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POLLUTION CONTROL HEARINGS BOARD
FOR THE STATE OF WASHINGTON

AIRPORT COMMUNITIES COALITION, Appellant, v. STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY; and THE PORT OF SEATTLE, Respondents.	))))))))))))	No. 01-133 DECLARATION OF WILLIAM A. ROZEBOOM IN SUPPORT OF ACC'S MOTION FOR STAY (Section 401 Certification No. 1996-4-02325 and CZMA concurrency statement, issued August 10, 2001, Related to Construction of a Third Runway and related projects at Seattle Tacoma International Airport)

William A. Rozeboom declares as follows:

1. I am over the age of 18, am competent to testify, and have personal knowledge of the facts stated herein.

2. I am a professional civil engineer licensed in the State of Washington. I am employed as a senior engineer with Northwest Hydraulic Consultants, located at Suite 350, 16300 Christensen Road, Seattle, Washington, 98188. I have over 20 years of specialized experience in surface water hydrology and hydraulics, including over 5 years as principal reviewer of all Master Drainage Plan, Stormwater Management Plan, and Storm Drainage Technical Information Report documents for the 1,300-acre Snoqualmie Ridge project currently under construction in the city of Snoqualmie. The Snoqualmie Ridge project is similar to the 3rd

ORIGINAL

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runway project in that it is a large site development which is subject to the requirements of the Washington State Department of Ecology Stormwater Management Manual and the King County Surface Water Design Manual (KCSWDM). Attached as Exhibit A is a copy of my curriculum vita.

3. Northwest Hydraulic Consultants has been retained since October 1999 on behalf of the Airport Communities Coalition (ACC) to provide technical reviews of stormwater facilities and related streamflow impacts from the proposed 3rd runway and other development at SeaTac airport. I have been responsible for this review work. I have reviewed all stormwater management plans, natural resources mitigation plans, low flow analyses, and related documents which have been prepared by or for the Port of Seattle for airport improvements. My review findings were expressed to Ecology and/or the Corps of Engineers in a series of letters dated 11/24/1999, 5/3/2000, 7/31/2000, 9/7/2000, 9/21/2000, 9/25/2000, 9/27/2000, 2/15/2001, 4/30/2001, 6/25/2001, 7/23/2001, and 8/6/2001. Internal review and quality assurance for these letters was provided by co-signer Dr. Malcolm Leytham, PE, who is a principal with NHC. Attached as Exhibit B is Dr. Leytham's curriculum vita. Independent reviews by King County and Pacific Groundwater Group, under separate contracts to Ecology, have generally corroborated the concerns expressed by our review letters.

4. The Port of Seattle's Third Runway Project and Master Plan Updates will alter surface and ground water hydrology in and around Sea-Tac International Airport. One of the impacts of these alterations will be to the quantity of water flowing in the streams surrounding

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the airport, specifically Des Moines, Miller and Walker Creeks. The most recent (July 2001) Stormwater Management Plan for airport improvements, unlike the previous November 1999 and August 2000 versions of the SMP, proposes stormwater detention facilities which should provide sufficient capacity to mitigate for quantitative airport impacts to peak flows (understanding that this capacity does not address water quality concerns). However, the airport activities will have additional impacts to low streamflows which have not been accurately assessed and for which sufficient mitigation is not assured. The concern is that the project as now proposed will have the net effect of reducing low flow in some or all of Miller Creek, Walker Creek, and Des Moines Creek during the late summer period, roughly July through October. Our comments below focus on low flow issues.

5. Storm water flows from the airport and discharges, either directly or through the storm drain system, by both surface and groundwater flow paths, to Des Moines, Miller and Walker Creeks. Alterations to the quantity of water in these streams surrounding the airport will result from activities which change the basin hydrology, the principal activities being: 1) a near-future increase of approximately 300 acres in the amount of impervious surfaces; 2) expansion of and improvements to the industrial wastewater system (IWS); and 3) long-term additional increase in basin impervious surface area consistent with basin land use zoning. Increased areas of impervious surface will decrease groundwater infiltration and groundwater seepage flow to the streams. The IWS collects water from areas naturally tributary to the streams surrounding the airport, and causes that water to bypass the streams and to be discharged directly to Puget Sound.

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Post-1994 expansion and improvements to the IWS, including lagoon linings and other leak reduction efforts, will further decrease the amount of water infiltrating into the ground and eventually feeding base flows in the streams. Long-term future land use changes creating additional impervious surfaces are anticipated from the eventual (per zoning) construction of a business park in now-forested areas of the Des Moines Creek basin where borrow pits are proposed to be developed as a major source of fill material for the third runway.

6. Low flow depletion in Des Moines, Miller and Walker Creeks is an impact of the Third Runway Project and Master Plan Updates that is recognized as requiring mitigation in fulfillment of Section 401 Certification requirements. To that end, the Port has endeavored to develop a Low Flow Technical Analysis and a low flow mitigation plan, termed the "Flow Impact Offset Facility Proposal," both of which have been submitted to the Department of Ecology in draft form only. The Port's conclusions about low flows were encapsulated in a 7-page letter transmitted from the Port to Ecology on July 23, 2001 under cover of a report entitled Low Flow Analysis – Flow Impact Offset Facility Proposal (Parametrix, Inc., July 2001). *See* Exhibit C. Elements of this report were corrected by a July 25, 2001 letter from the Port to Ecology. *See* Exhibit D. Ecology's Section 401 Certification, issued on August 10, 2001, references and incorporates this low flow analysis and identifies a number of conditions.

7. In analyzing the Port's low flow proposal it is important to keep in mind that the proposal is unprecedented and that no technical standards exist which are suitable to evaluate the proposal. There are uncertainties about both the quantity and quality of water proposed to

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mitigate for low flow impacts, as well as the practicality of the facilities and devices which will be required. These uncertainties are compounded by the fact that the Port's Low Flow Analysis is very clearly an incomplete draft document. The document's opening page states that "[T]he evaluation and low streamflow impact offset proposal is final. . ." However, the documentation of the evaluation is so poor as to make an informed review virtually impossible, and the impact offset proposal is inconsistent with other project documents. There is an absence of critical design and project operation information necessary to demonstrate how the system will function in practice. Because of these deficiencies, the present "final" proposal does not provide any assurance that impacts to low streamflows will be adequately mitigated.

8. The low flow analysis is also incomplete because it does not address all of the current and proposed activities associated with the airport construction and operation that will affect stream hydrology. For example, the analysis is deficient in that it does not address several of the airport activities and projects that I previously identified in comments to Ecology as likely to cause additional reductions to minimum streamflows in Walker and Des Moines Creeks. These deficiencies include: 1) a failure to account for low-flow impacts likely to result from the post-1994 expansion of and improvements to the Industrial Wastewater System, including lagoon linings and other leak reduction efforts; and 2) a failure to address low-flow impacts of future airport business park development at the site of proposed borrow pits which will eliminate what are now forested areas of the upper Des Moines Creek Basin. This latter point is significant

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because Des Moines Creek appears to be a gaining stream in these forested areas which sustain, in part, low stream flows in the lower creek.

9. Hydrologic model (HSPF) calibration utilized in the low flow analysis is either inadequate or absent, undermining conclusions about the magnitude and timing of impact. For example, for Walker Creek, the calibration of simulated (HSPF) low flows to recorded low flows at the upper basin gage is very poor. HSPF simulation results for all calibration years (1991-1996) produce base flows which become progressively smaller from June through October, with the lowest flows of the year generally occurring in October. These simulation results formed the basis for the low flow analysis report finding that the summer low flow period for Walker Creek begins on August 1 and ends on October 31 and that mitigation be provided for this period only. However, this pattern and definition of low flow period is inconsistent with the actual streamflow record. The recorded data show that the lowest flows of the year actually occurred in June and/or July in half of the years with recorded data. The consequence of using a poorly calibrated model in this situation is that the low flow analysis fails to recognize the low flows which occur in June and July and fails to provide any mitigation for impacts to low flows in those months. The figure below illustrates how the simulated streamflow record fails to adequately represent the low flow conditions in June and July, with the consequence that low streamflow impacts during those months will not be mitigated under the Port's current proposal.

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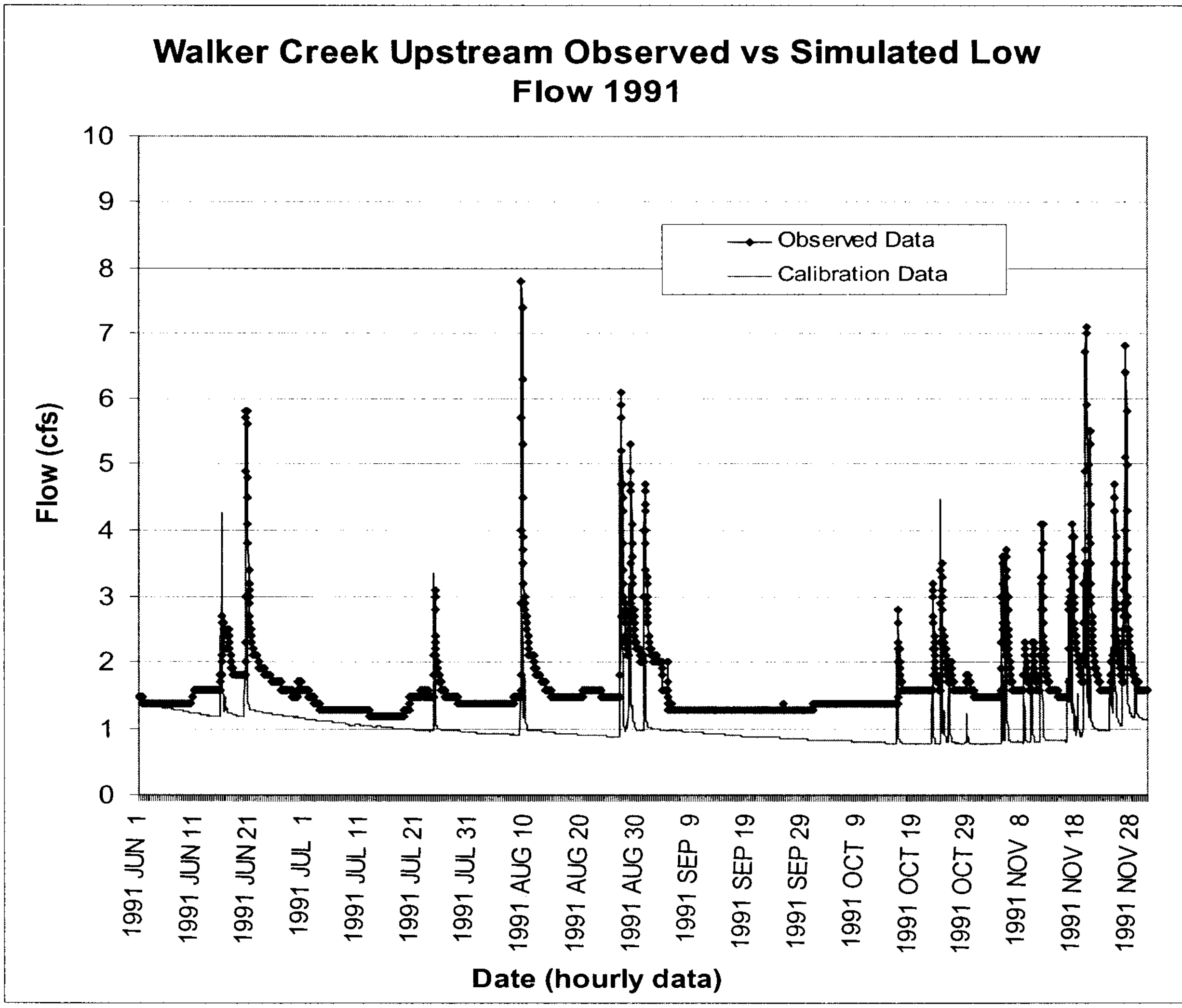

10. The comment above demonstrates that the poor model calibration in the Walker Creek basin has resulted in a mitigation plan which fails to provide any mitigation during part of the year when adverse impacts to low streamflows may be occurring. The comment below demonstrates that the model calibration in the Walker Creek basin may furthermore be so poor as to either significantly underestimate the magnitude of low streamflow impact or be incapable of quantifying the actual amount of low streamflow impact caused by airport activities.

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11. We have commented previously that Walker Creek appears to be vulnerable to low streamflow reductions as a result of impervious surface diversions to the Industrial Wastewater System. This comment was based on groundwater mapping shown by SMP Figure B2-23 which showed that the IWS service area covers nearly half of the non-contiguous groundwater recharge area for Walker Creek. We speculated that IWS expansion, and IWS leak reduction activities, could potentially cause progressive reductions in low streamflows. The low flow report's calibrated Walker Creek HSPF model data and the corresponding recorded data provides the basic information necessary to examine whether changes in streamflow are in fact occurring, unrelated to climatic variability.

12. The existing conditions Walker Creek hydrologic model serves to simulate streamflows for the land use conditions which existed in 1994. If the model were perfectly calibrated to the 1994 condition, then differences between the recorded and simulated data for other years could indicate changes in basin conditions. We examined the average summer low flow at the upper basin gage for each year of record, to see if the recorded (actual) flows were changing relative to the simulated flows. For this evaluation, days with observed and/or computed flows greater than 1.5 cfs (representing surface runoff) were excluded from the calculation of average summer low flows. Average value for simulated and recorded low flows were computed for each year, and plotted as a time series. The results are shown below.

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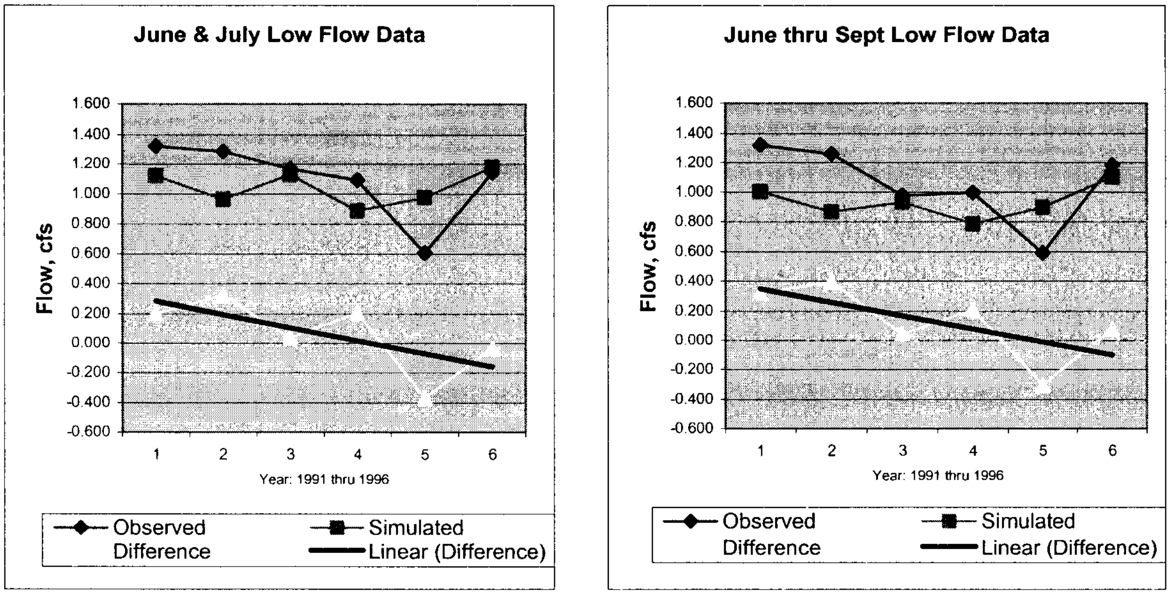

Walker Ck Streamflow Analysis Fig B

13. We have two alternative interpretations of these results. One interpretation is that there is a pronounced declining trend in the observed data relative to the simulated data for the same period. The analysis shows that summer streamflows are declining independent of climatic variability, and that there has been an average summer low flow reduction of about 0.5 cfs over the period 1991 to 1996. The alternative interpretation is that the Walker Creek HSPF model calibration to low flows, in conjunction with uncertainty as to the quality of observed streamflow data, is too poor to draw any conclusions about anything. Under the first interpretation, the proposed low streamflow mitigation of 0.09 cfs for Walker Creek is probably insufficient to compensate for actual airport impacts which may actually be greater than 0.5 cfs if the data are to be believed. Under the second interpretation, there is substantial uncertainty as to whether the

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HSPF model is useful for assessing low streamflow impacts or devising a mitigation plan for Walker Creek. Under either interpretation there is great uncertainty as the adequacy and efficacy of proposed low flow mitigation measures.

