and other potential drainage problems as determined by analysis, and identifies capital improvement projects needed to reduce flooding and achieve improved drainage management consistent with current surface water management standards. The DMP also includes an assessment of study area storm drainage programmatic measures and drainage policies, including recommended modifications and actions needed to conform to NPDES Phase II stormwater requirements and pending permit regulations.

1.2 Watershed and Study Area Definition

The Big Lake watershed and study area are located in the southwest portion of Skagit County, approximately 7 miles southeast of Mount Vernon along SR-9, and within the southeast portion of the Lower Skagit/Samish Water Resource Inventory Area (WRIA 3). Figure 1-2 shows the Big Lake study area (as defined by Skagit County Public Works and Planning Department staff) and that portion of the watershed area directly tributary to Big Lake that contributes runoff to drainage systems within the study area. The Big Lake total watershed covers approximately 19.8 square miles extending south to headwaters at Lake McMurray. Of that total, the portion of the watershed directly tributary to Big Lake (as shown on Figure 1-2) totals 5.3 square miles. In addition, the northeast portion of the study area (approximately 1 square mile) drains directly to Nookachamps Creek (Big Lake outlet channel).

Figure 1-2. Big Lake Watershed and Study Area

The study area consists of approximately 1.9 square miles (1,215 acres) of urbanizing area surrounding Big Lake, typically situated in a band extending approximately 1,000 feet from the lake ordinary high water limits. In some areas where existing or pending development exists, that limit extends out up to 2,500 feet from the lake. Within the study area, a Phase 1 pilot area (approximately 70 acres, see Figure 1-2) was defined within the southeast portion of the study area. The pilot area was used as an initial mapping and drainage inventory area to achieve concurrence on the mapping and inventory approach and products.

1.3 Drainage Management Plan Purpose and Goals

Skagit County Public Works is preparing drainage management plans for selected urbanizing areas in unincorporated Skagit County to review existing drainage infrastructure and assess improvement needs. The purpose of this drainage management plan is to provide mapping and documented inventory of the Big Lake study area local drainage systems and to establish the actions necessary to improve study area drainage conditions and drainage management practices. Upon approval, the DMP will be implemented by Skagit County Public Works Department and other affected stakeholders.

The plan is also intended to identify compliance actions required by current federal, state, and local stormwater regulations and standards. These regulations and standards include the Federal Clean Water Act and Endangered Species Act (ESA), the State NPDES Stormwater Phase II Stormwater Program and General Permit and associated Ecology Stormwater Management Manual for Western Washington standards, the County-administered provisions of the state Growth Management and Shoreline Management Acts, and County development regulation within the watershed.

The primary goals of the Big Lake DMP are as follows:

Goal No. 1 – Document Study Area Topography and Drainage System Infrastructure

- Obtain aerial photography coverage of study area as the basis for mapping and inventory
- Complete ground survey control and photogrammetric mapping of study area topography
- Conduct surveyed inventory of study area existing drainage facilities
- Document drainage system infrastructure in spreadsheets and graphically in AutoCAD and GIS formats

Goal No. 2 – Define Drainage Problems and Solutions to Reduce Study Area Flood Hazards

- Review and evaluate study area drainage complaints and other identified drainage problem areas
- Provide hydrologic analysis of the collective watershed to define expected Big Lake level fluctuations and associated flood hazards
- Define drainage system outfalls and conduct hydrologic analyses to define major drainage systems runoff potential and peak flood flows
- Conduct hydraulic evaluation of study area major drainage systems to define their adequacy to convey selected flood event peak flows
- Identify major drainage systems components in need of improvement

- Document priority solutions to reduce flood hazards in the form of recommended capital improvement projects

Goal No. 3 – Identify Study Area NPDES Phase II Permit Water Quality Program Compliance Needs

- Provide GIS-based drainage system inventory database and mapping
- Identify potential illicit discharge connections based on drainage system inventory data for implementation of a coordinated County program of detection, testing, and elimination of unauthorized discharges
- Provide recommendations for stormwater management program components consistent with six major elements of NPDES Phase II Permit and water quality monitoring needs

Goal No. 4 – Disseminate Plan Findings for Coordinated Use and Public/Resources Benefits

- Increase public awareness of flooding, water quality, and habitat issues as related to drainage system modification or development actions
- Provide improved knowledge of existing drainage systems for coordinated response to drainage problems and flooding issues
- Encourage use of DMP findings and identified needs by other agencies and stakeholders in their drainage management actions and practices
- Reduce the cost of maintaining publicly owned/operated storm drainage facilities

1.4 Stakeholder Involvement

Opportunities for stakeholder involvement in the planning process have been (or will be) provided by:

- Review and assessment of drainage complaints for possible improvement needs and response actions
- Discussions of drainage problem areas with local residents during field reconnaissance
- Holding a public meeting to review results and receive input after completion of the draft drainage management plan

1.5 Drainage Management Plan Organization

The remainder of this plan is organized as follows:

- Chapter 2 describes the applicable programs, policies, regulations, and standards and their relationship to this plan

- Chapter 3 addresses the watershed mapping, study area, and drainage basin characteristics products and findings
- Chapter 4 describes the drainage system data collection and inventory process and results
- Chapter 5 documents and discusses drainage complaints and problem areas and types investigated by this plan
- Chapter 6 discusses and documents the methods, assumptions, and results of watershed drainage system hydrologic and hydraulic analyses used to assess specific problems and develop drainage improvement recommendations
- Chapter 7 describes and provides input to the required elements of NPDES Phase II Stormwater Permit compliance as pertains to the Big Lake DMP study area
- Chapter 8 identifies the recommended capital improvement projects and programmatic action needs consistent with the plan goals and objectives
- Appendix A contains the Study Area Major Drainage System Figures
- Appendix B contains the Field Inventory Database
- Appendix C contains the Big Lake Watershed Scale Hydrologic Analysis
- Appendix D contains the Big Lake Local Subbasins Scale Hydrologic Analysis
- Appendix E contains the Hydraulic Analysis
- Appendix F contains Construction/Implementation Cost Estimates

2.0 Chapter 2 – Drainage Planning Regulatory Framework

Numerous Federal, State of Washington and County regulations, laws, policies, programs and standards affect how storm and surface water are managed in unincorporated Skagit County. This chapter describes those that are pertinent to the Big Lake drainage planning study area and its watershed.

2.1 Federal Regulations and Programs

Clean Water Act National Pollutant Discharge Elimination System

Amendments to the Federal Clean Water Act (CWA) in 1987 required the Environmental Protection Agency (EPA) to promulgate regulations for stormwater discharges. As a result, EPA defined certain stormwater discharges subject to federal regulations under the National Pollutant Discharge Elimination System (NPDES) Permit Program. Two broad categories of stormwater discharges were created:

- Stormwater discharges associated with industrial activity
- Municipal separate storm sewer systems (MS4s), with an associated two-phase permit process:
    - The Phase I permit and requirements apply to large and medium-size municipalities with populations greater than 100,000.
    - The Phase II permit and requirements apply to smaller jurisdictions with populations of 10,000 or more and certain census-defined urbanized areas. Big Lake falls into the Phase II category.

The responsibility for implementation of the NPDES permit program within Washington State was delegated by EPA to the Washington State Department of Ecology (Ecology). An NPDES Phase I permit does not currently apply within Skagit County since the County's population is beneath the Phase I Permit minimum population threshold; however, the NPDES Phase II Permit and program requirements do apply to urbanized areas within Skagit County that meet the population density threshold criteria.

The EPA NPDES final rule requires nationwide coverage of all operators of regulated small MS4s that are located within the boundaries of the U.S. Bureau of the Census-defined "urbanized area" based on the latest decennial census (2000). That census data shows that Big Lake is part of the Mount Vernon urban fringe, and consequently, is part of the Mount Vernon "automatically designated" area. Once a small MS4 is within the program based on the urbanized area boundaries, it cannot be waived from the program unless or until it meets the defined criteria for a waiver.

The Phase II permit, as required under paragraph 402(p)(3) of the CWA, requires regulated small MS4 permittees to develop a stormwater management program that effectively prohibits non-stormwater discharges into storm sewers that discharge to surface waters, and controls must be applied to regulated stormwater discharges that reduce the discharge of pollutants to the "Maximum Extent Practicable (MEP)". The permit implements "six plus two" minimum requirements for a stormwater management program as required by the EPA Phase II rules. The six stormwater program minimum requirements are:

- Public education and outreach
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site stormwater runoff control
- Post-construction stormwater management for new development and re-development
- Pollution prevention and good housekeeping for municipal operations

The two additional Phase II permit requirements are:

- Compliance with approved total maximum daily load (TMDL or water cleanup plan), or equivalent analysis, where appropriate
- Evaluation and assessment of program compliance

In addition, the permit requires jurisdictions with areas that are slated for future growth to include protection of groundwater resources if they are not covered by existing programs. Chapter 7 provides input on recommended NPDES Phase II Permit program components as applicable to the Big Lake study area.

The NPDES and State Waste Discharge General Permit for Discharges from Small MS4s in Western Washington (Phase II Permit) was re-issued for final public comment in February 2006. Skagit County provided review and comment on an earlier version of the permit by letter response dated August 17, 2005. The final permit was issued January 17, 2007 and became effective February 16, 2007. It is currently undergoing an appeals process from a consortium of Phase II entities.

Clean Water Act Section 303(d) List and Total Maximum Daily Loads

Section 303 (a, b, and c) of the CWA requires that states establish standards to protect the quality of waters in the United States. Ecology has classified all major water bodies in Washington based on their current or potential beneficial uses and has assigned a set of water quality standards for each class. In response to Section 303(d) of the CWA, Ecology has prepared a list of water bodies that are not meeting or will not meet water quality standards after application of the required technology-based effluent limits.

The most recent list of water quality-impaired waters, designated as Category 5 waters, was approved by EPA in November 2005. Nookachamps Creek, both upstream and downstream of Big Lake, is listed as Category 5 for Dissolved Oxygen (DO) and temperature.

Under the CWA, if a water body is not compliant with standards for a particular pollutant, then a total maximum daily load (TMDL) of the pollutant must be calculated. The TMDL is the maximum amount of a pollutant that can be discharged to the water body without violating the water quality standards for the pollutant. The loading limits for all pollutant sources discharging to the impaired water body are adjusted downward until the TMDL can be achieved.

In the Big Lake/Nookachamps Creek watershed, a TMDL does not specifically apply, except that under the Phase II Permit, a TMDL for fecal coliform does apply to the Lower Skagit River and mouths of tributaries, from the mouths of the North and South Forks upstream to river mile 24.6 at Skiyou Slough. Nookachamps Creek, with headwaters upstream of Big Lake, enters the Lower Skagit River in this reach. The Phase II permit lists the Mount Vernon Urban Area as a Phase II MS4 permittee. The actions required under this TMDL are to measure fecal coliform concentrations at selected locations (Nookachamps Creek not included) in accordance with a designated implementation plan and to target elements of the stormwater program to address fecal coliform control.

Clean Water Act Section 10 and 404 Permits

Placement of fill in water of the U.S. is regulated under Sections 10 and 404 of the CWA. Waters of the U.S. ("waters") typically include rivers and streams (within the ordinary high water [OHW] limits and non-isolated wetlands that are hydraulically connected to regulated streams. Section 10 applies to work in navigable waters below the mean higher high water (MHHW) tidal elevation including structures, dredging and disposal, excavation and filling, and other related actions. Section 404 applies to all other similar proposed actions affecting "waters", with regulation provided either under one or many nationwide permits or under an individual permit (which require broader review), where the limitations of nationwide permits are exceeded. Other regional (state and tribal) conditions may apply to achieve Section 10 and 404 permit approvals. For Skagit County, Section 10 and 404 permits are administered by the U.S. Army Corps of Engineers, Seattle District.

Endangered Species Act

Under the Endangered Species Act (ESA), the U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) Fisheries have promulgated a list of endangered and threatened species and have designated critical habitat for the listed species. Federally listed species include the Chinook salmon (listed as threatened in March 1999) and the bull trout (listed as threatened in October 1999). Additional species listed as candidate include the Coho salmon.

Based on the WRIA 3 mapping designations documented by Ecology, Chinook salmon (fall run) rearing in Nookachamps Creek is limited to the lower mainstem reach and East Fork. Those mapping designations suggest potential use of Nookachamps Creek, including Big Lake, by dolly varden/bull trout. Also, rearing habitat and potential spawning habitat for Coho salmon is shown in sections of the Nookachamps Creek system.

Section 9 of the ESA prohibits “taking” of endangered species. The “take” of a species can include “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct”. The term “harm” may include “significant habitat modification where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering”.

Under Section 7 of the ESA, proposed actions that could have an effect on listed species that require a permit from a federal agency, or that are federally funded, require the involved federal agency to consult with USFWS or NOAA Fisheries. This normally requires preparation of a biological assessment (BA), then after consultation, the applicable agency issues a biological opinion regarding the effects of the action. If the finding is that the action could jeopardize the continued existence of the species, then the action cannot be permitted. If, however, the finding is to the contrary, then the applicable agency issues an “incidental take statement” that allows the action to be permitted and proceed.

This regulation and process can have a significant effect on storm drainage and surface water management plans and targeted improvements. Therefore, water quantity, quality, and critical fish habitat that can be affected with solutions to flooding and drainage problems needs to be addressed in a manner to protect listed species.

National Flood Insurance Program

The National Flood Insurance Program (NFIP) was initiated in 1968 under the National Flood Insurance Act in response to the need to lower the burden of disaster relief on the national treasury. The NFIP is administered by the Federal Insurance Administration under the Federal Emergency Management Agency (FEMA).

The primary purpose of the NFIP is to make affordable flood insurance available to residents and businesses in communities that adopt approved floodplain management regulations. FEMA oversees a program of mapping of flood hazards along selected flooding sources under the NFIP. Those hazards are shown on FEMA’s Flood Insurance Rate Maps (FIRMs) and form the basis for local critical areas zoning of flood hazards. Revisions to FIRMs require certification letters, for example approval of a Letters of Map Revision (LOMR). Requirements for FIRM certifications can include changes in floodplains and floodway limits and elevations associated with stream channel and hydraulic structure modifications.

Under the NFIP, federally-subsidized flood insurance is made available to local residents within (or beyond) those identified hazards. Skagit County participates in the NFIP under conditions of a flood hazard ordinance and regulations modeled after minimum federal standards (County standards can be more stringent). Communities that do not participate in the NFIP have limited eligibility for federal flood disaster relief and other forms of projects with federal funding participation. An optional feature of the NFIP is participation in the Community Rating System (CRS), where actions that extend beyond minimum NFIP requirements can result in reductions in flood insurance premiums for community policy holders. Skagit County participates in the CRS and has a current rating of Class 6 on a 1 to 10 scale (Class 1 provides the greatest insurance premium reduction, Class 10 the least).

2.2 State Regulations, Programs, Permits, and Standards

State Water Quality Standards and Section 401 Water Quality Certification

The discharges of stormwater to surface waters and groundwater within Washington State are regulated under water quality standards contained in the 1997 Washington Administrative Code, (WAC) 173-201A and 173-200, respectively. WAC 173-201A sets standards for each regulated parameter for the various classes of surface waters. WAC 173-200 also calls for designation of special groundwater protection areas (e.g., aquifer protection areas, wellhead protection areas, or sole source aquifers).

In July 2003, Ecology adopted a new set of water quality standards, but EPA did not initially fully approve those revised standards (EPA notified Ecology in March 2006 of formal disapproval of parts of the 2003 standards because they did not go far enough to protect listed fish species in certain streams and rivers). Ecology subsequently developed supplemental revisions to the 2003-adopted water quality standards in response to EPA's disapproval of the state's standards. After public hearings were held in August 2006, Ecology issued the revised final standards on November 20, 2006 (replacing the standards adopted in 2003). Those standards became effective on December 23, 2006. Under these new standards, Ecology classifies fresh waters by actual use (e.g., fish habitat, swimming, water supply) instead of by class (e.g., AA, A, B, C, Lake Classes).

The water quality standards need to be considered for implications on proposed actions or activities in most storm drainage assessments and improvement projects. They are also the foundation for water quality programs such as NPDES and TMDL cleanup plans. Where certain project thresholds are exceeded by a proposed action, a Section 401 Water Quality Certification is the approval mechanism used by Ecology to document concurrence with a project's ability to maintain the state water quality standards for its long-term operation. For short term construction effects, an NPDES Stormwater General Permit is typically required (when over 1 acre of disturbance occurs) inclusive of a Stormwater Pollution Prevention Plan (SWPPP), a Stormwater Site Plan (SSP), and a Temporary Erosion and Sedimentation Control Plan (TESCP).

Growth Management Act and Skagit County Comprehensive Plan

Under the Washington State Growth Management Act (GMA), local governments in fast-growing communities were directed to prepare and adopt comprehensive plans and implementing regulations to better manage growth. The latest version of the Skagit County Comprehensive Plan was adopted in 1997. The following three GMA goals apply to storm drainage planning:

- Urban Growth – Encourage development in urban areas where adequate public facilities and services exist or can be provided in an efficient manner

- Environment – Protect the environment and enhance the state's high quality of life including air and water quality, and the availability of water

- Public Facilities and Services – Ensure that those facilities and services necessary to support development shall be adequate to serve the development at the time it is available for occupancy and use without decreasing service levels below locally-established minimum standards

The GMA affects storm drainage planning and facilities by requiring that:

- Frequently flooded areas (flood hazard areas) be identified and protected
- Urban facilities be constructed in urban areas only
- A level of service standard be established for storm drainage facilities
- Capital improvements be identified to the adopted level of service given planned land use

The GMA mandates that comprehensive plans be internally consistent and the counties take actions and make capital budget decisions in conformity with their comprehensive plans (RCW 36.70A.070 and 36.70A.120). Therefore, as elements of County's capital budget, drainage plans and their associated recommended capital improvement projects are required to be consistent with the County's comprehensive plan. This consistency is typically evaluated under a SEPA environmental checklist completed for the plan.

The County's comprehensive plan governs land use activities, which in turn influence stormwater runoff potential and drainage system infrastructure facility needs. The suitability of stormwater facility improvements are often affected by critical area designations along water resource features and require additional evaluation for siting of improvements. Findings of the drainage planning process can also provide important guidance for land use planning decisions and for periodic plan updates.

Shoreline Management Act

The Washington State Shoreline Management Act (SMA) establishes broad policy guidelines on how Shorelines of the State can be used, and provides preference to uses that:

- Protect the quality of waters and the natural environment
- Depend on proximity to the shoreline (water dependent uses)
- Preserve and enhance public access or increase recreational opportunities for the public along shorelines

Shorelines of the State include all marine waters, rivers and streams with a mean annual flow greater than 20 cubic feet per second (cfs), lakes larger than 20 acres (Big Lake), and upland areas 200 feet landward from mean high water (MHW). Shorelines of the State are further defined as biological wetlands, river deltas, and some or all of the 100-year floodplain, including all wetlands within the floodplain, when associated with the listed water.

The SMA compliance authority is split between local and State governments. The SMA is typically administered by cities and counties in accordance with adopted shoreline master programs and use regulations the follow State guidelines tailored to the specific needs of the community. Skagit County adopted its Shoreline Master Program and shoreline areas designation map in 1976. Shoreline use regulations are administered through a permit program.

Since Big Lake is a Shoreline of the State, study area recommended actions within the regulated zone will be subject to shoreline management review and permitting. The applicable shoreline designations for Big Lake and nearshore portions of the study area are aquatic shoreline, rural residential shoreline, and conservancy shoreline.

State Environmental Policy Act

The Washington State Environmental Policy Act (SEPA) was enacted in 1971 under RCW Chapter 43.21C. It provides the framework for agencies to consider the environmental consequences of a proposal before taking action. It also gives agencies the ability to condition or deny a proposal due to identified likely significant adverse impacts. The Act is implemented through the SEPA Rules, WAC Chapter 197-11.

Environmental review is required for any proposal that involves a government "action," as defined in the SEPA Rules (WAC 197-11-704), and that is not categorically exempt (WAC 197-11-800 through 890). Project actions involve an agency decision on a specific project, such as a stormwater improvement project. Non-project actions involve decisions on policies, plans, or programs, such as the adoption of a comprehensive plan or development regulations, or a six-year stormwater capital improvements plan.

One agency is identified as the "lead agency" under the SEPA Rules (WAC 197-11-924 to 938), and is responsible for conducting the environmental review for a proposal and documenting that review in the appropriate SEPA documents (DNS, DS/EIS, adoption, addendum). Two or more agencies may share lead agency status by agreement, but a single environmental analysis would be conducted and all SEPA documentation is issued jointly.

Skagit County authority and procedures and policies for local regulation under SEPA are contained in Skagit County Code Chapter 14.12. The SEPA rules (WAC 197-11) must be used in conjunction with Skagit County regulations.

State Hydraulic Code

The Washington State Hydraulic Code (RCW 77.55) regulates any activity affecting the bed or changes in flow of the State’s fresh waters with the goal to protect fish and wildlife and associated habitat. The Hydraulic Code is administered by the Washington State Department of Fish and Wildlife (WDFW). The Hydraulic Project Approval (HPA) is used by WDFW to condition projects such that a project is designed, scheduled, managed, sequenced, and constructed to minimize adverse effects on fish and wildlife.

Hydraulic Project Approvals typically apply to stormwater projects permitting during implementation of recommended drainage improvements (e.g., stream crossings and outfall improvements). In many of those cases the bed of waters of the State are altered with those improvements or the magnitude or timing of flows discharged to streams are modified (e.g., detention or treatment facilities).

Watershed Planning Act

The Washington State legislature passed ESHB 2514 in 1998, codified into RCW 90.82 to set a framework for developing local solutions to watershed issues on a watershed basis. This provides a process to allow citizens within a watershed to collaborate with resource agencies to determine how best to manage local watershed issues. The process uses a three-phased planning approach: Phase 1, Organizational Phase; Phase 2 – Assessment Phase; and Phase 3 – Planning Phase. Ecology provides grant funding assistance for watershed plan development.

