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Glossary of Terms

Air Operations Areas (AOA). Any area of an airport used or intended to be used for landing, takeoff, or surface maneuvering of aircraft.

Airport Certification Manual (ACM). The ACM is a document that FAA requires airports to produce in accordance with requirements contained in Title 14, Code of Federal Regulations (CFR) Part 139, Certification of Airports. The ACM serves as the bridge between the requirements of Part 139 and their application to a particular airport, taking into account the airport's size, type/level of activity, and configuration. For additional information, please refer to FAA Advisory Circular (AC) 150/5210-22 (FAA 2004c).

Airport wildlife biologist. A qualified airport wildlife biologist is a wildlife biologist capable of conducting a hazardous wildlife assessment. For certificated airports, this biologist must meet the qualifications in FAA Advisory Circular 150/5200-36 (FAA 2006c).

Airports District Office (ADO). The Seattle ADO is responsible for Idaho, Oregon, and Washington and may be reached at:

U.S. Department of Transportation
Federal Aviation Administration
Northwest Mountain Region
Seattle Airports District Office
1601 Lind Avenue, S.W., Suite 250
Renton, WA 98057-3356
Voice: (425) 227-2650
Fax: (425) 227-1650

Airside. Any location where aircraft operations, fueling, maintenance, or support activities are conducted. The AOA is included in the airside area.

Basic water quality treatment (versus *enhanced water quality treatment*). The Washington State Department of Ecology's performance goal is to achieve 80 percent removal of total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations greater than 200 mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/l, the facilities are intended to achieve an effluent goal of 20 mg/l total suspended solids.

Basin. The area of land drained by a river and its tributaries, which drains water, organic matter, dissolved nutrients, and sediments into a lake or stream (see *watershed*). Basins typically range in size from 1 to 50 square miles.

Basin plan. A plan that assesses, evaluates, and proposes solutions to existing and potential future impacts on the physical, chemical, and biological properties and beneficial uses of waters of the state within a drainage basin. A plan should include but not be limited to recommendations for the following elements:

- Stormwater requirements for new development and redevelopment
- Capital improvement projects
- Land use management through identification and protection of critical areas, comprehensive land use and transportation plans, zoning regulations, site development standards, and conservation areas
- Source control activities, including public education and involvement, and business programs
- Other targeted stormwater programs and activities, such as maintenance, inspections, and enforcement
- Monitoring
- An implementation schedule and funding strategy.

A basin plan that is adopted and implemented must have the following characteristics:

- Adoption by legislative or regulatory action of jurisdictions with responsibilities under the plan
- Recommended ordinances, regulations, programs, and procedures that are in effect or scheduled to go into effect
- An implementation schedule and funding strategy in progress.

Best management practices (BMPs). The structural devices, maintenance procedures, managerial practices, prohibitions of practices, and schedules of activities that are used singly or in combination to prevent or reduce the detrimental impacts of stormwater, such as pollution of water, degradation of channels, damage to structures, and flooding.

Biofiltration. The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials, such as vegetation.

Bioinfiltration. The process of reducing pollutant concentrations in water by infiltrating the polluted water through grassy vegetation and soils into the ground.

Clearway (CWY). A defined rectangular area beyond the end of a runway cleared or suitable for use in lieu of runway to satisfy takeoff distance requirements. This is the region of space above an inclined plane that leaves the ground at the end of the runway.

Closed depression. A low-lying area that has either no surface water outlet or such a limited surface water outlet that during storm events, the area acts as a retention basin.

Compaction. The densification, settlement, or packing of soil in such a way that its permeability is reduced. Compaction effectively shifts the performance of a hydrologic group to a lower permeability hydrologic group. Compaction may also refer to the densification of a fill by mechanical means.

Converted pervious surface. Land cover changed from native vegetation to lawn, landscape, or pasture areas. (See also *pollution-generating impervious surface*.)

Critical areas. At a minimum, areas that include wetlands; areas with a critical recharging effect on aquifers used for potable water; fish and wildlife habitat conservation areas; frequently flooded areas; geologically hazardous areas, including unstable slopes; and associated areas and ecosystems.

Design flow rate. The maximum flow rate to which certain runoff treatment BMPs are designed for required pollutant removal. Biofiltration swales, vegetated filter strips, and oil/water separators are some of the runoff treatment BMPs that are sized based on a design flow rate.

Design storm. A rainfall event of specified size and return frequency (see Design storm frequency) that is used to calculate the runoff volume and peak discharge rate to a stormwater facility. A prescribed hyetograph and total precipitation amount (for a specific duration recurrence frequency) are used to estimate runoff for a hypothetical storm for the purposes of analyzing existing drainage, designing new drainage facilities, or assessing other impacts of a proposed project on the flow of surface water. (A hyetograph is a graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.)

Design storm frequency. The anticipated period in years that will elapse before a storm of a given intensity and/or total volume will recur, based on average probability of storms in the design region. For instance, a 10-year storm can be expected to occur on the average once every 10 years. Facilities designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

Detention. The temporary storage of stormwater runoff in a stormwater facility, which is used to control the peak discharge rates and provide gravity settling of pollutants; the release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, with the difference held in temporary storage.

Dispersion. Release of surface water and stormwater runoff from a drainage facility system in such a way that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

Effective impervious surface. Replaced impervious surfaces minus those new and applicable replaced impervious surfaces that are noneffective impervious surfaces.

Energy dissipater. A means by which the total energy of flowing water is reduced, such as rock splash pads, drop manholes, concrete stilling basins or baffles, and check dams. In stormwater design, an energy dissipater is usually a mechanism that reduces velocity prior to or at discharge from an outfall to prevent erosion.

Enhanced runoff treatment, enhanced water quality treatment (versus *basic water quality treatment*). The use of runoff treatment BMPs designed to capture dissolved metals at a higher rate than basic treatment BMPs.

Erosion and sedimentation control (ESC). Any temporary or permanent measures taken to reduce erosion, trap sediment, and ensure that sediment-laden water does not leave the site.

Existing site conditions. The conditions (ground cover, slope, drainage patterns) of a site as they existed on the first day that the project entered the design phase.

Filter strip. A grassy area with gentle slopes that treats stormwater runoff from adjacent paved areas before it can concentrate into a discrete channel.

Flow control facility. A drainage facility (BMP) designed to mitigate the impacts of increased surface water and stormwater runoff flow rates generated by development. Flow control facilities are designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold runoff for a short period of time, and then release it to the conveyance system at a controlled rate.

Hydrologic soil groups. A soil characteristic classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one of four soil groups (A, B, C, or D) based on infiltration rate and other properties (based on *Water Quality Prevention, Identification, and Management of Diffuse Pollution* [Novotny and Olem 1994]):

- **Type A** – Low runoff potential. Soils with high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission.
- **Type B** – Moderately low runoff potential. Soils with moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
- **Type C** – Moderately high runoff potential. Soils with slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

- **Type D** – High runoff potential. Soils with very slow infiltration rates when thoroughly wetted, and consisting chiefly of clay soils with a high swelling potential; soils with a permanent high water table; soils with a hardpan, till, or clay layer at or near the surface; soils with a compacted subgrade at or near the surface; and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission.