14. The low streamflow analysis fails to provide any low streamflow calibration data for Des Moines Creek, such as was provided for Miller and Walker Creeks. Without such data, it is not possible to provide an informed review of the low streamflow analysis or mitigation plan for Des Moines Creek. Based on calibration issues we have raised previously relative to the Des Moines Creek basin, it is probable that the proposed Des Moines Creek low flow mitigation plan has flaws as serious as those identified above for Walker Creek.

15. The low flow analysis also contains inconsistencies that are generally resolved in favor of the Port. For example, the Port's low streamflow analysis makes the claim that summer flows in Miller Creek will be improved due to attenuation effects in the fill material which will be imported for the third runway embankment. Because significant quantities of that same fill is being excavated (to depths of up to 100 feet) and exported from borrow pits in the upper Des Moines Creek basin, it follows that there will be some corresponding impairment of summer flows in Des Moines Creek. The inconsistency is that while the benefits to Miller Creek are claimed, the corresponding impacts to Des Moines Creek are ignored.

16. The low flow mitigation plan, termed the "Flow Impact Offset Facility Proposal" is also deficient because it is incomplete, inconsistent with other project documents, and lacks critical design and project operation information that is necessary to demonstrate how the system

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will function in practice. Several of the sections identified in the report table of contents, and which are vital to understanding the analysis and flow offset proposal, are not provided. The missing sections of particular interest to our review include the Introduction (all but an opening paragraph is missing) and the major section discussing Determination of Impacts to Streamflow. The document does not include any preliminary facility drawings to show the feasibility of providing the proposed storage at the proposed locations. There are no preliminary drawings to show how or where various water quality elements and features described in the text for circulation, venting, aeration, and turbidity control would be accomplished in practice. There are no preliminary drawings showing outfall locations and outlet flow paths to demonstrate that the summer-period reserve storage flow releases could reach the streams without significant transit losses by evaporation, transpiration, and seepage. These omissions create uncertainty as to the feasibility and eventual performance of the flow offset proposal. Because of these deficiencies, it is not possible to know whether or how well the Port's low flow augmentation plan will work, including whether the plan will effectively mitigate impacts to aquatic resources.

17. The mitigation plan is inconsistent with other project documents, most importantly, the Comprehensive Stormwater Management Plan (SMP), which presumably is the master document identifying stormwater storage facilities for the Third Runway Project and Master Plan Updates. Reserve storage vaults were included in some preliminary facility drawings provided with the SMP, but the SMP contains no comprehensive summary of what facilities were proposed to provide reserve storage. The mitigation plan appears to propose

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facilities that are different from those for which preliminary reserve storage designs have been provided in the December 2000 SMP and recent SMP addenda. As late as July 2, 2001, the Port (by Parametrix) provided Ecology with SMP updates showing reserve stormwater storage and reserve stormwater release vaults different from the reserve storage vaults which are identified in the low flow analysis. It is impossible to ascertain from this conflicting documentation what is actually being proposed.

18. Another inconsistency involves the collection of reserve storage water for Walker Creek. The Walker Creek flow offset proposal includes installation of an impervious liner for approximately six acres of drainage swale, in order to establish a dependable water supply for the reserve storage vault. We understand that the swales would be lined primarily to ensure that runoff from runway impervious surfaces is not lost to groundwater, and is available to provide reserve storage. (Note that the previous December 2000 Low Streamflow Analysis by Earth Tech concluded that nearly all of the runway runoff would infiltrate to groundwater.) It seems counterproductive for this project to assert on one hand that runway runoff will infiltrate to groundwater (minimizing low flow impacts) and then propose the forced capture of that same runoff (maximizing low flow impacts) to support a low flow offset plan.

19. The low flow mitigation plan does not address and assess design and operational elements that control the effectiveness of the mitigation, calling into question the feasibility of the design. For example, the magnitude of dry-period transit losses from the storage facilities to the streams should be examined and accounted for at all reserve storage facilities. In particular,

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if flow paths include open ditches, then seepage losses (to groundwater or to supply transpiration by bank vegetation) could be significant and would need to be accounted for. If flow paths are via dispersal or infiltration systems which are set back some distance from the stream or which provide wetland recharge, then transpiration losses could be significant and would need to be accounted for. An evaluation of transpiration losses should examine the flow path and estimate the acres of soils that are hydraulically connected to the flow path. This would be a function of topography as well as soil type. The magnitude of transit losses by plant transpiration, assuming grass, would be in the order of one inch per week. At this rate, transit losses of 0.1 cfs (representing approximately the total amount of reserve storage flow for each stream) would occur if the flow path were hydraulically connected to about 17 acres of vegetation. The Miller Creek Detention Facility may provide the opportunity for a hydraulic connection and transit losses of this magnitude.

20. Another example of questionable design involves how the augmentation proposal will accomplish controlled release of water to streams, an element of the system for which no information is provided. Short of a closely monitored system which is actively managed in perpetuity, this is a technically challenging assignment. Flows will need to be released at heads varying from about zero to 10 feet at the release point (based on some preliminary designs) through small orifices which will be prone to plugging. If all storage facilities are operated for simultaneous flow release in proportion to their storage volumes, then facility release rates as low as 0.01475 cfs (Des Moines Vault SDS4) and 0.0129 cfs (Miller Creek Cargo Vault) are

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indicated. Flow rates this small, assuming a 5 foot head, would require an orifice with a diameter smaller than 0.5 inches. King County normally requires that flow control orifices be no smaller than 1.0 inches to minimize the likelihood of blockage. The report provides no assurance that constant-release flow controls are feasible for this application.

21. Hence, the low flow mitigation plan is flawed for its dependence on incomplete and inaccurate technical analysis that is likely to underestimate the magnitude of low streamflow impacts to Des Moines, Miller and Walker Creeks. It is also flawed for its inconsistency with other project documents, and its failure to describe design and operational elements of the mitigation plan that will directly influence the effectiveness of the proposal in offsetting low flow impacts and protecting the instream resource values of these local streams.

I declare under penalty of perjury under the laws of the State of Washington that the foregoing is true and correct.

DATED this 11 day of September, 2001, at Tukwila, Washington.

William A. Rozeboom

William A. Rozeboom, P.E.

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EXHIBIT A

W.A. ROZEBOOM, M.B.A., P.E.

EDUCATION

B.Sc.. in Civil Engineering (with Distinction), University of Alberta, 1978.

M.B.A., University of Alberta, 1986.

GENERAL

Mr. Rozeboom has 20 years' experience in water resources management and water resources engineering. He has broad technical expertise in surface water hydrology and hydraulics developed through substantive experience in the areas of streamflow gaging, sediment sampling, data processing, physical hydraulic model studies, hydrologic analyses and modeling to design stormwater and flood control facilities, and hydraulic modeling for inundation mapping and river crossing designs. Mr. Rozeboom also has broad expertise in the regulatory aspects of water rights administration in Washington and Hawaii and of Puget Sound stormwater quantity and quality controls and best management practices. While employed by the Hawaii Water Commission, Mr. Rozeboom helped establish the institutional framework for implementing the 1987 Hawaii Water Code. With NHC, Mr. Rozeboom's work has resulted in numerous client commendations.

CHRONOLOGICAL EXPERIENCE

November 1992 - Present: Hydrologist and senior engineer with Northwest Hydraulic Consultants, Seattle office.

June 1988 - November 1992: Hydrologist with the State of Hawaii Commission on Water Resource Management. Responsible for implementing new programs for water rights certification and dispute resolution under the 1987 State Water Code.

September 1986 - May 1988: Self-employed. Provided engineering and management consultant services for various projects, including two water supply development assignments in the West Indies.

September 1984 - August 1986: Full-time MBA student and graduate assistant. During summer employment with Alberta Environment Hydrology Branch, conducted field and office research studies of carriage losses from natural channels.

January 1979 - May 1984: Project engineer with Northwest Hydraulic Consultants, Edmonton office. Responsible for managing and conducting projects involving field inspections, river surveys, scale model design, construction, and testing, hydrologic and river engineering assessments, and development of computer models.

Summers, 1976 - 1977: Water survey technologist with Alberta Environment Water Survey Section. Responsibilities included flow meter measurements of river discharges by bridge and wading methods, integrated depth sampling of suspended sediments, data reduction, development of rating curves, and servicing of hydrometric gaging stations.

SELECTED PROJECT EXPERIENCE

Snoqualmie Ridge Post-Construction Monitoring Program: Provided comprehensive technical review and regulatory oversight, on behalf of the city of Snoqualmie, for the planning and implementation of a post-construction monitoring program for the 1,300-acre Snoqualmie Ridge Mixed Use Development. The development, which drains to numerous wetlands and fish-bearing streams, is one of the first projects in King County to implement the water quality requirements of the 1998 King County Surface Water Design Manual. The project employs a number of unique mitigation measures including sand blankets to preserve interflow conveyance across roadways, enclosed-storage water quality sand filters for golf course runoff, and flow splitting systems to divert undetained peak flows to large-capacity bypass pipelines. The multi-disciplinary monitoring plan, approved in 1998, was developed to: 1) assess the actual performance of the constructed stormwater facilities; 2) determine if impacts to measurable physical and biological characteristics of wetlands and streams were within the tolerances predicted by the project EIS, and 3) take remedial measures as necessary. The work is ongoing.

Snoqualmie River HEC-RAS Modeling: Managed the updating of an existing HEC-RAS hydraulic model of the Snoqualmie River at Snoqualmie to assess impacts of proposed modifications to the dam crest at the Snoqualmie Falls Hydroelectric Project. Work included a field survey, verification of model calibration to observed summer water level data, and hydraulic analyses to identify project water level impacts affecting summer river access and recreational opportunities.

Ledger Lake Wetland Impact Assessment: Performed hydrologic modeling and data analyses to evaluate potential impacts of city of Mount Vernon stormwater discharges to the Ledger Lake wetland complex. Modified a daily water balance simulation model of the area to accurately reflect the design characteristics of a proposed pump station at the lake outlet, and to assess near-term future water level conditions for comparison with existing and simulated long-term future conditions. Extracted wetland water level (stage) data from the simulation output and presented the results as a series of tables summarizing the wetland hydroperiod stage-duration data. Reviewed the data in the context of available regulatory guidelines for allowable wetland water level fluctuations.

Mill Creek Salem Hydrologic and Hydraulic Modeling: Developed, calibrated, and applied hydrologic and hydraulic models to assess flood control alternatives for Mill Creek at Salem, Oregon. HEC-1 and HEC-HMS models were developed of the 104-square mile upper basin, calibrated to the record flood of February 1996, and applied to compute design flow hydrographs for current conditions and future scenarios with regional detention facilities. Developed and calibrated an unsteady flow branched network hydraulic model, UNET, for 15 network reaches describing Mill Creek and its distributaries which flow through the city of Salem. The UNET model was calibrated to high water mark data and very limited hydrograph data from the record flood of February 1996, and updated to incorporate flood reduction works which had been constructed after flood event.

February 1996 Postflood Report: Managed preparation of a postflood report for the Portland District Corps of Engineers (COE) providing comprehensive qualitative and quantitative documentation of the major storm which struck the Pacific Northwest in February 1996, causing record or near-record flooding in many basins. Archived and summarized more than 1,200 hydrometeorological data sets from USGS, NOAA, COE, and NRCS sites, developed storm isopluvial maps, determined storm intensity and flood discharge return periods, assessed flood control operations at 13 COE flood control reservoirs and 4 Section 7 flood control projects, and described COE flood fight activities.

Thunder Ridge Erosion Control: Provided expert advice, on behalf of a downstream landowner, as to the adequacy of site erosion control measures at the 50-acre Thunder Ridge Estates Subdivision development in Snohomish County. Following a site inspection, prepared a legal declaration describing the development's substantial lack of compliance with required erosion control Best Management Practices, which led to a stop work order.

Mount Vernon Riverbend Stormwater Alternative: Determined the hydraulic effects of discharging stormwater from 230 acres of the City of Mount Vernon to lowlying fields outside the City limits, and identified mitigation alternatives. The fields are located in a diked meander loop of the Skagit River, and interact with the river by seepage flows and a flap-gated culvert. Developed a daily water balance model of the area and calibrated seepage functions and soil specific yields to reproduce historic conditions. Determined design parameters for alternative pump station and culvert improvements to mitigate impacts of the proposed stormwater discharge.

Lake Chelan Hydroelectric Project PMF Study: Developed and calibrated a HEC-1 model of the Lake Chelan basin to determine PMF rain-on-snow lake inflow and outflow hydrographs for the Lake Chelan Hydroelectric Project. The basin consists mostly of rugged mountain terrain with very steep precipitation and temperature gradients which greatly affecting local snowpack and precipitation amounts. Calibration was made to historic flood events, and PMF simulations evaluating alternative reservoir operational scenarios were made in accordance with National Weather Service and Federal Energy Regulatory Commission guidelines.

Snoqualmie Ridge Golf Course Drainage Reviews: Provided technical reviews of stormwater management plans and permanent utility plans and specifications for the Snoqualmie Ridge Golf Course on the Lake Alice Plateau above Snoqualmie Falls. Reviews were made for technical accuracy and compliance with City ordinances and MDP and EIS documents. The work required analyses of numerous requests to depart from the approved MDP and standard facility designs for purposes of golf course aesthetics and to construct a large lake combining functions of water quality treatment and storage of recycled water. Results were expressed by detailed review memoranda, meetings with the City and applicant, and participation at meetings of the City Planning Commission.

Wenatchee Alluvial Fan Flood Hazard Review: Reviewed flood hydrology and flood hazard mapping for alluvial fan streams in the City of Wenatchee to address a 20-year old dispute over the extent of 100-year flood hazard. Evaluated methodologies and assumptions used by previous studies, and developed updated flood hydrology estimates analyses based on HEC-1 modeling, regional analysis, and a 90-year archival record of flooding from local newspaper reports. Performed hydraulic analyses with the Federal Emergency Management Agency's FAN alluvial fan model. Study results led to an 80% reduction of the regulatory flood hazard zone, relieving more than 500 property owners from the need to purchase federal flood insurance.

North Fork Issaquah Creek Floodplain Mapping: Updated an existing HSPF hydrologic simulation model of the North Fork basin to determine flood quantiles for current land use conditions, and developed a HEC-2 hydraulic model to determine floodplain boundaries for 1.2 miles of channel ending at the confluence with the main stem Issaquah Creek. Flood flows and floodplain boundaries in the lower portion of the study reach were determined to be influenced significantly by inter-basin flood flows originating from the main stem channel and which overtop a ridge between the basins during major floods.

Nevada Flood Insurance Hydrology Studies: Updated hydrology studies and determined design flows for FEMA floodplain mapping of three mountain streams in Washoe County near Reno, and the North Las Vegas Wash Flood Control Project near North Las Vegas, Nevada. Design flows for the Washoe County streams were determined from a regional analysis to be governed by a population of relatively rare (about 50-year and higher return periods) cloudburst events accompanied by high sediment and debris loads. Existing HEC-1 models for the North Las Vegas Wash were reviewed and updated to more accurately predict 500-year flows. Methodologies used in the previous North Las Vegas Wash analyses were found to have substantially underestimated 500-year flows by overlooking the loss of peak flow control which will result when the 100-year design capacity of a major flood control detention facility is exceeded.

Watershed Assessments: Conducted surface water assessments of the Deschutes, Snohomish, and Walla Walla Water Resource Inventory Areas under a statewide program of initial watershed assessments for the Washington State Department of Ecology (DOE). The purpose of this work was to characterize the "health" of the surface water resources in each watershed to facilitate decision-making by DOE on water rights applications. Examined available flow data in relation to established instream flow regulations, and conducted time-series assessments of streamflow and precipitation data to determine whether there were indications of declining minimum or average annual flows unrelated to natural climatic fluctuations.

Cowlitz River Flood Analysis: Reviewed the controlled flow releases from the Cowlitz River Mossyrock Dam during flood events in November 1995 for compliance with FERC license requirements. Assessed alternative reservoir operating scenarios to determine the extent to which operating practices contributed to downstream flood damages.

Snoqualmie Ridge Parkway Plan Reviews: Reviewed Stormwater Management Plans, Temporary Erosion and Sediment Control Plans, and related construction drawings for stormwater aspects of the 3.2-mile long Snoqualmie Ridge Parkway. Principal stormwater facilities include water quality/detention ponds, biofiltration swales, and a large-diameter high-flow bypass pipeline. The high-flow bypass pipeline is sized to convey excess flow from the Parkway and the adjoining Snoqualmie Ridge and Falls Crossing sites for direct discharge into the Snoqualmie River. Plans and drawings were reviewed for technical accuracy and for compliance with the King County Surface Water Design Manual, City of Snoqualmie ordinances, and project MDP and EIS documents. Coordinated subconsultant reviews of water quality and wetlands issues and facilities.