A watershed plan must balance competing demands for resources and is required to address water quantity through an assessment of water supply and use within the watershed. One of the main goals is to develop a long-term strategy for water use within the watershed that satisfies minimum instream flow and out-of-stream water use demands. Optional elements that may be included in the plan are instream flow, water quality and habitat.

A Phase 3 draft watershed plan was completed in the Upper/Lower Skagit watershed (WRIA 3/4), with the Skagit Council of Governments as lead agency. That plan focused on the Samish River watershed including Phase 1 and 2 technical reports on instream flow, groundwater, and water rights and use. The planning unit was not, however, able to reach consensus on instream flows (Ecology is proceeding with establishing and adopting instream flows).

Ecology Stormwater Management Manual for Western Washington

In 2005, Ecology issued a revision to 2001 Stormwater Management Manual for Western Washington (SWMMWW) standards to update design criteria and procedures, apply recent research, and to clarify statements and correct errors in the 2001 manual. The SWMMWW is a guidance manual that includes stormwater requirements for new development and re-development, stormwater pollution prevention planning, and erosion and sediment control from construction sites. The manual is divided into five volumes as follows:

- Volume I – Minimum Technical Requirements and Site Planning
- Volume II – Construction Stormwater Pollution Prevention
- Volume III – Hydrologic Analysis and Flow Control Design/BMPs
- Volume IV – Source Control BMPs
- Volume V – Runoff Treatment BMPs

The intent is for local jurisdictions to use the manual or an Ecology-approved equivalent in their stormwater management program and practices. Under the current version of the NPDES Phase II Permit, the SWMMWW (or its equivalent) became regulatory when the Phase II permit was issued in final form.

2.3 Skagit County Policies, Regulations, Programs and Standards

Skagit County Comprehensive Plan and County-wide Planning Policies

The most recent update to the Skagit County Comprehensive Plan was adopted in May 1997 (Ordinance No. 16550). The plan forms the basis for county-wide planning policies that were established in June 2000. Those broad-based planning polices include requirements that:

- All elements of comprehensive plans, including amendments, shall comply with these policies
- All implementing regulations, including amendments, shall be consistent with these policies
- Each functional plan for the various comprehensive plan elements shall be coordinated and consistent with the Comprehensive Plan
- All disputes over the proper interpretation of functional plans and implementing regulations shall be resolved in favor of the interpretation that most clearly achieves county-wide planning policies

The Comprehensive Plan includes goals, objectives, and policies for 13 separate planning elements. Stormwater is addressed as Goal B (with five major objectives and associated policies in the Utilities Element of the plan). Goal B stipulates "Protect and enhance natural hydrologic features and functions by: maintaining water quality and fish and wildlife habitat; incorporating natural drainage patterns into measures to protect the public from health and safety hazards and property damage; maintaining a sustainable groundwater discharge/recharge budget; and by promoting beneficial uses as well as water resource education and planning efforts." The stormwater policies are structured around the following five objectives:

- Objective 1 - Prevent the loss of life, the creation of public health or safety problems and the loss or damage of public and private property
- Objective 2 – Establish and adopt a systematic and comprehensive approach to solving existing surface water and stormwater problems and prevent future problems
- Objective 3 – Address stormwater management in the context of the varied uses associated with the natural drainage system
- Objective 4 – Prevent the degradation of the quality of both surface water and the water entering the region's aquifers
- Objective 5 – Coordinate among public and private sectors to ensure compatibility of stormwater management measures

Skagit County Code Regulations

The Skagit County Code (SCC) contains numerous Chapters that address stormwater elements or associated components. Those sections include:

- Chapter 14.24 – Critical Areas Ordinance
- Chapter 14.32 – Drainage Ordinance
- Chapter 14.34 – Flood Damage Prevention
- Chapter 14.36 – Public Works Standards

The critical areas ordinance (CAO), adopted in 1996, was developed under the directives of the GMA to conserve and protect critical areas. Critical areas are defined as wetlands, aquifer recharge areas, flood hazard areas, geologically hazardous areas, and fish and wildlife conservation areas. The hazard areas are defined as critical since they represent either hazards to public health or preservation needs for public value. Critical areas are designated by definition, and are classified through site assessments so that they may be protected. SCC Chapter 14.24 addresses the process for classification and assessment of critical areas along with requirements for their protection. In 2002, the GMA was amended to require jurisdictions to update their comprehensive land use plans and development regulations (including CAOs) every seven years. Skagit County's update of the CAO is nearly complete. A Planning Commission public hearing was held in April 2007, with subsequent comment period ending May 7, 2007. Links to draft code changes are included on the Skagit County Planning and Development Services web page.. Jurisdictions are required to use best available science (BAS) in developing and updating policies and regulation to protect the functions and values of critical areas. Special consideration is required for conservation/protection measures that will preserve or enhance anadromous fish populations.

SCC Chapter 14.32 establishes the regulatory and submittal requirements and procedures for stormwater drainage design, review, approval, construction, maintenance and management (both temporary and long-term). This chapter addresses general provisions, regulated activities, financial liabilities and assurances, erosion and sediment control, grading, stormwater management, water quality, operations and maintenance, and critical areas. Regulated activities for new development and re-development are addressed, including requirements for off-site analysis, geotechnical analysis, soils analysis, and temporary erosion and sedimentation control for both small and large development. Stormwater management provisions include approved hydrologic methods for design, stormwater quantity and quality control, minimum design requirements, conveyance facility needs, wetlands protection requirements, and regional facility limitations. Water quality provisions include prohibition of illicit discharge connections, and uses. Within critical drainage areas, special drainage improvements may be required. The drainage ordinance includes adoption by reference of the Ecology Stormwater Management Manual for the Puget Sound Basin (1992 manual) or subsequent manuals adopted by Ecology as Skagit County's Stormwater Design Manual. A provision allows for amendment of the Stormwater Design Manual, with approval of the Board of Skagit County Commissioners, to reflect changing conditions and technology.

Flood damage prevention regulations contained within SCC Chapter 14.34 are intended to promote the public health, safety, and general welfare, and to minimize public and private losses due to flood conditions in specific areas:

- To protect human life and health
- To minimize expenditure of public money and costly flood control projects
- To minimize the need for rescue and relief efforts associated with flooding and generally undertaken, at the expense of the general public
- To minimize prolonged business interruption
- To minimize damage to public facilities and utilities located in areas of special flood hazard
- To help maintain a stable tax base by providing for the sound use and development of areas of special flood hazard
- To ensure that potential buyers are notified that property is in an area of special flood hazard
- To ensure those who occupy areas of special flood hazard assume responsibilities for their actions

Flood damage prevention regulations in this chapter include provisions for establishing areas of special flood hazard, reducing flood losses, development permit implications, and standards and limitations for proposed actions within flood risk zones and areas specifically reserved for flood flows conveyance (floodways). These requirements are tied to the minimum federal standards applicable for the County's participation under the NFIP.

Skagit County Stormwater Programs and Services

Skagit County Public Works, Engineering and Natural Resource Management Divisions, Surface Water Management Section, provides services for flood hazard management/reduction, stormwater drainage, water quality, and salmon recovery issues in Skagit County. This includes planning and design for stormwater drainage system improvement needs. The Road Maintenance Division has responsibility for storm drainage system O&M needs (with public rights-of-way). Other County Departments provide stormwater-related services including Planning and Land Use (community planning, development review and inspection, enforcement, environmental services, ordinances and code, zoning and land use), Geographic Information Services (mapping , data conversion and database design, remote sensing, GPS, etc.), and Emergency Management (e.g., flood damage response and recovery).

Skagit County Public Works Stormwater Standards

SCC Chapter 14.36 defines the standards that apply to roads, stormwater, sanitary sewers and water systems. This section documents the need to comply with the requirements of the Skagit County Drainage Code, SCC Chapter 14.32 and the most recent version of the Skagit County Public Works Standards as adopted by Resolution of the Board of Skagit County Commissioners.

2.4 Summary of Federal, State, and Skagit County Drainage Planning Regulatory Framework

Table 2-1 provides a summary of the regulations, policies, programs, standard, and resource agency permit requirements that will typically apply to drainage planning and improvements implementation within the Big Lake study area.

Table 2-1. Summary of Federal, State, and Skagit County Programs, Policies, Regulations, and Standards and Application to Big Lake DMP

Regulations, Policies, Programs, Standards, Resource Agency Permitting Requirements	Applicability to Big Lake DMP and Implementation Actions
Federal	
Clean Water Act National Pollutant Discharge Elimination System (administered by Ecology)	• NPDES Phase II Permit and requirements do apply via Mt. Vernon's Census-defined urbanized area. • Skagit County has commented on draft NPDES and State Waste Discharge General Permit for Discharges from Small MS4s in Western Washington. Final permit issued January 2007 (became effective February 16, 2007). Action: ensure DMP incorporates NPDES II permit minimum requirements
Clean Water Act Section 303(d) List and Total Maximum Daily Loads (administered by Ecology)	• Nookachamps Creek, upstream and downstream of Big Lake, is designated as Category 5 waters (water quality-impaired) for dissolved oxygen and temperature. • A TMDL does not specifically apply in the Big Lake/Nookachamps Creek watershed, although there is a TMDL for fecal coliform in the NPDES Phase II for the Lower Skagit River. • Nookachamps Creek is not included in the list of fecal coliform sampling locations for the NPDES permit. Action: ensure DMP incorporates NPDES II permit minimum requirements.
Clean Water Act Section 10 and 404 Permits (administered by US Corps of Engineers)	• CWA Sections 10 and 404 govern work within navigable waters below the mean higher high water tidal elevation and placement of fill in water of the US. • Proposed CIP improvements may trigger these permits, depending on the scope of work. Action: evaluate CIP program elements for improvements likely to fill in waters of US.

Regulations, Policies, Programs, Standards, Resource Agency Permitting Requirements	Applicability to Big Lake DMP and Implementation Actions
Endangered Species Act (administered by NOAA or USFWS)	• Threatened species in the project area include Chinook, (limited to lower mainstem and East Fork Nookachamps Creek) and dolly varden/ bull trout, (potentially in Nookachamps Creek and Big Lake). • Rearing habitat and potential spawning habitat for Coho salmon (candidate species) is shown in the Nookachamps Creek system. • Any action that could affect listed species and/or that requires a federal permit or uses federal funds requires consultation with USFWS or NOAA, typically through preparation of a Biological Assessment. A Biological Opinion is then issued to allow or disallow the proposed action. Action: design CIP program elements to ensure are not likely to significantly adversely affect listed species.
National Flood Insurance Program (administered by FEMA)	• Skagit County participates in the NFIP Community Rating System, which helps reduce flood insurance premiums. Action: Use DMP to help Skagit County improve its CRS rating and achieve a greater reduction in community flood insurance premiums.
State	
State Water Quality Standards and Section 401 Water Quality Certification (administered by Ecology)	• New Ecology water quality standards have been issued (became effective December 23, 2006) • Projects likely to exceed water quality thresholds require prior Section 401 approval from Ecology. • Short-term construction requires NPDES stormwater general permit, including Stormwater Pollution Prevention Plan, Stormwater Site Plan, and Temporary Erosion and Sedimentation Control Plan. Action: evaluate stormwater program and projects for compliance with new Ecology water quality standards and CIP elements for those that may require Section 401 certification.
Growth Management Act and Skagit County Comprehensive Plan (administered by Skagit County)	• GMA goals affect storm drainage planning by encouraging communities to control urban growth, protect water quality, and ensure public facilities and services are adequate. • GMA requirements influence stormwater runoff management and drainage system infrastructure facilities. • DMPs must be consistent with the County's comprehensive plan (generally determined through SEPA checklist). Action: ensure DMP is consistent with requirements of Skagit County Comprehensive Plan and provides guidance for County land use planning in study area.

Regulations, Policies, Programs, Standards, Resource Agency Permitting Requirements	Applicability to Big Lake DMP and Implementation Actions
Shoreline Management Act (administered by local and state governments)	• SMA requires the protection of water quality and the environment, and the preservation/ enhancement and increase of public access and recreational opportunities. • Skagit County has a Shoreline Mater Program (1976) Action: ensure DMP is consistent with local and state shoreline protection requirements.
State Environmental Policy Act (administered by Ecology and Skagit County)	• Environmental review is required for governmental policies, plans and programs, as well as for non-exempt projects • Skagit County is authorized as a lead agency for SEPA review Action: prepare SEPA checklist for DMP per Skagit County Code Chapter 14.12.
State Hydraulic Code (administered by Washington Department of Fish and Wildlife)	• Hydraulic code regulates activities affecting bed or changes in flow of State's fresh waters that are done to protect fish, wildlife and habitat. • Hydraulic Project Approval is required by WDFW to ensure projects have minimal adverse effect on fish and wildlife. Action: recognize potential HPA provisions in CIP projects planning.
Watershed Planning Act (administered by Ecology)	• State law requires watershed planning to develop local solutions for issues on a watershed basis. • The Upper/Lower Skagit watershed (WRIA 3 / 4) has completed a draft watershed plan. Action: ensure DMP is consistent with draft watershed plan as applicable
Ecology Stormwater Management Manual for Western Washington (administered by Ecology)	• Revised Stormwater Management Manual for Western Washington issued in 2005. • NPDES Phase II permit in effect February 16, 2007, with regulatory tie to Stormwater Management Manual for Western Washington (SWMMWW or Ecology-approved equivalent). Action: ensure DMP and projects are consistent with SWMMWW as applicable.
Skagit County	
Skagit County Comprehensive Plan and County-wide Planning Policies	• Comprehensive plan "Goal B" addresses stormwater with 5 major objectives and associated policies. Action: ensure DMP is consistent with the objectives and policies of Goal B of the Comprehensive Plan

Regulations, Policies, Programs, Standards, Resource Agency Permitting Requirements	**Applicability to Big Lake DMP and Implementation Actions**
Skagit County Code Regulations	• Chapter 14.24, Critical Areas Ordinance (update nearly complete). Best Available Science required for critical area conservation/protection measures. • Chapter 14.32, Drainage Ordinance, establishes comprehensive stormwater drainage design, review, approval, construction, maintenance and management requirements (short and long term). • Chapter 14.34, Flood Damage Prevention, promotes public health and safety and minimizes public and private losses due to flood conditions. Standards are tied to minimum NFIP requirements. • Chapter 14.36, Public Works Standards, set county requirements for roads, stormwater, sanitary sewers and water systems. Action: ensure DMP is consistent with the requirements of the Skagit County Code.
Skagit County Stormwater Programs	• Modifications to County stormwater programs are need for compliance with NPDES Phase II permit requirements. Action: ensure DMP recommended stormwater programs are consistent NPDES Phase II permit compliance needs.
Skagit County Public Works Stormwater Standards	• Defines standards that apply to roads and stormwater systems, as well as sanitary sewers and water systems. Action: ensure DMP is consistent with the Skagit County Stormwater Standards.

3.0 Chapter 3 – Study Area/Watershed Mapping and Drainage Basin Characteristics

3.1 Study Area Aerial Survey and Mapping

Study area mapping was developed using aerial photogrammetric methods including aerial photography and ground control surveys that were combined to produce topographic mapping and digital orthophotography of the study area. At the watershed scale beyond the study area, USGS topographic mapping was used to supplement the study area mapping for definition of watershed and drainage subarea boundaries used in hydrologic analysis. A brief description of the study area mapping process and resulting products is summarized below. Hard copies and digital files of the aerial photography and mapping products were provided to Skagit County Public Works separately from this report.

3.1.1 Aerial Photography

On March 20, 2004, Walker and Associates (as subconsultant to Montgomery Water Group) completed color stereo aerial photography of the study area. The photography was taken with a precision aerial mapping camera equipped with a gyroscopically stabilized mount and an image-motion compensated magazine. The nominal negative scale of the photograph is 1 inch = 600 feet (1:7,200). Simultaneous with the aerial photography, airborne GPS data was collected at one or one-half second epochs using receivers in the aircraft using two or more ground reference stations (locations established by the ground control survey). The airborne GPS data was post-processed to determine precise coordinates and elevations for each camera station. This provided the required horizontal and vertical control for development of the mapping products.

3.1.2 Ground Survey Control

A network of ground survey control points were selected by Walker and Associates in coordination with Skagit Surveyors and Engineers (SSE, survey subconsultant to Montgomery Water Group). Figure 3-1 shows the aerial photography flight lines and photo locations along with the network of ground survey control used for both standard photo control and airborne GPS control. The specific control points were pre-marked and coordinates were then established by ground surveys conducted by SSE. The coordinates of the control points were established based on horizontal and vertical datum previously established by SSE from prior PUD work around Big Lake (no USGS control monuments were found in the near vicinity of Big Lake). Horizontal control is based on the State Plane Coordinate System, and vertical control is based on the North American Vertical Datum of 1988.

Figure 3-1. Aerial Mapping Ground Survey Control

3.1.3 Photogrammetric Mapping

Topographic mapping of the study area was prepared using standard photogrammetric compilation methods to produce map panels at a scale of 1 inch = 100 feet (1:1,200) with a 2-foot contour interval. A total of 16 mapping panels were produced to cover the study area. The road network, the drainage network, and drainage structures were captured in the format of vector data. This data was provided on separate digital mapping layers. The mapping was produced using procedures for determining horizontal and vertical accuracy that have been demonstrated to comply with the National Standard for Spatial Data Accuracy (NSSDA).

Topographic contours in areas obscured by vegetation were dashed. To validate aerial mapping contours and topographic elevations in those areas (e.g., as a basis for stormwater facilities design), field topographic surveys should be completed to supplement the aerial mapping.

Pilot area mapping was originally prepared during Phase 1 study and was submitted to Skagit County Public Works in August 2004. Skagit County reviewed those products for adequacy and as the basis for requested adjustments to be incorporated with the remaining study area mapping products. The Phase 2 mapping products for the full study area (16 sheets including index map) were subsequently submitted in April 2005 (aside from the reserve reading Mylar map panels to be submitted with the final plan). The data sets and mapping files were submitted on CD-ROM in AutoCAD 2002 compatible format.

3.1.4 Digital Orthophotography

The aerial negatives were scanned at a resolution that provided for ¼-foot pixels on the final digital orthophoto. Using the digital terrain model (DTM) prepared for photogrammetric mapping and the scanned image data, digital orthophotos of the study area were prepared for hard copy at a plotting scale of 1 inch = 100 feet (1:1,200).

Digital orthophotography was also compressed using MrSID®. MrSID® mosaics and compresses large image files making the entire ortho data set widely usable. The MrSID® viewer can be downloaded from the internet and used to easily view the images. The program allows the user to view, crop, and enlarge specific areas. MrSID files are also readable by many GIS and CAD-based software packages.

The resulting digital orthophoto files in TIFF and MrSID format were submitted on DVD to Skagit County Public Works in April 2005. One set of glossy orthophoto hard copies printed at a 1” = 100 foot (1:1,200) scale were also provided to the County.

3.2 Study Area and Drainage Basin Characteristics

The study area surrounding Big Lake and its watershed are shown in Figure 1-2. The study area defines the area of urbanizing residential and recreational growth around the lake. Big Lake is an approximate 540-acre lake located within the Nookachamps valley between topographically-high ridges to the southwest and northeast. State Route 9 (SR-9) extends along the northeast side of the lake within the study area, and connects to SR-538 north and east of Mt Vernon and to SR-20 further north at Sedro Woolley. West Big Lake Boulevard extends around the west perimeter of the lake, with connection to SR-9 at the north end of the lake at the Town of Big Lake, and also back to SR-9 near the southeast corner of the lake. The Town of Big Lake contains a land area of approximately 4.0 square miles and in 2000 had a census-defined total population of 1,153 occupying 548 housing units.

The headwaters of the Big Lake watershed are at Lake McMurray, located about 5 miles south of Big Lake. Lake Creek (or otherwise shown as Upper Nookachamps Creek) connects Lake McMurray to Big Lake. The outlet of Big Lake discharges to Nookachamps Creek that combines further downstream with the East Fork Nookachamps Creek prior to discharge to the Lower Skagit River at approximately river mile 19.

3.2.1 Topography

Figure 1-2 shows the USGS 7.5 minute quadrangle topographic mapping within the Big Lake watershed. Aside from Big Lake, the watershed topography is relatively steep, ranging up to approximately 40% or greater in its steepest portions. Within the study area, drainage system slopes connecting to the lake range up to about 15%, but typically average between 5% and 10% (based on study area topographic mapping developed under this drainage plan).

3.2.2 Watershed Drainage Subbasins and Subareas

Figures 3-2a and 3-2b (respectively) depict the watershed-scale drainage subbasins and the local drainage subareas that contribute surface runoff to Big Lake. At the watershed-scale (Figure 3-2a), forty subbasins totaling 19.8 square miles were identified. Twenty-one of those subbasins drain to Lake Creek, which enters the south end of Big Lake. The remaining 19 subbasins are directly tributary to Big Lake along its west and east sides. In addition, two drainage subbasins were identified as draining directly to Nookachamps Creek downstream of the Big Lake outlet.

At the study area drainage-scale (Figure 3.2b), the local drainage subbasins (totaling 4.1 square miles) were further divided and refined into approximately 50 drainage subareas that drain to Big Lake through a total of 38 outfalls. For the Nookachamps subbasins (totaling 1 square mile), 12 drainage subareas were identified that discharge through six separate outfalls to Nookachamps Creek.

Figures depicting the major drainage systems as defined are provided in Appendix A.

Figure 3-2a. Big Lake Tributary Local Drainage Areas

Figure 3-2b. Big Lake Watershed-scale Subbasins

3.2.3 Climate

Climatic characteristics of the Big Lake study/watershed area were determined from review of statistically based data collected from a network of local and regional weather stations. Average temperatures in the study area range from average high temperatures approaching 75^{o}F in August to average low temperatures averaging about 32^{o}F in January. Study area monthly precipitation averages in excess of 6 inches in November and December, while declining to about 1.5 inch in August. Mean annual precipitation averages about 44 inches local to Big Lake, and ranges to approximately 52 inches at the upper limits of the watershed. On average, approximately 65 percent of the annual rainfall occurs between October and March.