Impervious surface. A hard surface area that either prevents or retards the entry of water into the soil mantle as occurs under natural conditions (prior to development), and from which water runs off at an increased rate of flow or in increased volumes. Common impervious surfaces include but are not limited to rooftops, walkways, runways, taxiways, parking lots, storage areas, gravel roads, packed earthen materials, and other concrete, asphalt, or oiled surfaces. Open, uncovered retention/detention facilities are not considered impervious surfaces for the purpose of determining whether the thresholds for application of minimum requirements are exceeded. Open, uncovered retention/detention facilities are considered impervious surfaces for the purpose of runoff modeling.

Industrial activities. Material handling, transportation, or storage; manufacturing; maintenance; treatment; or disposal. Areas with industrial activities include plant yards; access roads and rail lines used by carriers of raw materials, manufactured products, waste material, or byproducts; material handling sites; refuse sites; sites used for the application or disposal of process waste waters; sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas for raw materials and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater.

Infiltration rate. The rate, usually expressed in inches per hour, at which water moves downward (percolates) through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture, or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

Jurisdictional wetland. A jurisdictional wetland as defined under Section 404 of the Clean Water Act, is a wetland that is connected to a Water of the United States (WOUS) using the U.S. Army Corps of Engineers (Corps) definition of WOUS. If an area meets the three standard wetland criteria (hydric soils, hydrology, and hydrophytic vegetation) and is connected to a WOUS, then it is considered a jurisdictional wetland and is regulated by the Corps. Because the connectedness of a wetland to a WOUS is not always easily defined, it is critical to get a jurisdictional determination, in writing, from the Corps, as early as possible in the project planning process.

Landside. Areas of the airport outside of the AOA (e.g., parking, rental car lots, and terminals).

Landslide hazard areas. Those areas subject to a severe risk of landslide.

Level spreader. A temporary erosion and sedimentation control device used to distribute stormwater runoff uniformly over the ground surface as sheet flow (i.e., not through channels) to enhance infiltration and prevent concentrated, erosive flows.

Low-impact development (LID). An evolving approach to land development and stormwater management that uses a site's natural features and specially designed BMPs to manage stormwater; it involves assessing and understanding the site, protecting native vegetation and soils, and minimizing and managing stormwater at the source. Low-impact development practices are appropriate for a variety of development types.

Low-permeability liner. A layer of compacted till or clay, or a geomembrane.

Manning's equation An equation used to predict the velocity of water flow in an open channel or pipeline:

$$V = (1.486(R^{2/3})(S^{1/2}))/n$$

where:
- V = the mean velocity of flow in feet per second
- R = the hydraulic radius in feet
- S = the slope of the energy gradient or, for assumed uniform flow, the slope of the channel in feet per foot
- n = Manning's roughness coefficient or retardance factor of the channel lining.

Media filter. A filter that includes material for removing pollutants (e.g., compost, gypsum, perlite, zeolite, or activated carbon).

Media filter drain. A stormwater treatment facility constructed in the pervious shoulder area of a roadway, consisting of a vegetation-covered french drain containing filter media. Also referred to as an ecology embankment.

Mitigation. Measures to reduce adverse impacts on the environment, in the following order of preference:

1. Avoid the impact altogether by not taking a certain action or part of an action.
2. Minimize the impact by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts.
3. Rectify the impact by repairing, rehabilitating, or restoring the affected environment.

4. Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action.

5. Compensate for the impact by replacing, enhancing, or providing substitute resources or environments.

Monitoring. The collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

National Pollutant Discharge Elimination System (NPDES). The part of the federal Clean Water Act that requires point source dischargers to obtain permits, called NPDES permits, which in Washington State are administered by the Department of Ecology.

Native growth protection easement (NGPE). An easement granted for the protection of native vegetation within a sensitive area or its associated buffer.

Native vegetation. Vegetation consisting of plant species other than noxious weeds that are indigenous to the region and that reasonably could be expected to occur naturally on the site.

New impervious surfaces. Those surfaces that expand paved areas, and those surfaces that are upgraded from gravel to bituminous surface treatment (BST), asphalt, or concrete pavement. For the purpose of conducting a flow control analysis, the representative predeveloped land cover directly below the new impervious surface shall be based on the predominant land cover adjacent to the existing paved areas.

Noneffective impervious surfaces. Those new, applicable replaced, or existing impervious surfaces that are being managed by dispersion areas meeting the dispersion BMP criteria in the HRM. The equivalent area concept generally applies to engineered dispersion areas and may apply to natural dispersion areas, as described in the following: The existing site currently collects runoff in a ditch or pipe and discharges it to a surface water. By changing this condition to a natural dispersion situation through sheet flow or channelized flow dispersion, a surface discharge is eliminated, resulting in a flow control improvement. Equivalent area trades for natural dispersion are allowed for this specific case.

Noneffective pollution-generating impervious surface (PGIS). Those new, applicable replaced, or existing PGIS surfaces that are being managed by dispersion areas meeting the dispersion BMP criteria in the HRM. The equivalent area concept generally applies to engineered dispersion areas and may apply to natural dispersion areas, as described in the following: The existing site currently collects runoff in a ditch or pipe and discharges to a surface water. By changing this condition to a natural dispersion situation through sheet flow or channelized flow dispersion, a surface discharge is eliminated, resulting in a flow control improvement. Equivalent area trades for natural dispersion are allowed for this specific case.

Nonroad-related project. A project involving structures, including rest areas, maintenance facilities, and ferry terminal buildings.

Object-Free Area (OFA). An area on the ground centered on a runway, taxiway, or taxi-lane centerline provided to enhance the safety of aircraft operations by having the area free of aboveground objects protruding above the Runway Safety Area (RSA, defined below) edge elevation, except for objects that need to be located in the OFA for air navigation or aircraft ground maneuvering purposes.

Off-line facilities. Runoff treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow-splitter.

Oil control. The treatment of stormwater runoff with BMPs to remove oil, grease, and total petroleum hydrocarbons (TPH).

Oil/water separator. A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

On-line facilities. Runoff treatment facilities that receive all the stormwater runoff from a drainage area. Flows above the runoff treatment design flow rate or volume are passed through at a lower percentage removal efficiency.

Orifice. An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow; generally used for the purpose of measurement or control of water.

Outfall. Any location where concentrated stormwater runoff leaves the right-of-way. Outfalls may discharge to surface waters or groundwater.

Outlet protection. A protective barrier of rock, erosion control blankets, vegetation, or sod constructed at a conveyance outlet.

Overflow. A pipeline or conduit device with an outlet pipe that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has allowed the portion of the flow that can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Peak discharge. The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Pollution-generating impervious surface (PGIS). An impervious surface that is considered a significant source of pollutants in stormwater runoff, including surfaces that receive direct rainfall (or run-on or blow-in of rainfall) and are subject to vehicular use; industrial activities; or storage of erodible or leachable materials, wastes, or chemicals. Erodible or leachable materials, wastes, or chemicals are substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage container leakage. Metal roofs are also considered pollution-generating impervious surfaces unless they are coated with an inert, nonleachable material (e.g., baked-on enamel coating). A surface, whether paved or not, is considered subject to vehicular use if it is regularly used by motor vehicles. The following are considered regularly used surfaces: roads, unvegetated road shoulders, bicycle lanes within the travel lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways. The following are not considered regularly used surfaces: paved bicycle pathways separated from roads for motor vehicles, fenced fire lanes, and infrequently used maintenance access roads.