Mount Pinatubo Regional Hydrologic Analysis: Conducted a regional analysis of rainfall and streamflow data for the Mount Pinatubo region, assessed data reliability, prepared isopluvial maps of 2- through 500-year rainfall amounts for 24-hour through 5-day durations and, through HEC-1 modeling, developed flow duration and flood frequency curves for 39 potential sediment and flood control project sites on major streams affected by the 1991 eruption of Mount Pinatubo. Study results were published in COE Technical Report GL-94-16, Post Eruption Hydrology and Hydraulics of Mount Pinatubo, The Philippines.

Mount Vernon Regional Drainage Analyses: Used HSPF simulation models of current and future land use conditions in the City of Mount Vernon to identify drainage problems along main stem channels throughout the city. Developed designs and costs for proposed alternative solutions including pump stations, regional detention pond facilities, and culvert replacements.

Falls Crossing Master Drainage Plan (MDP) Review: Reviewed Draft MDP hydrologic analyses and flood impact analyses submitted to the City of Snoqualmie for approval of a development partially located within the Snoqualmie River floodplain. Coordinated reviews of water quality and wetlands issues by subconsultants.

Clarewood Development Review: Assessed drainage patterns and flood risk for properties located downstream of the proposed Clarewood development in Pierce County. Provided expert testimony at a development hearing on the uncertain performance of infiltration facilities to be constructed immediately upslope of an area with past flooding problems, and the downstream flood impact risk associated with the development as proposed.

Cedar Hills Gaging Services and Data Processing: Responsible for operation of a six-station gaging network at the Cedar Hills landfill for a period of one year to identify and eliminate persistent data discrepancy problems. Conducted field tests and theoretical reviews which positively identified two principal problems: control elevations which had been incorrectly reported on "as-built" drawings, and inaccuracies in the technical manual used to derive theoretical rating curves for multiple-orifice outlet structures. Developed revised stage-discharge relationships which eliminated the data discrepancies, and provided training to client staff in data processing and reporting practices.

Snoqualmie Ridge Master Drainage Plan (MDP) Review: Reviewed Draft MDP hydrologic analyses and conceptual facility designs submitted to the City of Snoqualmie for mixed use development approval. Reviewed hydrologic analyses for adequacy of HSPF model calibration and measures proposed to deal with uncertainty in the analyses. Reviewed conceptual facility designs for feasibility and compliance with applicable development standards. Coordinated reviews of water quality and wetlands issues by subconsultants.

Myrtle Creek Flood Study Review: Reviewed flood hydraulics and floodplain mapping studies for the Town of Myrtle Creek located at the confluence of Myrtle Creek and the South Umpqua River. The work was undertaken on behalf of the Federal Emergency Management Agency to resolve a 4-foot discrepancy in the 100-year flood elevation as reported by two other federal agencies. The discrepancy was resolved by identification of an error in one of the earlier analyses.

Snoqualmie Parkway EIS and SMP Reviews: Managed a multidisciplinary review of water quantity, water quality, and wetlands elements of Environmental Impact Statement materials and supporting documents submitted to the City of Snoqualmie for the proposed Snoqualmie Ridge Parkway. Subsequently reviewed the Stormwater Management Plans (SMP) and construction drawings for compliance with applicable standards and representations made in the environmental impact process. The work was undertaken for the City of Snoqualmie under the direction of the Director of Community Development.

Evans Creek HSPF Model Calibration: Calibrated the EPA's Hydrologic Simulation Program - Fortran (HSPF) to streamflow and wetland water level data collected at four sites in the Evans Creek West catchment of the proposed Northridge/Redmond Ridge Urban Planned Development in King County.

Water Use Inventory: Implemented Hawaii State Water Code legislation requiring registration of all wells and stream diversions statewide, declaration of water use, and monthly reporting of water use. Gave public workshops on water code requirements, developed systems, procedures, and databases to analyze and manage the contents of 7,300 declarations of water use, acted on all declarations, and coordinated field survey activities for verification of water facilities and uses.

Bank Protection Research: Conducted a comprehensive review of alternative methods of streambank protection, seeking those that might provide cost-effective alternatives to conventional riprap protection for highway bridges in Alberta. Computed present value project life costs of promising alternatives, considering allowable velocities, maintenance costs, local availability of materials, and transportation costs.

Database Development: Developed computer databases to track processing of Hawaii well and stream diversion works construction permits, to inventory wells, stream diversions, and water uses statewide, and to target specific groups by geographic area and/or activity for mailings of notices and informational materials.

Water Rights and Dispute Resolution: Administered the first contested case hearing before the Hawaii Commission on Water Resource Management, including mediating discussions between opposing expert witnesses, preparing the Findings of Fact, and drafting the Commission's Decision and Order. Prepared the Findings of Fact report which led to the designation of the Island of Molokai as a Water Management Area. Prepared Departmental testimony to the Legislature on proposed amendments to the State Water Code.

Satellite-Linked Water Resources Data Collection: Initiated and developed a pilot program for collecting real-time precipitation and other water resources data via satellite from remote areas in Hawaii.

Water Utility Privatization Study: Determined rate structures and impact on consumers which would result from the privatization of water and sewerage facilities for small municipalities.

Montserrat, W.I., Integrated Resource Development Project: Provided specialist water resources input on a five-person multidisciplinary mission in Montserrat, W.I. for the Canadian International Development Agency. Determined design and construction specifics and costs for small dam and irrigation projects to facilitate agricultural self-sufficiency.

Cedar Hills Hydrologic Data Review: Reviewed the accuracy of rain and flow data being collected at the Cedar Hills landfill to determine downstream impacts and for future calibration of a hydrologic model. Identified erroneous records through double-mass analysis, reviewed implications of stage measurement and theoretical rating curve errors, and recommended measures for improving data accuracy.

Supermall Downstream Impact Assessment: Developed current and future land use HSPF simulation models for the proposed Supermall of the Great Northwest to identify downstream impacts. Linked hourly HSPF simulation results to a finite difference unsteady flow model, FEQ, and assessed water level impacts through a complex system of wetlands, ditches, and culverts leading to the downstream receiving channel.

City of Yellowknife Municipal Financial Assessment: Assessed the impact of the City's 5-year capital improvements plan on financial stability and tax rates.

Jasper Park Lodge Water System Analysis: Conducted computer analysis of recirculating water system for Jasper Park Lodge; identified causes and recommended solutions to problems of low water pressure and fluctuating water temperatures.

St. Lucia W.I. Roseau River Carriage Loss Assessment: Determined water losses which would result from using a natural channel to transmit water from a proposed water storage reservoir to downstream agricultural users.

St. Lucia W.I. Roseau Basin Water Development Program: Provided hydrologic input towards site selection for a water supply reservoir in St. Lucia, W.I. Reviewed reliability of available hydrometric data and extended streamflow records using rainfall records and computer modeling techniques. Estimated low-flow sequences to determine reservoir storage needs, and design floods for spillway sizing. Conducted on-the-job training with local personnel for computer use and hydrologic techniques.

School Financial Planning Model: Refined a prototype computer model to project finances over a 5-year horizon, based on scenarios of economic and demographic growth, required facilities, debt structure, salary rates, and programs of government financing.

Ross Creek Basin Surface Water Supply: Developed a computer simulation model which accounted for varying precipitation, evaporation, runoff and water consumption within the Ross Creek Basin in southern Alberta. The model was used to develop a 50-year sequence of natural runoff conditions and to assess alternative water supply management proposals.

Peace River Basin Surface Water Supply: Determined surface water supply characteristics from limited streamflow records based on regional correlations and frequency analyses, and computed reliable water supplies for 22 communities in northwest Alberta based on intake characteristics, current and projected water consumption, and existing reservoir facilities.

Pipeline River Crossings: Conducted field surveys and determined hydraulic design parameters of scour, bank erosion and 1:100 year high water levels at 32 river crossings of the Alaska Highway Gas Pipeline and 7 river crossings of the Alberta Deep Basin Pipeline.

Gull Lake Regulation Study: Developed and calibrated a computer simulation model to determine causes of historical declines in lake levels and assessed the effectiveness of alternative lake management scenarios on the basis of historical hydrological conditions.

Carriage Loss Investigations: Designed and coordinated a field research study to monitor carriage losses over 60 km of natural channel in Southern Alberta; analyzed field data to determine the magnitude, uniformity, and causes of losses. Reviewed and evaluated all previous studies conducted to assess carriage losses in natural channels in Alberta and Saskatchewan, and developed techniques to predict carriage losses which affect reservoir release flows into natural channels.

Isle Lake - Lac Ste. Anne Stabilization: Developed and implemented a computer simulation model to examine proposals to stabilize lake water levels.

Alaska Highway Gas Pipeline Route Hydrology: Six-month in-house assignment with the Yukon Pipeline Design Joint Venture design team; provided hydrotechnical input on small basin hydrology, and for development of drainage and erosion control criteria.

Berry Creek Channel Losses: Determined channel losses affecting reservoir release flows over 12 km of natural channel in southern Alberta.

Willow Creek Water Supply: Determined causes of winter water supply shortage at communities drawing water from Willow Creek below Chain Lakes Reservoir in southern Alberta.

Little Bow Basin Water Supply: Assessed basin water supplies as affected by internal runoff and inter-basin water diversions.

Whitford Lake Basin Management: Developed a comprehensive study program to establish an engineering data base and methodologies to evaluate drainage and flood control projects in the Whitford Lake Basin in central Alberta.

Buffalo Bay - Horse Lakes Management Program: Developed a computer simulation model to assess water levels and discharges in the Buffalo Bay - Horse Lakes complex in north-central Alberta under alternative management schemes.

Rat Creek Bridge Crossings: Conducted field surveys, determined hydraulic design parameters, and designed abutment armoring for two single-span bridge crossings in central Alberta.

McLeod River Bank Stabilization: Conducted field surveys and designed rip-rap armoring for bank stabilization at a railway bridge in central Alberta.

Channel Ice Surveys: Conducted winter ice and breakup surveys at 52 river crossings encountered along the British Columbia segment of the proposed Alaska Highway Gas Pipeline.

Red Deer River Floodplain Development: Determined open water and ice jam design flood levels and developed measures for floodplain development in Red Deer, Alberta.

St. Mary Canal Sedimentation: Conducted field sedimentation studies to assess sources and mechanisms of canal sedimentation in southern Alberta.

Dickson Dam Diversion Tunnel Model Study: Constructed a 1:54 scale physical model of dual 5.5 m diameter diversion tunnels: assessed and optimized intake and outlet flow patterns, minimized transition losses, and assessed outlet scour. Supervised construction of a 1:70 scale model of the 60 m wide, 190 m long service spillway for the dam project.

Port McNeill Harbour Breakwater Model Study: Constructed a 1:100 scale physical model of the Port McNeill harbour region in British Columbia. Developed a breakwater design to shelter a proposed harbour expansion from ocean waves.

Elbow River Channel Improvement: Conducted field surveys and designed channel improvements to increase side-channel flows in the City of Calgary, Alberta.

Harvey Creek Channelization Model Study: Constructed 1:15 and 1:25 scale physical models of a steep 12 degree channel in British Columbia. Determined the stability of 1.0 m boulders under flood conditions, and assessed flow patterns through transitions and curves in a channelized reach of channel.

Cooling Pond Circulation Model Studies: Constructed and tested physical scale models of cooling ponds formed in natural topography for three thermal generating stations in central Alberta: the Calgary Power Ltd. Keephills Thermal Plant, the Edmonton Power Genesee Power Project, and the Alberta Power Ltd. Sheerness Generating Station. Assessed alternative dike arrangements to optimize circulation patterns under conditions including thermally stratified flow and adverse wind shear.

Sundance Helper Cooling System Model Study: Developed 1:12 scale model of a 20 m long sump bay with a 2.1 m diameter, 100,000 GPM pump intake: designed baffles to produce smooth intake flow conditions, and determined intake energy losses.

Field Surveys: Conducted hydrometric surveys over two summers of more than 100 rivers and lakes throughout the Province of Alberta. Responsibilities included surveying of seasonal lake level elevations, streamflow gaging by wading and bridge crane methods, sampling of suspended sediment at bridge and cableway sites, hydrographic soundings and mapping of lake bottom contours, field servicing and repair of strip-chart water level recorders, and assisting in the construction and installation of housings and equipment for stream gage stations.

PROFESSIONAL REGISTRATION

Washington
Alberta

ASSOCIATIONS

American Water Resources Association
Northwest Regional Floodplain Managers Association
Washington State Water Resources Advisory Committee
Washington State Water Use Measurement Technical Advisory Group

AWARDS

National Science and Engineering Research Council Postgraduate Scholarship, 1978.

RELEVANT PUBLICATIONS

"Use of a Scale Model to Improve Pond Circulation," Proceedings of the Specialty Conference on Computer and Physical Modeling in Hydraulic Engineering; Chicago, Illinois; August, 1980.

"Carriage Losses in Natural Channels in Southern Alberta," with S.J. Figliuzzi. "Proceedings of The 1986 Canadian Hydrology Symposium on Drought: The Impending Crisis?"; Regina, Saskatchewan, June 1986.

EXHIBIT B

K.M. LEYTHAM, Ph.D., P.E.

EDUCATION

B.Sc. in Civil Engineering, University of Birmingham, U.K., 1971

S.M. in Water Resources, Massachusetts Institute of Technology, 1974

Ph.D. in Hydrology, University of Washington, 1982, specialized in stochastic modeling of large scale droughts.

GENERAL

Dr. Leytham has broad experience as an engineering hydrologist primarily with specialist consulting engineering organizations. He has worked on projects throughout North America and in South America and the Far East. He has particular expertise in the analysis and synthesis of hydrologic data and in the development and application of catchment hydrology models for such uses as estimation of design floods, for flood forecasting, for seasonal snow-melt forecasting, and for the design of urban stormwater management facilities.

CHRONOLOGICAL EXPERIENCE

January 1987 - Present: Principal with Northwest Hydraulic Consultants. Responsible for hydrology studies in the Seattle office.

March 1986 - December 1986: Senior Hydrologist with Northwest Hydraulic Consultants. Responsible for hydrology studies in the Seattle office.

August 1985 - March 1986: Senior Hydrologist with Ott Water Engineers Inc., Bellevue, Washington. Responsible for hydrology studies in the Northwest regional office.

January 1983 - August 1985: Self-employed consultant providing services primarily in the area of deterministic catchment modeling and the development of computer models for flow forecasting.

May 1982 - January 1983: Senior Hydrologist with Crippen Consultants Inc., Seattle, Washington. Responsible for hydrology work related to hydropower developments.

September 1979 - May 1982: Ph.D. program at the University of Washington. Research into the stochastic generation of multi-site precipitation data for modeling large-scale droughts.

August 1975 - May 1979: Hydrologist with Hydrocomp Inc., Palo Alto, California. Involved in a wide variety of hydrology projects, including development of simulation models, catchment hydrology studies and analysis of hydrologic and meteorologic data.

SELECTED PROJECT EXPERIENCE

Lewis River Project Relicensing Studies: Project manager for flood management aspects of relicensing studies for Swift, Yale, and Merwin Dams on the Lewis River, Washington. Investigated the flood management benefits of alternative project operating policies, including development of inundation maps for the Lewis River from Merwin Dam downstream to its confluence with the Columbia River (ongoing).

Kelsey Dam Safety Review - Hydrologic and Hydraulic Aspects: Participated in the hydrologic and hydraulic aspects of a dam safety review for Kelsey Generating Station on the Nelson River, Manitoba. Responsible for reviewing estimates of the Inflow Design Flood.

Travers Dam PMF Review: Undertook a comprehensive review of the PMF estimated for Travers Dam on the Little Bow River, Alberta.

Mill Creek, Salem, Flood Reduction Study: Project manager for development of hydrologic and hydraulic models of Mill Creek, Salem, Oregon for use in the investigation of system improvements to reduce urban flooding through the city of Salem. Hydrologic modeling was done using HEC-HMS. Hydraulic modeling was done using an unsteady flow UNET model to represent complex multiple flow breakouts, flow splits, and flood storage facilities. Both models were calibrated to data from the major flood of February 1996.

Nechako Reservoir Inflow Analysis. Directed analyses of inflow data for Nechako Reservoir, British Columbia, to determine the best way of forecasting average annual inflows for a reservoir expansion study. The current record of inflows exhibits a cyclicity with inflows above or below the long-term average for extended periods of time. The analysis found a relatively strong relationship between reservoir inflows and the Pacific Decadal Oscillation (PDO), a long-lived (decadal) bimodal pattern of climate variability in the North Pacific. Estimates of average reservoir inflows for an approximately 25 year planning horizon were provided on the basis of a recent phase change in PDO.