3.2.4 Existing Land Use

Existing developed and undeveloped parcels in the study area and watershed are shown in Figure 3-3. Generally, development is concentrated within the study area surrounding Big Lake, in particular, between the perimeter road and the lake's edge. More development is occurring in upslope areas, and to some rural parcels south and north of the lake. Similar, although less intense, development patterns exist around Lake McMurray at the headwaters of Lake Creek. The remainder of the watershed is primarily forest and pasture in areas previously logged. In the

Nookachamps watershed area at the northeast corner of Big Lake, a major residential development is in progress that has modified the hydrologic response within those drainage subbasins. Detention systems are evident from the mapping and field observation, which are intended to control runoff response from that development.

Figure 3-3. Existing Developed and Undeveloped Parcels

3.2.5 Future (Comprehensive Plan) Land Use

Comprehensive land use designations in the study and watershed area are shown in Figure 3-4. The majority of the study area falls within the Rural Village (RV) land use designation. Under that category, the allowable development levels are limited to 1 – 5 acre minimum lot sizes depending upon wastewater treatment. The upslope areas west and east of Big Lake are designated as either Rural Reserve (RRV) or Rural Resource (RR), which typically limits development to 10 and 40-acre minimum lot sizes, respectively. Similar designations apply around Lake McMurray. The remainder of the watershed is zoned primarily Rural Reserve (RR), Secondary Forest (SF), or Industrial Forest (IF), where controlled harvesting of timber is permitted.

In many portions of the study area large homes are being built and land cover is being modified by re-development such that impervious areas are increasing. Those increased impervious areas (where not attenuated through detention and/or infiltration systems) result in larger peak flows and larger runoff volumes to Big Lake. As the more intense development area is typically close to the lake, the effect on major drainage systems runoff is muted (provided development doesn’t infringe into those drainage courses); however, effects can be more significant on minor (lateral) drainage systems where changes in runoff may be somewhat magnified. Chapter 6 provides details on changes in study area land cover and effects on the hydrologic response to Big Lake and Nookachamps Creek downstream from the lake.

Figure 3-4. Future Comprehensive Plan Land Use Designations

3.2.6 Soils/Geology

Figure 3-5a shows the surficial soils hydrologic group classification within the study and watershed areas directly tributary to Big Lake. Those soils classifications range from hydrologic soil group D in the Nookachamps Valley (including soils underlying Big Lake) and along sections of Lake Creek and Nookachamps Creek to hydrologic soils group C, typically located on the east side of the lake, and hydrologic soils group B typically along the west side of the lake. Table 3-1 provides a description of the soil group classifications as pertains to runoff response characteristics.

Figure 3-5a. Soil Hydrologic Groups Classification

Table 3-1. Hydrologic Soil Group Classifications and Soil Characteristics

Hydrologic Soil Group	Soil Characteristics
A	Group A soils have low runoff potential. They have high infiltration rates even when thoroughly wetted and have a high rate of water transmission (greater than 0.3 in/hr). They consist of deep well to excessively well drained sands or gravels.
B	Group B soils have moderate infiltration rates when thoroughly wetted and have a moderate rate of water transmission (0.15 to 0.30 in/hr). They consist of deep moderately well to well drained soils with moderately fine to moderately course texture.
C	Group C soils have low infiltration rates when thoroughly wetted and have a low rate of water transmission (0.05 to 0.15 in/hr). They consist of soils with a layer that impedes downward movement of water or moderately fine to fine textured soils.
D	Group D soils have a high runoff potential. They have very low infiltration rates when thoroughly wetted and have a very low rate of water transmission (0.0 to 0.05 in/hr). They consist of either clay soils or shallow soils over nearly impervious materials.

From the watershed perspective and considering runoff potential, soils were grouped into three categories representative of surficial soils conditions coupled with the underlying geologic parent material characteristics. Those classifications are outwash, till, and saturated, as shown on Figure 3-5b. Outwash, or permeable soils, typically exists along the west fringe of Big Lake, along the Lake Creek corridor, and surrounding the north end of Lake McMurray. Till-classified soils (typically mostly impermeable) typically comprise the remainder of the watershed, with the exception of Big Lake, Lake McMurray, and other water bodies that are classified as saturated. These soils characterizations are used in watershed-based continuous simulation hydrologic modeling evaluations documented in Chapter 6.

Figure 3-5b. Geologic Parent Material Classification

3.2.7 Wetlands

Wetlands are typically integral to open water bodies and drainage systems (where not hydrologically isolated). As such, they are an important consideration in stormwater management planning since there are many restrictions/limitations on filling or excavating within wetlands and they can be significantly impacted and damaged by discharges of untreated stormwater or construction runoff to them.

Wetlands are classified as critical areas that are regulated at all levels of government; at the federal level by the Army Corps of Engineers under Sections 10 and 404 of the Clean Water Act (CWA), by the State Department of Ecology under Section 401 of the CWA, and by Skagit County Code Regulations. The presence of wetlands are defined by a three parameters: hydrology, or the presence of surface water or saturated soil conditions for a minimum of 7 days durations during the growing season; hydric soils conditions; and the presence of wetland plant materials adapted to prolonged or intermittent soil saturation conditions. Wetlands provide important functional benefits within a watershed including flood flow attenuation to reduce downstream flooding frequency and magnitude, water quality preservation, aquifer recharge, base flows preservation, critical habitat and food supply for fish and wildlife species, and visual buffers within the developed landscape. Healthy wetland environments have extensive vegetated buffer complexes that work as part of the natural system to preserve and protect wetlands functions and values.

Wetlands identified within the Big Lake study area and watershed, as shown on Figure 3-6, were defined solely based on published National Wetland Inventory (NWI) sites. Throughout the study area, NWI sites are limited to a few wetland areas beyond the perimeter roads within existing ponds, along stream corridors, or at topographically-depressed areas along open drainage systems. Those include a large wetland complex at the south end of the Big Lake, ponds along the golf course on the east side of the lake, a significant wetland system along the west-central side of Big Lake (west of West Big Lake Boulevard), and some smaller wetlands near outfalls to within the Nookachamps subbasin areas. Other wetlands may exist, but their identification was not included in the scope of this drainage plan.

Figure 3-6. NWI Wetland Areas

3.2.8 Streams, Drainage Courses, and Other Water Bodies

Steams, creeks, and other open drainage courses crossing through the study area are shown on Figure 3-7. Lake Creek (Upper Nookachamps Creek) drains through the south end of the study area with discharge to Big Lake. Nookachamps Creek flows out of Big Lake to the north with downstream connection to the Lower Skagit River. The largest drainage system flowing laterally to the lake exists in the west-central portion of Big Lake and flows through a wetland complex, then northeast through an unnamed drainage course, culverts, and bridges to the BL9 lake outfall. Other unnamed water bodies are present in the study area, and in most cases, are fed by surface water inputs from the local drainages. They function to provide some attenuation of flood flows and also provide some water quality benefits through settling of suspended sediments and attached pollutants that may be transported from upstream steeper gradient reaches.

Figure 3-7. Study Area Streams and Water Bodies

3.2.9 Other Critical Areas

Other critical areas exist within the study area, but their identification is beyond the scope of this plan. Beyond wetlands, streams, and other water bodies as described above, they include floodplains (included for Big Lake), floodways, shorelines, steep or unstable slopes, landslide hazard areas, stream and wetland buffers, aquifer recharge areas, and priority fish and wildlife species and habitat areas (with database as administered by the WDFW Priority Habitats and Species [PHS] program).

4.0 Chapter 4 – Drainage Systems Inventory and Data Collection

4.1 Site Reconnaissance and Drainage Systems Identification

One objective of this drainage plan is to document the existing drainage system infrastructure present within the Big Lake study area for analysis and development of solutions to drainage system complaints and problems. There are many open and closed drainage systems present in the study area, the majority of which discharge to Big Lake; the remainder outfall to Nookachamps Creek downstream from the Big Lake outlet. As Skagit County Public Works had limited documentation of existing drainage systems available, a combined aerial mapping/field survey approach was used to develop the storm drainage facilities inventory. The inventory approach was initially completed within a pilot area during the Phase 1 study to determine the most efficient methods of inventory, validate the accuracy of the collected data, and provide sample products to County staff for approval.

Initial Phase 1 study site reviews were conducted in March 2004 by SSE survey staff in coordination with MWG during ground control field procedures prior to aerial photography. Site reviews were used to determine the type and extent of drainage facilities to be inventoried and also formed the basis for pre-marking of drainage facilities. A second site reconnaissance of drainage facilities within the pilot area was completed by MWG staff in coordination with SSE field survey staff during Phase 1. This review was conducted to investigate the pilot area drainage systems and confirm the specific field inventory data needs for each type of drainage system.

Additional field reviews were conducted by MWG staff in Phase 2 to further coordinate with SSE survey crews regarding the storm drainage facilities inventory for the remainder of the study areas, to investigate drainage subbasins/subareas boundaries and hydrologic characteristics (with MGS Engineering Consultants, MGS (subconsultant to MWG), and to evaluate hydraulic conditions within specific drainage systems. Drainage complaints and problem areas were also investigated by field review and with input from local residents. A further field reconnaissance was conducted by MWG staff to review all major drainage systems for continuity, facilities missing from the inventory, and to evaluate possible solutions to identified drainage complaints and problems. The conditions at the inlet and outlet of Lake McMurray and along a major drainage on the west side of Big Lake (within BL9) were also investigated for beaver activity.

4.2 Aerial Mapping Facilities Inventory and Documentation

Prior to aerial survey, drainage facilities throughout the study area that were visible at the surface were pre-marked by SSE field staff. This consisted of painting a white spot on the tops of culverts and storm drains at inlets and outlets, and on visible drainage structures. Based on the aerial survey, Walker and Associates ascertained the coordinates and elevations of those pre-mark spots from the aerial survey using photogrammetric methods. This effectively reduced the extent of required controlled field survey needed to complete the facilities inventory. Measure downs from those spot elevations were then made during the surveyed field inventory to determine the invert elevations and sizes of the pre-marked culverts and storm drains.

During the Phase 1 pilot area inventory, field surveyed checks were made on selected pre-marked, photogrammetrically-derived spot elevations. Field surveyed elevations were typically found to match closely to the aerial-based elevations (typically within 0.1 foot), which was deemed acceptable accuracy for drainage planning purposes. Walker and Associates generated the coordinates and elevations for the remaining pre-marked spots within the pilot area under Phase 1, and subsequently for the remainder of the study area in Phase 2. The resulting pre-mark data sets from the aerial mapping effort were transmitted to SSE for integration with the field surveyed inventory data set. MWG reviewed the collective data set for missing data or obvious data errors to be re-checked. Where required, Walker and Associates provided the missing data or corrected the erroneous data.

4.3 Field Surveyed Facilities Inventory and Documentation

SSE, in coordination with MWG, initially conducted the field survey of drainage facilities in 2004 for the Phase 1 pilot area, and subsequently in 2005 for the remaining study area. Drainage systems and facilities inventoried within the study area included:

- The Big Lake outlet channel (to determine outflow hydraulic control)
- The Lake McMurray north/south outlet channels (to determine outflow hydraulic control)
- Storm drains including interconnecting hydraulic structures
- Perimeter road culverts including allowable headwater in adjacent roadside ditches
- Other public/private culverts and interconnecting open drainages including abandoned railroad grade ditches

The drainage systems identified for inventory are gravity systems (no pump stations were found), and in most cases do not appear to have associated detention storage. A few ponds do exist (e.g., for the current large site development draining to Nookachamps Creek). Roadside ditches with cross-culverts and lateral storm drains that outfall to natural or modified drainage courses are the most common mode of runoff conveyance within the study area. On the larger drainage courses, small (assumed private) bridges also exist in a few locations.

Field surveys for the drainage facilities inventory were conducted by SSE using a combination of GPS and conventionally controlled survey methods. Survey control was tied to that used for the aerial mapping. All inventory elevation data sets are in reference to the NAVD 88 datum.

MWG staff established the specific facility inventory measurements to be made and worked with SSE to develop a spreadsheet to document the combined aerial and field survey inventory data sets. A description of the database collected is summarized in Table 4-1 as an index to the inventory data sheets. A unique numerical identification number was assigned to each aerial or survey-based data point (e.g., for each end of a culvert or storm drain, for each drainage structure). Aside from the type, size, location, material parameters, measurements were also made to define the approximate maximum headwater depth at the upstream side of culverts or storm drains prior to overflow (for use in hydraulic capacity evaluation). Data on estimated pipe obstruction due to damaged end sections or sediment/debris accumulation was also included under "percent obstruction". The spreadsheet data also indicate the source of the coordinate and elevation data (either from aerial or field survey).

Table 4-1. Drainage Facilities Surveyed Inventory Summary

Inventory Item Abbreviation	Description of Inventory Item
ID	identification number
	ID modifier used to note direction of multiple pipes in catch basins
Origin	origin of the survey elevation data: P=aerial photo, S=survey
Northing	State plane coordinate
Easting	State plane coordinate
Obs'vd Descr.	description of item observed from aerial survey (i.e. culvert, catch basin, manhole)
Obs'vd. Elev.	elevation of the top of culvert or other feature determined from aerial survey
Meas. Down to Inv.	measurement from the top of the culvert to the invert
Link to ID	link to the ID number of the opposite end of the culvert
Material	culvert material: 1=RCP 2=CMP 3=HDPE/CPE 4=Other
End Type	culvert end treatment: 1=Square 2=Mitered 3=Projecting 4=Headwall
Max Depth Above Invert	maximum depth of water that could occur above the invert of the upstream end of a culvert
% Obs. Damage	percent of culvert depth blocked by damage
% Obs. Debris	percent of culvert depth blocked by debris
Nom. Size	nominal (ID) size of culvert in inches

4.4 Drainage Inventory Results and Products

The drainage facility inventory datasheets are provided in Appendix B. The drainage facilities coordinate and elevation data was translated into AutoCAD drawing file format. A composite file at 1" = 100 feet (1:1,200) was created for plotting those study area facilities along each side of the lake. Inventory data layers were also translated into ESRI GIS-compatible format for use by the County's GIS Department and to comply with NPDES Phase II facilities inventory documentation needs. A draft digital version of the collective inventory database and mapping materials was provided to Skagit County Public Works in December 2005.

Major drainage systems and Big Lake and Nookachamps Creek outfalls identified from the facilities inventory data are shown on set of aerial photo-based figures in Appendix A. Documentation of the Lake McMurray outlets is provided in Figure 4-1 including comments on beaver dam effects. Figure 4-2 shows the Subbasin BL9 large wetland complex including comments on potential beaver dam effects.

Figure 4-1. Lake McMurray Outlets and Beaver Activity Areas

Figure 4-2. Subbasin BL9, BL15, Wetlands and Beaver Activity Areas

5.0 Chapter 5 – Drainage Complaints and Problem Areas Documentation and Assessment

5.1 Drainage Complaints Documentation

Drainage complaints and problems in the study area surrounding Big Lake were reviewed and evaluated as a basis of identifying drainage improvement solutions that will address the concerns of local stakeholders. The County has documented drainage complaints in the Big Lake study area since November 2001. Table 5-1 identifies a total of 37 drainage complaints that have been logged through September 2005 based on County records. Generally the complaints only provide a street address or a parcel identification number and the date of the complaint. The complaints do not document a particular source or problem. The complaint data were mapped within the project GIS database and are shown on Figure 5-1. Interestingly, a number of the complaints are from the summer months when stormwater would not be expected to be a problem. It appears, in some cases, that these summer complaints may be related to groundwater seepage.

Drainage Complaints

Skagit County Public Works provided a list of drainage complaints from residents of the Big Lake community (Table 5-1). The drainage complaint record provides no record of the problem, but identifies the location of the drainage problem by either street address or parcel number. Based on the inventory of the stormwater infrastructure, topographic maps, aerial photos, the hydrologic and hydraulic models and a site visit, possible explanations are provided that identify the likely problem. In some cases, the drainage complaints appear related to problems that occur on private property and are not related to County-owned infrastructure.

Figure 5-1. Study Area Drainage Complaints

Table 5-1. Drainage Complaint Records and Observed Problem Source

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
3	18498 S Westview Rd	Prothero		11/26/2001	WTR	This complaint appears to be related to private modifications of the local drainage system. Many home owners have improved the land opposite their homes to provide parking. In many cases, the roadside ditches have been filled and under sized culverts have been installed. The fill and cross slope of the road prevents stormwater from entering the ditch and culvert system causing floodwaters to sheet over the road.
4	17164 Lakeview Blvd	Holdt		11/28/2001	WTR	This complaint appears to be related to a problem that has likely been repaired. Comparing aerial photographs from 2001 and 2004 shows that the landscape has changed significantly in this area. A 12-inch culvert conveys flows under SR 9 to an undeveloped parcel. It appears that a driveway may have blocked the drainage from this undeveloped parcel possibly causing flooding on the parcel or on Lakeview Blvd. The inventory shows that a 36-inch culvert is now in place to convey water under the driveway.
61	18524 S Westview Rd	Campbell		11/30/2001	WTR	See explanation of #3. In addition, the inventory also identified an 18-inch culvert of unknown origin that discharged to the land surface near this complaint. The discharge is located where the stormwater is conveyed under driveways and there appears to be no inlet to the storm system.

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
129	18070 State Route 9	French		6/6/2002	CJH	Could not find a potential source of this complaint. It appears that the culverts along SR9 have adequate capacity and are free of damage and debris. There has been some new construction in the vicinity of the complaint between 2001 and the time that inventory was completed; it is possible that the culverts were obstructed with sediment or construction debris at the time of the complaint.
149	22982 Little Mtn Rd	Govaert		11/30/2001	WTR	This complaint is at the limit of the detailed study area, as such, no inventory data were collected.
193	1749 Lake Terrace Pl	Berglin		12/20/2001	WTR	This complaint appears to be related to runoff that is not being captured by the stormwater infrastructure. This causes stormwater to flow down the road and wash out the gravel driveways of the down gradient homeowners. There is possible transport of gravels down to Little Mountain Road (complaint 410) and blocking the stormwater infrastructure along that road. Recently it appears that the local water company filled the entrance to the main 24” culvert when installing water meter boxes.
281	17671 West Big Lake Blvd	Skiles		12/20/2001	WTR	This complaint seems to be related to runoff captured by a roadside ditch and conveyed to a large depressional area. The inventory did not identify an outlet to the depression. Topographically it would be reasonable to have an outlet under the road that discharged to the natural valley on the down gradient side of the road.
301	16546 State Route 9	Brown		8/5/2002	JEN	Could not find a potential source of this complaint. An 18” RCP conveys stormwater under SR9 to Nookachamps Creek. The pipe is free of debris and damage. The culvert has adequate capacity to carry the anticipated flows.

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
325	17163 Lakeview Blvd	Ammons		8/1/2003	CJH	See explanation #4
390	17306 Lakeview Blvd			2/8/2002	CJH	See explanation #4
410	22940 Little Mtn Road			2/13/2003	CJH	See explanation #193
415	22833 Lake Terrace Lane	Rick H.		2/6/2003	CJH	See explanation #193
423	18889 West Big Lake Blvd	Fisk		11/2/2001	WTR	This compliant is related to a stream channel that flows adjacent to this homeowner. It appears that the owner has erected a cinderblock wall to redirect the flow of the creek around his patio area.
428	Mahonia Lane			9/27/2001	WTR	This complaint appears to be associated with the lack of any drainage facilities. There are a number of homes with no apparent local drainage system that either connects to the existing drainage system that discharges to the lake or discharges to the lake directly.
466	18560 S Westview Rd	West		11/26/2001	WTR	See response to explanations #3 and #61
468	18333 Eagle Point Lane	Cassidy		11/1/2001	WTR	This complaint appears to be associated with the lack of any drainage facilities. There are a number of homes with no apparent drainage system to the lake. It appears their parking area may retain water. Additionally, it appears that runoff, from a neighbor with farm animals (horses and mules), may flow across the road into the driveway and parking area.

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
478	Oakland Lane	Miller		4/9/2002		This complaint appears to be related to a lack of a local drainage system. A major drainage system with a 36" RCP culvert crosses West Big Lake Blvd. and then enters a 30" HDPE culvert before discharging to an open channel and the lake. The homes are generally lower in elevation than the main drainage system and consequently the home owners cannot add their local drainage to the system. Additionally, runoff from the roadway adjacent to their properties flows down the driveway to a common parking/turning area.
529	Lakeview Blvd	Brown		4/11/2003	CJH	Cannot determine location of this complaint; for a possible explanation see responses to complaints on Lakeview Blvd (#4)
533	Westview Rd	Jensen		6/9/2003	CJH	This drainage complaint is related to groundwater seepage from the upgradient stormwater system. Water is discharged to a ditch above the abandoned railroad bed. Vegetation and the grade prevent water from freely draining from the ditch. Consequently, the water recharges the shallow groundwater and seeps to the homes down gradient of the ditch.
537	S. Westview Road	Miller-Figenshow		6/30/2003	CJH	See explanation #3
539	Lake Cavanaugh Rd.	Walker		7/22/2003	CJH	Lake Cavanaugh Road is Outside the Study Area
544	Lake Cavanaugh Rd.	Palmer		9/24/2003	CJH	Lake Cavanaugh Road is Outside the Study Area
557	West Big Lake Blvd	Dodd		12/1/2003	CJH	Cannot determine location complaint; for a possible explanation see responses to complaints on West Big Lake Blvd. (#281, #428).

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
566	N. Westview Road	Nystrom	74752	3/5/2004	ECA	This complaint appear to be related to damage to the ends of the culvert that convey local flows under N. Westview Road. Undamaged the culvert has adequate capacity to convey local flows. However, the inventory indicates that the end of the culvert is about 40% obstructed. In addition the local drainage system has been modified by filling or paving over the roadside ditches, preventing stormwater from entering the culvert system. Where the ditch has been filled, often undersize pipe has been installed.
583	N. Westview Road	Snelson	74751	4/22/2004	ECA	See explanation #566
585	West Big Lake Blvd	Maricich	62022	4/22/2004	ECA	See explanation #478
593	W. Lakeview Blvd		varies	7/2/2004	JDF	See explanation #4
594	S. Big Lake Blvd.	Lidtke	29906	7/19/2004	JDF	This complaint appears to be related to accumulation of water in a marshy area upstream of the culvert that passes under West Big Lake Blvd. The culvert has the appropriate capacity and is set at an elevation such that the area should drain.
597	Coots Cove	Moore	62017	5/9/2005	ECA	See explanation #478
599	Trout Drive	Lutgen	120770	6/22/2005	ECA	This drainage complaint appears to be related to over flow of the roadside drainage system. From the inventory data it appears that the ditch has an adverse slope and the elevation change is great enough that the ditch spills across the road rather than flowing through the culvert system.