Pollution-generating pervious surface (PGPS). Any pervious surface subject to the ongoing use of pesticides and fertilizers or loss of soil, such as lawns and landscaped areas.

Pretreatment. The removal of material such as solids, grit, grease, and scum from flows to improve treatability prior to biological or physical treatment processes; may include screening, grit removal, settling, oil/water separation, or application of a basic treatment BMP prior to infiltration.

Professional engineer (P.E.). A person registered with the state of Washington as a professional engineer.

Project limits. For road projects, the beginning project station to the end project station and from right-of-way line to right-of-way line. For nonroad projects, the legal boundaries of land parcels that are subject to project development (also called the project area perimeter).

Redevelopment. On a site that is already substantially developed (i.e., has 35 percent or more of existing impervious surface coverage), the creation or addition of impervious surfaces; the expansion of a building footprint or addition, or replacement of a structure; structural development including construction, installation, or expansion of a building or other structure; replacement of impervious surface that is not part of a routine maintenance activity; and land-disturbing activities.

Regional detention facility. A stormwater quantity control structure designed to correct surface water runoff problems within a drainage basin or subbasin, such as regional flooding or erosion problems; a detention facility sited to detain stormwater runoff from a number of new developments or areas within a catchment.

Release rate. The computed peak discharge rate in volume per unit time of surface and stormwater runoff from a site.

Replaced impervious surface. Those paved areas that are excavated to a depth at or below the top of the subgrade (pavement repair work excluded) and replaced in kind. The subgrade is taken to be the crushed surfacing directly below the pavement layer (ACP, PCCP, BST). If the removal and replacement of existing pavement do not go below the pavement layer, as with typical PCCP grinding, ACP planning, or "paver" projects, the new surfacing is not considered replaced impervious surface. For the purpose of conducting a flow control analysis, the representative predeveloped land cover directly below the replaced impervious surface shall be based on the predominant land cover adjacent to the existing paved area.

Riprap. A facing layer or protective mound of rocks placed to prevent erosion or sloughing of a structure or embankment due to flow of surface and stormwater runoff.

Riser. A vertical pipe extending from the bottom of a pond that is used to control the discharge rate from a stormwater facility for a specified design storm.

Road and parking lot-related projects. Pavement projects, including shoulders, curbs, and sidewalks.

Runoff. Rainwater or snowmelt that directly leaves an area as surface drainage.

Runoff treatment. Pollutant removal to a specified level via engineered or natural stormwater management systems.

Runoff treatment BMP. A BMP specifically designed for pollutant removal.

Runway Protection Zone (RPZ). An area off the runway end to enhance the protection of people and property on the ground.

Runway Safety Area (RSA). A defined surface surrounding the runway prepared or suitable for reducing the risk of damage to aircraft in the event of an undershoot, overshoot, or excursion from the runway.

Sand filter. A manmade depression or basin with a layer of sand that treats stormwater as it percolates through the sand and is discharged via a central collector pipe.

Saturated hydraulic conductivity. The rate of movement of water through a saturated porous medium.

Sensitive area. Any area designated by a federal, state, or local government as having unique or important environmental characteristics that may require additional protective measures (also see *critical areas*). These areas include but are not limited to:

- "Critical habitat" as defined in Section 3 of the federal Endangered Species Act of 1973.
- Designated "critical water resources" as defined in 33 CFR Part 330, Nationwide Permit Program.

- Water bodies designated as "impaired" under the provision of Section 303d of the federal Clean Water Act enacted by Public Law 92-500.
- Sole-source aquifers as defined under the federal Safe Drinking Water Act, Public Law 93-523.
- Wellhead protection zones as defined under WAC 246-290, Public Water Supplies.
- Areas identified in local critical area ordinances or in an approved basin plan.

Sheet flow. Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Short-circuiting. The passage of runoff through a stormwater treatment facility in less than the design treatment time.

SIC code. Standard industrial classification code developed by the U.S. Department of Commerce to classify types of industry. Now often used by environmental agencies to assign regulatory requirements.

Silt fence. A temporary sediment barrier consisting of a geotextile fabric stretched across and attached to supporting posts, which are entrenched. Adding rigid wire fence backing can strengthen a silt fence.

Slope. Degree of deviation of a surface from the horizontal, measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise); e.g., 2H:1V. A 2H:1V slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plane, so that a 90° slope is vertical (maximum), and a 45° slope is 1H:1V (i.e., a 100 percent slope).

Soil amendments. Materials that improve soil fertility for establishing vegetation or permeability for infiltrating runoff.

Sole-source aquifer. An aquifer or aquifer system that supplies 50 percent or more of the drinking water for a given service area and for which there are no reasonably available alternative sources should the aquifer become contaminated, and the possibility of contamination exists. The U.S. Environmental Protection Agency designates sole-source aquifers, and Section 1424(e) of the Safe Drinking Water Act is the statutory authority for the Sole-Source Aquifer Protection Program.

Source control. A structure or operation intended to prevent pollutants from coming into contact with stormwater, either through physical separation of areas or through careful management of activities that are sources of pollutants.

- *Structural source control BMPs* are physical, structural, or mechanical devices or facilities intended to prevent pollutants from entering stormwater.
- *Operational BMPs* are nonstructural practices that prevent or reduce pollutants entering stormwater.

Spillway. A passage such as a paved apron or channel carrying surplus water over or around a dam or similar obstruction; an open or closed channel used to convey excess water from a reservoir. A spillway may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

Steep slope. A slope of 40 percent gradient or steeper with a vertical elevation change of at least 10 feet.

Stopway (SWY). A defined rectangular surface beyond the end of a runway prepared or suitable for use in lieu of runway to support an aircraft without causing structural damage to the aircraft during an aborted takeoff.

Swale. A natural depression or shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than 1 foot, used to temporarily store, route, or filter runoff.

Taxiway Safety Area (TSA). A defined surface alongside the taxiway prepared or suitable for reducing the risk of damage to an aircraft unintentionally departing the taxiway.

Threshold discharge area (TDA). An on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within ¼ mile downstream (as determined by the shortest flow path).

Total Maximum Daily Load (TMDL) – water cleanup plan. A calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL (also known as a water cleanup plan) is the sum of allowable loads of a single pollutant from all contributing point sources and nonpoint sources. The calculation must include a margin of safety to ensure that the water body can be used for the purposes the state has designated. The calculation must also account for seasonal variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each water body: for example, drinking water supply, contact recreation (such as swimming), and aquatic support (such as fishing) and the scientific criteria to support each use. The federal Clean Water Act, Section 303, establishes the water quality standards and TMDL programs.

Touchdown. Section at the end of the runway where aircraft tires first meet the runway.

Trash rack. A structural device used to prevent debris from entering a spillway or other hydraulic structure.

Treatment train. A combination of two or more treatment facilities connected in series.

Underdrain. Plastic pipes with holes drilled through the top, installed on the bottom of an infiltration facility, that are used to collect and remove excess runoff.

Vegetated filter strip. A facility designed to provide runoff treatment of conventional pollutants (but not nutrients) through the process of biofiltration.

Wildlife hazard assessment. A wildlife hazard assessment, identified as an ecological study in FAA Title 14 Code of Federal Regulations, part 139.337(a), is conducted by a wildlife damage management biologist when any of the following events occurs on or near the airport:

- An air carrier aircraft experiences multiple wildlife strikes;
- An air carrier aircraft experiences substantial damage from striking wildlife;
- An air carrier aircraft experiences an engine ingestion of wildlife; or
- Wildlife of a size, or in numbers, capable of causing an event described in (1), (2), or (3) (above) is observed to have access to any airport flight pattern or aircraft movement area.