Black Butte Dam Rainfall-Runoff Model and PMF Estimate: Project manager for development of a HEC-HMS rainfall-runoff model of the Stony Creek basin above Black Butte Dam, Northern California. The calibrated model was subsequently used to develop Probable Maximum Flood (PMF) estimates at the dam site. Probable Maximum Precipitation (PMP) estimates used as input to the PMF analysis were obtained from the National Weather Service HMR58 guidelines.

Masonry Dam Flood Control Operations Study: Project manager for the investigation of alternative flood control operating policies for Masonry Dam on the Cedar River, Washington. Work included development of alternative operating policies and assessment of the impacts of those policies on flood damage, hydropower generation, water supply safe yield, and downstream fisheries production.

Shillapoo Lake Ecological Restoration: Project manager for hydrologic and hydraulic studies for the proposed restoration of Shillapoo Lake, an approximately 900-acre area in the Columbia River floodplain, Washington. Analysed alternative means for re-establishing hydraulic connections between Shillapoo Lake and the Columbia River to restore ephemeral wetland conditions. Produced conceptual level designs for the preferred alternative including: levees, water control structures, conveyance systems, and pump station.

South Heart River Dambreak Studies: Directed the performance of dambreak simulations using the U.S. National Weather Service FLDWAV model to determine the required spillway capacity of a dam on the South Heart River, Alberta, under the Incremental Hazard Evaluation methodology.

Walker River Hydrology Studies: Project manager for comprehensive hydrologic studies of the Walker River Basin, a 4,000 sq. mi. closed basin in eastern California and western Nevada.

Seven Mile Dam PMF Review and Characterization of Extreme Floods: Reviewed the PMF for Seven Mile Dam on the Pend Oreille River, British Columbia and performed detailed flood frequency analyses to estimate the magnitude and frequency of extreme floods for use in risk analyses undertaken by others.

Lewis River Flood Study: Project manager for an investigation of the severe flooding which occurred in February 1996 along the Lewis River, Washington, downstream from Merwin Dam. Work involved field identification of high water marks, reconstruction of natural (i.e. unregulated) flows, development of a hydraulic model of the Lewis River from the dam to its confluence with the Columbia River, and determination of flood profiles and areas of inundation for actual and hypothetical project operations.

Iron Gate PMF Study: Project manager for the determination of the probable maximum flood at Iron Gate Dam on the Klamath River, California.

Lake Chelan Project PMF Study: Project manager for determination of the probable maximum flood for the Lake Chelan Hydroelectric Project on the Chelan River, Washington.

Juri River Flood Warning System: Provided advice and assistance in the evaluation of a low-cost flash flood warning system on the Juri River in northeastern Bangladesh. The work involved the design and implementation of a network of rainfall and streamflow gauges, analysis of hydrometeorologic data, and conceptual level design of the flood warning system and flood disaster management program.

Snoqualmie Ridge Parkway: Reviewed the design of temporary erosion control facilities for the construction of the Snoqualmie Ridge Parkway, Washington.

Evaluation of Rainfall - Runoff Models: Conducted an evaluation of rainfall-runoff models for the Northwest Region, National Rivers Authority, U.K.. The study included an interview program with agency staff to determine needs, review of models potentially suitable for adoption by the agency, and test case application of selected models to several catchments.

Mill Creek (Auburn) Flood Control Plan: Technical lead for the development of the Mill Creek Flood Control Plan, a multi-objective, multi-jurisdictional effort to develop and implement a comprehensive flood control and environmental restoration plan for the Mill Creek Basin, Auburn, Washington. As technical lead, managed all technical input to the project, provided direction to and coordinated the work of wetland, fisheries, water quality, and hydraulic and hydrologic modeling specialists, developed and analysed conceptual flood control alternatives consistent with the project's environmental goals, provided technical liason with project stakeholders, and advised on stakeholder selection of a preferred flood control alternative.

North Umpqua River Flow Forecasting Model: Project manager for the development of seasonal and short-term flow forecast models for use in the operation of hydro-electric generation facilities on the North Umpqua River, Oregon.

Hydrologic Analysis and Modeling for Remedial Works on Mt. Pinatubo: Project manager for development of hydrometeorologic database and estimation of design flows for use in the planning and design of sediment and flood control measures on the eight major water courses affected by the 1991 eruption of Mt. Pinatubo, Philippines.

Northridge Master Drainage Plan: Project manager for the conceptual design of stormwater management facilities for a proposed 1500 acre mixed-use (commercial and residential) development in King County, Washington.

Beaverdam Master Drainage Plan: Project manager for hydrologic monitoring, hydrologic analysis, and conceptual level design of stormwater control facilities for a residential golf course development in an environmentally sensitive area in western King County, Washington.

Snoqualmie Ridge Master Drainage Plan Review: Project manager for detailed technical review of the analysis and design of stormwater control facilities for a proposed 1300 acre mixed use development in the City of Snoqualmie, Washington.

Small-Scale Flood Control Structure Operation and Maintenance Mission: Participated in a mission to design and develop a program for improving the operation and maintenance of small-scale flood control structures throughout Bangladesh.

Mill Creek Upper Detention Pond Operation Study: Conducted hydrologic studies to develop an optimal operating policy for a regional stormwater detention facility at the head of Mill Creek Canyon, Kent, Washington.

Sammamish River Multi-Objective Corridor Management Plan: Project manager for hydraulic modeling aspects of a study to enhance fishery and recreational use of the Sammamish River corridor, King County, Washington. Responsible for developing a water surface profile model for the river and for evaluating the effects of proposed environmental enhancements on flood levels along the river corridor.

East Side Green River Drainage Study: Project manager for hydrologic modeling aspects of a study to alleviate local flooding associated with the East Side Green River drainage system in the lower part of the Green River valley, Washington.

BWDB/CIDA/AIT Training Course: Developed and taught the hydrology component of a two-month training course for water resources engineers from the Bangladesh Water Development Board.

Issaquah Creek HSPF Model Calibration: Project manager for calibration of an HSPF hydrologic simulation model to streamflow and rainfall data from the Issaquah and Tibbetts Creek catchments in King County, Washington.

City of Lynnwood Flood Plain Mapping Study: Project manager for a flood plain mapping study on Scriber Creek in the City of Lynnwood, Washington.

City of Lynnwood Stormwater Modeling: Performed detailed hydrologic analyses of stormwater runoff in the City of Lynnwood, Washington.

Highwood River/Little Bow River PMF Study: Conducted hydrologic modeling and dambreak analyses for estimation of the probable maximum flood and the spillway design flood for a proposed dam on the Little Bow River, Alberta. The PMF is generated by a major flood on the neighboring Highwood River, which spills over a low topographic divide into the headwaters of the Little Bow River. Dambreak simulations were performed using the U.S. National Weather Service DAMBRK model.

Kent Lagoons Hydraulic Design: Project manager for the conceptual hydraulic design of a regional off-channel stormwater detention facility in Kent, Washington.

Miller Creek Regional Stormwater Detention Facility Design: Performed hydrologic modeling for the design of two regional stormwater detention facilities in the Miller Creek basin, King County, Washington.

Lilliwaup Creek Hydropower Review: Reviewed power production potential of a small hydropower facility on Lilliwaup Creek, Washington.

Scriber Creek Watershed Management Plan: Project manager for hydrologic modeling (using the EPA's HSPF continuous simulation model) for the Scriber Creek Watershed Management Plan, Snohomish County, Washington. Work included model calibration, simulation of flows for future land-use conditions, and simulation and analysis of various strategies for stormwater control in this rapidly developing suburban watershed.

Small Scale Water Control Structures: Developed hydrologic criteria to meet both engineering and agro-economic goals for the design of small scale water control structures in Bangladesh.

Surface Water Design Manual Review: Project manager for detailed technical review of proposed design manual for surface water and stormwater management facilities to be built in King County, Washington.

Tony Creek Hydrology Study: Conducted hydrologic studies for the design of a small hydropower plant on Tony Creek, Montana.

Mill Creek Regional Stormwater Detention Study: Project manager for a detailed study of a proposed regional off-channel stormwater detention facility in Kent, Washington, including collection of hydrologic data, hydrologic modeling (using EPA's HSPF model), and analysis of the system's performance.

Black and Fannegusha Creek Watersheds Hydrologic and Hydraulic Analyses: Project manager for hydrologic and hydraulic studies on Black and Fannegusha creeks, Mississippi for the design and evaluation of a system of flood water retarding structures.

Clear Creek Hydrology Study: Performed field work and hydrologic analyses for a fish farm on Clear Creek, Washington to identify and document the causes of high stream turbidity believed to have resulted from upstream urban development.

Licorice Fern Stormwater Management and Erosion Control Study: Project manager for conceptual design of stormwater management and erosion control facilities for a 170-acre residential development on steep terrain in King County, Washington.

Skagit River Flood Forecast Model: Project manager for the development of a flood forecast model for the Upper Skagit River basin, Washington.

Wabamun Lake Water Level Simulation Study: Developed monthly water balance model of Wabamun Lake, Alberta, and performed long-term simulation of lake levels to evaluate various proposed modifications to the lake outlet control structure.

Lake Washington Basin Runoff Model: Project manager for development of a daily water balance model for Lake Washington.

Leach Creek Hydrology and Geomorphology Study: Performed hydrologic studies on Leach Creek, Washington to document the effects of urban development on the stream's hydrologic regime and to identify the causes of severe stream bank and bed erosion.

Washington Basin Climatic Data Base: Project manager for the development of a data base of daily and monthly hydrologic and climatic data for Lake Washington and the surrounding area.

Similkameen River Flood Control Study: Project manager for a flood study for a proposed dam on the Similkameen River, Washington.

Dissolved Nitrogen Modeling for the Columbia and Snake Systems: Developed a system simulation/optimization model for deriving reservoir operating policies which would minimize nitrogen supersaturation levels below 13 major dams on the lower Snake and Columbia rivers while meeting power production constraints.

Veazey Quarry Master Drainage Plan: Project manager for the conceptual design of stormwater and sediment control facilities for a major rock quarry in Washington.

Nisqually River PMF Study: Project manager for the estimation of probable maximum floods at Alder and LaGrande dams on the Nisqually River, Washington.

Snowmelt Forecasting for the Skokomish, Cowlitz and Nisqually Rivers: Developed and implemented a seasonal snowmelt forecasting model for the operation of hydroelectric generation facilities on the Skokomish, Cowlitz and Nisqually rivers, Washington.

Surface Water Appraisal Study: Conducted a field appraisal of surface water supply potential for a resort development on the island of Lanai, Hawaii.

Coal Creek Basin Plan: Provided advice and assistance in the application of an HSPF hydrologic simulation model for the development of the Coal Creek Basin Plan. Responsible for designing the overall modeling approach, directing model calibration, providing training, and assisting in the design and interpretation of production runs for future land use scenarios.

Green River Low Flow Study: Managed a study to develop alternative low flow operating policies for the Hanson Dam on the Green River, Washington, to enhance downstream water quality and fisheries.

Strategies for Coping with Drought: Participated in research into the effect of drought on hydro- and thermal-electric power production. Developed techniques for evaluating the spatial characteristics of widespread drought.

Flood Forecasting for the Salt and Verde Rivers, Arizona: Developed and implemented a real-time flood forecasting model for the operation of a system of reservoirs on the Salt and Verde rivers in Arizona.

Iskut River PMF Study: Estimated the probable maximum flood for three dams on the Iskut River in northern British Columbia. Special consideration was required for runoff from heavily glacierized areas of the basin.

Hydropower Reconnaissance Studies: Performed numerous hydrologic studies related to the development of small-scale hydroelectric projects on Burlington Northern land holdings throughout the northwestern U.S.A., including estimation of flow duration and flood frequency curves for both gaged and ungaged catchments, preliminary sizing of equipment, and assessment of energy production.

Water Supply Studies for Homer, Alaska: Conducted hydrologic simulation studies to determine the water supply yield of several small streams in the vicinity of Homer, Alaska.

Sunset Falls Hydroelectric Study: Conducted flood studies and conceptual design of flood control works for a proposed hydroelectric project on the South Fork Skykomish River, Washington.

Transmigration Project Village Water Supplies: Conducted reconnaissance level hydrologic studies and yield analyses for village water supplies in Sumatra, Indonesia.

Hurricane Modeling for Probable Maximum Precipitation (PMP) Estimates, Dominican Republic: Developed a computer model of hurricane-generated rainfall for PMP estimates for spillway design studies for dams on the Rio Blanco, Dominican Republic.

Paranaiba River Hydrology and PMF Studies, Brazil: Performed extensive hydrology studies for hydroelectric development on the Paranaiba River, Brazil, including estimation of PMF at three dam sites, stochastic generation of long flow sequences and training of Brazilian personnel.

Sediment Transport Modeling: Developed mathematical models for simulating sediment transport in river systems and for predicting soil loss from agricultural lands.

SELECTED PUBLICATIONS

Karpack, L.M. and K.M. Leytham. AA Simple Short-Term Flow Forecast Model For Small Hydropower Systems.≅ Mountain Hydrology: Peaks and Valleys in Research and Application, Canadian Water Resources Association, 1995.

Peck, H.W., K.W. Eriksen, M.L. Pearson, and K.M. Leytham. APost Eruption Hydrology and Hydraulics of Mount Pinatubo, The Philippines.≅ Tech. Rep. 9L-94-16, Waterways Experiment Station, U.S. Army Corps of Engineers. May 1994.

Leytham, K.M. "A Joint Rank Test for Assessing Multivariate Normality in Hydrologic Data", Water Resources Research, 23 (12):2311-2317, 1987.

Leytham, K.M., D.P. Lettenmaier and E.G. Altouney. "Widespread Drought and the Hydroelectric Industry", Hydro Review, VI(V):26-31, 1987.

Tangborn, W.V., J.L. Keane and K.M. Leytham. "Application of Streamflow Forecasts to Operating a Multi-Reservoir System in Central Arizona", in A Critical Assessment of Forecasting in Western Water Resources Management, Technical Publication TPS-84-1, American Water Resources Association, 1984.

Leytham, K.M. "Maximum Likelihood Estimates for the Parameters of Mixture Distributions", Water Resources Research, 20(7):896-902, 1984.

Leytham, K.M. "Scale Problems in the Synthesis of Multi-Site Precipitation" in Proceedings of the International Symposium on Hydrometeorology, Denver, CO., June 1982, American Water Resources Association, 1983.

Tangborn, W.V. and K.M. Leytham. "Snowmelt Forecasting for Peak Flow Rates and Runoff Volumes in Mountainous Areas", WMO Technical Conference on Mitigation of Natural Hazards Through Real Time Data Collection and Hydrological Forecasting, Sacramento, CA., 1983.

Leytham, K.M. "Physical Considerations in the Analysis and Synthesis of Hydrologic Sequences" Tech. Rep. No. 76, Charles W. Harris Hydraulics Lab., Dept. of Civil Engineering, University of Washington, Seattle, WA., June 1982.

Leytham, K.M. and D.D. Franz. "Techniques for the Generation of Long Streamflow Sequences" in "Improved Hydrologic Forecasting: Why and How" Proceedings of the Engineering Foundation Conference, Asilomar, CA., May 1979, ASCE, New York, 1980.

Leytham, K.M. and R.C. Johanson. "Watershed Erosion and Sediment Transport Model" Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA, March 1979.

Johanson, R.C. and K.M. Leytham. "Modeling Sediment Transport in Natural Channels" in Watershed Research in Eastern North America: A Workshop to Compare Results, D. Correll, Ed. Chesapeake Bay Center for Environmental Studies, Smithsonian Institute, 1977.

Fleming, G. and K.M. Leytham. "Real-Time Forecasting for Southern California" Symposium on Weather Radar and Water Management, Water Research Centre, Berkshire, England, December 1975.

Leytham, K.M. "A Search Technique for Formulating Improved Water Resource Configurations" in Systematic Approach to Water Resource Plan Formulation, J.C. Schaake Jr., Ed. Tech. Rep. No. 187, Ralph Parsons Laboratory for Water Resources and Hydrodynamics, MIT, July 1974.