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
602	N. Westview Road	Brown	74663	6/13/2005	ECA	Could not find a potential source of this complaint. It appears that since 2001, a parking area has been established across the road from the homeowner. An 18” HDPE culvert has been installed. The culvert appears to have adequate capacity.
624	S. Westview Road	Jensen	74714	5/29/2004	ECA	See explanation # 533.
625	West Big Lake Blvd	Smith	61981	4/27/2005	ECA	This complaint appears to be related to undersized private infrastructure. Water is conveyed under West Big Lake Blvd. via an 18” culvert. At one time the water likely flowed through a natural channel to the lake. Currently there is a private system consisting of catch basins and 8” corrugated plastic drain pipe. At present, the inlets to the catch basins are above grade.
647	Kokanee Court	Sehorn	113896	8/26/2004	ECA	This complaint appears to be related to interception of shallow groundwater and stormwater discharged to the land upgradient of the homeowner’s property. Aerial photograph shows water flowing across the roadway when homeowner’s house was under construction. The inventory also shows a trench system to distribute stormwater on to the hill slope above the homeowner’s property.
654	Lake Terrace Lane	Pace	29769	11/4/2004	ECA	See explanation #193
655	State Route 9	Xaver	18021	7/20/2005	ECA	This complaint is beyond the detailed study area so no inventory data has been collected. The complaint may be related to flows in Lake Creek between SR9 and Big Lake. A windshield survey of the area indicated no apparent problems. With the abundance of beaver activity in the region, Lake Creek may have been temporarily dammed, resulting in flood conditions.

SWM File #	Location	Owner	Parcel#	Date	Init.	Complaint Explanation
656	West Big Lake Blvd	Rekevics	67135	9/15/2005	ECA	This complaint appears to be related to overflow of the natural channel between West Big Lake Blvd. and Big Lake. The natural channel drains approximately 230 acres to the west of West Big Lake Blvd and passes under the road in a 36-inch RCP culvert. Based on the inventory, the culvert is was not blocked or damaged in 2005; however during a site visit in April 2006, the culvert was substantially obstructed with sediment. The channel between the road and the lake is overgrown with vegetation, which likely caused the sediment to accumulate.

5.2 Drainage Problems Assessment

Potential drainage problem areas were identified and assessed during field reconnaissance and analysis based on the following criteria:

- Existing drainage problems identified by stakeholder complaints made to the County
- Drainage facilities found to be damaged (typically at inlet or outlet) or obstructed by sediment or debris during the field inventory
- Culverts and storm drains that were evaluated to be undersized based on the hydrologic and the hydraulic calculations made as part of this study
- Other drainage problems (e.g., water quality [potential illicit discharge], erosion) established from the drainage inventory or observed during study area field review

5.2.1 Drainage Complaints Observed Problems/Sources

All drainage complaint areas were investigated based on the facilities inventory database and during field reconnaissance in attempt to identify the problem and its source. This included talking with residents (when available) during field review about their perception of specific drainage problems and flooding history. The findings from this review and assessment are briefly summarized in the last column of Table 5-1.

5.2.2 Damaged or Obstructed Culverts and Storm Drains

During the field survey inventory conducted by SSE, the ends of each culvert or storm drain were examined to determine its condition. If the pipe was partially obstructed by either damage or by accumulated sediment or debris, an estimate was made of the percent obstruction. Tables 5-2 and 5-3 summarize those fully or partially obstructed culverts and storm drains by drainage facility ID number for the pipe ends that were obstructed by either damage or by sediment/debris, respectively. The locations of the damaged or obstructed culverts and storm drains were also mapped within the project GIS and are shown on Figures 5-2 and 5-3.

Many of the culverts or storm drains, particularly those located along ditches parallel to roads and used for driveway access (typically without headwalls), have damaged end sections (e.g., they have been partially crushed by vehicle access across them). Many of those would have adequate capacity if not obstructed, so the need is for replacement of the end sections or the entire culvert as required. Consideration for addition of headwalls to protect the pipe end sections should also be made with those repairs. For those culverts and storm drains that were evaluated to have capacity limitations due to size (for fully unobstructed condition), an increase in pipe size is needed.

For pipe end sections that are fully or partially obstructed due to sediment or debris, associated drainage problems may be resolved through maintenance actions that would remove the obstruction at the pipe entrance or exit to restore its targeted capacity. This may include the need to remove accumulated sediment in a section of the upstream drainage ditch. In some cases, debris racks with larger open area (e.g., projecting from culvert entrances), or other actions, such as control of upstream erosion may be necessary to limit future problems. Consideration of the adequacy of the pipe entrance's fully unobstructed hydraulic capacity is also needed in assessing improvement actions.

Figure 5-2. Study Area Culverts Partially Obstructed by Sediment and/or Debris

Figure 5-3. Study Area Damaged Culverts

Table 5-2. Culverts Obstructed by Sediment or Debris

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1698	UK	UK	100%
1828	UK	UK	100%
1472	RCP	36	70%
1815	RCP	36	65%
5237	CMP	36	40%
1473	CMP	30	5%
1513	CMP	30	5%
5386	CMP	24	75%
1930	CMP	24	20%
5387	CMP	24	20%
1933	RCP	24	5%
1707	Other	18	100%
5346	HDPE	18	100%
1908	CMP	18	75%
5341	RCP	18	60%
1622	CMP	18	50%
1820	RCP	18	50%
1827	CMP	18	50%
1894	HDPE	18	50%
2022	RCP	18	50%
2082	CMP	18	50%
1639	HDPE	18	40%
1640	HDPE	18	30%
1783	CMP	18	30%
1784	CMP	18	30%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1873	HDPE	18	30%
1892	HDPE	18	30%
1893	HDPE	18	30%
2006	RCP	18	30%
5175	HDPE	18	30%
5361	RCP	18	30%
5508	HDPE	18	30%
1217	HDPE	18	20%
1227	HDPE	18	20%
1248	HDPE	18	20%
1250	CMP	18	20%
1447	RCP	18	20%
1573	CMP	18	20%
1695	CMP	18	20%
1819	RCP	18	20%
1891	HDPE	18	20%
2045	HDPE	18	20%
5342	RCP	18	20%
5372	HDPE	18	20%
5499	RCP	18	20%
1449	RCP	18	10%
1523	RCP	18	10%
1572	CMP	18	10%
1708	CMP	18	10%
1821	CMP	18	10%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1825	CMP	18	10%
1825	CMP	18	10%
1826	CMP	18	10%
2005	RCP	18	10%
5250	RCP	18	10%
5500	HDPE	18	10%
5505	RCP	18	10%
5507	HDPE	18	10%
1469	RCP	18	5%
5400	RCP	18	5%
1960	CMP	16	10%
5286	HDPE	16	5%
1276	HDPE	14	10%
1230	RCP	12	100%
1477	CMP	12	100%
1645	RCP	12	100%
5370	RCP	12	100%
5420	HDPE	12	100%
5283	HDPE	12	95%
1316	HDPE	12	90%
1353	RCP	12	90%
1526	CMP	12	90%
5045	HDPE	12	90%
5343	CMP	12	90%
1350	HDPE	12	80%
1388	HDPE	12	80%
1579	CMP	12	80%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
5237	RCP	12	80%
1335	CMP	12	70%
1618	RCP	12	70%
1741	CMP	12	70%
5382	CMP	12	70%
1365	HDPE	12	60%
1626	RCP	12	60%
1651	RCP	12	60%
2019	HDPE	12	60%
5294	CMP	12	60%
1334	HDPE	12	50%
1336	HDPE	12	50%
1411	CMP	12	50%
1428	HDPE	12	50%
1446	HDPE	12	50%
1613	RCP	12	50%
1614	RCP	12	50%
1619	RCP	12	50%
1631	HDPE	12	50%
1701	CMP	12	50%
1941	RCP	12	50%
1948	RCP	12	50%
5293	CMP	12	50%
5299	CMP	12	50%
5321	CMP	12	50%
5322	CMP	12	50%
5326	CMP	12	50%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
5333	HDPE	12	50%
5418	HDPE	12	50%
5419	HDPE	12	50%
5434	RCP	12	50%
5474	HDPE	12	50%
1461	CMP	12	40%
1574	RCP	12	40%
1620	RCP	12	40%
1656	HDPE	12	40%
1971	CMP	12	40%
1999	CMP	12	40%
5117	HDPE	12	40%
5338	HDPE	12	40%
5364	CMP	12	40%
5369	RCP	12	40%
5407	CMP	12	40%
1325	HDPE	12	30%
1466	CMP	12	30%
1657	HDPE	12	30%
1676	RCP	12	30%
1947	RCP	12	30%
1976	HDPE	12	30%
1984	RCP	12	30%
5260	HDPE	12	30%
5270	HDPE	12	30%
5325	CMP	12	30%
5385	CMP	12	30%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
5421	CMP	12	30%
5687	HDPE	12	25%
1246	HDPE	12	20%
1264	HDPE	12	20%
1313	CMP	12	20%
1323	HDPE	12	20%
1464	HDPE	12	20%
1529	RCP	12	20%
1590	RCP	12	20%
1599	HDPE	12	20%
1615	HDPE	12	20%
1616	HDPE	12	20%
1617	RCP	12	20%
1625	RCP	12	20%
1658	HDPE	12	20%
1660	HDPE	12	20%
1675	RCP	12	20%
1693	RCP	12	20%
1694	RCP	12	20%
1716	CMP	12	20%
1746	HDPE	12	20%
1754	HDPE	12	20%
1817	RCP	12	20%
1818	RCP	12	20%
1830	CMP	12	20%
1831	CMP	12	20%
1832	RCP	12	20%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1833	RCP	12	20%
1972	CMP	12	20%
1983	HDPE	12	20%
2018	HDPE	12	20%
5109	HDPE	12	20%
5127	HDPE	12	20%
5143	CMP	12	20%
5207	CMP	12	20%
5332	HDPE	12	20%
5340	CMP	12	20%
5344	CMP	12	20%
5355	CMP	12	20%
5374	HDPE	12	20%
5422	HDPE	12	20%
5481	CMP	12	20%
5495	RCP	12	20%
5686	HDPE	12	20%
1244	HDPE	12	10%
1245	HDPE	12	10%
1344	HDPE	12	10%
1346	CMP	12	10%
1354	RCP	12	10%
1364	HDPE	12	10%
1366	HDPE	12	10%
1416	CMP	12	10%
1429	RCP	12	10%
1441	HDPE	12	10%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1532	RCP	12	10%
1554	RCP	12	10%
1593	RCP	12	10%
1689	HDPE	12	10%
1699	RCP	12	10%
1727	HDPE	12	10%
1823	CMP	12	10%
1824	CMP	12	10%
1826	CMP	12	10%
1881	HDPE	12	10%
1934	CMP	12	10%
1935	HDPE	12	10%
1936	HDPE	12	10%
1940	RCP	12	10%
1942	CMP	12	10%
1950	CMP	12	10%
1951	CMP	12	10%
2085	HDPE	12	10%
5153	HDPE	12	10%
5213	CMP	12	10%
5275	HDPE	12	10%
5350	RCP	12	10%
5396	CMP	12	10%
5445	RCP	12	10%
5807	Other	12	10%
1242	HDPE	12	5%
1317	HDPE	12	5%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1448	CMP	12	5%
1719	HDPE	12	5%
1854	HDPE	12	5%
1996	RCP	12	5%
1998	RCP	12	5%
5002	HDPE	12	5%
5004	HDPE	12	5%
5483	HDPE	10	100%
1594	HDPE	10	30%
5082	HDPE	10	20%
1342	CMP	10	10%
2078	HDPE	8	100%
2069	HDPE	8	90%
5433	RCP	8	80%
1559	RCP	8	60%
1560	RCP	8	50%
1776	RCP	8	50%
1802	Other	8	50%
5497	CMP	8	50%
5219	RCP	8	40%
5054	HDPE	8	30%
5054	HDPE	8	30%
2080	CMP	8	20%
5055	HDPE	8	20%
5218	RCP	8	20%
5518	Other	8	20%
5498	CMP	8	10%

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1545	PVC	6	50%
5282	CMP	6	50%
1591	PVC	6	20%
5268	HDPE	6	10%
5288	Other	4	60%
2016	Other	4	30%
1931	HDPE	4	20%
5287	Other	4	10%

Table 5-3. Culverts Obstructed by Damage

Culvert ID	Material	Nominal Size (in)	Percent Blocked
1371	CMP	24	20%
1710	RCP	24	10%
5521	CMP	24	10%
5688	CMP	24	10%
2022	RCP	18	50%
1784	CMP	18	40%
1783	CMP	18	30%
1571	CMP	18	10%
1573	CMP	18	10%
1827	CMP	18	10%
1858	HDPE	12	blocked in middle, possible collapse
1467	CMP	12	95%
1898	CMP	12	70%
1636	CMP	12	50%
5213	CMP	12	50%
5382	CMP	12	50%
1716	CMP	12	40%
1717	CMP	12	40%
5383	CMP	12	40%
1715	CMP	12	20%
1740	CMP	12	20%
1741	CMP	12	20%
5207	CMP	12	20%
5396	CMP	12	20%
1552	CMP	12	15%
5340	CMP	12	15%
1526	CMP	12	10%
1613	RCP	12	10%
1701	CMP	12	10%
1745	CMP	12	10%
5356	CMP	12	10%
1934	CMP	12	5%
5395	CMP	12	5%
1578	CMP	8	20%
5053	HDPE	4	10%

5.2.3 Undersized Drainage Facilities with Inadequate Hydraulic Capacity

Major drainage system facilities within the study area (those along the primary trunk drainage systems with discharge to Big Lake and Nookachamps Creek) were evaluated for hydraulic capacity as compared to projected design event peak flows. This included review of facilities in over 40 drainage systems within the Big Lake study area. Chapter 6 documents the methods, assumptions, and results of that technical analysis. Based on that analysis, inventoried drainage facilities were identified that had inadequate hydraulic capacity to convey existing or future flood flows for selected design events (25-year, 24-hour event for existing conditions, 100-year, and 24-hour event for future conditions). Those drainage facilities were added to the list of problem areas to be reviewed for improvement needs.

In most cases the need was simply to upsize those facilities to improve their flood flow capacities; however, in some cases, the extent of drainage problems dictate that a network of improvements or re-routing of drainage by storm drains is needed to minimize future flooding risks. Other areas were also identified where drainage problems appeared (by observation) to be associated with high localized groundwater conditions (in some cases, where no drainage facilities exist to intercept that water).

5.2.4 Potential Illicit Discharge Connections

Potential illicit discharge connections (other than authorized stormwater discharges) to the major drainage systems and associated outfalls were identified based on identified small pipe (less than 6-inch diameter) connections to the inventoried drainage systems where no upstream connection was found. In most cases, these connections are likely individual residence roof, footing, or wall drain connections, which are authorized stormwater discharges under the NPDES program. Further field investigation and testing will be needed to confirm that those connections are not illicit discharges of other unauthorized waters (e.g., gray water/septic, commercial drains, etc.) that are not permitted under State water quality standards and NPDES Phase II permit requirements. Figure 5-4 shows the locations and drainage facility identifier numbers for those facility locations requiring further investigation of potential illicit discharge connections. A full tabulation of those locations is shown in Chapter 7, Section 7.6.

Figure 5-4. Study Area Potential Illicit Discharge Connection Locations

5.2.5 Open Drainage Systems Erosion and Sediment Deposition

Field observations were made during study area reconnaissance to identify locations and potential sources of significant erosion along the major drainage systems. For the most part, significant erosional problems were not evident or could not be readily identified due to vegetative cover conditions. From review of Figure 3-5b, the areas designated with outwash geologic parent material (west and south sides of Big Lake) are most susceptible to erosion. Slopes along the major drainage systems are typically adequate to result in erosive action, although erosion is more likely to occur in the upstream reaches of those drainages where gradients are even steeper. The network of culverts and storm drains along the drainage channels (typically with restricted inlets) along with ponds and topographically depressed areas act as sedimentation controls leading to deposition of the suspended sediment (the larger size fraction). The mouths of the drainage outfalls to Big Lake become the ultimate depositional area for suspended sediments that are not otherwise deposited in the upstream drainage system reaches.

Localized erosion at culvert and storm drain outfalls exists, but documentation of these occurrences was beyond the scope of the drainage facilities inventory. Table 5-2 provides an indication where sediment deposition is most significant along the major drainage systems.

6.0 Chapter 6 – Watershed and Drainage System Hydrologic and Hydraulic Analyses

6.1 Big Lake Watershed and Lake Level Hydrologic Analysis

Hydrologic and hydraulic analyses were completed at the watershed scale to evaluate and characterize expected Big Lake inflows and outflows and to assess associated lake level fluctuation. Hydrologic and hydraulic analyses were also completed at the local drainage system scale to evaluate drainage facilities design event peal flows and hydraulic capacities. These two levels of analysis required different analysis methods and data requirements. MGS Engineering Consultants (MGS, subconsultant to MWG) completed the watershed-scale modeling based on data inputs from and in coordination with MWG. MWG completed the local drainage systems hydrologic and hydraulic analysis in assessment of solution options to identified problems that ultimately define the capital improvement program needs. This section describes the watershed-scale analysis and findings.

6.1.1 Hydrologic Modeling Approach (HSPF)

MGS developed a continuous simulation model for the Big Lake study area to estimate runoff response of the full tributary watershed area. Appendix C provides the MGS draft report, HSPF Hydrologic Analysis of the Big Lake Watershed (February 2006). The following sections briefly describe the modeling approach, the key input variables, and a summary of the results.

The US EPA's Hydrologic Simulation Program Fortran (HSPF) was selected for use. This model is used extensively in western Washington, and the US Geologic Survey (USGS) has done extensive work in the region to develop model parameters. HSPF simulates, for extended periods of time, the hydrologic processes on pervious and impervious land surfaces and in streams and well-mixed impoundments. HSPF uses continuous rainfall and other meteorological records to compute stream flow runoff response. HSPF simulates interception, soil moisture, surface runoff, interflow, base flow, snow pack depth and water content, snowmelt, evapotranspiration, ground-water recharge, and channel and storage routing. The program can simulate one or many pervious or impervious unit areas discharging to one or many river reaches or reservoirs. Frequency-duration analysis can be done for any data output time series. The model is generally run at a 1-hour simulation time step. HSPF is typically used to assess the effects of land-use change, reservoir operations, flow diversions, etc. on selected hydrologic parameters (e.g., flood frequency, flow- or stage-duration, etc.).

Hydrologic analyses of the entire Big Lake watershed were conducted through development of a watershed-specific HSPF model including channel and level-pool routing of runoff through streams and storage units (Lake McMurray and Big Lake). Output from the model was used to provide statistically based recurrence interval flood flows and flow-duration for Big Lake inflows and outflows along with associated lake water surface elevation-frequency and duration statistics. Appendix C provides a detailed discussion of the model development, input parameters, assumptions, and results of the HSPF modeling.

Flood flow frequency and flow-duration analyses were performed on the Big Lake inflows and outflows, and on the computed water surface elevations within Big Lake for 158 years of simulated hourly runoff response from the HSPF model. Existing and future build-out watershed land use conditions were analyzed based on existing land cover from the 2003 aerial photography and GIS coverages, and based on the allowable (future) land cover changes under Comprehensive Plan land use designations, respectively.

The HSPF model estimates runoff response from a watershed based on several key land characteristics. These characteristics relate to regional parameters developed by the USGS for application within HSPF. The watershed is subdivided into smaller basins based on similarities in slope, land use, geology, and land cover. ARCMap, a geographic information system (GIS) program, was used by MWG to delineate and calculate the areas of each subbasin, then to intersect subbasin areas with the watershed land cover, soils, and topography to develop the required HSPF input parameters. The following parameters were evaluated for each subbasin.

6.1.2 Tributary Subbasins

As described in Chapter 3 (Section 3.2.2), the Big Lake watershed was divided into 40 subbasins that are connected by channel reaches. Subbasin delineations are based on topography, hydrologic characteristics, the channel and storage basin network, and locations where computed stream flows are desired.

Big Lake receives runoff from several unnamed stream systems and Lake Creek, which originates at Lake McMurray. The total drainage area tributary to Big Lake is approximately 18.6 square miles. The watershed ranges in elevation from 85 ft at the lake to over 1,700 feet on Devil's Mountain. The mean annual precipitation ranges from 40 to 56 inches. For purposes of this hydrologic analysis, the Big Lake watershed was partitioned as shown in Figure 3-2a.

6.1.3 Land Cover and Soils

Land Cover

Two land use scenarios were analyzed with the HSPF model: existing and future build-out as described in the current Skagit County Comprehensive Land Use Plan (Comprehensive Plan, CP). Existing land use was derived by analysis of aerial photograph, GIS coverage of the watershed, and supplemental field reconnaissance. Six land cover classes were considered in analyzing the watershed hydrology: forest, clear cut, pasture, grass, wetland/lake, and impervious (Appendix C, Figures 3 and 4)

The dominant zoned CP land use in the watershed is rural residential with forest practices permitted in some of the more remote subbasins (within Industrial Forest CP land use designation). Urban-zoned land uses are concentrated around Big Lake and Lake McMurray. Given the rural land use designation for the majority of the watershed, there is relatively little difference between existing and future land use in terms of effective impervious cover (Tables 6-1a and 6-1b).