The assessment provides the scientific basis for the development, implementation, and refinement of a wildlife hazard management plan, if needed. Although parts of the wildlife hazard assessment may be incorporated directly in the wildlife hazard management plan, they are two separate documents.

Wildlife hazard management plan. Pending results and approval of a wildlife hazard assessment, an airport may be required to produce a wildlife hazard management plan. This is a document that addresses the specific issues/requirements prescribed in the FAA Title 14 Code of Federal Regulations, part 139.337. A summary of the requirements for a wildlife hazard management plan can be found at http://www.faa.gov/airports_airtraffic/airports/regional_guidance/central/airport_safety/part139/best_practice/wildlife/media/Summary_Wildlife_Management.pdf.

Water cleanup plan. See *total maximum daily load*.

Watershed. A geographic region within which water drains into a particular river, stream, or body of water. Watersheds can be as large as those identified and numbered by the state of Washington as water resource inventory areas (WRIAs), defined in WAC 173-500.

Appendix A – Vegetation Recommendations for Airport Settings

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Tables

Vegetation Recommendations for Airport Settings

A-1. Introduction

A-1.1. General Description

WSDOT has promoted the use of native plant species because of the effective treatment, lower irrigation and maintenance needs, and reduced requirements for pesticides and fertilizers (WSDOT 2003). Many of these plant species provide important food sources and habitat for native birds and other wildlife. ***These vegetation characteristics are not desirable in airport settings because of the potential hazards to aircraft posed by wildlife.*** This appendix provides guidance on vegetation selection in airport settings. It is intended for use as a starting point for the selection of appropriate vegetation in and around stormwater best management practices (BMPs) in conjunction with the BMP descriptions in Chapters 5 and 6 of the Aviation Stormwater Design Manual (ASDM).

Vegetation plays a crucial role in many water quality treatment facilities, enhancing physical and biological treatment processes such as filtration, sedimentation, adsorption, and uptake. The dense root zone of many plant species enhances filtration and straining of pollutants. In addition, landscaping can improve the aesthetics of treatment facilities and provide a public benefit.

Vegetation is important to wildlife because it provides both food and cover. Some waterfowl species eat the bulbs and roots of aquatic plants such as pondweed, cattails, and arrowhead. Many species of wildlife eat the fruit, nuts, and seeds produced by aquatic and riparian plants, whereas other wildlife feed on the leaves and/or stems of the plants. Herrera (2007) includes a table that shows the food types that attract birds to an area.

In addition to vegetative food sources, wildlife may be attracted to frogs, fish, or invertebrates that are often associated with stormwater facilities. For example, raptors feed on small rodents that hide in grassy vegetation. A less obvious problem reported by many airports is worms. Large numbers of worms may find their way onto paved areas after rainstorms, attracting birds, leading to potential collisions between the feeding bird and aircraft (Transport Canada 2004). Plants also provide cover for some wildlife species that serve as prey for other species. Many aquatic plants provide habitat for fish and invertebrates, which may also attract birds.

Plants can attract and provide hazardous wildlife with cover to shield them and protect their nests from predators. Plants can also shelter wildlife during periods of inclement weather. The appeal of vegetation to wildlife species depends both on the types of vegetation and the height of the plants.

A-1.2. Applications and Limitations

The focus of this appendix is vegetation for stormwater BMPs, in particular, information about vegetation that is suitable for flow control and runoff treatment facilities in the airport environment. This appendix presents lists of plant species, identifying certain species of plants as either “recommended” or “not recommended” for use at Washington airports.

The recommended plant list presents information on species that have been used in the airport and/or stormwater setting with documented satisfactory results. These species are often perennial, easy to establish, readily available, suitable for erosion control, require minimal maintenance, adapted to stormwater facility conditions, and do not possess notable morphological characteristics that are clearly attractive to wildlife. Plants may be less attractive to wildlife if they have low forage value; produce few, low-nutritional value seeds; have low-nutrition roots or tubers; are low growing if groundcover; or produce minimized flowering parts with limited value to pollinators.

Those plant species identified as not recommended have been documented as inappropriate for use in an airport environment because they contain morphological characteristics that are considered wildlife attractants, or they possess behavioral characteristics that are considered overly aggressive or invasive. While they may be available in your area, use of these plants is discouraged since they may present wildlife-aircraft hazard risks or require significant additional maintenance.

In general, native plants possess many of the characteristics desired for vegetation stormwater BMPs. Many are perennial, low maintenance, have deep roots that stabilize soils, and are adapted to fluctuating water conditions. However, they may also possess morphological characteristics attractive to wildlife, making them unsuitable for use near airports. Conversely, many nonnative or ornamental plants do not possess functional characteristics necessary for planting in stormwater facilities. However, some of the nonnatives that do exhibit these characteristics also possess aesthetic traits suitable for use in high-visibility areas that require stormwater facilities. In generating the recommended plant lists, native and nonnative plants have been provided with a balance of characteristics that minimize risks and maintenance liability.

This appendix is not a comprehensive resource on vegetation suitable for use in the airport stormwater treatment environment. There may be plant species that are not included in the recommended plant lists that are, in fact, appropriate for use in the airport stormwater environment. Similarly, site-specific conditions may render recommended plants unsuitable for use in certain airport environments. To ensure final selection of the plants that are most appropriate for your site, designers are encouraged to contact an agency landscape architect, consulting landscape architect, or other regional vegetation expert to determine the site-specific needs with regard to plant selection, installation, and establishment of vegetation associated with stormwater BMPs. Regionally oriented plant guides can provide additional guidance (e.g., Brenzel 2001, Pojar and MacKinnon 1994) but are no substitute for informed local knowledge and experience.

When selecting plants for use in stormwater treatment facilities, determining the overall diversity of selected plantings is an important consideration. For example, increased plant species diversity within an applied seed mix can improve the likelihood of meeting plant establishment objectives, since this increased diversity will result in a greater likelihood that one or more of the selected species is well adapted to the fluctuating and often unpredictable hydrologic conditions typically encountered within stormwater treatment facilities. However, increasing vegetative diversity can contribute to the diversity of habitats and therefore greater potential for a facility to attract wildlife. To limit the potential for a stormwater facility to attract wildlife, plant diversity should be limited to the greatest degree possible while still achieving high plant establishment rates. This can be achieved by thorough site assessment that accurately characterizes site conditions, plant selection that matches these conditions to specific plant capabilities, and site construction and maintenance care that maximize the success of plant establishment.

A-2. Recommended Plants for Airports Stormwater BMPs.

Tables A-1 and A-2 identify plants that are recommended for use in or around stormwater facilities at airports west and east of the Cascades, respectively. The common name, scientific name, plant structural type, maximum height and spread, and moisture requirements are summarized. The recommended species list for west of the Cascades (western Washington) is based primarily on information originally prepared for Sea-Tac International Airport (Port of Seattle 2007). The recommended species list for east of the Cascades (eastern Washington) is based on approved highway planting lists from WSDOT Eastern Region (WSDOT undated a,b,c,d,e) and Spokane County Public Works (Spokane County 1998).