PROFESSIONAL AFFILIATIONS

Registered Professional Engineer in the States of Washington and Oregon
Registered Professional Engineer in the Province of Manitoba
Registered Professional Hydrologist, American Institute of Hydrology
American Geophysical Union
American Society of Civil Engineers

EXHIBIT C

Port of Seattle

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JUL 23 2001

DEPT OF ECOLOGY

July 23, 2001

Ann E. Kenny
Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, WA 98008-5452

Dear Ms. Kenny:

SUBJECT: Low Streamflow Analysis, Summer Low Flow Impact Offset Facility Proposal, Seattle–Tacoma International Airport

This letter summarizes the Port of Seattle's evaluation of summer low streamflow impacts in Des Moines, Miller, and Walker Creeks calculated to result from proposed airport Master Plan Update projects. This letter also summarizes the Port's proposal to offset these impacts to maintain existing summer low streamflow conditions in these creeks post project. The methodology used to determine the effects and the plan to offset the impacts was developed and discussed in a series of meetings between the Port of Seattle (Port), Department of Ecology (Ecology), and King County, with staff from Floyd Snider McCarthy, Inc., acting as facilitators.

The evaluation and low streamflow impact offset proposal is final, subject to potential conditions associated with your review during 401 permit deliberations. The Port plans to submit final documentation of the low streamflow evaluation and operational plan for mitigation facilities in the form of a detailed Low Streamflow Analysis Report and Summer Low Flow Impact Offset Facility Operational Plan, outlines of which are included as an attachment to this letter.

Summary

The Port's proposal is to detain stormwater in underground vaults and release the detained water continuously into each creek during the summer low streamflow period at a rate equal to the calculated summer low streamflow impact to that creek from planned Port projects. The summer low streamflow impacts in each creek were determined through detailed modeling analysis. The summer low streamflow periods were determined through statistical analyses of modeled streamflow from the calibrated HSPF models and discussions with biologists on the effects of low streamflow periods on stream biology. Details of the analysis used to arrive at the proposed summer low streamflow offset periods, low streamflow magnitudes, impacts to summer low streamflows from Port projects, and sizing of the vaults are included as attachments to this letter A summary of the calculated summer low streamflow impacts and flow impact-offset proposal is listed below:

Seattle-Tacoma International Airport
P.O. Box 68727
Seattle, WA 98168 U.S.A.
TELEX 703433
FAX (206) 431-5912

	Des Moines Creek	Miller Creek	Walker Creek
Summer low flow period	July 24-October 24	August 1-October 31	August 1-October 31
2-year 7-day low flow (1994)	0.35 cfs	0.74 cfs	0.79 cfs
Port impact on streamflow[1]	0.10 cfs	0.13 cfs	0.09 cfs
Vault size needed	12.2 acre-feet	18.8 acre-feet	15.0 acre-feet
Maximum vault fill time	32 days[2]	58[3] days	282 days[3]

1 Difference between 1994 and 2006 2-year, 7-day low flow, including non-hydrologic impacts.
2 Vault filling starts January 1.
3 Vault starts filling November 30.

Vaults to detain stormwater for release during summer low streamflow periods were sized based on the duration within which summer low streamflows have historically occurred (generally +/- 90 days from late July through late October), the modeled impact to streamflow in each creek, and an allowance for precipitation events during the summer low streamflow periods that will partially refill the vaults. The resulting storage volumes (12.2 acre-feet in Des Moines Creek, 18.8 acre-feet in Miller Creek, 15.0 acre-feet in Walker Creek) will provide enough water every year to offset the impacts to streamflow throughout the historic summer low streamflow period. For two years within the period of record (1977 and 1979), the Walker Creek vault does not fill up entirely by the start of the summer low streamflow period. However, in these two years, rainfall that occurs during the summer low streamflow period provides enough water so that offset flows are provided throughout the entire summer low streamflow period. The vaults will include features (both structural and operational) for managing water quality to ensure there are no adverse impacts from discharges from the flow impact offset facility. Additional details on all these issues are presented in this letter.

Determination of the Duration of Summer Low Streamflow Periods

Determination of the summer low streamflow period for each creek was done by analyzing modeled streamflow from the calibrated HSPF model for each creek, which used 1994 (existing) land use conditions. The HSPF models for each watershed were calibrated by comparing model output with streamgauge data and adjusting model parameters until a satisfactory match was obtained. Additional low streamflow calibration information is provided in the attachments. Assumptions of model parameters (land use, basin delineations, impervious areas, etc.) are the same as detailed in the Comprehensive Stormwater Management Plan. The seven-day low flow period for each year (using 1994 flow conditions) in the 47-year period (1949-1995) for each creek was determined at points of compliance near the airport (200th Street in Des Moines Creek, SR 509 in Miller Creek, and at the outlet of the wetland near Des Moines Memorial Drive in Walker Creek). The seven-day low flow was selected as an indicator of persistent dry season flow. For example, a longer low streamflow would have the same or higher flow, since flows tend to have a downward trend (flows become gradually lower) before a storm increases flow. In addition, summer low streamflows tend to decrease gradually, therefore, a shorter low streamflow period is unlikely to result in significantly lower average flows or target flows. Finally, consultation with biologists concludes that summer low flows with durations of less than two weeks do not affect the carrying capacity of the creeks or cause behavioral changes to salmonids (see attachment).

The occurrences of the annual seven-day low flow periods were plotted and a histogram showing the distribution of the summer low flow periods was developed for each creek. The summer low streamflow period for each creek was selected to include all the historical seven-day low flow occurrences, with the exception of three specific occurrences during the forty-seven year record that occurred during November and December – periods typically associated with two of the three wettest months of the rainy season. The summer low streamflow periods for each creek are:

Des Moines Creek	July 24 through October 24
Miller Creek	August 1 through October 31
Walker Creek	August 1 through October 31

The Port's proposal is to provide water to offset the impacts to summer low streamflows throughout these time periods in each creek.

Determination of Streamflow Magnitudes (Target Streamflows)

The magnitude of existing summer low streamflow (target streamflow) in each creek was determined through analysis of the seven-day low flow periods under existing (1994) conditions described above. The annual seven-day low flows for each creek were ranked and recurrence intervals were determined based on this ranking. The seven-day low flow with a two-year (50 percent) recurrence interval was selected as the streamflow target in each creek. The two-year seven-day low flow was selected because the magnitude of the estimated impact to seven-day low flows decreases with greater recurrence interval; i.e., the estimated reduction in the seven-day two-year frequency low flow rate is greater than that for the seven-day, ten-year frequency low flow rate. Therefore, providing mitigation equivalent to the seven-day, two-year frequency impact will provide mitigation sufficient to mitigate all of the more extreme summer low streamflow events. **Based on this analysis, the existing summer low streamflows (two-year, seven-day pre-project conditions) are determined to be:**

Des Moines Creek	0.35 cfs
Miller Creek	0.74 cfs
Walker Creek	0.79 cfs

Determination of Impacts to Streamflow

The effects to flow during the summer low streamflow periods were determined by comparing modeled streamflows before project construction to modeled streamflows after project construction. Each creek has different post-development conditions that potentially affect low streamflow; therefore each has a different approach for determining impacts. In Des Moines Creek, 2006 land use conditions ("post-project") were modeled for the full 1949-1995 period of record. The seven-day low flow for each year was selected, ranked, and the streamflow with a two-year recurrence interval was determined. In Des Moines Creek, the two-year post project summer low streamflow is 0.25 cfs. The impact to streamflow from proposed Port projects is the difference between this flow and the existing pre-project summer low streamflow described above, as determined from the modeled 1994 ("existing") land use conditions (0.35 cfs). Therefore, the impact to summer low streamflows in Des Moines Creek from proposed Port projects is the difference between the post project and existing condition flows, or 0.10 cfs. The flow rate is the magnitude of offset that will be provided during the summer low streamflow period for Des Moines Creek described above (July 24 through October 24).

In Miller Creek, a different approach was applied because of the need to model the effect of the proposed runway embankment on streamflows. In areas where the embankment is proposed, recharge entering the embankment was calculated using the post-project HSPF model. The recharge was then input to the Hydrus-2D model, which simulated the spreading of recharge fronts through the unsaturated zone of the embankment fill. Output from the Hydrus-2D model were input to the "slice" model, which is a finite-difference groundwater model used to simulate flow through the proposed embankment underdrain layer. Output from the "slice" model was then input back into the HSPF model to determine the quantity and timing of discharge from the embankment, and the groundwater effects on Miller Creek. This approach was selected to accurately simulate the flow of groundwater through the proposed embankment. The analysis was a more discrete application of the Hydrus-2D and "slice" modeling approaches used in the Runway Fill Hydrologic Studies Report (Pacific Groundwater Group, June 19, 2000), prepared for Ecology.

For the post-project conditions in Miller Creek, the four-year period from 1991 through 1994 was modeled. This period was chosen as a representative dry period in the precipitation record. Output from the HSPF model was analyzed to determine the annual seven-day low streamflows for each of the four years. To determine the impact between 1994 (existing) low streamflow and 2006 (post-project) flows, the impact during 1991 was used. This year was selected because it was the only year in the four years of detailed embankment flow analysis that low streamflows were greater than the two-year flow. In Miller Creek, the estimated summer low streamflow impact due to the project is 0.11 cfs.

In addition to hydrologic impacts in Miller Creek, additional impacts, both positive and negative, will result from removal of septic tank flows (negative impact) and cessation of water uses for residential and agricultural uses (positive impact). The impact of these "non-hydrologic" changes in Miller Creek is an additional net -0.02 cfs (-0.08 cfs for septic tanks which is then adjusted by 0.7 for loss to DEEPFR; water use withdrawals are +0.04 cfs). The total Miller Creek impact (both hydrologic and non-hydrologic) is 0.13 cfs.

For the post-project conditions in Walker Creek, the entire record from 1949 through 1995 was used. To determine hydrologic impacts, it was assumed in the post-project (2006) model that new impervious areas and new fill area is simply removed from the model and can no longer contribute to low streamflow. This is a conservative assumption, since some precipitation will undoubtedly contribute to groundwater flow. This approach was chosen to allow for the largest impervious area possible to refill the Walker Creek low streamflow vault. The Port proposes to line the filter strips with impermeable material to collect infiltrated stormwater that will be directed to the low streamflow vault. The lined area (approximately six acres) does not exceed the effective impervious area used in the Comprehensive Stormwater Management Plan.

In Walker Creek, much of the groundwater that supports summer low streamflows comes from areas where surface water drains to Des Moines Creek or Miller Creek. Under existing (1994) conditions, approximately 630 acres of pervious land is included in the Walker Creek groundwater basin, which contributes to Walker Creek summer streamflows. Thirty-eight acres of new impervious area is proposed in the approximate area of the 630 acres pervious acre area. The thirty-eight acre area is adjusted (multiplied) by 0.86 to reduce the area to effective impervious area. The result (32.7 acres) is deducted from the 630-acre pervious area in the existing conditions model to determine the post project (2006) contribution to the Walker Creek groundwater basin.

To determine the magnitude of the hydrologic impact in Walker Creek, the seven-day low flow for each year was selected, ranked, and the streamflow with a two-year recurrence interval was determined for existing (1994) and post-project (2006) conditions. The two-year 1994 seven-day low streamflow is 0.79 cfs; the 2006 summer low streamflow is 0.71 cfs. Therefore, the impact to summer low streamflow in Walker creek from proposed Port projects is the difference between the post-project and existing conditions flow, or 0.08 cfs.

In addition to hydrologic impacts in Walker creek, additional impacts will result from the removal of septic tanks. The impact of this change in Walker Creek is an additional 0.01 cfs (0.014 cfs for septic tanks which is then adjusted by 0.7 for loss to DEEPFR). The total Walker Creek impact (both hydrologic and non-hydrologic) is 0.09cfs.

Based on the analyses described above, total net summer low streamflow impacts that the Port proposes to offset throughout the summer low streamflow periods in each creek are:

Des Moines Creek	0.10 cfs
Miller Creek	0.13 cfs
Walker Creek	0.09 cfs

Sizing/Filling of Vaults and Vault Release

Several of the stormwater vaults proposed in the Comprehensive Stormwater Management Plan will have storage areas sized and designed to detain the volume of water needed to continuously release a flow equivalent to the calculated summer low streamflow impacts throughout the summer low streamflow duration in each creek. The vault sizes were calculated in the following manner: the offset flow rate was multiplied by the duration of the summer low streamflow period. Analysis of precipitation records show that some amount of rainfall always occurs during the summer low streamflow period. Rainfall amounts during the summer low streamflow period from the worst (driest) year on record were converted into a volume based on the amount of impervious area that drains to each vault. This water was subtracted from the total volume to arrive at the final volume. These calculations were done on a daily basis to account for the dynamics of filling and draining the vaults throughout the summer low streamflow period in each creek. This conservative approach assures that the volume of water needed to offset the impacts to summer low streamflow will be available in a range of extreme conditions such as those found in the 47-year period of record. The net storage volumes of water needed for each creek are:

Des Moines Creek	12.2 acre-feet
Miller Creek	18.8 acre-feet
Walker Creek	15.0 acre-feet

The vaults will be filled each year during the winter, by closing the flow offset discharge outlet no later than January 1 each year, allowing stormwater to accumulate in the vaults. Analysis of historical rainfall records and the amount of impervious area that drains to each vault were used to determine the length of time required to fill the vaults. This length of time was applied to the beginning of the summer low streamflow period in each creek (the date the flow impact offset would start each year) to determine when to begin accumulating water. Based on this analysis, the maximum time needed to fill the vaults during the period of record are:

Creek	Closure Date	Longest Fill Time in Record
Des Moines Creek	January 1	32 days
Miller Creek	January 1	58 days
Walker Creek	December 1	282 days

The impervious area in each basin used to fill the vaults is as follows:

Des Moines Creek	234 acres impervious area
Miller Creek	82 acres impervious area
Walker Creek	3.5 acres impervious area
	6 acres lined pervious area
	2 acres Pond F cover

It is important to note that using the period of record (except for the worst (driest) year on record), the vaults will always have water remaining in them at the end of the summer low streamflow period. The Port proposes to continue releasing this water at the determined flow rate for as long as possible before the vault outlets are actually closed (after the end of the summer low streamflow periods). The operational plan will call for the vaults' outlets to be **closed no later than January 1 each year to allow the filling of the vaults to take place when precipitation is generally most abundant.**

Water Quality Considerations

The Summer Low Streamflow Impact Offset Facilities will be designed and operated to avoid in-stream water quality violations. Class AA water quality standards are used as the applicable in-stream standards. Water quality parameters of concern include dissolved oxygen, temperature, turbidity, copper, lead, and zinc. A variety of best management practices (BMPs), facility designs, and monitoring programs are proposed (or already in place) to ensure that in-stream water quality violations will not result from operation of the flow offset facility.

Structural features of the vaults include sediment traps, settling areas, and special placement of inflow and outflow pipes to reduce turbidity, vents to allow air circulation to enhance aeration, placement of inlets to facilitate periodic flushing with "fresh" stormwater, and discharge pipes configured to enhance passive aeration. The underground configuration of the vaults will facilitate temperature management. Provisions are included to allow for additional filtration and aeration of discharges, as needed. BMPs in place in the drainage areas on the airfield will minimize the amount of sediment that will enter the vaults. An extensive water quality monitoring program is proposed to characterize the water discharged from the offset facility, and to ensure that the facilities can be managed and operated without causing in-stream water quality violations.

Operational Plan
A detailed operation, maintenance, and monitoring plan will be completed for the summer low streamflow impact offset facilities. The operational plan proposes an annual schedule of activities to ensure that the facilities are meeting performance goals. An adaptive management system is proposed to allow the operation of the facilities to be refined as experience is gained. The vaults will be monitored as they are filled and as water is released. Periodic monitoring of water quality will be completed, both of the discharge water and in the creeks, to ensure that water quality criteria are not violated in the creeks. Biological monitoring is proposed as part of the Natural Resources Mitigation Plan. This monitoring will evaluate changes in the Benthic Index of Biotic Integrity (BIBI) over a ten-year period.

Information provided for review attached to this letter include:

- Outline of Summer Low Streamflow Flow Analysis and Summer Low Streamflow Impact Offset Facility Operations Plan
- Selected Draft sections of Summer Low Streamflow Impact Offset Facility Operations Plan
- Technical backup material for low flow impact evaluation and impact offset proposal including the following
    - Des Moines Creek
    - Miller Creek
    - Walker Creek
    - Stream Biology Information
    - Embankment Modeling Information
    - Non-Hydrologic Analysis
        - Methodology
        - Data (electronic only)
    - Daily Average Creek Flows (electronic only)

In addition, selected model data files have been electronically sent to Kelly Whiting for his review.

Please contact me at 206/988-5528 if you have any questions.