Table 6-1a. Watershed Land Use Summary Tributary to Big Lake Outlet (Expressed as Total Acreage in Watershed)

Land Cover	Watershed Area Land Use (acres)		
	Existing	Future	Change
Forest	6128	3449	-2679
Clear Cut	3144	3447	+303
Pasture	1248	2920	+1672
Grass	353	948	+595
Wetland/Lake	939	939	0
Effective Impervious	113	222	+109
Total	**11925**	**11925**	**0**

Table 6-1b. Watershed Land Use Summary Tributary to Big Lake Outlet (Expressed as Percentage of Total)

Land Cover	Watershed Area Land Use (Percentage)		
	Existing	Future	Change
Forest	51.4%	28.9%	-22.5
Clear Cut	26.4%	28.9%	+2.5
Pasture	10.5%	24.5%	+14
Grass	3.0%	7.9%	+4.9
Wetland/Lake	7.9%	7.9%	0
Effective Impervious	0.9%	1.9%	+1.0
Total	**100%**	**100%**	**100%**

Vegetative Cover. Using aerial photographs of the watershed, the vegetated cover was categorized as forested, clear-cut, pasture, or grass. Vegetation intercepts some precipitation.

The intercepted precipitation may be delayed on its fall to the ground or may evaporate, reducing both the peak and volume of runoff.

Wetlands. Wetlands were taken from National Wetland Inventory (NWI) available from the County GIS coverage. Areas identified as wetlands in the NWI, lakes, ponds, and suspected wetlands identified by aerial interpretation were categorized as wetlands. Saturated wetlands and water bodies behave as impervious areas, and essentially all intercepted precipitation is available for runoff.

Roads. The area of roads in each subbasin was taken from the County GIS coverage. The County maintains information on the centerlines of paved roads. For this project, all paved roads were assumed to be 32 feet wide. Paved roads are generally impervious and essentially all intercepted rainfall is available for runoff.

Other Impervious Area. Other impervious areas such as rooftops and driveways were estimated from the land use classifications in the CP, which describes the density of housing and limitation on building sizes in each land use category. A drive-by basin reconnaissance was conducted of the watershed, which found that most parcels were developed as residential and that they were not developed to the maximum extent allowed. The County has GIS coverage of land use designations and parcel boundaries. The aerial photos were overlain by the parcel map to determine if a parcel was developed. If a parcel was developed, an impervious area was then assigned based on the land use classifications. Larger lots generally support larger homes, more out–buildings, and longer driveways.

Future Conditions at Build-Out. To estimate future impervious area in each subbasin, it was assumed that all undeveloped parcels would be developed to support residential uses based on the CP land use classification and on the existing patterns of development observed during the drive-by basin reconnaissance. From this, the effective impervious cover percentage was estimated along with the pervious cover land type for each CP land use classification. In addition, areas designated as forest practice (Industrial Forest) under the CP were assumed to be 50-percent clear-cut under future land use.

Soils

The geology of the watershed was delineated based on 1:100,000 scale mapping (WDNR 2001). For hydrologic modeling purposes, each geologic association was assigned to one of three categories: bedrock/till, outwash, or wetland (Appendix C, Figure 2). In areas where the geologic units are aggregated, the soil survey was used to better define the appropriate category (WDNR 2000).

The soils in the majority of the watershed are underlain by glacial till or bedrock. The majority of infiltrated moisture in these areas moves laterally along the bedrock or till surface and reaches the stream as interflow. The rate of interflow is proportional to the slope of the bedrock and is much slower than the rate of surface overland flow.

Small pockets of alluvium, defined as outwash for hydrologic modeling purposes, are present in or near the flat valley bottom. Near-surface soils found in these areas consist of sand and gravels that have high infiltration rates. The majority of rainfall in these areas is infiltrated and percolates to the ground water table and does not contribute to a large degree to surface runoff and storm flows.

6.1.4 Stream and Lake Hydrologic Routing

Runoff computed by the HSPF model was routed along Lake Creek and through Lake McMurray and Big Lake using the Kinematic Wave hydrologic routing algorithm. The principal HSPF input for this is a stage-storage-discharge rating table, called an FTABLE. Those ratings were computed for stream sections using representative cross-sections selected from field review for the major stream reaches. The outlets of Big Lake and Lake McMurray were independently rated for discharge at corresponding lake stages based on surveyed cross-section(s) collected along the outlet streams (Nookachamps Creek and Lake Creek). For Big Lake, the HEC-RAS hydraulic model was applied for the section of Nookachamps Creek between the control section and the lake outlet to provide a more refined stage-discharge rating relationship. Lake McMurray outflow was rated based on uniform flow at a single control section near the Lake Creek outlet. The resulting stage-discharge-storage ratings used for the Lake McMurray and Big Lake are shown in Tables 6-2a and 6-2b.

Table 6-2a. Stage, Storage, and Discharge Relationships for Big Lake

Stage (ft NAVD88)	Storage (af)	Discharge (cfs)
86.30	3,405	0
86.41	3,464	1
86.46	3,491	2
86.56	3,545	5
86.67	3,604	10
86.82	3,686	20
86.95	3,756	30
87.07	3,821	40
87.17	3,875	50
87.26	3,923	60
87.36	3,977	70
87.44	4,021	80
87.53	4,069	90
87.61	4,112	100
87.80	4,215	125
87.97	4,307	150
88.14	4,399	175
88.29	4,480	200
88.58	4,637	250
88.84	4,777	300
89.32	5,037	400
89.74	5,263	500

Stage (ft NAVD88)	Storage (af)	Discharge (cfs)
90.12	5,469	600
90.48	5,663	700
90.81	5,842	800
91.12	6,009	900

Table 6-2b. Stage, Storage, and Discharge Relationships for Lake McMurray

Stage (ft NAVD88)	Storage (af)	Discharge (cfs)
228.70	807	0
228.86	833	1
228.94	845	1
229.10	871	3
229.29	902	5
229.56	946	10
229.78	981	15
229.95	1,009	20
230.51	1,099	40
230.96	1,171	60
231.35	1,234	80
231.70	1,291	100
232.11	1,357	125
232.48	1,417	150

6.1.5 Future Land Use On-site Detention Assumptions for New Development

On-site detention facilities were simulated for the future land use scenario by including simulated ponds in each subbasin that represent the cumulative effects of all potential future stormwater ponds in that subbasin. The detention assumptions are consistent with the 2005 Ecology Stormwater Management Manual for Western Washington (SWMMWW) flow-duration standard. That standard requires that the post-development runoff rate and durations be maintained to pre-developed levels from ½ of the pre-developed 2-year to the 50-year recurrence interval storm. The ponds were sized using a pre-developed pasture or forest land cover depending on the dominant land cover in the subbasin under existing conditions. The simulated ponds were also based on the glacial till and outwash soil types, resulting in up to four ponds per subbasin (depending on the geologic and land cover composition of the subbasin).

6.1.6 Precipitation and Evaporation Time Series Input

Successful application of continuous simulation hydrologic modeling is dependent upon having a high-quality, long-term, precipitation time series that is representative of the watershed under study. A precipitation time series with a long record length is needed for several reasons. Estimation of unusually dry periods or rare flood events is always of interest in hydrologic modeling. The long record provides a diversity of wet and dry years, storm temporal patterns, multi-day sequences of storms, and seasonality of occurrence of storm events that are possible.

Long-term precipitation time series developed for WSDOT for use in continuous hydrologic modeling in western Washington were used in the analysis of the Big Lake watershed (MGS Engineering Consultants, 2005). The extended time series, which are 158 years in length, were developed by combining and scaling records from distant precipitation stations in a manner that the statistics of the scaled time series possess the regional statistics at the target site.

Mean annual precipitation in the Big Lake watershed varies from 40 to 56 inches with a watershed average of 48 inches (Appendix C, Figure 5). The watershed was divided into two zones of mean annual precipitation (44 and 50 inches) with each subbasin assigned to one of the zones. Extended precipitation and evaporation time series developed for each zone were used as input to the model for hydrologic analyses. This approach preserved the 48 inch watershed average mean annual precipitation.

6.1.7 HSPF Model Calibration/Validation

There were no streamflow or lake water surface elevation data available for calibration of the HSPF watershed model. Therefore, HSPF parameters developed by the USGS for use in ungaged watersheds in western Washington were adopted for use in this study.

To verify the validity of flood discharge rates computed by the model, simulated flood magnitude-frequency estimates were compared with values obtained from USGS regional regression equations. The USGS regression equations used in the comparison were developed from streamflow records with climatic conditions similar to the Big Lake area. Based on this comparison, the simulated peak discharge rates were found to compare favorably (within expected statistical variability) with discharge rates predicted by the USGS equations (Appendix C, Figure 6).

6.1.8 HSPF Model Analysis Results (Flood Frequency, Lake Level, Flow Duration)

Tables 6-3a and 6-3b present the peak flood flow and Big Lake water surface (flood) elevation resulting from the HSPF modeling analysis for existing and future land use conditions. Flood-frequency results for existing and build-out land use are summarized in those tables. The relatively small change in development and clearing in the watershed between existing and build-out conditions resulted in minor changes in the peak inflow to Big Lake. The Big Lake outlet peak flow increases between simulated existing and future runoff conditions are only 5 cfs (2.5 percent increase from existing) at the 2-year flood frequency, and 8 cfs (1.5 percent increase from existing) at the 100-year flood frequency. Similar small changes in Big Lake peak inflow are shown, except that for the local basin total discharge, future peak flows closely match or are slightly lower than existing condition peak flows. This outcome is due to the effects of the assumed Ecology SWMMWW onsite detention standards application.

The relatively small change in development and clearing in the watershed between existing and build-out conditions also resulted in minor changes in the maximum lake stage (Tables 6-3a and

6-3b). The Big Lake 100-year water surface elevation was predicted to increase by less than 0.1 feet relative to existing conditions. The Big Lake 100-year floodplain limits (at computed water surface elevation of 89.9 NAVD 88) are provided in Appendix A. Residential and commercial structure finish floor elevations were not collected as part of this plan, but from review of the flooding limits, eight residential structures (beyond out buildings and docks) appear to be potentially affected by 100-year flooding (they should be checked by survey of first floor elevations). Fixed docks may also be damaged by uplift forces at elevated flood levels. For future conditions, and considering the assumptions included in this analysis, the 100-year lake flood elevation is predicted to increase by only 0.04 feet relative to existing conditions. The maximum expected lake level fluctuation between a no outflow condition (water surface at top of log weir at control section, elevation 86.3) and the 100-year outflow is 3.6 feet. By comparison, at the 2-year flood frequency, the expected lake level fluctuation is 2.0 feet to elevation 88.3.

Table 6-3a. Big Lake Watershed Peak Flood Flows and Water Surface Elevation Magnitude-Frequency, Existing Land Use

Big Lake Watershed Peak Flood Flows (cfs) and Lake Elevation Estimates (ft NAVD 88)						
Location	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Lake McMurray Discharge	38	54	66	79	88	102
Subbasin LC6 Discharge	59	86	104	129	136	153
Subbasin LC3 Discharge	107	160	188	243	252	284
Subbasin LC2 Discharge	164	242	292	407	441	466
Subbasin LC1 Discharge	226	338	405	563	646	709
Local Subbasins Discharge	111	177	228	300	327	398
Big Lake Cumulative Inflow	337	515	633	863	973	1,107
Big Lake Discharge	197	278	348	425	472	546
Big Lake Stage (WSEL)	88.27	88.72	89.07	89.43	89.62	89.91

Table 6-3b. Big Lake Watershed Peak Flood Flows and Water Surface Elevation Magnitude-Frequency, Future Land Use

Big Lake Watershed Peak Flood Flows (cfs) and Lake Elevation Estimates (ft, NAVD 88)						
Location	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Lake McMurray Discharge	41	56	71	87	98	110
Subbasin LC6 Discharge	61	90	112	139	145	160
Subbasin LC3 Discharge	111	171	199	257	272	302
Subbasin LC2 Discharge	170	261	313	423	471	488
Subbasin LC1 Discharge	233	352	425	578	668	740
Local Subbasins Discharge	110	174	229	300	325	395
Big Lake Cumulative Inflow	343	526	654	878	993	1,135
Big Lake Discharge	202	280	353	434	493	554
Big Lake Stage (WSEL)	88.30	88.73	89.10	89.46	89.71	89.95

Tables 6-4a and 6-4b show the monthly statistics for Big Lake water surface elevations under existing and simulated future land use conditions. The results show that the seasonally the average monthly lake level only varies a few inches and that the projected land use changes would have essentially no effect on those lake levels statistics.

Table 6-4a. Big Lake Water Surface Elevation Duration Statistics, Existing Land Use

	Percentage of Simulation Time Lake Water Surface Elevation (as Tabulated) is Equaled or Exceeded (ft, NAVD 88)			
Month	**90%**	**50%**	**20%**	**10%**
October	86.5	86.7	86.8	86.9
November	86.7	86.9	87.3	87.5
December	86.8	87.2	87.6	87.8
January	86.9	87.2	87.6	87.8
February	86.9	87.3	87.6	87.8
March	86.9	87.2	87.5	87.7
April	86.8	87.1	87.3	87.5
May	86.7	86.9	87.0	87.2
June	86.6	86.7	86.9	87.0
July	86.6	86.6	86.7	86.8
August	86.4	86.6	86.6	86.7
September	86.4	86.6	86.7	86.7
Annual	**86.6**	**86.9**	**87.3**	**87.5**

Table 6-4b. Big Lake Water Surface Elevation Duration Statistics, Future Land Use

	Percentage of Simulation Time Lake Water Surface Elevation (as Tabulated) is Equaled or Exceeded (ft, NAVD 88)			
Month	**90%**	**50%**	**20%**	**10%**
October	86.5	86.7	86.8	87.0
November	86.7	87.0	87.3	87.5
December	86.8	87.2	87.6	87.8
January	86.9	87.2	87.6	87.9
February	86.9	87.3	87.6	87.9
March	86.9	87.2	87.5	87.7
April	86.8	87.0	87.3	87.5
May	86.6	86.8	87.0	87.2
June	86.6	86.7	86.9	87.0
July	86.4	86.6	86.7	86.8
August	86.3	86.6	86.6	86.7

	Percentage of Simulation Time Lake Water Surface Elevation (as Tabulated) is Equaled or Exceeded (ft, NAVD 88)			
Month	**90%**	**50%**	**20%**	**10%**
September	86.4	86.6	86.7	86.7
Annual	**86.6**	**86.9**	**87.3**	**87.5**

6.2 Study Area Local Subbasins Hydrologic Analysis

This section describes the local subbasin-scale hydrologic analysis completed by MWG for the local drainage systems included in the study area. For this level of hydrologic analysis, the Corps of Engineers Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), an event-based hydrologic model, was developed for each of the major subbasins (including subareas) that discharge to Big Lake, but not including the upstream Lake Creek watershed area south of Big Lake. The methods, hydrologic inputs, assumptions, and results of that analysis are documented in this section.

6.2.1 Hydrologic Modeling Approach (HEC-HMS)

The HEC-HMS model is a rainfall-runoff response event simulation model that includes both basin and precipitation model elements. The model allows several different approaches that can be used to estimate the volume and rate of runoff. Typically the basin conditions, the expected type of runoff response, and available input data dictates which modeling approach should be used.

The HEC-HMS basin model consists of four components: loss, transform, baseflow, and reach. These components describe how much of the precipitation volume will become runoff, how the runoff is conveyed over the land surface, how base flow is determined, and how runoff flows in channels. Each of these basin model components offers several computational methods to use depending on the available database. The precipitation model element consists of Type 1A, 24-hour hydrographs with a 10 minute time increment.

For this modeling analysis, the basin model loss component was determined using the SCS Curve Number methodology. This methodology uses the hydrologic soil group, land cover and condition, and the antecedent moisture condition to determine the SCS Curve Number. The overland flow (transform) component was modeled using the SCS Lag method. The SCS Lag method uses slope and travel distance to calculate the flow to the point of concentration. For this analysis within the relatively small local drainages, it was assumed that base flow does not exist. Also because of the relatively short travel distance between drainage basins and the targeted points of analysis, flows were not routed. The following sections describe the data collected or developed to complete the basin model input.

6.2.2 Tributary Subbasins and Subareas

Review of the inventory data indicated that there are approximately 38 defined drainage system outfalls to Big Lake that provide upstream conveyance of runoff through the study area from the associated tributary drainage subbasins. Other nearshore areas to Big Lake discharge directly to the lake via sheet flow. The local tributary drainage subbasins to be modeled for runoff response were divided into a number of subareas. Subbasin and subarea delineations were based on topography, hydrologic characteristics, the drainage facilities network, and the analysis locations where computed stream flows were desired. For the initial modeling analyses, the desired points of analysis consisted of the location were the major drainage systems crossed Highway 9 (SR 9) or West Big Lake Boulevard (whichever applies). Further analysis were then completed considering other key points of evaluation including the lake (or Nookachamps Creek) outfalls and at other key upstream or lateral drainage system locations. This resulted in the local subbasins being divided into over 60 drainage subareas (Figure 3-2b) for hydrologic analysis used to estimate recurrence interval peak flows.

The HEC-HMS basin model uses several key land characteristics, similar to those used for the HSPF model, to estimate runoff from a watershed. ARCMap was used to delineate and calculate the areas of each tributary subarea, then to intersect subareas with the land cover, hydrologic soils groups, and topography to develop the required HEC-HMS model input parameters. Land cover/condition and soils parameters were evaluated for each subbasin to determine the SCS Curve Number for pervious areas and the percentage of impervious drainage area. Table 6-5 shows the SCS Curve Number selected for each subbasin as well as the percent of impervious area. Antecedent moisture condition III was conservatively used for analysis as requested by the County. This moisture condition simulates the condition where the pervious areas are near saturated by antecedent rainfall prior to the design storm event.

6.2.3 Land Cover and Soils

Land Use

Similar to the HSPF watershed modeling, both existing and future (Comprehensive Plan) land use runoff response conditions were analyzed with the HEC-HMS model for each drainage area. Existing land use was documented by analysis of aerial photography, GIS coverage of the watershed, and supplemental field reconnaissance information. Four land cover classes were considered for existing and future land use conditions; vegetative cover, wetlands, roads, and impervious area.

The dominant land use in the watershed is rural residential with forest practices permitted in the upper portions of the watershed (within Industrial Forest zoned lands).

Vegetative Cover. Using aerial photographs of the watershed, the vegetated cover was categorized as forest or grass. Vegetation intercepts some precipitation. The intercepted precipitation may be delayed on its fall to the ground or may evaporate, reducing both the peak and volume of runoff. Generally, the developed pervious areas are classified as grass and undeveloped areas as forest; however, some forested land have been permanently cleared for utility right of ways or has been converted to pasture. Based on windshield surveys of the project areas the ground cover was assumed to be in good condition.

Wetlands. Wetlands were taken from National Wetlands Inventory available from the County GIS. Areas identified as wetlands in the National Wetland Inventory, lakes, ponds, and suspected wetlands identified by aerial interpretation are all categorized as wetlands. Saturated wetlands and water bodies behave as impervious areas, and essentially all intercepted precipitation is available for runoff.

Roads. The area of roads in each sub-basin was taken from County GIS coverage. The County maintains information on the centerlines of paved roads. For this project, all paved roads were assumed to be 32 feet wide. Paved roads are generally impervious and essentially all intercepted rainfall is available for runoff.

Other Impervious Area. Other impervious areas such as rooftops and driveways were estimated from the land use classifications in the CP, which describes the density of housing and limitation on building sizes in each land use category. A drive-by basin reconnaissance was conducted of the watershed, which found that most of the large parcels outside of the defined residential areas around Big Lake were also developed as residential and that they were not developed to the maximum extent allowed. The County has GIS coverage of land use designations and parcel boundaries. The aerial photos were overlain by the parcel map to determine if a parcel was developed. If a parcel was developed, an impervious area was then assigned based on the land use classifications. Larger lots generally support larger homes, more out–buildings, and longer driveways.

Future Conditions at Build-Out. To estimate future impervious area in each subbasin, it was assumed that all undeveloped parcels would be developed to support residential uses based on the CP land use classification and on the existing patterns of development observed during the drive-by basin reconnaissance. From this, the effective impervious cover percentage was estimated along with the pervious cover land type for each CP land use classification. In addition, areas designated as forest practice (Industrial Forest) under the CP were assumed to be 50-percent clear-cut under future land use.

Table 6-5. Local Subbasins Runoff Parameters, Existing and Future Land Use

Subbasin	Area (acres)	SCS Curve Number (AMC III)	Percent Impervious	
			Existing Land Use	Future Land Use
BL1	231.3	86	4%	4%
BL2	87.4	86	3%	3%
BL3	139.5	81	4%	4%
BL4	75.2	81	4%	4%
BL5	112.0	78	1%	1%
BL5b	23.0	83	2%	2%
BL6	31.1	80	3%	4%
BL7	16.5	75	4%	5%
BL8	71.2	74	1%	1%
BL8b	6.9	78	8%	11%
BL9	671.1	77	6%	6%
BL10	3.4	76	11%	11%
BL10b	6.5	76	4%	7%
BL11	24.1	74	2%	3%
BL12	12.0	75	10%	12%
BL12b	0.4	74	19%	19%
BL13	7.1	74	4%	6%
BL14	10.9	74	12%	12%
BL14b	4.2	74	10%	12%
BL15	93.5	75	3%	4%
BL15b	1.5	76	5%	5%
BL17	411.6	76	0%	0%
BL17b	1.1	89	14%	14%
BL17c	34.0	76	1%	1%

Subbasin	Area (acres)	SCS Curve Number (AMC III)	Percent Impervious	
			Existing Land Use	Future Land Use
BL18	24.4	86	4%	4%
BL19	47.5	86	2%	3%
BL19a	2.5	88	33%	37%
BL20	23.3	86	1%	1%
BL20a	6.6	88	28%	33%
BL22	19.7	87	8%	8%
BL23	5.2	87	5%	5%
BL23a	3.9	88	34%	37%
BL24	72.7	86	5%	7%
BL24a	6.4	88	19%	24%
BL24aa	6.0	90	20%	23%
BL24b	59.8	85	4%	5%
BL24c	14.5	86	3%	4%
BL24d	60.8	85	3%	3%
BL25	6.7	88	5%	13%
BL25a	11.5	88	31%	35%
BL26	117.5	86	3%	3%
BL26a	5.9	88	30%	40%
BL26b	21.3	81	11%	14%
BL27	16.5	86	4%	4%
BL27a	1.7	90	30%	43%
BL27b	2.5	89	25%	27%
BL27c	3.0	90	13%	13%
BL27d	3.9	90	8%	8%

Subbasin	Area (acres)	SCS Curve Number (AMC III)	Percent Impervious	
			Existing Land Use	Future Land Use
BL27e	7.4	88	2%	2%
BL27f	3.8	88	11%	14%
BL28	4.5	91	41%	42%
NC1	376.4	85	5%	6%
NC1a	84.4	87	2%	3%
NC1b	8.5	88	9%	13%
NC2	17.2	88	18%	21%
NC2a	12.2	87	20%	23%
NC2b	30.4	88	12%	14%
NC2c	9.8	89	19%	21%
NC2d	13.1	88	23%	26%
NC2e	15.2	88	16%	18%
NC3	68.1	87	4%	4%
NC4	13.2	90	2%	2%
NC5	13.4	88	6%	7%

Soils

The soils of the watershed were obtained from the NRCS (NRCS 2005). For hydrologic modeling purposes, each soil map unit is assigned to one of three hydrologic groups: B, C, or D, as shown in Table 6-5 and Figure 3-6. The hydrologic grouping depends on the slope, texture, and the depth of the soil to a confining layer. Since most of soils in the watershed are on slopes, have relatively course texture, are shallow, and are underlain by either glacial till or bedrock they fall predominantly into the hydrologic group C or D.