A-2.1. Plant Moisture Requirements

Selecting vegetation appropriate for the expected moisture conditions is critical if the vegetation is expected to survive and provide benefits to a stormwater BMP. Because moisture regimes commonly vary within a given BMP, it is important that the designer be aware of the expected conditions and be prepared to select a variety of plants that will achieve stormwater treatment goals. For example, the upper slopes of a biofiltration swale will be much drier than the lower slopes and the swale bottom. An appropriate planting design will consider this and specify appropriate plants for each moisture zone. To aid the designer, the plant list tables include information on typical moisture requirements for the listed plants. Specific moisture requirements or zones include dry, moist, wet, saturated, and submerged. Many plant species are able to adapt across a range of moisture regimes. This has been noted wherever possible by including hyphenated categories such as dry–moist, which indicates that a given plant is comfortable in conditions ranging from dry to moist.

- **Dry:** A dry moisture regime is one in which soils are moist only during seasons of high precipitation (in general, winter and early spring). The rest of the year, the soils are very dry except for short periods of moisture provided by rare summer rains. Vegetation adapted to these conditions has a flush of growth in the spring, followed by a period of dormancy or semidormancy. Grasses tend to have rapid growth followed by seed production, after which their foliage dries out and appears to be dead. Deep-rooted trees and shrubs also have a spring flush of growth but are able to remain green throughout the summer by tapping deep soil moisture. Plants suitable for a dry moisture regime are appropriate for revegetating upland areas adjacent to stormwater facilities and many stormwater facilities in arid regions of the state east of the Cascades. These plants are also appropriate for the side slopes of infiltration ponds and detention ponds above the design water surface elevation. Grasses in this category would be suitable for vegetated filter strips (AR.12) or media filter drains (AR.14).

- **Moist:** A moist moisture regime has a consistent source of moisture available for plant growth throughout the growing season. Both shallow and deep-rooted plants are able to survive and actively grow even through periods of little or no precipitation. The soil surface is generally dry, with moisture evident 2 to 4 inches below the surface. Plants in the moist moisture zone category are appropriate for the bottom of continuous inflow biofiltration swales (AR.13) west of the Cascades. These plants are also suitable for the lower cell of detention ponds (AR.09) and infiltration ponds (AR.04) below the design water surface elevation.
- **Wet:** A wet moisture regime is constantly wet without a period of surface drying. It does, however, have aerobic soil conditions for at least part of the year. Plants in the wet moisture zone category are suitable for periodically inundated areas of constructed stormwater treatment wetlands or wet ponds. Note that newly constructed wetlands or wet ponds are not recommended for airports, but airports may have existing facilities with permanent wet pools.
- **Saturated:** A saturated moisture regime is one in which soils are at or exceeding their saturation point. A small pit excavated in the soil will fill with water. The surface is constantly wet but without permanent standing water that exceeds 1 inch in depth. Soils are generally anaerobic.
- **Submerged:** A submerged moisture regime has standing water the entire year. Plants in the submerged moisture zone category are suitable for permanent pool areas of constructed wetlands or wet ponds. Note that newly constructed wetlands or wet ponds are not recommended for airports, but airports may have existing facilities with permanent wet pools. Many aquatic plant species are also attractive to waterfowl as a food source.
- **Moist–wet:** Plants that can handle a range of conditions from wet to moist are appropriate for moist–wet regimes. Plants suitable for moist–wet conditions are recommended for flow-through facilities with

appropriate hydrologic conditions, such as the biofiltration swale below the design water surface (AR.13).

- **Moist–dry:** Plants that can handle seasonal conditions of moist soils yet survive a dry period are suitable for the moist–dry regimes. Plants suitable for moist-dry conditions are recommended for infiltration facilities, such as the bioinfiltration pond (AR.03) or infiltration pond (AR.04). These plants are also appropriate for the side slopes of biofiltration swales (AR.13) and the upper cell of detention ponds (AR.09) below the design water surface elevation. These plants may also be used in “live storage” areas of constructed wetlands or wet ponds subject to periodic inundation. Note that newly constructed wetlands or wet ponds are not recommended for airports, but airports may have existing facilities with permanent wet pools.

- **Moist–saturated:** Many wetland plants are able to handle a range of moisture, from moist to wet and saturated. Most of the plants that survive this range have physiological mechanisms to obtain oxygen during mid- to long-term anaerobic conditions.

- **Wet–saturated:** Plants in the wet–saturated moisture zone category are suitable for permanent pools of water in constructed stormwater treatment wetlands (HRM, RT.13) or wet ponds (HRM, RT.12). Note that new constructed wetlands or wet ponds are not recommended for airports, but airports may have existing facilities with permanent wet pools.

Tables A-1 and A-2 list the recommended plant species for use in or around airport stormwater facilities. The recommended plant lists are intended to serve only as a starting point for selection of plant species.

It is important to note that there are pronounced and extreme variations in climate, hydrology, and soil types east of the Cascades despite generally dry conditions. For this reason, it is critical that the designer consult with experienced vegetation specialists in eastern Washington including WSDOT staff, regional landscape architects, or the Roadside and Site Development Unit within the WSDOT headquarters Design Office with any questions related to vegetation, planting times, and methods, as well as for assistance in selecting the appropriate vegetation for stormwater BMPs.

A-3. Plants Not Recommended for Use on Airports

Table A-3 lists the plant species that are NOT appropriate for use in or around airport stormwater facilities. These plants are either known wildlife attractants, or have other characteristics undesirable in the airport environment. In general, plants with fruits, shoots, roots, seeds, tubers, roots, or other vegetative features that could provide wildlife forage or habitat should be avoided.

Table A-1. Recommended plants for airports west of the Cascades.

Native?	Genus	Species var.	Common Name	Plant Category and Type	Moisture Regime	Height (ft)	Spread (ft)	Notes
N	*Alisma*	*plantago-aquatica*	Water Plantain	Groundcover	Wet-Saturated	2.5-4	N/A	Wetland associate
	Alopecurus	*geniculatus*	Water Foxtail	Groundcover	Moist-Wet	1	1.5	Wetland associate
N	*Aster*	*subspicatus*	Douglas' Aster	Groundcover	Moist-Dry	0.6-2.5	N/A	
N	*Bromus*	*sitchensis*	Alaska Brome	Groundcover	Moist-Dry	1.5-6	N/A	
N	*Bromus*	*vulgaris*	Columbia Brome Grass	Groundcover	Moist-Dry	1.5-6	N/A	
N	*Carex*	*densa*	Dense Sedge	Groundcover	Moist	1–2	N/A	
N	*Carex*	*hendersonii*	Henderson Sedge	Groundcover	Moist	1–2	N/A	
N	*Carex*	*vesicaria*	Inflated Sedge	Groundcover	Moist	1–2	N/A	
N	*Carex*	*aperta*	Columbia Sedge	Groundcover	Moist-Wet	1–2	N/A	Wetland associate
N	*Carex*	*deweyana*	Dewey Sedge	Groundcover	Moist-Wet	0.7-4	N/A	Wetland associate
N	*Deschampsia*	*caespitosa*	Tufted Hairgrass	Groundcover	Moist-Dry	1–2	2	
N	*Eleocharis*	*acicularis*	Needle Spike-Rush	Groundcover	Moist	1–2	N/A	
N	*Eleocharis*	*ovata*	Ovate Spike Rush	Groundcover	Wet-Saturated	0.2-1.6	N/A	Wetland associate
N	*Eleocharis*	*palustris*	Creeping Spike Rush	Groundcover	Wet-Saturated	0.3-3.3	N/A	Wetland associate
	Epimedium x	*rubrum*	Bishop's Hat	Groundcover	Dry	2	1	
	Heuchera	*sanguinea*	Coral Bells	Groundcover	Dry	2	2	
N	*Iris*	*tenax*	Oregon Iris	Groundcover	Moist-Dry	1.3	N/A	
N	*Juncus*	*effusus*	Common/Soft Rush	Groundcover	Moist-Wet	2.5	2.5	Wetland associate
N	*Juncus*	*ensifolius*	Dagger-leaf Rush	Groundcover	Moist-Wet	0.5-2	N/A	Wetland associate
N	*Juncus*	*oxymeris*	Pointed Rush	Groundcover	Moist-Wet	1-2.5	N/A	Wetland associate
N	*Juncus*	*patens*	Grooved Rush; Spreading Rush	Groundcover	Moist-Wet	2	2	Wetland associate
N	*Juncus*	*tenuis*	Slender Rush	Groundcover	Moist-Saturated	0.5-2.3	N/A	Wetland associate
	Lavandula	*angustifolia*	Jean Davis; English Lavender	Groundcover	Dry	5	3	
N	*Lupinus*	*micranthus/polycarpus*	Small Flowered Lupine	Groundcover	Moist-Dry	0.3-1.5	N/A	
N	*Lupinus*	*polyphyllus*	Large-leaved Lupine	Groundcover	Moist-Wet	1.5-4	1-2.5	Wetland associate