Sincerely,

Keith R. Smith
Water Resources Manager

C: Kelly Whiting, KCDNR

AR 008175

Draft Low Flow Analysis/Flow Effect Offset Facility Report

- **Executive Summary**
  - Report summarizes effects to streamflow in Miller, Walker, and Des Moines Creeks caused by proposed Port projects and associated "non-hydrologic" effects (buyouts, displaced water use/irrigation/septics/etc.) and provides a flow offset facility/plan
  - Impacts of embankment seepage were modeled using a combination of tools (HSPF, Hydrus, Slice) for an agreed upon dry period (1991-1994)
  - Non-hydrologic effects were combined with modeled effect to determine net effects to streamflow
  - Result was the effect on streamflow from the project (CFS)
  - That impact was used to calculate the amount of stormwater needed to be detained for release during summer low flow periods
  - This calculation was based on release rates, refilling (precip), and vaults not going dry
  - Seven vaults will provide reserved storage and release at appropriate rates to offset impacts
  - Vaults will include design considerations for water quality treatment
  - Operational plan will include test releases and monitoring to ensure water quality meets standards
  - Regular maintenance will be performed to ensure proper function
  - Performance standards will be (have been) developed
    - Water always available to discharge at needed Q throughout summer low streamflow period
    - In-stream WQ standards met throughout operation
  - Refinements can be made based on observed performance

- **Introduction**
  - Purpose of Report
  - Organization of Report
  - Relationship to other documents (SMP)
  - Project description
    - Master Plan Third Runway Embankment
    - Impacts to Streamflow
    - Low Flow Analysis
    - Mitigation Plan
    - Objectives of flow offset plan

- **Determination of impacts to streamflow**
  - Brief description of overall approach
    - Compare modeling of existing conditions to modeling of post project conditions to determine effect to streamflow
    - Existing condition determined by HSPF modeling in SMP
    - Post project condition (embankment) determined by slice, hydrus, and HSPF modeling to determine flow and timing impacts of embankment

- Post project condition modeling uses 1991-1994 precipitation (dry period)
- Non-hydrologic effects conservatively estimated, converted into daily time series, and input to model of built condition
- Result of post project condition modeling gives (total) impact to streamflow of Port's projects
- This results is applied to a spreadsheet analysis and used to size storage to provide offset water throughout summer

- o Modeling of Existing (Pre-embankment) Conditions - HSPF approach – pull language from SMP and frame for low flow
- o Modeling of Proposed (Built embankment) Conditions
    - Summary of HSPF/Hydrus/Slice Modeling Approach
    - Results of Embankment Modeling

- o Non-hydrologic effects on flows
    - Changes/revisions based on SMP
    - Conversion to time series for inclusion in HSPF modeling

- o Results of all impacts to streamflow/net effect to streamflow

- **Mitigation of Impacts (Reserved Stormwater Release)**
    - o Methodology used to size/design stormwater vaults
        - Criteria
        - Spreadsheet analysis based on discharge rates and periodic refilling from rainfall
        - Refilling based on rainfall in driest year in period of record (1949-1995)
    - o Performance standards
        - **Always able to meet flow offset requirements (vaults never go dry during** summer low streamflow periods)
        - Instream water quality standards met
    - o Water Quality Design Aspects
        - ▪ Sediments/Turbidity
            - Discussion of water quality standards for turbidity
            - Airfield BMPs minimize sediments/turbidity getting into vaults (typical)
            - Compartmentalized dead storage (typical)
            - Floor sloped away from outlet (typical)
            - Allow for installation/operation of filters if test releases show turbidity of reserved releases won't meet standards (reserved outlets only)
        - ▪ Temperature
            - Discussion of water quality standards for temperature
            - No special design considerations for temperature

- Nature of underground vaults ensures that water will be relatively cool compared to typical summer stream temperatures
- Port collecting temperature data from existing vaults starting summer 2001 to provide baseline data
- Dissolved Oxygen
  - Discussion of water quality standards for DO
  - No oxygen consumption in vaults (low BOD, no solar radiation driving biological activity that would consume oxygen)
  - Inlet to vaults positioned to allow flushing of reserved area to prevent accumulation of stagnant (potential low DO) water
  - Passive aeration provided by turbulent flow in steep discharge pipes and energy dissipaters at/near outlets
  - Air vents provided to allow supply of fresh air for passive aeration
  - Provide for (portable) aerators if DO still too low or if slopes not sufficient to aerate water
    - List possible/applicable technologies (microbubble diffusers, gas injection, air injection, aeration hose)
    - Discuss each reserved stormwater outlet
    - Selection will be made as part of final design
- Nutrients
  - No water quality standards to meet, but possibility of algae blooms in summer has been raised as a concern
  - Usually a concern in lakes and ponds, none in creeks downstream of airport, residence time of water in creek only a few hours
  - No special design considerations proposed for nutrients
  - No fertilizers used on airfield
  - Bioswales provide treatment
  - No solar radiation in vaults to stimulate algae growth
- Metals
  - Discussion of water quality standards for metals
  - Airport water quality data show that (total recoverable) metals in airfield runoff lower than typical urban stormwater
  - Higher metals in airport runoff associated with non-airfield basins, which won't be providing water to reserved stormwater vaults
  - Most metals associated with particulates, data shows low dissolved metals in discharges
  - Vault design and BMPs for turbidity will be effective in reducing total metals (list again)

- Other
  - Reserved stormwater discharge points will be the same as normal stormwater discharge points – no additional HPAs needed

- Discussion of valve/outlet location for each proposed reserved stormwater vault relative to creeks
- Security – facilities and controls located inside airport fence to minimize vandalism potential
- Performance – POS will continue to operate/inspect/monitor/report/maintain system throughout its life; adjustments/refinements can be made based on observed performance

- **Operational Plan/Annual schedule of activities**
  - Before initial operation port will submit to Ecology a operations/maintenance/monitoring plan containing:
    - Monitoring/sampling protocols (follow NPDES permit requirements) and schedule
    - Specific monitoring locations (discharge and in-stream)
    - Recording/reporting plan
    - Detailed operation plan based on proposal below
    - Inspection/maintenance plan
    - Summary of characterization of discharge and creeks' water quality during summer seasons, based on existing data or data collected prior to implementing facilities
  - Calendar Year Operating Schedule
    - Jan – June (varies by vault)– operate as normal stormwater vaults, flow offset outlet closed to accumulate water
    - June/July – small test release from each vault
      - Confirm discharge rate (gage/measure flow)
      - Sample specified in monitoring plan
      - Compare samples to existing or collected data from creeks from summer (when reserved stormwater discharges would be occurring)
      - Review existing data to see if summer low flow water quality is adequately characterized by data. If not, collect during next few summers (prior to facilities going on-line) to characterize. This work will be included/discussed in final monitoring plan submitted to Ecology prior to implementation.
      - If potential water quality violations are indicated, take appropriate actions prior to initiating operational discharge, such as:
        - Install/maintain filters for sediments/turbidity/metals
        - Install portable aerators for DO
        - No actions proposed for temperature and nutrients
    - July/August - Open each flow offset outlet on date specified in analysis
    - July – October – inspect/monitor operation of each discharge
      - Sample per monitoring plan
      - Any water quality violations will be immediately investigated and corrected

- If data show water quality standards are consistently being met after (at least) one year of operation, Port may submit/modify monitoring plan.
    - November – December – Drain, inspect, maintain, operate as normal stormwater vault
    - December/January – close flow offset outlet to begin accumulating water

  - Monitoring Plan
    - Characterization of expected water quality
    - Monitoring of Test Discharges
    - Operational Monitoring
    - NRMP BIBI monitoring
    - Reporting
    - Monitoring/Analysis Protocols

  - Maintenance Plan
    - Refer to Port's stormwater maintenance plans for typical vault maintenance
    - Each reserved stormwater vault will have an operational manual/maintenance plan and schedule developed for it as part of final design which will be submitted to Ecology prior to implementation
    - Typical maintenance includes periodic inspection of vaults, discharge structures, valves, discharge points, etc.
    - At least annual removal of sediments, etc.

- **Summary**
  - Effects to streamflows calculated based on modeling and spreadsheet analysis, **both based on selected period (1991-1994) representing dry period**
  - Design, operation, and monitoring plan will ensure that system operates as designed and water quality standards are met
  - Airport/POS staff will be managing facility in perpetuity.
  - Adjustments/refinements to system can be made based on observed performance

- Appendices
  - Non-Hydrologic Impacts
  - Modeling
    - Existing Conditions (HSPF)
    - Built Conditions (Slice/Hydrus/HSPF)
  - Design Considerations
    - Aerators
    - Filters (media?)
  - Sample O&M Plan
- Other Appendices?

Executive Summary

This report presents the analyses performed to estimate the timing and volume of discharges to local receiving streams and wetlands during low flow periods from Seattle-Tacoma International Airport (STIA) considering improvements defined in the Port of Seattle's Master Plan Update. This report also presents a Flow Impact Offset Facility Plan, which is the Port's proposal to offset impacts to flows in the receiving waters during annual low streamflow periods, typically experienced in late summer/early fall. The plan is based on a detailed evaluation of the hydrologic impacts of the proposed third runway embankment and associated non-hydrologic impacts on streamflow in Miller, Walker, and Des Moines Creeks. This report, an update of the Low Flow Analysis prepared by Earth Tech in December 2000, is submitted for consideration by the Washington State Department of Ecology in reviewing permit applications related to the proposed Third Runway project. This report builds upon previous reports by Earth Tech and Pacific Groundwater Group. Analyses presented in this report were prepared by Earth Tech, Pacific Groundwater Group, AquaTerra, and Parametrix. The Washington Department of Ecology was consulted throughout the development of the plan to ensure that agency concerns are addressed in this report.

Impacts to streamflow in the three creeks were evaluated using a suite of modeling tools. The Hydrologic Simulation Program – FORTRAN (HSPF) was used to develop overall stormwater models of STIA (existing conditions and proposed conditions), as described in the Comprehensive Stormwater Management Plan (CSMP) (Parametrix 2000). These models were also used to evaluate stormwater flows and volumes in the low flow analysis. The hydrologic properties of the proposed third runway embankment were modeled using a combination of

Hydrus-2D and a finite-difference "slice" model. Hydrus-2D was used to simulate the movement of water between the root zone and water table in the proposed embankment, and the slice model was used to simulate the movement of water through the saturated portion of the proposed embankment. Results of the Hydrus and Slice modeling, along with the associated non-hydrologic impacts, were incorporated back into the HSPF model to estimate the post construction flows. By comparing these model results to the pre-project conditions model, the impacts of the proposed embankment on streamflows were determined. Statistical analyses of model output, precipitation and streamflow data for the available period of record predicted a net low-flow impact to Miller Creek of 0.19 cubic feet per second (cfs) 0.08 cfs in Walker Creek, and 0.10 cfs in Des Moines Creek..

The Port's proposal to offset effects to low streamflow is to detain stormwater runoff and release it to the impacted creeks during the predicted annual low streamflow period. The volume of water required to offset the predicted impacts was determined by multiplying the predicted **impact for each creek by the duration of the summer low streamflow period (+/- 90 days from** late July through late October). The resulting volumes of stormwater (__ acre-feet for Miller Creek, __ acre-feet for __ Creek) were incorporated into selected proposed stormwater vaults in each watershed. Several considerations are proposed to be included in the design of these vaults to allow the management of stormwater discharges to offset the predicted low-flow impacts. Additional considerations in the design and operation of the proposed stormwater vaults to improve the water quality of discharges will also be included. In addition, an analysis of the availability of stormwater required to fill the vaults showed that even during the driest years in the period of record, enough water can be collected and stored to offset the impacts to streamflow during the annual low streamflow period.

Key goals and objectives (performance standards) of the proposed Flow Impact Offset Facility include:

- Always being able to provide flow at the rate required to offset the predicted impacts of the proposed embankment for the entire 92-day annual low streamflow period each year.
- Operate the facility to prevent in-stream water quality violations during the annual low streamflow periods.
- To design the facility and its operation, monitoring, and maintenance plan so that an adaptive management strategy can be applied.

As stated in Ecology's draft Stormwater Management Manual for Western Washington, the objective of stormwater management is to "control the quantity and quality of stormwater produced by new development and redevelopment such that they comply with water quality standards and protect beneficial uses of the receiving water." The Department of Ecology has determined that stormwater management activities in Washington state do not require a water right. Since the Port's proposal to offset flow impacts to the receiving waters consists of stormwater management activities, a water right is not required for the flow Impact Offset Facility.

Introduction

The purpose of this report is to evaluate the impacts to streamflows in Miller, Walker, and Des Moines Creeks resulting from construction projects included in the Master Plan Update for Seattle-Tacoma International Airport, and to propose a Flow Impact Offset Facility to mitigate the impacts during low streamflow periods. The principal projected expected to impact streamflows in the creeks is the third runway embankment.

Section not complete

Water Quality Design Aspects

The Washington State Department of Ecology (Ecology) has defined standards for water quality related to stormwater release, including periods of low flow. Ecology has jurisdiction to monitor and enforce these standards through their National Pollution Discharge Elimination System (NPDES) Permit. These standards include turbidity, dissolved oxygen, temperature, and dissolved metals. The Port's current stormwater design plans for the third runway expansion include a stormwater system and operational procedures to provide the storage and managed release of stormwater during low flow periods. These stormwater storage facilities employ biofiltration strips, catchbasins, detention ponds and vaults to meet current King County water quality requirements. In addition, the facilities are designed to be retrofit according to the Ecology water quality measures if specific water quality concerns are identified during post construction monitoring. The Port's monitoring and reporting program (see Section XX) is proposed to assess the performance of the facilities, allowing adaptive management to be used in the implementation of additional water quality measures to ensure that standards will continue to be met.

Des Moines, Miller, and Walker Creeks are all assumed to be Class AA (extraordinary) waters (WAC 173-201A-030). As such, the water quality standards discussed in this report are those listed for Class AA water bodies, which are the most stringent standards. Water quality standards for metals are based on toxicity, are independent of the receiving water classification, and are listed in WAC 173-201A-040 (Toxic substances). Although Ecology's proposed revisions to water quality standards from a class-based system to a use-based system is not expected to impact the design and operation of the proposed facility, the Port will further evaluate the proposed changes as part of the final design process and make any needed changes to the facility.

The state water quality standards applicable to the managed release of stormwater to offset flow impacts are discussed below. Specific design features, assumptions and other information considered in the design of the facility are included. Operational and monitoring proposals are presented in section xxxx. References to stormwater vaults refer only to those vaults proposed to detain stormwater to offset impacts to streamflows. Likewise, references to stormwater and stormwater discharges refer only to the managed release of stormwater to offset flow impacts.

<u>Turbidity</u>

The state water quality standard for turbidity in class AA waters is a two tier standard. For receiving water with turbidity less than or equal to 50 NTU (background flow), discharged water may not increase the receiving waters more than 5 NTU over background. For receiving water **with turbidity greater than 50 NTU, discharged water may not increase turbidity of the receiving** waters more than 10 percent. Turbidity levels in the creeks vary between less than 5 NTU to over 1,000 NTU. The lowest turbidity levels in the creeks generally occur during low streamflow (baseflow) conditions, which correspond to the majority of periods when the stormwater would be released to the creeks to offset flow impacts. It is assumed that the releases of stormwater to offset flow impacts would have to meet the 5 NTU standard most, if not all of the time. To minimize the need to provide constant background level monitoring of the creek above and below the release locations, releases can be limited to 5 NTU or less in order to be in compliance at all times.

There are several operational considerations and water quality Best Management Practices (BMPs) on the airfield to reduce the sediment and turbidity levels in runoff water going into stormwater storage. The Port uses catchbasins, the Industrial Wastewater System (IWS) system, and biofiltration strips as BMPs on the existing airfield, and the SMP proposes to retrofit the existing airfield with additional sediment trap BMPs in the bottom of each new detention vault facility. The new airfield surface will incorporate similar BMP's to minimize the amount of sediment and suspended solids that get into the stormwater vaults. The primary BMP consists of the construction of biofiltration strips in the new and existing airfield areas that treat stormwater as it drains directly from impervious areas of runways and taxiways. The Port will also maintain catch basins to ensure they continue to trap sediments. Filter strips are already in place in the existing Taxiway "C" airfield area that drains to the stormwater vault (SDS3) located in the Des Moines Creek watershed (see Section 7 in the Comprehensive Stormwater Management Plan). In addition, the airfield is a controlled area subject to very low levels of travel by ground vehicles and frequent cleaning and inspection for debris that could be harmful to aircraft. Consequently, the airfield is generally much cleaner than most urban areas that generate stormwater runoff.

There are also operational procedures outlined in the airport's Stormwater Pollution Prevention Plan (SWPPP) that will minimize opportunities for sediment and suspended solids to enter the stormwater vaults. These include:

- Sweeping ramp areas several times per week.

- Annual inspection of catch basins and cleaning if the depth of sediment equals or exceeds one-third the depth from bottom of the basin to the invert of the lowest pipe.

- Proper storage and disposal of sediment removed from catch basins.

- Hydroblasting of runway skid-mark rubber. Water and removed rubber is vacuumed by the same machine, drained, and deposited at the decant station until disposed as solid waste.