6.2.4 Design Storm and Precipitation Inputs

The HEC-HMS hydrologic model was used to simulate design storm events to estimate peak flows at selected points of analysis within the subbasin drainage systems. The following design storms were used in the analyses:

- 2 year – 24 hour storm
- 10 year – 24 hour storm
- 25 year – 24 hour storm
- 100 year – 24 hour storm

The standard rainfall hyetograph for the Puget Sound (SCS Type 1A, 24-hour duration, 10 minute time step intervals) was used for each event. Because the Big Lake basin is relatively small and the subbasin breakout is very fine, precipitation for each subbasin can be simulated by a single rain gauge. Table 6-6 shows the total precipitation for each subbasin for each of the storm events analyzed.

Table 6-6. Subbasin Precipitation for Selected Storm Events

Subbasin	Design Storm Precipitation Amount (inches)			
	2-yr., 24-hr.	10-yr., 24-hr.	25-yr., 24-hr.	100-yr., 24-hr.
BL1, BL2, BL3, BL8, BL8b. BL9, BL10, BL10b, BL11, BL12, BL12b, BL13, BL14 BL14b, BL15, BL15b, BL17, BL17b, BL17c, NC2c, NC5	2.25	2.75	3.25	4.50
BL4, BL5, BL5b. BL6, BL7	2.25	3.00	3.25	4.50
BL18, BL19, BL19a, BL20, BL20a, BL22, BL23, BL23a, BL24c, BL26, NC1, NC1a, NC1b, NC2, NC2a, NC2b, NC2d, NC3, NC4	2.25	2.75	3.25	3.75
BL24, BL24a, BL24aa, BL24b, BL24d, BL25, BL25a, BL26a, BL26b, BL27, BL27a, BL27b, BL27c, BL27d, BL27e, BL27f BL28, NC2e	2.25	2.75	3.25	4.50

6.2.5 HEC-HMS Model Calibration/Validation

There were no local streamflow data available for calibration of the HEC-HMS hydrologic model. Therefore, the results of initial model simulations were tabulated and compared for reasonableness to results based on other methods of analysis including the HEC-HMS Kinematic Wave methodology, the HSPF model continuous simulation results, and with values obtained by use of the applicable USGS regional regression equation for ungaged watersheds similar to Big Lake. A comparison of unit discharges was made based on the peak flow values computed for each subbasin. Those comparisons are included in Appendix D.

The results of this comparison showed that the HEC-HMS unit discharges were typically higher than those computed with other methods, but there are differences between the methods. For example, hourly precipitation data are used in the HSPF model. Since the local basins in the watershed are small, typically with lag times less than 1 hour, HSPF-generated peak flows for high intensity, short duration design events in small subbasins are under-predicted (use of a 15-minute precipitation data set would be needed to obtain comparable results). The HEC-HMS unit discharge results are considerably lower than would be obtained by other (non-hydrograph based) empirical equations that can be applied in small urban watersheds for design event peak flow estimates (e.g., Rational Method). Therefore, the HEC-HMS computed estimates were accepted as appropriate for planning level analysis.

6.2.6 HEC-HMS Model Analysis Results (Design Event Flood Flows)

Table 6-7 summarizes the selected design event peak flow estimates generated through use of the HEC-HMS model for all drainage subareas analyzed for both existing and future land use conditions. The results identify 2-year and 100-year, 24-hour design flows ranging to in excess of 20 and 60 cfs (respectively) for the largest subbasins. For selected points of analysis, 25-year existing and 100-year future flood flows are also shown graphically in Appendix A figures.

Please see also Appendix C for additional hydrologic calculations and spreadsheets that document analysis results.

Table 6-7. Subbasin Estimated Peak Discharges for Selected Design Storm Events, Existing and Future Land Use Conditions

Subbasin (at Outlet)	Computed Peak Flows (cfs) for Design Storm Events							
	2-yr., 24-hr.		10-yr., 24-hr.		25-yr., 24-hr.		100-yr., 24-hr.	
	Existing	Future	Existing	Future	Existing	Future	Existing	Future
BL1	19.0	19.2	27.2	27.3	36.4	36.5	59.9	60.0
BL2	8.3	8.4	12.1	12.1	16.2	16.3	26.9	27.0
BL3	11.5	11.6	16.6	16.7	22.3	22.4	37.6	37.7
BL4	6.3	6.4	11.8	11.9	11.8	11.9	19.5	19.6
BL5	5.2	5.3	11.6	11.7	11.6	11.7	21.2	21.3
BL5b	2.0	2.0	4.4	4.4	4.4	4.4	7.9	7.9
BL6	2.4	2.4	6.1	6.1	6.1	6.1	11.4	11.5
BL7	1.4	1.4	3.1	3.1	3.1	3.1	5.6	5.6
BL8	3.0	3.0	4.9	5.0	7.3	7.3	14.0	14.0

Subbasin (at Outlet)	Computed Peak Flows (cfs) for Design Storm Events							
	2-yr., 24-hr.		10-yr., 24-hr.		25-yr., 24-hr.		100-yr., 24-hr.	
	Existing	Future	Existing	Future	Existing	Future	Existing	Future
BL8b	0.5	0.6	0.9	1.0	1.4	1.4	2.7	2.7
BL9	22.5	22.6	34.6	34.7	48.5	48.6	63.5	63.7
BL10	0.2	0.2	0.4	0.4	0.6	0.6	1.1	1.1
BL10b	0.4	0.5	1.6	1.7	1.2	1.2	2.3	2.4
BL11	0.8	0.8	1.3	1.3	2.0	2.0	4.1	4.1
BL12	0.8	0.8	1.3	1.3	1.9	2.0	3.6	3.7
BL12b	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
BL13	0.4	0.5	0.8	0.9	1.3	1.3	2.7	2.7
BL14	0.7	0.7	1.1	1.1	1.6	1.6	3.0	3.1
BL14b	0.3	0.4	0.6	0.6	0.9	0.9	1.7	1.7
BL15	3.4	3.4	5.5	5.6	8.5	8.5	16.8	16.9
BL15b	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.5
BL17	12.8	12.9	20.1	20.1	28.4	28.5	52.8	52.9
BL17b	0.4	0.4	0.6	0.6	0.7	0.7	1.1	1.1
BL17c	1.3	1.3	2.4	2.4	3.8	3.8	7.7	7.7
BL18	4.0	4.0	5.8	5.8	7.7	7.7	9.7	9.7
BL19	6.9	7.0	10.1	10.1	13.5	13.6	17.1	17.2
BL19a	0.8	0.8	1.0	1.0	1.2	1.3	1.5	1.5
BL20	3.7	3.7	5.3	5.4	7.2	7.2	9.1	9.1
BL20a	1.4	1.4	1.8	1.9	2.3	2.4	2.8	2.8
BL22	3.9	3.9	5.5	5.5	7.2	7.2	9.0	9.0
BL23	1.1	1.1	1.5	1.5	2.0	2.0	2.5	2.5
BL23a	1.2	1.2	1.5	1.5	1.9	1.9	2.9	2.9
BL24	8.3	8.5	11.9	12.1	15.8	16.0	25.8	26.0
BL24a	1.5	1.6	2.1	2.1	2.7	2.7	4.1	4.2
BL24aa	1.2	1.3	1.7	1.7	2.1	2.2	3.3	3.3
BL24b	6.6	6.6	9.4	9.4	12.4	12.5	15.6	15.6
BL24c	2.5	2.5	3.4	3.5	4.5	4.5	7.2	7.3
BL24d	5.0	5.1	7.3	7.4	9.9	10.0	16.7	16.8
BL25	1.2	1.3	1.7	1.8	2.2	2.3	3.6	3.6
BL25a	2.0	2.1	2.7	2.8	3.4	3.5	4.1	4.2
BL26	10.0	10.0	14.0	14.0	18.5	18.6	30.1	30.2
BL26a	1.3	1.3	1.7	1.8	2.1	2.2	3.2	3.3
BL26b	3.0	3.1	4.2	4.4	5.6	5.8	9.4	9.5
BL27	2.3	2.3	3.3	3.3	4.3	4.3	7.0	7.0
BL27a	0.5	0.6	0.7	0.7	0.9	0.9	1.4	1.4
BL27b	0.8	0.8	1.0	1.0	1.3	1.3	2.0	2.0

Subbasin (at Outlet)	Computed Peak Flows (cfs) for Design Storm Events							
	2-yr., 24-hr.		10-yr., 24-hr.		25-yr., 24-hr.		100-yr., 24-hr.	
	Existing	Future	Existing	Future	Existing	Future	Existing	Future
BL27c	0.8	0.8	1.0	1.0	1.3	1.3	2.0	2.0
BL27d	0.9	0.9	1.3	1.3	1.6	1.6	2.5	2.5
BL27e	1.5	1.5	2.1	2.1	2.8	2.8	4.4	4.4
BL27f	0.9	0.9	1.2	1.2	1.5	1.6	2.4	2.4
BL28	1.1	1.1	1.4	1.4	1.8	1.8	2.6	2.6
NC1	20.0	20.2	29.9	30.1	41.0	41.2	52.4	52.7
NC1a	6.1	6.2	10.3	10.4	15.0	15.2	20.0	20.1
NC1b	2.1	2.2	2.9	3.0	3.8	3.9	4.8	4.9
NC2	3.2	3.3	4.3	4.4	5.6	5.7	6.8	6.9
NC2a	0.9	0.9	1.2	1.2	1.5	1.5	1.8	1.8
NC2b	4.1	4.2	5.7	5.7	7.3	7.4	11.6	11.6
NC2c	1.2	1.2	1.6	1.6	2.1	2.1	2.5	2.5
NC2d	2.7	2.7	3.6	3.6	4.5	4.6	7.0	7.0
NC2e	2.7	2.7	3.7	3.7	4.7	4.7	5.7	5.8
NC3	8.3	8.3	11.7	11.7	15.3	15.4	19.1	19.1
NC4	2.4	2.4	3.3	3.3	4.2	4.2	6.7	6.7
NC5	2.4	2.4	3.4	3.4	4.4	4.4	7.0	7.1

6.3 Hydraulic Capacity Analysis of Drainage System Infrastructure

The study area drainage systems tributary to Big Lake and Nookachamps Creek near the Big Lake outlet consist primarily of open ditches and culverts that pass under roads or driveways. In some cases, the closed portion of the drainage system includes storm drains with periodic catch basins at angle points, grade breaks, and for maintenance access. Generally runoff from the watershed collects from sheet flow in forested or pasture areas into a series of natural drainage channels in undeveloped areas or man-made ditches and culvert/storm drain systems in developed areas. Those drainage conveyances discharge to roadside ditches along West Big Lake Boulevard and State Route 9 (the perimeter roads that ring the lake). Culverts are located along those roadside ditches (parallel to perimeter roads) at driveways and local access roads. At locations of natural stream crossings and other topographically low points, culverts pass under the perimeter roads to convey tributary surface runoff to downstream natural or improved drainage systems that outfall to Big Lake. On the west side of the lake, there is generally one row of parcels that extend between West Big Lake Boulevard and the lake. On the east side of the lake, the runoff west of SR 9 must pass through several rows of parcels that are separated by an abandoned railroad grade and another smaller parallel road (South and North Westview Road). Runoff from roofs and driveways typically contributes by sheet flow across landscaped areas; however, in areas with new homes, the runoff is captured and routed directly to the local drainage systems through small diameter private drain pipes.

Spreadsheet-based uniform flow and backwater analysis programs were used to assess the unobstructed flow capacities of the major drainage system facilities, including approximately 35 culverts that route runoff under State Route 9 or West Big Lake Boulevard and other downstream major drainage system culverts and storm drains. The perimeter road culverts were selected for priority analysis since it was assumed that those roads provide emergency access to the Big Lake community and that maintaining access was critical to the County emergency management operations.

Flooding problems generally result from culvert or storm drain hydraulic capacities not being adequate to convey design event runoff. In this study, the 25-year existing land use peak flow was used to evaluate existing conditions, and the 100-year future land use peak flow was used to evaluate improved conditions. Overflows from the existing roadside ditches and/or roadway result in backwater flooding of adjacent areas upstream of crossings along with sheet or concentrated overflow flooding of downstream properties and potentially of residential structures. Beyond hydraulic capacity problems associated with undersized facilities (when fully unobstructed), culverts and storm drains may not have adequate hydraulic capacity due to damaged end sections or sediment and debris obstruction. The hydraulic analyses conducted in this section for existing culvert and storm drain facilities adequacy take into consideration the extent of obstruction by damage. For those facilities partially obstructed by sediment/debris, unobstructed hydraulic capacity was assumed, meaning that if obstruction exists due to sediment, the analysis assumes that full-flow capacity could be restored through proper maintenance. If the culverts were obstructed by damage of the culvert (typically end sections), the restricted hydraulic capacity of those culverts was not specifically analyzed, but those culverts were programmed for repair or replacement under the capital improvement program.

The length, size, slope, material, maximum head, and the end treatment of each culvert segment was collected during the field inventory. This data was used in the analysis to estimate the hydraulic capacity of facilities based on their physical properties and conditions, which were then compared to design event flood flows to define needed drainage facility improvements. For this evaluation, hydraulic capacity is considered as the conveyance flow at which overflow from the drainage feature is expected to occur.

6.3.1 Hydraulic Analysis Approach and Assumptions

Hydraulic analyses for the perimeter road culverts were conducted using the Corps of Engineer's HEC-RAS hydraulic model. This model allows for input of the physical characteristics of the culverts, hydraulic parameter (e.g., hydraulic roughness, entrance and exit loss conditions), and upstream and downstream channel sections in estimating the conveyance capacity under a range of tailwater and headwater conditions. For purposes of this analysis, the downstream tailwater was assumed to not exceed the soffit elevation of the culvert outlet, and maximum headwater depth was established based on the inventory and mapping database.

Additional hydraulic analysis of other portions of the major drainage systems was conducted using a simplified Excel spreadsheet model to determine hydraulic capacity considering tailwater and headwater conditions. This was done for time-efficient analysis of a large number of culverts and storm drains along the major drainage systems. In some cases, the headwater elevations at downstream culverts control the tailwater elevations and facilities capacity may be limited by this condition. The scope of the hydraulic analysis did not allow for a complete backwater analysis of the major drainage systems.

Further hydraulic analysis was also conducted using these methods to size proposed drainage facility improvements as recommended in Chapter 8.

6.3.2 Hydraulic Analysis Results (Drainage Facilities Hydraulic Capacity)

Table 6-8 summarizes the results of the drainage facilities hydraulic capacity analysis for the major drainage systems, culverts and storm drains under existing conditions. Those tables include the physical properties of the culverts or storm drains as the basis for the capacity check. Comparison is made to the estimated design event peak flow for existing conditions (at 25-year design standard) at those facilities (taken from Section 6.2) to assess adequacy of hydraulic capacity.

Based on this analysis, three major drainage system culverts or storm drains were determined to be capacity deficient and in need of improvement. Only a few of the major drainage system improvements are obstructed by damage. However, many lateral (minor) drainage system facilities have damaged end sections with restricted hydraulic capacity and are in need of repair or replacement. For culverts documented to be obstructed due to sediment or debris (and having adequate unobstructed hydraulic capacity), maintenance actions were assumed to resolve potential capacity problems versus drainage facility repair or replacement. Chapter 8 discusses the major drainage system improvements and presents recommended CIP improvements for those facilities determined to be deficient due to size or obstruction due to damage. Please see also Appendix D for supplemental hydraulic spreadsheets that document analysis results.

Table 6-8. Characteristics and Unobstructed Hydraulic Capacities of Perimeter Road and other Major Culverts with 25-Year Peak Flows Comparison

Culvert ID	Outfall ID	Model ID	Length (ft)	Slope (ft/ft)	Max. Head (ft)	End Treatment	Material	Size (in)	Estimated Capacity (cfs)	Q25(E) (cfs)	Adequate? (Y/N)
1816	BL1	BL1	50	0.031	7.0	Square	RCP	36	97	36.3	Y
1933	BL2	BL2	45	0.023	4.0	Square	RCP	24	31	16.2	Y
1955	BL3	BL3	61	0.001	5.0	Headwall	RCP	36	71	22.3	Y
5450	BL4	BL4	34	-0.009	5.0	Square	RCP	24	36	11.7	Y
1829	BL5	BL5	42	0.015	6.5	Headwall	CMP	24	45	11.6	Y
1696	BL6	BL5b	48	0.059	5.1		RCP	18	23	4.4	Y
5006	BL7	BL6	49	0.101	7.5	Square	RCP	24	49	6.0	Y
not surveyed	BL8	BL7				Projecting	RCP	36	35+	3.0	Y
1710	BL9	BL8	59	0.112	5.0	Square	RCP	24	40	7.2	Y
1957	BL10	BL8b	57	-0.038	5.5	Square	RCP	18	16	1.3	Y
1839	BL11	BL9	74	1.388	5.5	Projecting	CMP	60	120	48.4	Y
1836	BL12	BL10b	45	0.043		Projecting	RCP	18	8	0.5	Y
5312	BL13	BL10	89	0.029	8.0	Square	RCP	24	52	1.1	Y
not surveyed	BL14	BL11			20.0	Projecting	RCP	24	15+	1.9	Y
5324	BL15	BL12	75	0.062	11.5	Projecting	RCP	24	64	1.8	Y
5341	BL16	BL12b	41	0.078	4.5	Square	RCP	18	21	0.1	Y
5350	BL17	BL13	45	0.023	3.5	Projecting	RCP	12	8	1.2	Y
5701	BL18	BL14b	45	0.033	4.0	Projecting	RCP	18	19	0.8	Y
5357	BL19	BL14	44	0.009	4.0	Projecting	RCP	24	31	1.5	Y
5361	BL20	BL15b	37	0.021	3.5	Square	RCP	18	17	0.2	Y
5378	BL21	BL15	108	0.013	18.0	Projecting	CMP	72	575	8.4	Y
5393	BL22	BL17	45	-0.011	4.5	Projecting	RCP	36	56	28.3	Y

Culvert ID	Outfall ID	Model ID	Length (ft)	Slope (ft/ft)	Max. Head (ft)	End Treatment	Material	Size (in)	Estimated Capacity (cfs)	Q25(E) (cfs)	Adequate? (Y/N)
5399	BL23a	BL17b	50	-0.011	6.5	Square	RCP	18	25	0.6	Y
5401	BL23b	BL17c	53	0.016	6.5	Projecting	RCP	24	45	3.7	Y
5403	BL24	BL18	105	0.102		Square	CMP	18	21	7.6	Y
1495	BL25	BL19	38	0.003	3.0	Projecting	CMP	18	11.5	13.5	N
1805	BL25	Junction-19	79	0.120	4.0	Headwall	RCP	24	48	14.3	Y
1450	BL26	BL20	33	0.027	3.0	Mitered	RCP	24	22	7.1	Y
1686	BL26	Junction-20	45	0.003	8.5	Square	CMP	36	114	16.4	Y
1459	BL27	BL22	32	0.065	4.0	Square	RCP	18	19	7.2	Y
1442	BL27	BL23	34	0.059	3.0	Projecting	RCP	12	7	1.9	Y
5226	BL27	Junction-23	11	0.161	4.1	Square	RCP	20	21	13.8	Y
1469	BL28	BL24b	50	0.186	5.0	Projecting	RCP	18	22	12.4	Y
1556	BL28	BL24c	34	0.059	3.0	Mitered	RCP	24	24	4.4	Y
1486	BL28	BL24d	37	0.166	1.3	Projecting	RCP	12	4	9.9	N
1929	BL28	Junction-24a	37	0.045	5.0	Projecting	RCP	24	30	12.9	Y
1528	BL29	BL24		0.000	5.0	Mitered	RCP	24	30	15.78	Y
1859	BL29	Junction-24	31	0.098	2.8	Projecting	HDPE	24	21	16.8	Y
1531	BL30	BL25	51	0.119		Projecting	CMP	18	8	2.2	Y
1851	BL30	Junction-25	137	0.054	7.7	Projecting	HDPE	24	40+	5.2	Y
1542	BL31	BL26	79	0.010	3.0	Mitered	CMP	18	11	18.5	N
1717	BL31	BL26a	21	0.071	2.0	Projecting	CMP	12	6	2.0	Y
1519	BL31	BL26b	39	-0.004	5.0	Projecting	RCP	18	22	5.6	Y

Culvert ID	Outfall ID	Model ID	Length (ft)	Slope (ft/ft)	Max. Head (ft)	End Treatment	Material	Size (in)	Estimated Capacity (cfs)	Q25(E) (cfs)	Adequate? (Y/N)
1848	BL31	Junction-26	101	0.164	5.0	Square	HDPE	36	62	21.7	Y
1577	BL32	BL27f	38	0.094	4.0	Projecting	RCP	12	9	1.5	Y
1644	BL33	BL27e	36	0.061	4.0	Projecting	CMP	18	17	2.7	Y
1651	BL34	BL27d	44	0.126	5.0	Square	RCP	12	10	1.6	Y
1655	BL35	BL27	49	0.067	5.0	Projecting	RCP	12	12	4.3	Y
1587	BL35	BL27b	43	0.118	3.5	Square	CMP	12	8	1.3	Y
1584	BL35	BL27c	41	0.061	3.0	Projecting	RCP	12	7	1.2	Y
1965	BL35	Junction-27	86	1.131	2.6	Square	CMP	18	14	4.7	Y
1977	BL36	BL28	177	0.039			HDPE	18	6	1.7	Y
5487	NC1	Junction-4	90	0.145	2.0	Square	HDPE	18	9	3.9	Y
2063	NC1	Junction-8	35	0.054	4.4	Square	CMP	48	80+	40.5	Y
1873	NC2	Junction-5	56	0.137	2.3	Projecting	HDPE	18	10.5	10.2	Y
2044	NC2	Junction-6	71	0.000	4.5	Projecting	HDPE	18	20	9.1	Y
not surveyed	NC2	Junction-7				Projecting	CMP	2X24	40+	21.9	Y
1432	NC2	NC2	64	0.039	4.5	Mitered	HDPE	18	16	5.5	Y
1328	NC2	NC2a	55	0.019	4.0	Projecting	CMP	18	20	1.4	Y
1969	NC2	NC2c	44	0.089	3.5	Square	RCP	12	8	2.0	Y
5810	NC3	NC3	111	0.028	7.0	Square	CMP	36	60+	15.3	Y
2005	NC4	NC4	43	-0.005	4.0	Square	RCP	18	15	4.2	Y
2067	NC5	NC5	161	0.025	2.9	Square	CMP	12	8	4.4	Y

7.0 Chapter 7 – NPDES Phase II Components and Compliance Needs

7.1 NPDES Phase II Requirements

As described in Section 2.1, the NPDES Phase II permit (effective Fall 2006) requires regulated small MS4 permittees to develop a stormwater management program (SWMP) that effectively prohibit non-stormwater discharges into storm sewers that flow to surface waters. It also requires that controls be applied to stormwater discharges that reduce the discharge of pollutants to the "Maximum Extent Practicable (MEP)". The EPA Phase II rules require permittees to develop and implement, at a minimum, the following six stormwater program elements with annual reporting to measure progress and compliance effectiveness:

- Public education and outreach
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site stormwater runoff control
- Post-construction stormwater management for new development and re-development
- Pollution prevention and good housekeeping for municipal operations

In addition the permit promulgated by Ecology requires additional Phase II requirements:

- Compliance with approved total maximum daily load (TMDL or water cleanup plan), or equivalent analysis, where appropriate
- Evaluation and assessment of program compliance

7.2 Stormwater Management Program Components

Table 7-1 summarizes the elements and associated key activities required under the SWMP for compliance with the NPDES Phase II Permit. It also shows the required schedule (in Phase II permit) for the program elements/activities development and implementation.