Table A-1 (continued). Recommended plants for airports west of the Cascades.

Native?	Genus	Species var.	Common Name	Plant Category and Type	Moisture Regime	Height (ft)	Spread (ft)	Notes
	Ophiopogon	*planiscapus*	Nigrescens; Black Mondo Grass	Groundcover	Moist	1	1	Evergreen
N	*Scirpus*	*americanus*	Three-square or American Bulrush	Groundcover	Wet-Saturated	0.5-3.3	N/A	Wetland associate
N	*Scirpus*	*microcarpus*	Small-fruited Bulrush	Groundcover	Wet-Saturated	5	N/A	Wetland associate
N	*Scirpus*	*acutus*	Hardstem Bulrush	Groundcover	Wet-Saturated	3–9	N/A	Wetland associate
N	*Sisyrinchium*	*idahoense*	Blue-eyed Grass	Groundcover	Moist	0.5-2	0.5-2	
	Abeilia	*grandiflora*	Edward Goucher Abelia	Shrub	Dry	5	5	Evergreen
N	*Athyrium*	*felix-femina*	Lady Fern	Shrub	Moist	4	2–3	
	Ceanothus	*prostratus*	Mahala Mat	Shrub	Dry	<1	N/A	
N	*Ceanothus*	*sanguineus*	Redstem Ceanothus	Shrub	Moist-Dry	3–10	N/A	
	Cistusx purpureus		Orchid Rock Rose; Purple Rock Rose	Shrub	Dry	10	6	
	Cistus	*corbariensis (hybridus)*	White Rock Rose	Shrub	Dry	5	5	Evergreen
	Erica	*carnea*	Pink Heather; Springwood Pink	Shrub	Moist	1	3	Low shrub
	Escallonia	*langleyensis*	Apple Blossom Escallonia	Shrub	Dry	5	6	Evergreen
	Euonymus	*alatus compactus*	Winged Euonymus; Dwarf Burning Bush	Shrub	Dry	10	8	Deciduous
	Euonymus	*fortunei coloratus*	Wintercreeper Euonymus	Shrub	Dry	2	3	Evergreen
	Hydrangea	*quercifolia*	Oakleaf Hydrangea	Shrub	Dry	10	8	Deciduous
	Leucothoe	*axillaris*	Coast Leucothoe	Shrub	Moist	4	6	Evergreen
	Osmanthus	*delavayi*	Delavay Osmanthus	Shrub	Dry	10	10	
	Osmanthus	*heterophyllus (Variegatus)*	Variegated Holly Leaf Osmanthus	Shrub	Dry	10	8	Evergreen
	Pachysandra	*terminalis*	Japanese Spurge	Shrub	Dry	2	3	Evergreen
N	*Philadelphus*	*lewisii*	Mock Orange	Shrub	Dry	20	8	Deciduous
	Phyllodoce	spp.	Mountain Heath	Shrub	Moist	1	N/A	Low shrub
N	*Physocarpus*	*capitatus*	Pacific Ninebark	Shrub	Moist-Wet	8	8	
N	*Polystichum*	*munitum*	Western Sword Fern	Shrub	Dry	5	3	
N	*Rosa*	*gymnocarpa*	Baldhip Rose	Shrub	Moist	5	N/A	
N	*Rosa*	*nutkana*	Nootka Rose	Shrub	Moist	6	4	

Table A-1 (continued). Recommended plants for airports west of the Cascades.

Native?	Genus	Species var.	Common Name	Plant Category and Type	Moisture Regime	Height (ft)	Spread (ft)	Notes
N	*Rosa*	*piscocarpa*	Wild Clustered Rose	Shrub	Moist	10	N/A	
N	*Salix*	*lucida* (or *S. lasiandra*)	Pacific Willow	Shrub	Moist-Wet	40	N/A	Arboreal Shrub
N	*Salix*	*sessilifolia*	Soft leafed Willow	Shrub	Moist-Wet	40	N/A	Arboreal Shrub
N	*Salix*	*fluviatalis*	Columbia Willow	Shrub	Moist-Saturated	N/A	N/A	
N	*Salix*	*hookeriana*	Hookers Willow	Shrub	Moist-Saturated	20	N/A	
N	*Salix*	*scouleriana*	Scouler's Willow	Shrub	Moist	6–40	N/A	
N	*Salix*	*sitchensis*	Sitka Willow	Shrub	Moist-Saturated	3–25	N/A	
N	*Spiraea*	*betulifolia*	Shiny-leaf Spiraea	Shrub	Moist-Dry	2	N/A	
N	*Spiraea*	*douglasii*	Douglas Spirea	Shrub	Moist	3–6	3–6	
N	*Alnus*	*rubra*	Red Alder	Tree	Moist-Wet	45-50	20-30	Deciduous
N	*Arbutus*	*menziesii*	Madrone	Tree	Dry	20-100	N/A	Evergreen
	Betula	*jacquemontii*	Jacquemontii Birch	Tree	Moist	40+	N/A	Deciduous
N	*Betula*	*occidentalis*	Water Birch	Tree	Moist-Wet	40+	N/A	Deciduous
N	*Castanopsis*	*chrysopylla*	Chinquapin	Tree	Dry	25-45	20-25	Evergreen
	Ceanothus	*thyrisiflorus*	Victoria Ceanothus	Tree	Dry	9	12	Evergreen
	Cupressocyparis	*leylandii*	Leyland Cypress	Tree	Dry	40+	25	Evergreen
N	*Fraxinus*	*latifolia*	Oregon Ash	Tree	Moist-Wet	40-80	30-50	Deciduous
N	*Pinus*	var. *contorta*	Shore Pine	Tree	Dry	40+	N/A	Evergreen
N	*Pinus*	*monticola*	Western White Pine	Tree	Moist-Dry	60	20	Evergreen
	Thuja	*Occidentalis 'Emerald'*	Emerald Green Aborvitae	Tree	Moist	20	4	Evergreen
	Thuja	*Occidentalis 'Little Gem'*	Little Gem; Dwarf Aborvitae	Tree	Moist	5	3	Evergreen
N	*Tsuga*	*heterophylla*	Western Hemlock	Tree	Moist	70-130	20-30	Evergreen

Sources: Port of Seattle (2007) and City of Portland (2004).