All of these BMPs will limit the amount of sediments and suspended solids that enter the stormwater vaults, and therefore will reduce the turbidity of the water stored in the vaults and discharged to the creeks.

All of the proposed stormwater vaults, including those associated with the Flow Impact Offset Facility, employ features designed to provide treatment (settling and removal) of suspended solids and turbidity. These features include:

- Dividing the dead storage area (similar to the areas in the vaults where the stormwater detained to offset flow impacts will be held) into several compartments by constructing short walls within the dead storage area of each vault. The compartments allow areas for suspended solids to settle out and be contained. Each compartment's outlet will be configured so that the suspended solids are captured in the compartments during low flow release periods. Design considerations of this type are typically included in stormwater vaults. Details will be provided at final design of the stormwater vaults.

- The vaults will include an extra 6-inch depth for the first third of the bottom (minimum) to facilitate trapping sediment that reaches the vault.

- Maintenance of the vaults will remove and properly dispose of collected sediments prior to the anticipated low flow release periods.

- The vaults will be designed to allow installation of additional water quality measures, if needed. Additional water quality features may include filtration of the discharges.

The design of the stormwater vaults, in combination with the operational and monitoring considerations discussed below, will assure that release of stormwater will not cause violations in the turbidity standards. The Port is currently investigating filtration of stormwater associated with discharges from a landside drainage basin. This research includes determining the effectiveness of several filtration media in treating the stormwater. The results of this study will be completed before final design of the flow offset facilities, and the data will be used to select the filtration method most appropriate to treat the stormwater discharge, if needed.

Operational and monitoring considerations for the Flow Impact Offset Facility for turbidity are discussed in Section xxxx.

Temperature

The state water quality standard for temperature in class AA waters is not to raise the temperature of the receiving water to over 16 degrees Celsius. If the baseline temperature of the receiving water is greater or equal to 16°C discharges cannot raise the temperature more than 0.3 ° C. To date, Ecology has not applied these requirements to stormwater discharges, although they have required temperature monitoring of certain stormwater discharges. Ecology could apply the temperature standard to future stormwater discharges.

The highest annual temperatures in the creeks are usually reached during the summer months, which is the period when the Flow Impact Offset Facility is expected to be in operation. Solar radiation is the primary mechanism by which stormwater temperatures increase in detention ponds. Since the stormwater vaults are typically underground structures (although some be partially exposed), there will be no direct solar warming. Underground storage provides a constant temperature that will be lower than open storage facilities, more closely matching a native seep temperature. **Water release from the Flow Impact Offset Facility is not expected to increase the in-stream water temperature at all.** Since the proposed underground stormwater vaults will result in relatively cool water being discharged, no special design considerations are proposed to manage water temperatures in the vaults associated with the Flow Impact Offset Facility.

The Port is collecting water temperature data from existing stormwater vaults in order to characterize the expected temperatures of the reserved stormwater discharges. Commencing in the summer of 2001, average daily water temperature data is being collected from the North

Employee Parking Lot vault and the SDS3 vault located near the south end of the airfield. Data will be collected from June though October of each year from the dead storage area of each vault. These existing vaults were selected because they are similar in size to the proposed stormwater volumes associated with the Flow Impact Offset Facility. The NEPL vault is partially exposed to sunlight (on its west side and top), while the SDS3 vault is completely underground. By collecting temperature data from both vaults, a range of expected temperatures can be established. Temperature data will be collected from the dead storage zone in each vault in order to approximate the vaults associated with the Flow Impact Offset Facility. This data will be compared to stream temperature data also being collected by the Port to characterize any cooling effects of stormwater releases on water temperatures in the creeks.

Operational and monitoring procedures for the Flow Impact Offset Facility for temperature are discussed in Section xxxx.

Dissolved Oxygen

The state water quality standard for dissolved oxygen (DO) in Class AA waters is 9.5 milligrams per liter (mg/l). Low DO levels in creeks during summer low flow periods is a potential water quality concern. The Flow Impact Offset Facility will be designed and operated in a manner that will not decrease the DO levels in the creeks, and under typical conditions, may actually increase DO levels.

Dissolved oxygen levels in the stormwater vaults will not be significantly reduced while the water is stored. There will be little, if any, biological activity in the vaults that could consume

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oxygen as a result of the lack of sunlight and the low biological oxygen demand (BOD) typically seen in stormwater runoff from the airfield (Annual Stormwater Monitoring Report, September 2000). The infrequent and short-lived episodes of elevated BOD due to runway deicing activities are not expected to impact the DO concentrations of the stormwater detained in the Flow impact Offset Facility because the stormwater associated with these events moves through the stormwater management system in a matter of hours, is replaced with runoff with the low BOD concentrations more typical of airport runoff (Deicing/DO Study Report, November 2000), and typically happens during the early winter months when reserved stormwater releases from the Flow Impact Offset Facility would not take place. In addition, the Port operates BMPs to remove snow containing deicing chemicals (a potential source of BOD) to snowmelt areas that drain to the Industrial Wastewater System, further reducing the BOD in water that drains to stormwater vaults.

Vents will be included in the stormwater vaults associated with the Flow Impact Offset Facility to allow for the circulation of fresh air to occur. **This will help maintain the dissolved oxygen** concentration of the stormwater.

An additional design consideration is the positioning of the inlet(s) to the stormwater vaults associated with the Flow Impact Offset Facility. The inlet(s) will be placed lower in the vault in order to facilitate flushing of the vault each time there is sufficient rainfall to generate stormwater runoff. Typically, stormwater inlets in vaults are placed at higher elevations within the vault. As a result, water in the lower or dead storage areas may not be circulated and may stagnate. By placing the inlet at a lower elevation, water already in the lower portions of the vault will be displaced by the incoming water and will not have the opportunity to stagnate. By continually replacing the water in the stormwater vaults, the dissolved oxygen levels in the stormwater in the vaults will benefit. Each stormwater vault associated with the Flow Impact Offset Facility will have its inlet position carefully considered during the final design phase, and placed to enhance this circulating effect.

Passive aeration of stormwater can be achieved through natural turbulence or agitation of the discharges. Steeply sloped pipes with periodic drop structures will be required to move the water from the vault outlets to the creek elevation. An energy dissipating structure will be required near the release point at creek level to slow the velocity adequately for entering the creek safely, without causing scour or erosion. Both the steeply sloped discharge pipes and the energy dissipating structures will provide the turbulence or agitation needed to provide passive aeration. The Pond G storage vault is located within the runway embankment and has adequate fall from the vault outlet to the creek discharge location to provide aeration.

Where insufficient fall is available for this natural aeration process, the installation and operation of aeration devices may be necessary. Other vaults are located near the level of the creek discharge elevation such that active aeration measures may be required through the installation of some type of aeration device. Active aeration systems that could be utilized include microbubble diffusers, gas injection, air injection, mechanical aerators, or aeration hoses. Microbubble diffusers consist of a porous ceramic plate (similar to aquarium aeration stones) and a pump to inject air through the plate. Gas and air injection systems inject a controlled amount of gas or air under pressure into the discharge water pipe. Mechanical aerators physically agitate water and allow air to become mixed with the water. Aeration hoses are flexible porous rubber hose, and have air pumped through them similar to the microbubble diffusers. Information on each of these devices is included in Appendix xx. Although the selection of the device(s) to be installed will be made during the final design of the Flow Impact Offset Facility, it is likely that the microbubble diffuser will be selected and installed because of their simplicity, effectiveness, cost, and ability to be installed in the discharge pipes. Other attractive features of the microbubble diffuser include low maintenance requirements, their use of a small compressor or pump to provide air instead of the use of compressed gas tanks, and their ability to be automated to function anytime the reserved stormwater discharge valve is open. Currently, the Flow Impact Offset Facility vaults associated with SDN3X, SDN2X/4X, SDN1, Cargo, NEPL, SDS4, SDW3A, and SDW2 may require aeration of their discharges through the installation of aeration devices. ***(need to update this section based on final selection of vaults in facility)***

Operational and monitoring considerations for the Flow Impact Offset Facility related to managing dissolved oxygen are discussed in Section xxxx.

Nutrients

There are no water quality standards for nutrients in the current water quality standards. However, nutrients typically found in stormwater could be of potential concern. If nutrient-rich stormwater is stored for long periods of time, exposure to solar radiation can cause algae blooms. However, it is expected that there will be no adverse water quality impacts associated with nutrients in the release of stormwater for the following reasons:

- There is no significant source of nutrients associated with the airfield areas (i.e., sources of water for the Flow Impact Offset Facility). Primary sources for nutrients in urban stormwater are fertilizers applied to lawns and landscaped areas. However, the grass infield areas of the airfield are not fertilized or irrigated because lush growth could become a wildlife attractant concern. Any landscaped areas to which fertilizers are applied are located near the terminal, and drain to stormwater basins that do not contribute flow to the Flow Impact Offset Facility. The Port's use of fertilizers includes applying the BMPs listed in the airport's Stormwater Pollution Prevention Plan, which further reduces the amount of fertilizers and nutrients that enter stormwater. With careful management of fertilizer use at the airport, there is no major source of nutrients for the drainage areas that contribute stormwater to the Flow Impact Offset Facility.

- The operation of BMPs on the airfield (biofiltration swales) would reduce the opportunity and concentrations of any nutrients that exist prior to the stormwater entering the vaults.

- Since the vaults are underground facilities, there is no sunlight that would stimulate the growth of algae often associated with elevated nutrient levels.

- In-stream residence time for the stormwater discharged from the Flow Impact Offset Facility is only a matter of hours (the time it takes water to flow from the discharge points in the airport vicinity to the creeks' discharge points in Puget Sound). Therefore, there will be minimal opportunity for biological activity (algae blooms) in the creeks. Such water quality impacts from nutrients are typically associated with lakes and ponds, where long residence time would provide the opportunity for excess algae growth to occur. Since no lakes or ponds occur in the creeks between the airport and Puget Sound, this is not an issue.

Given the above, the Port does not propose any monitoring for nutrients in the discharges from the Flow Impact Offset Facility. Through continued implementation of the SWPPP, the BMPs currently in place that manage the use of fertilizers will continue to minimize the opportunities for nutrients to enter stormwater runoff.

Metals

Metals of concern include copper, lead, and zinc. Water quality standards for metals are based on the dissolved fraction, are dependant of the hardness of the water, and are applicable to the receiving waters. Chemistry data from existing airfield stormwater discharges (which are typical of the stormwater that would be reserved for release during low flow periods) have been reported **in the Annual Stormwater Monitoring Reports. Metal concentrations in these discharges are** reported as total recoverable metals, which are not directly comparable to the dissolved fraction listed in the water quality standards. However, this data does serve as an indication of metal concentrations to be expected in the discharges of stormwater from the Flow Impact Offset Facility. Median metals concentrations from airfield stormwater range from 0.014 – 0.031 mg/l copper, 0.001 – 0.002 mg/l lead, and 0.020 – 0.052 mg/l zinc. Note that these values are for end-of-pipe or within-pipe discharges, not the receiving waters. These metal concentrations are also less than typical urban runoff, as discussed in the Annual Stormwater Monitoring Reports. In addition, the Port has conducted Whole Effluent Toxicity testing of stormwater discharges, as required by its NPDES permit, as discussed in the Annual Monitoring Reports. Stormwater associated with airfield sub-basins met the performance standards for whole effluent toxicity according to Ecology guidelines. All this information indicates that the Flow Impact Offset Facility can be managed to meet the water quality standards for metals in the receiving waters

The following items should be considered in the management of the Flow Impact Offset Facility for compliance with state water quality standards:

- A large portion of metals in urban stormwater is attributed to motor vehicle activity. This is illustrated in the Annual Stormwater Monitoring Reports that show higher metal concentrations are associated with the landside basins where motor vehicle activity is concentrated. Since access to the airfield is strictly controlled, motor vehicle activity is kept to a minimum, therefore metal concentrations in stormwater runoff is minimized. The airfield basins are the areas that will be providing stormwater to the Flow Impact Offset Facility, and these areas typically have the lowest lead and zinc concentrations of all airport stormwater discharges (copper concentrations are more consistent in all airport stormwater discharges, but are still relatively low in airfield stormwater).

- Data collected by the Port show that a large fraction of the metal concentrations are associated with particulates, i.e., the metal ions are bound to particulate matter. Therefore, the design and management practices proposed to minimize or reduce particulates and turbidity will also reduce total metal concentrations in the stormwater discharges. Biofiltration swales, settling in vaults, and (additional) filtration are all effective in reducing particulates, and therefore total metal concentrations will be reduced as well. Although these BMPs are not effective in removing dissolved metals, the majority of the metals are bound to particulates and will be removed. The design features proposed for the reserved stormwater vaults (compartmentalized storage, sloping the vault floor away from the stormwater outlets, careful placement of the stormwater outlets, and the provision for installation of filters) will ensure that the discharge of sediments and metals bound to particles will be minimized.

- The Port is currently investigating filtration of stormwater associated with discharges from a landside basin. This research includes determining the effectiveness of several filtration media in treating the stormwater. The results of this study will be completed before final design of the flow offset facilities, and the data will be used to select the filtration method most appropriate to treat the discharge from the Flow Impact Offset Facility, if needed.

Operational and monitoring considerations for the Flow Impact Offset Facility related to managing metals are discussed in Section xxxx.

Other Considerations

There are several other considerations relating to the design and operation of the Flow Impact Offset Facility. They include:

- The discharge points for Flow Impact Offset Facility will be the same as the typical ("live") discharge point for each vault or pond they are associated with. This eliminates the need to permit and construct additional discharge points to the creeks. The proposed location of each stormwater discharge point for the Flow Impact Offset Facility are illustrated in the drawings in Appendix xx.

- All stormwater management facilities, including those associated with the Flow impact Offset facility, will be located within the airport's perimeter fencing, thereby controlling access to the facilities and reducing the potential for damage to the facilities from vandalism.

- The Port will operate, inspect, monitor, and maintain the Flow impact Offset Facility as long as there is an airport at the site. In addition, the Port will provide annual monitoring reports to ensure that the Flow Impact Offset Facility is meeting its performance goals. **An adaptive management method will be used to allow for needed adjustments in the** operation of the facilities, and to allow for the installation of new management/monitoring technology, if needed.

Operation and Monitoring Plan/Annual Schedule of Activities

This section discusses details of the Port's proposed Operation and Monitoring Plan for the Flow Impact Offset Facility. The Operation and Monitoring Plan will be finalized and submitted to Ecology after final design of the facility is competed and before operation commences. The final plan will be based on the proposal discussed in this section and will include:

- A detailed annual schedule of operation for each stormwater vault associated with the Flow Impact Offset Facility
- A monitoring plan, including specific monitoring locations, sampling protocols, etc.
- A reporting plan
- An inspection/maintenance plan
- Characterization of the stormwater quality associated with the Flow Impact Offset Facility, based on existing data and data currently being collected.

The proposal discussed in this section includes information on all the points listed above. However, slight changes in configurations of vaults and conveyance may take place during final design of the facilities, and data currently being collected by the Port may suggest other modifications to the proposed facilities. The Final Plan will include the details and specificity that is not available at the present time.

Annual Operating Schedule

This section contains the proposed annual operating schedule for the Flow Impact Offset Facility. The schedule is based on a calendar year for ease of presentation. The proposed schedule also combines the four proposed stormwater vaults associated with the Flow Impact Offset Facility into a common schedule. It is envisioned that each vault may have a specific operating schedule once final design details are available. The specific operating schedule for an individual vault may be determined based on the final size of the vault, the contributing drainage area to the vault, the time required to fill the vault, and the hydrologic regime of the stream system to which it discharges. Specific operating schedules for each vault will be submitted to Ecology in the Final plan.