Table 7-1. NPDES Phase II Required Program Components and Required Schedule for Implementation

NPDES Phase II Program Element	Required Activities	Required Implementation Schedule
Element S5.1, 5.2 Public Education and Outreach (PEO), Involvement, and Participation	Develop/Implement PEO program including water quality awareness, impacts avoidance, yard care and chemicals/hazardous materials BMPs awareness, construction runoff BMPs awareness, promote LID techniques, illicit discharge awareness and fix incentives, public environmental stewardship	Within 2 years of EPD (effective permit date)
	Public involvement with the Stormwater Management Plan (SWMP) update to meet NPDES permit requirements	
	Public dissemination of County NPDES submittals (on website)	Within 1 year of EPD
Element S5.3 Illicit Discharge Detection and Elimination (IDDE)	Periodic updates to GIS drainage facilities inventory mapping, furnish to Ecology	Ongoing, within 2 years of EPD
	Incorporate IDDE discharge prohibition regulations in ordinance and SCC	Within 1 year of EPD
	Develop/implement a program to detect, control, and eliminate non-authorized illicit discharges including procedures, notifications, inspections, enforcement	180 days prior to permit expiration
	Notification of public employees, businesses, and public of illicit discharge hazards	180 days prior to permit expiration
	Institute/monitor “hotline” for reporting of illicit discharges and spills	Within 2 years of EPD
	Provide IDDE training to County staff	Within 2.5 years of EPD

NPDES Phase II Program Element	Required Activities	Required Implementation Schedule
Element S5.4, 5.5 Controlling Runoff from New Development, Re-development, and Construction Sites	Update new development and re-development runoff control program	Within 2 years of EPD
	Update ordinance and SCC provisions to provide regulation equivalent to NPDES Phase II permit and Ecology manual minimum requirements	Within 2 years of EPD
	Institute LID program provisions to reduce impervious area and pervious area disturbance	
	Expand development plan review, inspection, and enforcement implementation for standards compliance	Within 2 years of EPD
	Expand O&M program for public stormwater facilities including maintenance/inspection ordinance, update maintenance standards, establish inspection requirements for flow control and water quality treatment, develop inspection schedule, annual implementation	Within 2 years of EPD
	Expand development review, inspection, and O&M training	Within 1 year of EPD
Element S5.6 Pollution Prevention and Operations/Maintenance for County Operations	Develop program for County operations pollution prevention	Develop/Implement all activities within 3 years of EPD
	Adopt Ecology-equivalent maintenance standards; conduct annual inspections off all MS4 flow control/treatment facilities	
	Expand program for cleaning, repair, snow/ice control, pavement maintenance, and vegetation/dust control for highways, roads, and parking areas owned by County	
	Establish/implement policies and procedures for pollutant reduction from all County-owned lands	
	Develop and implement SWPPPs for County equipment/materials storage yards	
	Maintain inspections, maintenance, and repair activity records	
	Provide ongoing pollution prevention training for County construction, operations, and maintenance staff	

NPDES Phase II Program Element	Required Activities	Required Implementation Schedule
Element S8 Monitoring	Establish/implement monitoring program to characterize stormwater discharges	Identify monitoring program/sites 180 days prior to permit expiration; Monitoring not required in initial permit cycle, however, if conducted, results should be forwarded to Ecology
Element S9 Annual Reporting	Complete annual reports beginning March 2008 for each component of SWMP and implementation actions Maintain all records related to permit and SWPPP for a minimum of 5 years, and make available for public review upon request.	Initial annual report due March 2008, then annually

7.3 GIS-Based Drainage System Inventory

As part of this plan, a stormwater facilities inventory within the Big Lake study area was completed (see Table 4-1 for summary of components) and was also incorporated into GIS format. The inventory database is attached as Appendix B in MS Excel format. The database can be sorted, manipulated, or combined with other County GIS data to present information in both graphic and tabular formats. Use of the GIS-based inventory system allows the County to readily update the inventory database as development continues in the community. In addition, use of the GIS system will allow the County to track maintenance activities, illicit discharges, drainage complaints, distribution of mailings, and other information which can be extracted to meet the monitoring and reporting requirements of the NPDES Phase II permit.

7.4 Water Quality Management Regulations and Standards

Coverage under the NPDES Phase II permit requires local entities to demonstrate compliance with the federal Clean Water Act (CWA), Washington State surface water, groundwater, and sediment management standards, and human health criteria in the national Toxics Rule. The permit requires permittees to reduce the discharges of pollutants to the maximum extent practicable (MEP) and permittees shall use all known, available, and reasonable methods of prevention, control, and treatment (AKART) to prevent and control pollution of the waters of the State of Washington. To meet the goals of the CWA and demonstrate compliance with the MEP and AKART provisions, permittees are required to demonstrate compliance with the requirements of the NPDES Phase II permit.

Specific requirements of several of the SWMP elements are discussed in the following sections. The requirements for new development/re-development and construction activities are not discussed since those specific requirements are defined in the Phase II Permit Appendices (1 and 4). The permit references to and requires compliance with the Ecology's Stormwater Management Manual for Western Washington (2005 version) or an Ecology-approved equivalent manual.

7.5 Public Education and Outreach Program

The Phase II Permit outlines specific tasks that must be carried out to meet the minimum requirements of the "Public Education and Outreach" and the "Public Involvement and Participation" elements of the SWMP. This program element is focused on promoting and disseminating information regarding water quality awareness and potential impacts along with "Best Management Practices (BMPs)" to minimize those impacts. The various stakeholder audiences include residents, businesses, industries, elected officials, policy makers, agency staff, etc. The goal of this element is to reduce or eliminate practices that cause or contribute to adverse stormwater impacts on water quality. Some of the activities to be included are marking the stormwater infrastructure to increase public awareness, providing education materials on a variety of subjects to minimize illicit or unauthorized discharges to the stormwater system, and providing the stakeholders with the opportunity to participate and comment on the development of the SWMP. Table 7-2 summarizes these minimum requirements and identifies major milestones for compliance.

Table 7-2. Public Education/Outreach Program Needs Summary

Program Element and Key Task	Task Description	Major Milestones	Completion Date	Ongoing Activities
Public Education and Outreach				
Label (Stencil) Storm Drain Inlets	All storm drain inlets shall be labeled with the message "Dump no waste" and identify the point of discharge as a lake, stream, river etc. e.g. "Dump no waste discharges to lake"	50% - 3 years	180 days prior to permit expiration	Must be re-labeled with 90 days when label is no longer clearly visible or readable.
Distribute Educational Materials	Disseminate education materials to stakeholder (via WEB sites, public meetings, colleges/universities, etc.) on the impact of stormwater discharges on receiving waters.	Within 2 years of effective permit data (EPD)	180 days prior to permit expiration	Annually - different combinations of topics can be addressed each year.
Public Involvement and Participation				
Solicit Public Review of SWMP	Publish a public notice in the local newspaper and solicit public comment on the SWMP; hold public meetings as needed		180 days prior to permit expiration	Repeat for each permit cycle

Program Element and Key Task	Task Description	Major Milestones	Completion Date	Ongoing Activities
Post SWMP on WEB	Make the latest version of the SWMP available on the Counties WEB site.		180 days prior to permit expiration	Maintain on WEB site.

7.6 Illicit Discharge Detection and Elimination Program

Federal rules require permittees to develop, implement and enforce a program to detect and eliminate illicit discharges into their small MS4. Federal regulations define an illicit discharge as "any discharge to a municipal separate storm sewer that is not composed entirely of storm water except discharges pursuant to a NPDES permit and discharges resulting from fire fighting activities". Non-stormwater discharges are illicit because MS4s are not designed to accept, process, or discharge such wastes. Illicit discharges enter the MS4 through deliberate or mistaken, direct or indirect, illicit connections or illegal dumping.

Ecology has concluded the following types of non-stormwater discharges are not likely significant sources of pollutants and therefore need not be addressed by either the permittees ordinances or SWMP: diverted stream flows, rising ground waters, uncontaminated ground water infiltration, uncontaminated pumped ground water, foundation drains, footing drains, air conditioning condensation, springs, water from crawl space pumps, and flows from riparian habitats and wetlands.

In some areas of Washington, agricultural irrigation infrastructure has become part of the MS4 and it would be unreasonably burdensome (and not beneficial to water quality) to separate out these discharges. Therefore, Ecology has decided to include irrigation water from agricultural sources that is commingled with urban stormwater in the list of non-stormwater discharges that do not need to be addressed either by ordinance or in the SWMP.

Water line flushing and hydrant testing are common, required practices in all municipalities. Ecology met with water purveyors to better understand common practices and methods available for containment and reuse of water, and for dechlorination of released water. For the Phase II permit, Ecology established a required concentration of less than or equal to 0.1 ppm chlorine for these discharges and for chlorinated swimming pool discharges to control potential downstream water quality impacts on aquatic resources. This concentration is the detection limit for simple, easy-to-use field test kits.

Ecology specifies that as long as the municipality is reducing such discharges through public education efforts, water conservation efforts, and minimization of municipal use, the ordinance and SWMP does not need to prohibit discharges from lawn watering, landscape irrigation, street wash water, dust control water and building wash down (where detergents are not used).

Ecology has maintained a prohibition regarding residential car washing. The requirement to prohibit these discharges does not establish a local priority or define a required approach to addressing these discharges; it merely prevents individual residential car washing from being considered an insignificant discharge. Ecology generally expects municipalities to emphasize public education rather than punitive enforcement to reduce these discharges. BMPs such as directing runoff to vegetated areas where it can infiltrate are easy to implement in order to reduce the environmental impact of these discharges.

Review of the permit materials indicates that the permit conditions for the Illicit Discharge Detection and Elimination Program were developed with more focus on urban development rather than rural development. In rural residential communities like Big Lake, the stormwater infrastructure is comprised primarily of open ditches and culverts to convey water under roads and driveways. Potential illicit discharge connections include cross-connections between sanitary and storm sewers, floor drains connected to the drainage systems, and illegal dumping.

In the Big Lake study area, it is likely that most illicit discharges are related to inappropriate disposal of household wastes to the stormwater system or inappropriate application of household chemicals (fertilizers, pesticides, detergents) that may be conveyed to the stormwater system. Illicit discharges from boating/recreational activities may also be a source of pollutants to the lake and Nookachamps Creek at its outlet. Many of these problems or sources can be eliminated through implementation of an effective Public Education and Outreach Program (See Section 7.5).

The stormwater infrastructure was screened for potential illicit discharges (Figure 5-5 and Table 7-3). Approximately 150 connections exist where small pipes (3 to 6 inch diameter typical) of unknown origin where identified from field inventory. Since most of the Big Lake stormwater system consists of open ditches and culverts, expensive water quality sampling, video techniques, or tracer studies should not be required to verify the sources. In most cases, the sources can probably be detected by visual inspection or use of smoke or dye testing. One more recent technique that could be considered is use is aerial thermography that can detect areas of elevated ground temperature as an indicator or possible illicit discharges.

Table 7-3. Potentially Illicit Connections

Culvert ID	Material	Nominal Size (in)	Connects to
5526 N	Other	3	5484S
5526 W	Other	3	Unknown
5526 E	Other	3	Unknown
1256	Other	4	Unknown
1322	Other	4	Unknown
1326 S	Other	4	1322
1378 NE	Other	4	Unknown
1387	PVC	4	Unknown
1398 E	Other	4	Unknown
1403 SE	HDPE	4	Unknown
1405 NE	Other	4	Unknown
1405 SE	Other	4	Unknown
1407 NEB	Other	4	Unknown
1407 NEC	Other	4	Unknown
1408 SE	Other	4	Unknown
1408 NE	Other	4	Unknown
1419	PVC	4	1418
1422 NE	HDPE	4	Unknown
1480 SW	Other	4	Unknown
1499	HDPE	4	Unknown
1612	Other	4	Unknown
1677	RC	4	Unknown
1730 NE	Other	4	Unknown
1736 S	Other	4	Unknown
1738	HDPE	4	1716
1800 E	Other	4	Unknown

Culvert ID	Material	Nominal Size (in)	Connects to
1802 E	Other	4	Unknown
1803 E	HDPE	4	Unknown
1867 SW	Other	4	Unknown
1867 NE	Other	4	Unknown
1869 W	Other	4	pond to W
1869 E	Other	4	5563W
1931 S	HDPE	4	Unknown
1938 S	Other	4	Unknown
1939 S	Other	4	Unknown
1975 S	HDPE	4	Unknown
2015	Other	4	2016
2016	Other	4	2015
2039	Other	4	Unknown
5053 SE	HDPE	4	Unknown
5059	HDPE	4	Unknown
5077	HDPE	4	Unknown
5081	HDPE	4	Unknown
5085	HDPE	4	Unknown
5086	HDPE	4	Unknown
5088	Other	4	5087
5094	Other	4	Unknown
5128	Other	4	Unknown
5130 S	Other	4	Unknown
5130 W	Other	4	5033
5133	HDPE	4	5130W
5140 E	Other	4	Unknown
5185 E	Other	4	Unknown
5199	Other	4	Unknown
5200	HDPE	4	Unknown
5201	HDPE	4	Unknown
5222	Other	4	Unknown
5265 N	Other	4	Unknown
5269	HDPE	4	Unknown
5287	Other	4	5288
5288	Other	4	5287
5428	Other	4	Unknown
5429	HDPE	4	Unknown
5430	Other	4	Unknown

Culvert ID	Material	Nominal Size (in)	Connects to
5431 E	HDPE	4	Unknown
5438 E	HDPE	4	Unknown
5460 N	HDPE	4	Unknown
5468 S	Other	4	Unknown
5476 N	HDPE	4	5477
5476 S	HDPE	4	Unknown
5477	HDPE	4	5476N
5484 S	Other	4	5526N
5805	Other	4	Unknown
5812 W	RCP	4	Unknown
5819 W	Other	4	1869E
1397 S	Other	5	1398
1069	CMP	6	1041
1229	Other	6	Unknown
1318	Other	6	Unknown
1389	Other	6	Unknown
1418	PVC	6	1419
1545	PVC	6	Unknown
1561	Other	6	Unknown
1588	HDPE	6	1589
1589	HDPE	6	1588
1591	PVC	6	5188
1663 E	Other	6	Unknown
1664 E	Other	6	Unknown
1665 W	Other	6	Unknown
1669 SW	Other	6	Unknown
1673 NE	Other	6	Unknown
1684 E	HDPE	6	Unknown
1713	Other	6	Unknown
1760 SW	Other	6	Unknown
1761 S	Other	6	Unknown
1762 E	HDPE	6	1663
1791	Other	6	Unknown
1797 NW	Other	6	Unknown
1888 NE	HDPE	6	Unknown
1928 W	Other	6	Unknown
1975 W	HDPE	6	Unknown
2074 SW	Other	6	Unknown

Culvert ID	Material	Nominal Size (in)	Connects to
5005	HDPE	6	1628
5009	HDPE	6	Unknown
5020	CMP	6	Unknown
5030	Other	6	Unknown
5034	HDPE	6	Unknown
5060 NE	HDPE	6	Unknown
5080	Other	6	Unknown
5119	HDPE	6	Unknown
5185 NW	Other	6	Unknown
5186 S	Other	6	Unknown
5188	Other	6	1591
5192 W	Other	6	Unknown
5197 SE	CMP	6	Unknown

Culvert ID	Material	Nominal Size (in)	Connects to
5232	Other	6	5517
5235	Other	6	Unknown
5266	HDPE	6	5268
5268	HDPE	6	5266
5282	CMP	6	1420N
5296 S	Other	6	5297
5297	Other	6	5296S
5408	HDPE	6	5409
5409	HDPE	6	5408
5423 N	HDPE	6	Unknown
5453	RCP	6	1828
5517	Other	6	5232
5806	Other	6	Unknown

Table 7-4 summarizes the Phase II Permit requirements for the Illicit Discharge Detection and Elimination element of the SWMP.

Table 7-4. Illicit Discharge Detection and Elimination Needs Summary

Key Task	Description	Completion Date	Ongoing Activities
Ordinances and Regulations	To effectively eliminate illicit connections, the County code must provide provisions that expressly prohibit illicit discharges, layout procedures and timeframes for compliance, and provide for corrective actions if compliance is not voluntary (i.e. fines and funds to implement improvements and bill property owner)	Within1year from EPD, develop and adopt policies that prohibit discharges and identify enforcement mechanisms No later than 18 months from date of permit, develop and implement enforcement plan	
Inventory	Develop a storm sewer system map that identifies all known outfalls and contributing discharges.	180 days prior to expiration of the permit	Update as needed
Inspection	Conduct filed inspections and visually inspect for illicit discharges at all known outfalls to that discharge to surface waters	Visually inspect 1/3 of known outfalls each year beginning not later than the second year of permit coverage	Ongoing

Key Task	Description	Completion Date	Ongoing Activities
Spill Response Plan	Develop and implement a spill response plan that includes coordination with a qualified spill responder	180 days prior to permit expiration	Revise as needed
Training	Provide staff training or coordinate with existing efforts to educate relevant staff on proper BMPs for preventing spills and illicit discharges	Not later than the beginning of the second year of permit coverage	Ongoing

7.7 Stormwater Monitoring Program

The EPA rules require permittees to have a monitoring program to detect illicit discharges and to evaluate program compliance, appropriateness of BMPs, and progress toward achieving measurable goals. At this time stormwater water quality monitoring is not required for compliance with the Phase II Permit (in initial permit cycle). However, some water quality monitoring could be required for implementing the illicit detection and elimination program.

Compliance monitoring, including documentation of achieving measurable goals and qualitative assessment of the effectiveness of BMPs, is required by Ecology as part of the NPDES Phase II Permit. Ecology will determine, through information gathering and in the process of developing the next permit, what, if any, environmental effectiveness monitoring will be required in the next five-year permit cycle.

The primary objective of the monitoring program is to provide a feedback loop for “adaptive management” of the SWMP and Ecology’s municipal stormwater permitting program. Adaptive management means constantly looking at what is being done, finding what works and what doesn’t, and changing what is done based on what has been learned. Stormwater management programs require a substantial expenditure of funds at both the local and state levels, and by private development. Knowing that these funds are being spent effectively is a major concern. It is also important to know whether the stormwater programs are adequate to protect aquatic resources and uses, and whether progress is being made toward reduction of existing water quality problems and associated impacts.

Skagit County Surface Water Management has undertaken several monitoring projects that characterize the water quality of discharges from the County. These studies have primarily focused on drainage from agricultural areas or discharges to sensitive shellfish receiving waters. Although these studies are not focused on urban stormwater, the Skagit County Monitoring Program, implemented as an extension of the Skagit County Baseline Monitoring Plan, has monitoring stations above and below Big Lake (Big Lake outlet and Lake Creek at SR9). The Baseline Monitoring Plan describes monitoring of water quality in streams flowing in agricultural lands of the county. This plan provides a baseline that characterizes streams in Skagit County's agricultural areas and provides a foundation to identify trends in watershed health in the agricultural areas of the Samish and Skagit River Basins. The Skagit County Monitoring Program targets determining the water quality conditions and trends in agricultural-fed streams in the county. Study under that program began in October 2003, and is being conducted by Surface Water Management through September 2009. Future water quality monitoring needs in the Big Lake study area could be dealt with as an extension of that program.