Table A-2. Recommended plants for airports east of the Cascades.

Native?	Genus	Species var.	Common Name	Plant Category and Type	Moisture Regime	Height (ft)	Spread (ft)	Notes
	Achillea	*millefolium*	Common Yarrow	Groundcover	Dry	0.5-3	N/A	
N	*Balsamorhiza*	*sagittata*	Arrowleaf Balsamroot	Groundcover	Dry	N/A	N/A	
N	*Bromus*	*marginatus*	Mountain Brome	Groundcover	Dry-Moist	1.5-5	N/A	Grass
N	*Distichlis*	*Stricta/ spicata*	Inland Saltgrass	Groundcover	Wet-Saturated	0.5	N/A	
N	*Koeleria*	*cristata*	Prairie Junegrass	Groundcover	Dry	N/A	N/A	Grass
N	*Lupinus*	*sericeus*	Silky Lupine	Groundcover	Dry	1.5-2	1	
N	*Poa*	*sandbergii*	Sandberg Bluegrass	Groundcover	Moist-Wet	0.75	N/A	Grass
N	*Pseudoroegneria*	*spicata*	Bluebunch Wheatgrass	Groundcover	Dry	N/A	N/A	Grass
	Artemisia	*tridentata*	Big Sagebrush	Shrub	Dry	2–6	N/A	
N	*Ericameria Teretifolia*	*nauseosus*	Rubber Rabbitbrush	Shrub	Dry	6	3	
	Ericameria Nauseosa	*vicidiflorus*	Green Rabbitbrush	Shrub	Dry	3	4	
N	*Physocarpus*	*malvaceus*	Mallow Ninebark	Shrub	Moist	5	N/A	
N	*Purshia*	*tridentata*	Antelope Bitterbrush	Shrub	Dry	N/A	N/A	
N	*Salix*	*exigua*	Coyote Willow/ Narrowleaf Willow	Shrub	Moist-Saturated	20	N/A	
N	*Spiraea*	*douglasii*	Spirea	Shrub	Moist	6	N/A	Deciduous
N	*Betula*	*occidentalis*	Water Birch	Tree	Moist-Wet	40+	N/A	

Table A-3. Plant species identified as inappropriate for use in airport settings.

Native?	Genus	Species var.	Common Name
N	*Agropyron*	*smithii*	Western Wheatgrass
N	*Amelanchier*	*alnifolia*	Serviceberry
	Berberis	*thunbergii*	Atropurpurea Nana; Crimson Pygmy Barberry
	Betula	*pendula*	Weeping Birch
	Chamaecyparis	*lawsoniana*	Lawson Cypress
	Clematis	*ligusticfolia*	White Clematis
N	*Cornus*	*sericea (stolonifera)*	Redosier Dogwood
	Cornus	*alba elegantissima*	Elegantissima; Varigated Tatarian Dogwood
N	*Corylus*	*cornuta*	Hazel
	Cotoneaster	*adpressa praecox*	Early Cotoneaster
	Cotoneaster	*lucida*	Hedge Cotoneaster
	Cotoneaster	*horizontalis*	Rockspray Cotoneaster
	Eleagnus	*angustifolia*	Russian Olive
	Fagus	*grandifolia*	American Beech
	Fagus	*sylvatica*	Purple Beech
	Festuca	*ovina duriuscula*	Hard Fescue
	Festuca	*ovina L.*	Covar/Sheep Fescue
N	*Gaultheria*	*shallon*	Salal
	Hamamelis	*virginiana*	Witchhazel
	Hedera	*Helix*	English Ivy, Hahn's Ivy, Hahnii
N	*Holodiscus*	*discolor*	Oceanspray
	Lolium	*perenne L.*	Elka Perrenial Rye
N	*Mahonia*	*aquifolium*	Oregon Grape
N	*Mahonia*	*nervosa*	Longleaf Mahonia
N	*Mahonia*	*repens*	Creeping Mahonia
N	*Malus*	*ioensis*	Betchel Crabapple
	Oemleria	*cerasiformis*	Indian Plum
N	*Oplopanax*	*horridus*	Devil's Club
N	*Parthenocissus*	*quinquefolia*	Virginia Creeper
	Parthenocissus	*tricuspidata*	Vietchi Boston Ivy
	Poa	*compressa*	Reubens Canadian Bluegrass
	Populus	*nigra*	Theves Popular or Thevestina
N	*Populus*	*tremuloides*	Quaking Aspen
N	*Prunus*	*emarginata*	Bitter Cherry
	Prunus	*cerasifera*	Pissard Plum
	Prunus	*maackii*	Amur Choke Cherry
	Prunus	*padus commutata*	May Day Tree
	Prunus	*subhirtella*	Autumn Flowering Higan Cherry
	Prunus	*tomentosa*	Western Sand Cherry

Table A-3 (continued). Plant species identified as inappropriate for use in airport settings.

Native?	Genus	Species var.	Common Name
	Prunus	*triloba*	Flowering Almond
N	*Prunus*	*virginiana*	Shubert Choke Cherry
N	*Rhamnus*	*purshiana*	Cascara
	Rhododendron	Spp.	Rhodendron
	Rhus	*typhina*	Staghorn Sumac
N	*Ribes*	*aureum*	Golden Currant
N	*Ribes*	*cereum*	Wax Currant
	Ribes	*alpinum*	Alpine Currant
	Rosa	*foetida*	Austrian Brier Rose
	Rosa	*nitida*	Shining Rose
	Rosa	*rubrifolia*	Redleaf Rose
	Rosa	*spinosissima*	Burnett Rose
	Rubus	*calycinoides*	Blackberry
N	*Sambucus*	*ceruleum*	Blue Elderberry
N	*Symphoricarpos*	*albus*	Snowberry
N	*Vaccinium*	*ovatum*	Evergreen Huckleberry
	Viburnum	*plicatum tomentosum*	Marie's Double File viburnum
	Viburnum	*carlesii*	Korean spice Viburnum
	Viburnum	*lantana*	Wayfaring Tree
	Viburnum	*opulus*	European Highbush Cranberry

Sources: Port of Seattle (2007), Transport Canada (2004), Morin and Salisbury (2007), WSDOT (Undated ae), and Spokane County (1998).

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Appendix B – Detention and Infiltration Pond Design Analyses–Technical Documentation (Parametrix Technical Memorandum)

Parametrix
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M E M O R A N D U M

Date: **July 18, 2007 – Revised July 31, 2007**

To: **Mark Ewbank; Herrera**
Dave Felstul; Herrera

From: **Jenna Friebel**

Subject: **Detention and Infiltration Pond Design Analyses Technical Documentation**

cc: **Tom Atkins; Parametrix**
Paul Fendt; Parametrix
Joan Lee; Parametrix

Project Number: **558-2535-005 AZ.AZ4**

Project Name: **Airport Runoff Manual**

OVERVIEW

Many of the traditional methods for managing stormwater identified in the Washington State Department of Ecology (Ecology) 2005 Stormwater Management Manual for Western Washington (Ecology Manual), such as open ponds, attract wildlife that can pose a hazard for aircraft (Washington State Department of Transportation [WSDOT] Aviation 2006). However, airports in Washington are still required to manage stormwater runoff for new development and facility upgrades. This Technical Memorandum provides documentation on how the Western Washington Hydrology Model (WWHM) and the Ecology Manual were used to evaluate traditional detention and infiltration pond designs and develop recommendations for modifications to these designs resulting in the facilities being less of a wildlife attractant and more appropriate for use at airports.