Following is the proposed general operating schedule for the Flow impact Offset Facility:

- January through May
  - Operate as "normal" stormwater detention vaults
    - Flow Impact Offset outlet closed to accumulate water
    - Placement of inlet will allow stormwater to be flushed with "fresh" water
    - Monitor filling of stormwater vault (see monitoring plan for details)
- June/July
  - Continue to accumulate stormwater
  - Conduct small test release from each vault associated with the Flow Impact Offset Facility
    - Confirm/adjust discharge rates for Flow Impact Offset Facility (gauge/measure flow)

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- Collect water quality samples from each discharge (see monitoring section for details)
- Compare test discharge water quality samples to existing water quality collected data from creeks during summer periods (corresponding to the periods when the Flow Impact Offset Facility would be discharging)
- If potential water quality violations are indicated, take appropriate actions prior to initiating operational discharge, such as:
  - Install/maintain filters for sediments/turbidity/metals
  - Install portable aerators for DO
  - No actions proposed for temperature and nutrients
- Continue to monitor filling of vaults associated with the Flow Impact Offset Facility

- July/August
  - Open each outlets associated with the Flow Impact Offset Facility
    - July 24th for Des Moines Creek facility
    - August 1 for Miller and Walker Creek Facilities
  - Conduct sampling as described in monitoring plan

- August through October
  - Operation of Flow Impact Offset Facility
    - Inspection/monitoring of each discharge

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- Inspect/monitor (sample) weekly throughout duration of operation
- Any water quality violations will be immediately investigated and corrected
- Continue to monitor water levels in reserved stormwater storage areas

- November 1 (or later, upon commencement of seasonal rains)
  - o Close outlets associated with the Flow Impact Offset Facility
    - ▪ If water remains in vaults and seasonal rains have not commenced, allow discharge to continue until water is exhausted or rains begin
  - o Inspect vaults/complete annual maintenance
  - o Compile collected data
  - o Begin accumulating water in vaults associated with the Flow Impact Offset Facility
    - ▪ Close outlets associated with Flow Impact Offset Facility upon completion of inspection/maintenance, but no later that January 1
  - o Continue monitoring water levels in vaults associated with the Flow Impact Offset Facility
- December 31
  - o Submit annual data report to Ecology by December 31

Monitoring Plan

The Port is proposing a comprehensive monitoring plan for the Flow Impact Offset Facility to ensure that the water quality performance standards are met and no violations of state water quality standards occur in the receiving waters. Monitoring consists of three elements: characterization of existing/expected water quality, monitoring of annual test releases from the Flow Impact Offset Facility, and monitoring of the discharges and receiving waters during operation of the facility. Each element is discussed below.

Characterization of existing/expected water quality

A great deal of water quality data already exists on the Port's stormwater discharges and on the creeks. This data has been collected for a variety of purposes including satisfying the Port's NPDES permit requirements, basin planning activities, and other studies done in the area by the Port and others. The data set includes water quality measurements within the stream systems during the summer periods when the Flow Impact Offset Facility will be scheduled to discharge to the streams. **In addition, the Port has started to collect data to characterize the discharges from** the Flow impact Offset Facility. Temperature data is being collected starting in 2001 from the NEPL vault and the SDS3 vault in order to characterize the expected temperatures of the Flow Impact Offset Facility. The Port has collected temperature data in the creeks since September 2000, so comparisons can be made. The NEPL vault is partially exposed to sunlight (on its west side and top), while the SDS3 vault is completely underground. By collecting temperature data from both vaults, a range of expected temperatures can be established for each type of vault (buried and partially exposed). Temperature data will be collected from the dead storage zone in each vault in order to approximate the Flow impact Offset Facility. Other data may be collected, as needed, prior to the operation of the Flow Impact Offset Facility, that can be used to characterize the proposed discharges and expected water quality within the creeks during the summer months, when the facility will be discharging. All of this data will be analyzed and presented in the Final Operation and Monitoring Plan, which will be submitted to Ecology prior to the initial operation of the Flow Impact Offset Facility.

Monitoring of annual test releases from the Flow Impact Offset Facility.

Each year, in May or June, prior to the operation of the Flow Impact Offset Facility, the Port proposes to conduct small test discharges from each outlet. The test discharges are intended to confirm the operation of each discharge, and to detect and respond to potential problems prior to the annual operation of the Flow Impact Offset Facility. For example, because of the small orifices needed to control discharges to the required rate, small amount of debris in the orifice could significantly impact the discharge rates. Debris can be removed at this time to prevent impacts to the annual operation of the facility. Any other problems that may occur within the facility can be detected and corrected at this time.

Water quality sampling of small-volume test discharges is proposed. By conducting this sampling, potential water quality problems can be detected and corrective measures taken prior to scheduled annual releases to the stream systems. Water quality data obtained from the test discharges will be compared to the characterization data in the creeks to determine the potential for water quality violations. If any are indicated, the Port will take corrective action prior to the annual operation of the facility, such as installing portable aerators or additional filtration in the discharges prior to their entry into the creeks.

Water quality sampling of the test discharges will include:

- Flow (measured/gauged in the field)
- Turbidity (field measurement)
- Dissolved Oxygen (field measurement)
- Temperature (field measurement)
- Metals (copper, lead, and zinc, (grab samples)

Operational Monitoring

The Port is proposing to monitor the operation of the Flow Impact Offset Facility to provide assurance that the facility is achieving its performance goals and not causing any water quality violations in the receiving waters. This will be accomplished by periodic monitoring of both the discharge and receiving waters during the annual operation of the facility. The specific monitoring proposal for the Flow Impact Offset Facility includes:

- Water levels within the stormwater vaults
  - Installation of a pressure transducer and datalogger in each vault will allow daily water levels to be collected
  - This data can be applied to the vault geometry to calculate the volume of water in the stormwater vaults
  - Vault filling and emptying (average daily water levels) will be monitored throughout the year

- Flow
  - Measured/gauged in the field
  - Taken upon opening of the Flow Impact Offset Facility outlets
  - Taken weekly throughout annual operation of facility

- Turbidity
  - Field Measurements
  - Measured in discharges, upstream in receiving waters, downstream in receiving waters after thorough mixing
  - Taken upon opening of Flow impact Offset Facility outlets
  - Taken weekly throughout operation of facility

- Dissolved Oxygen
  - Field Measurements
  - Measured in discharges and downstream in receiving waters after thorough mixing
  - Taken upon opening of Flow Impact Offset Facility outlets
  - Taken weekly throughout operation of facility

- Temperature
  - Field Measurements

- Measured in discharges, upstream in receiving waters, downstream in receiving waters after thorough mixing
- Taken upon opening of Flow Impact Offset Facility outlets
- Taken weekly throughout operation of facility

- Metals
  - Grab samples analyzed for copper, lead, and zinc
  - Measured in discharges and receiving waters downstream after thorough mixing
  - Measured upon opening of Flow impact Offset Facility outlets
  - Measured monthly throughout operation of facility

Weekly monitoring of the discharges for the quality parameters (except metals) is sufficient because the facility will be discharging from a stored volume of water, i.e., the water quality of the discharges is not expected to change. In the event of a significant rainfall event during the operation of the facility (greater than 0.5 inches in a 24-hour period), the Port will conduct additional sampling to ensure that the rainfall did not substantially change the character of the water within the Flow Impact Offset Facility that could potentially cause a violation of in-stream water quality standards. Monthly sampling for metals is sufficient because existing data shows that the metals concentrations in stormwater runoff from the airfield is relatively consistent and low compared to stormwater discharges from other urban areas.

Specific monitoring locations, both of the discharges and in-stream, will be included in the Final Operation and Monitoring Plan to be submitted to Ecology prior to the initial operation of the

Flow impact Offset Facility. All water quality data will be recorded and reported in an annual monitoring report to be submitted to Ecology by December 31 of each year. If the monitoring data show that the discharges from the Flow Impact Offset Facility consistently meet water quality standards within the receiving waters, the Port may propose a modified monitoring plan for subsequent operation of the facility. If any water quality problems were encountered during operation of the facilities, the Annual Report will include a discussion of the immediate actions taken to address the problem, and actions taken or proposed to prevent a reoccurrence of the problem in the future. All sampling and analytical methods used to monitor the Flow Impact Offset Facility will conform to the latest revision of the *Guidelines Establishing Test Procedures for the Analysis of Pollutants* contained in 40 CFR Part 136 or to the latest revision of *Standard Methods for the Examination of Water and Wastewater* (APHA). This will make the monitoring methods for the Flow Impact Offset Facility consistent with other water quality monitoring done under the NPDES permit for the airport.

<u>Biological Monitoring</u>

Biological monitoring is proposed as part of the Natural Resources Mitigation Plan. This monitoring will evaluate changes in the Benthic Index of Biotic Integrity (BIBI) over a ten-year period. This monitoring will be able to be used in assessing any biological effects of the flow offset facility in the receiving waters.

Maintenance Plan

The Port develops operation and maintenance manuals for all of its stormwater facilities. While the manuals follow the same generalized schedule for inspection and maintenance, each facility has its own specific manual to address the unique features of each facility. Following is an outline of what is contained in existing operation and maintenance plans for facilities including the Tyee Pond Detention Facility, the Miller Creek Detention Facility, the North Employee Parking Lot, the North Cargo Area Pump Station, the North End Snow Melt Facility, the North Satellite Snow Melt Facility, and the South End Snow Melt Facility. Typical inspection/maintenance activities occur on monthly, quarterly, semi-annual, or annual intervals, depending on the facility and activity. Operation and maintenance manuals developed for the stormwater vaults associated with the Flow Impact Offset Facility will contain similar elements and at least the same frequency of activities.

General Operation and Maintenance Manual Outline

- **Purpose of Facility/Purpose of Manual**
- Description of Facility and Operation
  - General Description
  - Hydraulic Properties
  - Water Quality Properties
  - Monitoring Systems/Alarms
- Historical Maintenance Operations (as applicable)
- Site/Facility Access
- Personnel and Emergency Contacts

- Inspection and Maintenance Procedures (items included as applicable to each facility)
    - Culverts
    - Ponds
    - Vegetation
    - Inlet Structure(s)
    - Outlet Structure(s)
    - Sensors and Alarms
    - Pumps and Valves
    - Filters/other water quality facilities
    - Access Roads/Hatches
    - Berms/Dikes/Levees
    - Spillways/Slopes
    - Creek/Stream Protection
    - Photographs
- **Inspection and Maintenance Schedule**
- Sediment/Waste Disposal Requirements
- Inspection Forms and Maintenance Checklist
- Maintenance Work Order Request Form
- Maintenance Crew/Shop Crew Responsibilities
- Health and Safety Plan
- Combined Space Entry Program
- Drawings/As Built Diagrams
- Process Diagrams

- References/Equipment Manuals

A sample operation and maintenance manual is included in Appendix XX. Each stormwater vault associated with the Flow Impact Offset Facility will have its own operation and maintenance manual developed as part of the final design process. The operation and maintenance manual for these stormwater vaults will be included in the overall operation and maintenance manual for the Flow Impact Offset Facility to be submitted to Ecology prior to initial operation of the facility.

EXHIBIT D

Port of Seattle

July 25, 2001

Ann E. Kenny
Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, WA 98008-5452

Dear Ms. Kenny:

SUBJECT: Low Streamflow Analysis, Summer Low Flow Impact Offset Facility Proposal, Seattle–Tacoma International Airport

The purpose of this letter is to provide some clarifications on my letter to you dated July 23. These clarifications are a result of the discussions that occurred yesterday on a conference call between the Port, Ecology, King County, Parametrix, Aquaterra, and Floyd Snider McCarthy. Specific items for clarification are listed below.

1. On page 4, the second sentence in paragraph 2 should read, "In areas where the embankment is proposed, recharge entering the embankment was calculated using 'flat outwash grass.' "

2. The paragraph that discusses the non-contiguous groundwater contributions to Walker Creek (paragraph starting on the bottom of page 4 and continuing on page 5) contains two errors. The new impervious area is 69 acres, not 38. The effective impervious area is 59.3 acres, not 37.2. The modeling and back up are correct and consistent with these areas.

3. The sixth to the last page in the Walker Creek package entitled "Reserve Storage Vaults for Walker Creek" includes a section called "Contributing Drainage Area." This page has been revised as follows:

Subbasin	Vaults	Area	% Contribution
SDW2	F	6.0	52
SDW2 Lined Area	F	3.5	30
SDW2 Pond Cover	F	2.0	18
	Total	**11.5**	

The modeling is consistent with this table.

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4. Additional information on the Hydrus/slice modeling of the embankment is included. This information consists of a draft figure and text explaining how the slice modeling results were integrated over the fill length in each basin. This information was provided as an interim deliverable on July 9.

5. Non-hydrologic effects are described in a section that begins with a table entitled "Summary of Non-Hydrologic Impacts". Additional information regarding how the summary table was developed is provided in this section. Data for each column were determined as follows:

   Number of Septic Tanks
   The number of septic tanks was determined using information provided by Southwest Suburban Sewer District. Breakdown of septic tanks in each basin is determined by the surface watershed in which the parcel was located. Estimated septic tank usage was determined as described on the page entitled "Estimated Recharge Quantity". The column headings, which were inadvertently left off this page, are "Miller Creek", "Walker Creek", and "Des Moines Creek", respectively. Total recharge from septic systems (the last row on the "Estimated Recharge Quantity" page) is shown as 52,963 gallons per day (gpd) for Miller Creek and 9,201 gpd for Walker Creek, which convert to 0.082 cfs and 0.014 cfs for Miller Creek and Walker Creek, respectively.

   Septic Tank Adjusted
   This column refers to an adjustment of septic tank seepage that can be made in the Miller Creek basin to reflect water that is lost to deep groundwater. This seepage adjustment was incorrectly made to Walker Creek, and has been corrected in the summary table below. This correction does not change the total non-hydrologic impact in Walker Creek.

   Withdrawals
   The estimated water withdrawals in Miller creek are summarized in Table G-2 (attached), which was not included with the July 23rd letter. This table has been reviewed and approved as part of the SMP review.

   With the modifications described above, the "Summary of Non-Hydrologic Impacts" table is corrected as follows:

Creek	Number of Septic Tanks	Septic Tank Estimated	Septic Tank Adjusted	Withdrawals[b]	Total Impact
Miller	236	-0.082	-0.057[a]	+0.042	-0.02
Walker	41	-0.014	-0.014	N/A	-0.01

6. In the non-hydrologic impact section, references were made to spreadsheets that were submitted on the CD. The files are "MillerWaterPumpage.xls" and "SepticRecharge.xls

7. In the final low flow report, details will be provided demonstrating the feasibility of vault construction and discharge mechanisms.

8. The model output used for 2006 in the Walker Creek basin was not included in the attachments in the July 23rd letter. This information was forwarded to Kelly Whiting on July 24th, and is included in the attached CD (filename "wwcnofill.inp" and "mnofill.inp").

I apologize for the confusion. Please contact me at 206/988-5528 if you have any questions.

Sincerely,

Keith R. Smith
Water Resources Manager

Attachments

C: Kelly Whiting, KCDNR

Table G-2. Update of Estimated Water Pumpage from Miller Creek.

Parcel	Notes	Last Name	Available Pumping Rate (gpm)	Acres	Estimated Months of Water Use Per Year	Estimated Actual Pumping Rate[5] (gpm)	Updated Useage Estimate (cfs)	Comments
068R	1	Genzale	2.5	4	5	0.52	0.001	4 acres, 2.5 gpm June to mid-October
185R	1	Berry	5	1	6	1.25	0.003	Less than 1 acre, summer only
244R	1	Randall	5	0.5	6	1.25	0.003	Only in summer/garden
097R	1, 6	Smith	20	0.6	4	3.33	0.007	Pump 4 months for orchard, lawn, and garden
311R	1	Rhoton	5	1.7	6	1.25	0.003	Water in summer - unknown quantity
316R	1	Roullard	0	0.25			0.000	1940-60 maximum, 1990's no water usage
050R	1	Eisiminger	0				0.000	None to very little
246R	1	Galando	0	0.75			0.000	Unknown - doesn't remember dad pumping water
093R	2	Raffo	0	3.5			0.000	Table indicates no water
055R	1	Mason	0				0.000	Municipal water
060R	1	Vacca	0				0.000	Municipal water
061R	1	Vacca	0				0.000	Municipal water
143R	1	Brate	0	1			0.000	Water right not used
182R	1	Illes	0	1			0.000	Water right not used
253R	1	Kobela	0	0.5			0.000	Water right not used
298R	1	Warner	0				0.000	Water right not used
302R	1	Lopez	0				0.000	Water right not used
062R	1	Scarsella	0	1.2			0.000	Water right not used
142R	1	Wind of the Willows Condos	0	0.75			0.000	Water right not used
214R	3	Kamp	20	1	6	5.00	0.011	Information from table G-1 only
321R	3	Beaudin	20	0.75	6	5.00	0.011	Information from table G-1 only
088R		Goodmansen					0.000	Information from table G-1 only
322R	4	Longridge	4.5		6	1.12	0.003	Information from table G-1 only
Estimated Historical Water Use						18.72	0.042	

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NOTES gpm = gallons per minute cfs = cubic feet per second

[1] Information from owner

[2] Table G-1 indicates that Miller Creek water was not used

[3] Table G-1 indicates 20 gpm; assume 6 months of water use for irrigation

[4] Table G-1 indicates no information; assume minimum water right of 0.01 cfs

[5] Available pumping rate x estimated months of water use per year x 0.5 (12 hours per day)

[6] Available pumping rate estimated from Q (annual); Q (instantaneous) appeared to be abnormally high