7.8 Compliance Assessment and Cost Tracking

Compliance monitoring includes documentation of achieving measurable goals and qualitative assessment of the effectiveness of BMPs. This requires documenting the level-of-effort and expense of the activities required to implement the program element and the development of goals and criteria to be used in evaluating success. Table 7-5 summarizes the program elements and various costs that should be tracked for each program element and possible goals and criteria for success.

Table 7-5. SWMP Compliance Assessment and Cost Tracking Needs Summary

Stormwater Management Program Element	Cost of Program Implementation			Possible Goals	Possible Criteria for Success
	Labor	Materials	Consultants		
Public education and outreach	X	X	X	Reduced intentional or unintentional dumping of wastes to the stormwater system	Reduced complaints of illegal dumping, increased volumes of hazardous household waste materials recovered
Public involvement and participation	X	X	X	Public participation in the process	Comments received and response to stakeholders
Illicit discharge detection and elimination	X	X	X	Elimination of illicit discharges	Number of discharges detected and eliminated
Construction site stormwater runoff control	X	X	X	Construction site erosion sediment control	Reduced complaints and enforcement activities
Post-construction stormwater management for new development and re-development	X	X	X	Urban pollutant control	reduced drainage complaints and reduced system maintenance activities
Pollution prevention and good housekeeping for municipal operations	X	X	X	Spill prevention	Reduced emergency spill response activities
Evaluation and assessment of program compliance	X	X	X	Cost effectiveness	Extent of compliance achieved

8.0 Chapter 8 – Improvement Needs and Drainage Management Plan Recommendations and Costs

8.1 Major Drainage Systems Solutions Assessment and Recommended CIP Improvements

Based on drainage complaints, field reconnaissance, hydrologic analysis, and hydraulic capacity evaluation of the major drainage systems (as documented in Chapter 6), the following seven outfall drainage systems were identified as being in need of capital improvements to address reported or potential drainage problems. The following sections briefly describe the drainage problems and recommended solutions (improvements) to alleviate them. Within each of those drainage systems, a recommended CIP project is identified and illustrated to provide documentation of findings and direction for further design assessment and CIP projects implementation. Figure 8-1 provides an index to the recommended drainage system improvement figures and shows all perimeter road culverts (along with those recommended for improvement).

8.1.1 Outfall BL3 Drainage System

Within the Outfall BL3 drainage system, multiple drainage complaints (Nos. 193, 410, 415, 654) exist along Lake Terrace Lane west of Big Lake Boulevard as documented in Table 5-1. Based on field reconnaissance of this drainage system, the required solution to the observed problem (also based on discussion with residents) is improved collection of sheet flow and concentrated drainage along the north side of Lake Terrace Lane upstream of an existing entrance to a 24-inch storm drain (an 18-inch drain is located further downstream). According to residents, a ditch existed at that location in the past, but has been filled resulting in accumulated flow bypassing the storm drain inlet and causing localized flooding and erosion along that road.

The recommended solution is installation of a rock-lined (or otherwise erosion protected) interceptor channel along the north side of the road upstream from the 24-inch storm drain inlet. A check of capacity of the existing storm drain (including the 18-inch downstream storm drain) indicated adequate capacity for 25-year (existing) peak flow conveyance, so no storm drain improvements are needed. In addition, it is recommended that asphalt concrete cross-berms be installed at three locations along the road to direct localized road runoff to the adjacent improved drainage system. These collective improvements constitute recommended CIP 01-BL3 as shown in Figure 8-2.

8.1.2 Outfall BL6 Drainage System

Assessment of the Outfall BL6 drainage system indicated that drainage complaint No. 625, adjacent to and downstream of West Big Lake Boulevard, was caused by installation of an undersized (8-inch) storm drain system (assumed by private ownership) between the 18-inch culvert crossing of West Big Lake Boulevard and the lake outfall. It appears that this was previously an open drainage conveyance channel.

The recommended solution is replacement of the 8-inch storm drain with an 18-inch system with catch basins to allow connection to the West Big Lake Boulevard cross-culvert and to provide for private drainage systems connection and maintenance access. The improved 18-inch storm drain was verified to provide adequate hydraulic capacity for 100-year (future) peak flows conveyance. That improvement is designated as CIP 02-BL6 as shown in Figure 8-3.

8.1.3 Outfall BL25 Drainage System

Although no drainage complaints were identified for this drainage system, hydraulic capacity analysis of the BL25 Outfall drainage system indicate that the State Route 9 culvert (existing 18-inch) is somewhat undersized to convey the 25-year (existing condition) peak flow estimate. The downstream culvert under Four Jay Lane is 24-inch diameter, and was confirmed as having adequate capacity to convey required design event peak flows.

It is recommended that the SR 9 culvert be replaced with a larger 24-inch culvert (with rock outfall pad). Also, an upstream 12-inch culvert (parallel to SR 9) at an unnamed local access road does not have adequate hydraulic capacity and is in need of upgrade to an 18-inch diameter replacement culvert. Other components of this drainage system appear to have sufficient capacity to convey required flood flows. Therefore, the recommended improvement, designated as CIP 03-BL25 and shown in Figure 8-4, is to replace both of these undersized culverts.

8.1.4 Outfall BL27 Drainage System

For this drainage system tributary to Outfall BL27, two drainage complaints (#533, #624) document an existing drainage problem along South Westview Road. Two drainage subbasins (BL23 and 24b) deliver runoff to this location through 12-inch storm drains that discharge to an open channel extending parallel to the road and along the east side of an abandoned railroad grade. Shallow groundwater seepage from water impounded in that open channel combined with apparent road modifications along South Westview Road have affected the adequacy of drainage collection in this area, resulting in drainage problems noted at residences along the west side of the road.

The recommended improvement is to install a section of 12-inch storm drain along the open channel segment to provide containment of runoff adjacent to the railroad grade. Also, a section of 12-inch subsurface interceptor drain with local inlets along South Westview Road is needed to collect residual local drainage. Proceeding downstream from South Westview Road, a short section of 24” storm drain with catch basins is needed to eliminate a large plunge out of that 24-inch storm drain that is in very close proximity to an existing residence. This requires that a drop structure (catch basin) be installed with a downstream section of 24-inch storm drain to connect to the existing 24-inch storm drain that outfalls to the lake. These collective improvements are designated as CIP 04-BL27 and are shown in Figure 8-5.

8.1.5 Outfall BL28 Drainage System

The Outfall BL28 drainage system has multiple drainage complaints filed in the County’s records (Nos. 3, 61, 466). These complaints are associated with inadequate drainage collection conditions along South Westview Road (a lateral drainage system to the major drainage system). These drainage problems appears to have been caused by modifications in the roadside drainage systems associated with parking areas constructed on the east side of the road. Also, review of the upslope major drainage system and tributary subbasins (BL24c and BL24d) showed that some re-routing of drainage patterns on the east side of SR-9 has likely occurred over time due to upslope road construction, and that the majority of runoff now flows to the SR-9 12-inch culvert (subbasin BL24d) rather than to the larger 24-inch cross-culvert (subbasin BL24c) to the north.

In consideration of the existing undersized culverts and storm drains at SR 9 and downstream, a 24-inch storm drain system improvement extending between SR 9 and South Westview Road is recommended with an 18-inch tie to the north lateral section of the drainage system (replacing a section of 12-inch storm drain). This will improve collection and conveyance of the major drainage system runoff upstream of South Westview Road and should reduce groundwater seepage affecting downslope residences along South Westview Road. In addition, drainage conveyance along that road (in the area of the drainage complaints) is recommended to be improved by installation of sections of 12" interceptor drains with associated inlets since the prior roadside ditches have been eliminated. The collective improvements for this drainage system are designated as CIP 05-BL28 and are shown in Figure 8-6.

8.1.6 Outfall BL31 Drainage System

The Outfall BL31 drainage system collects runoff from subbasin BL26 (ponds along golf course) and a smaller subbasin BL26b to the south. This is a sizeable drainage with 100-year routed flows in excess of 30 cfs. Drainage from this system combines at the SR 9 –Walker Valley Road intersection, crosses Walker Valley Road and SR-9 (downstream) in an 18-inch culvert, and continues downstream through an open drainage channel to North Westview Road. Drainage complaints (Nos. 566 and 583) exist at that location. Runoff is conveyed under that road in a 24-inch culvert (and a 12-inch parallel culvert for localized runoff), and combined flows enter a 36-inch storm drain with outfall to the lake. The drainage complaints at North Westview Road appear to be associated with the damaged (obstructed) condition of the 12-inch culvert adjacent to the major drainage system.

Based on review of existing hydraulic capacities of the major drainage system, the magnitude of design event peak flows, and considering erosion potential within the existing moderately steep open drainage system, the recommended drainage improvement consists of a system of a 24-inch storm drain with some rock-lined open channel segments between Walker Valley Road and North Westview Road. The improved drainage system would have adequate capacity to convey 100-year (future) peak flows. In addition, the damaged 12-inch culvert under North Westview Road requires replacement to improve local drainage and associated problems reported by residents along the west side of the road. A 12-inch interceptor lateral drain is also recommended along a section of the east side of the road where constructed parking areas have modified the drainage collection system. The improvements described above are collectively designated as CIP 06-BL31 and are shown in Figure 8-7.

8.1.7 Outfall NC2b Drainage System

This drainage system is part of a large residential development under construction that drains to Nookachamps Creek downstream of the Big Lake outlet. The drainage conveyance system within the Outfall NC2b drainage system consists of a network of rock-lined ditches fronting the road network with numerous cross-culverts at road intersections and at driveways crossings. This drainage system discharges to detention (and assumed treatment) ponds prior to discharge to Nookachamps Creek. Two drainage complaints have been documented within this drainage system (Nos. 599 and 647). Complaint No. 599 is associated with the lack of a cross-culvert at the intersection of Trout Drive and River Rock Road. This is a topographic low point and water impounds behind Trout Drive and periodically overflows across it to the north. Complaint No. 647 is associated with drainage problems experienced downslope of an improved drainage system in Copper River Court west of Sockeye Drive. That system discharges to a level-spreader device upgradient of an open space area. Some adjacent downslope lots appear to have been affected by surface or shallow groundwater levels associated with that discharge.

The recommended solutions for these drainage problems are as follows. For complaint No. 599, install a new 18-inch culvert under River Rock Road just south of Trout Drive to provide positive drainage conveyance without road overflow to the downstream drainage system. For complaint No. 647, install an overflow 12-inch storm drain from the catch basin at the west end of Copper River Court to a downstream roadside channel along the east side of Trout Drive. That improvement should be designed to bypass all but low flows delivered to the spreader device (unless it is acceptable to disconnect and remove the flow spreader), and should alleviate the problems associated with the resulting elevated downslope surface and groundwater levels affecting newly constructed residences. The collective improvements for this drainage system are designated as CIP 07-NC2b and are shown in Figure 8-8.

Figure 8-1 Index Map to Recommended CIP Drainage Improvement Projects

Figure 8-2 Recommended CIP Improvements Outfall BL3 Drainage System (CIP 01-BL3)

Figure 8-3 Recommended CIP Improvements Outfall BL6 Drainage System (CIP 02-BL6)

Figure 8-4 Recommended CIP Improvements Outfall BL25 Drainage System (CIP 02-BL25)

Figure 8-5 Recommended CIP Improvements Outfall BL27 Drainage System (CIP 02-BL27)

Figure 8-6 Recommended CIP Improvements Outfall BL28 Drainage System (CIP 02-BL28)

Figure 8-7 Recommended CIP Improvements Outfall BL31 Drainage System (CIP 02-BL31)

Figure 8-8 Recommended CIP Improvements Outfall NC2b Drainage System (CIP 02-NC2b)

8.2 Minor Drainage Systems Improvement Needs

8.2.1 Damaged Culverts Replacement

The drainage system inventory identified approximately 30 culverts or storm drains within the minor (lateral) drainage systems tributary to the major systems that had damaged entrances or outlets causing obstruction of the drainage conveyance capacity of those facilities. Analysis was done to confirm that, if unobstructed (repaired/replaced), the hydraulic capacity of those facilities would be adequate to convey 25-year (existing) peak flood flows. Those facilities were grouped by percent obstruction, as reported in the drainage facilities inventory, and assigned priorities for replacement as follows: low (5% to 20% obstruction), medium (25% to 45% obstruction), and high (50% to 100% obstruction). Figure 8-9 illustrates those culverts and storm drains along with facility identification numbers that are grouped by the assigned replacement priority. Those culverts replacement needs are summarized by number and size for each priority group in Table 8-1 (Section 8.4).

Figure 8-9. Recommended CIP Improvements – Minor Drainage Systems – Damaged Culverts Replacement (CIP 08-CR-HP, MP, LP)

8.2.2 Culverts Obstructed by Sediment or Debris

Culverts inventoried to be obstructed by sediment or debris are tabulated and shown in Chapter 5 (Table 5-2 and Figure 5-3). Hydraulic analyses, described in Chapter 6 (Section 6.3), confirmed those facilities that have adequate hydraulic capacity (assuming the obstruction is removed). Under those conditions, the recommended action is periodic maintenance of those culverts and storm drains to remove the sediment and/or debris such that future drainage problems at those facilities can be avoided. Therefore, no capital improvements are recommended for those facilities. It was assumed that the County's storm drainage operation and maintenance program would be responsible for ongoing O&M activities to maintain those facilities such that drainage improvement benefits would result.

8.3 Recommended NPDES Phase 2 Program Measures

Stormwater program measure (programmatic) modifications recommended in response to the NPDES Phase II Permit requirements are outlined in detail in Chapter 7. Section 8.4 summarizes the resulting major program elements and required activities along with estimated costs that should be considered in annual County budgeting.

8.4 Estimated Project and Program Costs

8.4.1 Recommended CIP Project Improvements Cost

Planning-level estimates of the construction and implementation costs for recommended CIP drainage improvement projects were developed considering rough estimates of material quantities and construction/installation requirements. Those estimates (May 2006 for draft plan) assumed typical applicable costs for construction general requirements (e.g., surveying, temporary water pollution/erosion control, utilities location and protection, mobilization, traffic control) in addition to costs for earthwork, surface treatments and pavement, drainage structures, and miscellaneous construction. Beyond those costs directly estimated, a 40% construction cost contingency was added (typical for planning-level estimates) to establish total estimated construction cost. To estimate total expected costs for project implementation, sales tax (8.0%) and engineering, legal, administrative, and construction management service estimated costs (30% of total construction cost assumed) were added. No costs for right-of-way, easements or other unknown items at this planning level of assessment are included. The resulting total estimated planning-level implementation costs (escalated to November 2007 dollars, estimated 20% increase) are shown in Table 8-1 for each recommended CIP project. Cost spreadsheets as the basis for the recommended CIP project estimated costs are included in Appendix F.

Table 8-1. Recommended CIP Drainage Improvements and Estimated Implementation Costs

Outfall No.	CIP No.	Drainage Complaint Nos. Addressed	Proposed Improvement	Estimated Project Implementation Cost
Major Drainage System Improvements				
BL3	01-BL3	193, 410, 415, 654	Lake Terrace Ln. Drainage Collection Improvement	$56,900
BL6	02-BL6	625	Storm Drain/Outfall Replacement (Enlargement)	$90,600
BL25	03-BL25	None	SR 9 Parallel & Cross Culvert Replacements	$51,500
BL27	04-BL27	533, 624	New Storm Drain and Interceptor Drain Replacement	$221,100
BL28	05-BL28	3, 61, 466	New/Replacement Storm Drain System	$365,200
BL31	06-BL31	566, 583	New/Replacement Storm Drain System and Rock Lined Channel	$326,200
NC2b	07-NC2b	599, 647	New Overflow Storm Drain and Culvert	$95,100
			Subtotal Major Drainage System CIP Costs	$1,206,600
Minor Drainage System Improvements				
High Priority	08-CR-HP	Various	6 – 12 inch and 1 – 18 inch damaged culverts repair or replacement	$92,900
Medium Priority	08-CR-MP	Various	2 – 12 inch and 1 - 18-inch damaged culverts repair or replacement	$44,700
Low Priority	08-CR-LP	Various	11 – 12 inch, 3 – 18 inch, and 4 – 24 inch damaged culverts repair or replacement	$305,000
			Subtotal Minor Drainage System CIP Costs	$442,600
			Total Recommended Drainage System CIP Estimated Costs	$1,649,200

8.4.2 NPDES Phase II Program Costs (Big Lake Study Area)

Estimated costs for NPDES program major element requirements are shown in Table 8.2. These costs are suggested only for budgeting consideration and will depend on how the County treats the larger NPDES Phase II compliance actions throughout the Mt Vernon defined urban area of which the Big Lake study area is a part. Also, many of these cost components are required to be completed over a multi-year period in the permit (aside from required annual activities); therefore, the annual costs need to reflect where the emphasis may be in a given year in meeting the NPDES permit target compliance schedules. The costs identified are considered to be representative of NPDES program activities expected as needed and applicable to Big Lake.

Table 8-2. Recommended Study Area NPDES Phase II Components and Estimated Annual Program Costs

NPDES Phase II Program Element	Required Activities	Estimated Annual Program Cost
Element S5.1, 5.2 Public Education and Outreach (PEO), Involvement, and Participation	• Develop/Implement PEO program including water quality awareness, impacts avoidance, yard care and chemicals/hazardous materials BMPs awareness, construction runoff BMPs awareness, promote LID techniques, illicit discharge awareness and fix incentives, public environmental stewardship • Public involvement with the Stormwater Management Plan (SWMP) update to meet NPDES permit requirements • Public dissemination of County NPDES submittals (on website)	$10,000 $8,000 $2,000 **$20,000**
Element S5.3 Illicit Discharge Detection and Elimination (IDDE)	• Periodic updates to GIS drainage facilities inventory mapping, furnish to Ecology • Incorporate IDDE discharge prohibition regulations in ordinance and SCC • Develop/implement a program to detect, control, and eliminate non-authorized illicit discharges including procedures, notifications, inspections, enforcement • Notification of public employees, businesses, and public of illicit discharge hazards • Institute/monitor “hotline” for reporting of illicit discharges and spills • Provide IDDE training to County staff	$4,000 $3,000 $12,000 $2,000 $4,000 $5,000 **$30,000**

NPDES Phase II Program Element	Required Activities	Estimated Annual Program Cost
Element S5.4, 5.5 Controlling Runoff from New Development, Re-development, and Construction Sites	• Update new development and re-development runoff control program • Update ordinance and SCC provisions to provide regulation equivalent to NPDES Phase II permit and Ecology manual minimum requirements • Institute LID program provisions to reduce impervious area and pervious area disturbance • Expand development plan review, inspection, and enforcement implementation for standards compliance • Expand O&M program for public stormwater facilities including maintenance/inspection ordinance, update maintenance standards, establish inspection requirements for flow control and water quality treatment, develop inspection schedule, annual implementation • Expand development review, inspection, and O&M training	$5,000 $5,000 $5,000 $15,000 $25,000 $5,000 **$60,000**
Element S5.6 Pollution Prevention and Operations/Maintenance for County Operations	• Develop program for County operations pollution prevention • Adopt Ecology-equivalent maintenance standards; conduct annual inspections off all MS4 flow control/treatment facilities • Expand program for cleaning, repair, snow/ice control, pavement maintenance, and vegetation/dust control for highways, roads, and parking areas owned by County • Establish/implement policies and procedures for pollutant reduction from all County-owned lands • Develop and implement SWPPPs for County equipment/materials storage yards • Maintain inspections, maintenance, and repair activity records • Provide ongoing pollution prevention training for County construction, operations, and maintenance staff	$5,000 $15,000 $20,000 $5,000 $8,000 $2,000 $5,000 **$60,000**
Element S8 Monitoring	• Establish/implement monitoring program to characterize illicit discharges • Conduct SWMP BMPs effectiveness monitoring focused on two selected questions to be answered and complete associated annual reporting • Select a minimum of one site (commercial or HD residential) for long-term stormwater quality monitoring	$10,000 $12,000 $3,000 **$25,000**

NPDES Phase II Program Element	Required Activities	Estimated Annual Program Cost
Element S9 Annual Reporting	• Complete annual reports beginning March 2008 for each component of SWMP and implementation actions • Maintain all records related to permit and SWPPP for a minimum of 5 years, and make available for public review upon request.	$20,000 $5,000 **$25,000**
	Total Estimated NPDES Phase II (Big Lake) Annual Program Costs	**$220,000**

8.5 CIP Improvements Priorities

There is need to prioritize potential projects for County implementation given limited annual resources to implement those projects. As can be seen there are approximately 300 culverts that are partially obstructed due to either damage or debris. Some culverts do not provide the targeted level of flood protection considering current standards. Ideally all infrastructure would be maintained and repaired to ensure full capacity. In establishing improvement needs, the rated hydraulic capacities of drainage facilities were compared to the calculated runoff rates to determine which undersized major drainage system facilities should be included as prioritized capital improvement projects. The extent and type of drainage problems from drainage complaints and field reconnaissance were also considered to identify potential project improvement priorities. Culverts and storm drains with the largest size and the greatest percent obstruction (due to damage) have been assigned the highest priority within that improvements grouping.

Additionally, the potential effects and expected extent of flooding need to be considered to refine priority projects selection. For example, an undersized culvert that leads to overland flow to the natural drainage map pose less flood damage threat when compared to an overflow that would flow directly into a home or block a road required for emergency access.

Table 8-3 suggests the priorities for the various recommended CIP projects based on these criteria, recognizing that those priorities will need to be reviewed by the County for consideration of actual implementation sequence when funding is allocated to complete them.

Table 8-3. Suggested Priorities for Recommended CIP Projects Implementation

Recommended CIP No.	Suggested Implementation Priority
01-BL3	7
02-BL6	6
03-BL25	8
04-BL27	3
05-BL28	2
06-BL31	5
07-NC2b	7
08-CR-HP	1
08-CR-MP	4
08-CR-LP	9