DESIGN GUIDANCE

A number of operational and regulatory requirements determine how airports in the State of Washington must manage stormwater on their property. Ecology is the lead agency responsible for stormwater regulations in the state and has developed two stormwater management manuals (one for eastern Washington and one for western Washington), which include standards and criteria related to controlling the quality and quantity of stormwater runoff (Ecology 2004, 2005).

In addition, the Federal Aviation Administration (FAA) has developed the following recommendations for mitigation techniques to reduce wildlife hazards associated with existing stormwater facilities (FAA 2004). These mitigation techniques include the following:

- Modify stormwater detention ponds to allow a maximum 48-hour detention (ponding) period for the design storm.
- Use steep-sided, narrow, linear-shaped detention basins.

- Increase the depth of the facility and make it more linear to achieve capacity without increasing surface area.
- Use a two-chambered design if necessary, and design the pond with at least a ½ to 1 percent gradient from the upper to lower pond, making sure that the outlet/control structure is at the absolute lowest point.

To meet the mitigation techniques, the required modifications to the traditional methods for managing stormwater generally fell into two categories:

- Category 1 Modifications: Modifications in the first category are intended to minimize the duration and frequency of inundation of water to less than 48 hours. Hydrologic modeling was used to generate recommendations for modifications to detention and infiltration best management practices (BMPs) to help achieve this goal. The methods used for the hydrologic modeling and the associated results are documented in the following sections.

- Category 2 Modifications: The second category includes simple modifications to the physical geometry of the BMP to make it less likely to attract wildlife. These modifications did not require hydrologic or hydraulic analysis and are the same for both detention and infiltration BMPs. These modifications are included in the proposed BMP fact sheets and are not discussed further in this Technical Memorandum.

DETENTION POND HYDROLOGIC ANALYSIS

As discussed in the previous section, traditional detention ponds are considered a wildlife attractant. For verification, a hydrologic analysis was performed for a traditional detention pond (Step 1). Once it was verified that a traditional pond design is a wildlife attractant, a more detailed analysis was performed to modify the pond geometry to reduce the attractant potential (Step 2).

Step 1: Hydrologic Model to Evaluate Traditional Detention Pond Design

The WWHM and Ecology Manual (Ecology 2005) were used to design a traditional detention pond (Table 1; Attachment 1).

Table 1. Land Use for Traditional Pond Design

	Land Use (Acres on Till Soils)					
	Pre-Development			**Post-Development**		
	Forest	**Landscape**	**Impervious**	**Forest**	**Landscape**	**Impervious**
Pond 1	5.0	0.0	0.0	0.0	2.0	3.0

Once the pond was sized, the hourly volume information in the WWHM output files for the entire data set (50 years) was exported to excel. The duration of time in consecutive hours, that the pond had a volume greater than zero was calculated for each year. Based on output from WWHM, it was determined that Pond 1 had a volume of water greater than 0.0 for an average of 80 consecutive days per year (Attachment 1). It was assumed that the analysis performed on Pond 1 is representative of detention ponds designed for a variety of land-use conditions in western Washington. Therefore, it was assumed that all detention ponds sized to meet Ecology requirements would exceed the 48-hour maximum inundation criteria and would be considered a wildlife attractant.

Based on these results, Parametrix recommended that the traditional detention pond design be modified for use in the vicinity of an airport to reduce the risk of attracting hazardous wildlife.

Step 2: Recommended Detention Pond Modifications

The recommended detention pond modifications include designing the pond with two cells instead of the traditional one cell. The first cell (adjacent to the discharge structure) would be inundated frequently and for more than 48 hours; the second cell would be inundated less frequently and for less than 48 hours. Therefore, only the first cell would require additional wildlife deterrent such as wire grid or bird balls. This design approach minimizes installation and maintenance costs and still meets Ecology's stormwater management requirements and FAA's wildlife deterrent goals.

In order to recommend a size for the first cell of the pond, a return frequency analysis using WWHM was performed on the pond volume for four different land use scenarios (Table 2).

Table 2. Land Use for the Return Frequency Analysis

	Land Use (Acres on Till Soils)						
	Pre-Development			Post-Development			
	Forest	Landscape	Impervious	Forest	Landscape	Pasture	Impervious
Pond 1	5	0	0	0	2	0	3
Pond 2	4	0	0	0	3	0	1
Pond 3	10	0	0	0	2	2	6
Pond 4	40	10	0	5	15	0	30

The average daily pond volume was selected for this analysis because it is more representative of project goals, which are to reduce the area ponded for more than 48-hours and to minimize the area that required additional wildlife deterrent BMPs. The average daily pond volume for each year of record was calculated for each pond. This value was then ranked, the return frequency was determined using Weibull's equations, and the values were plotted (Figures 1 through 4) (Linsley et al. 1982).

Although the ponds represent a wide range of land uses, the results for each pond were consistent. Based on this analysis, the large, less frequent storm events accounted for most of the pond volume. Storms with a frequency of less than 5 years only accounted for between 13 and 21 percent of the total pond volume and storms with a 10-year return frequency accounted for between 16 and 29 percent of the total pond volume (see Figures 1 through 4). Therefore, it was recommended that the first cell of the pond be designed to have a volume that is 20 to 30 percent of the total pond volume[1]. To optimize this recommendation and calculate the actual time the second cell is inundated additional modeling would be required.

INFILTRATION POND ANALYSIS

As discussed in the previous section, traditional infiltration ponds may also be considered a wildlife attractant. To evaluate this, a hydrologic analysis was performed for a traditional infiltration pond using a variety of infiltration rates to determine if the pond meets the 48-hour drawdown time requirement. The Pond 1 land use (see Table 2) was used to size the infiltration facility. As shown in Table 3, the period of inundation varies depending on the infiltration rate selected.

---

[1] The Ecology Manual (or equivalent) should be used to determine the total pond volume and allowable discharge rates.

Table 3. Infiltration Pond Analysis Results

Results	Infiltration = 1.0 in/hr[a]	Infiltration = 0.5 in/hr[a]
Average days per year inundated	8.6	18.7
Maximum days per year inundated	13	26.8
Maximum consecutive hours of inundation	39	77
Number of years with greater than 48-hours inundation	0	6

[a] Safety factor of 4 applied per Section 3.3.6 Vol. 3 Ecology 2005

As shown in Table 3, the infiltration pond designed with an infiltration rate of 0.5 inch per hour results in a pond that exceeds the 48-hour maximum ponding period six times during the 50-year record time, and therefore would be considered a wildlife attractant. Based on these results, Parametrix recommends that airport infiltration ponds only be permitted at locations where the native underlying soils have an infiltration rate greater than 1.0 inch per hour[2].

[2] Infiltration rates should be determined using the guidance in the Ecology (or equivalent) Manual.

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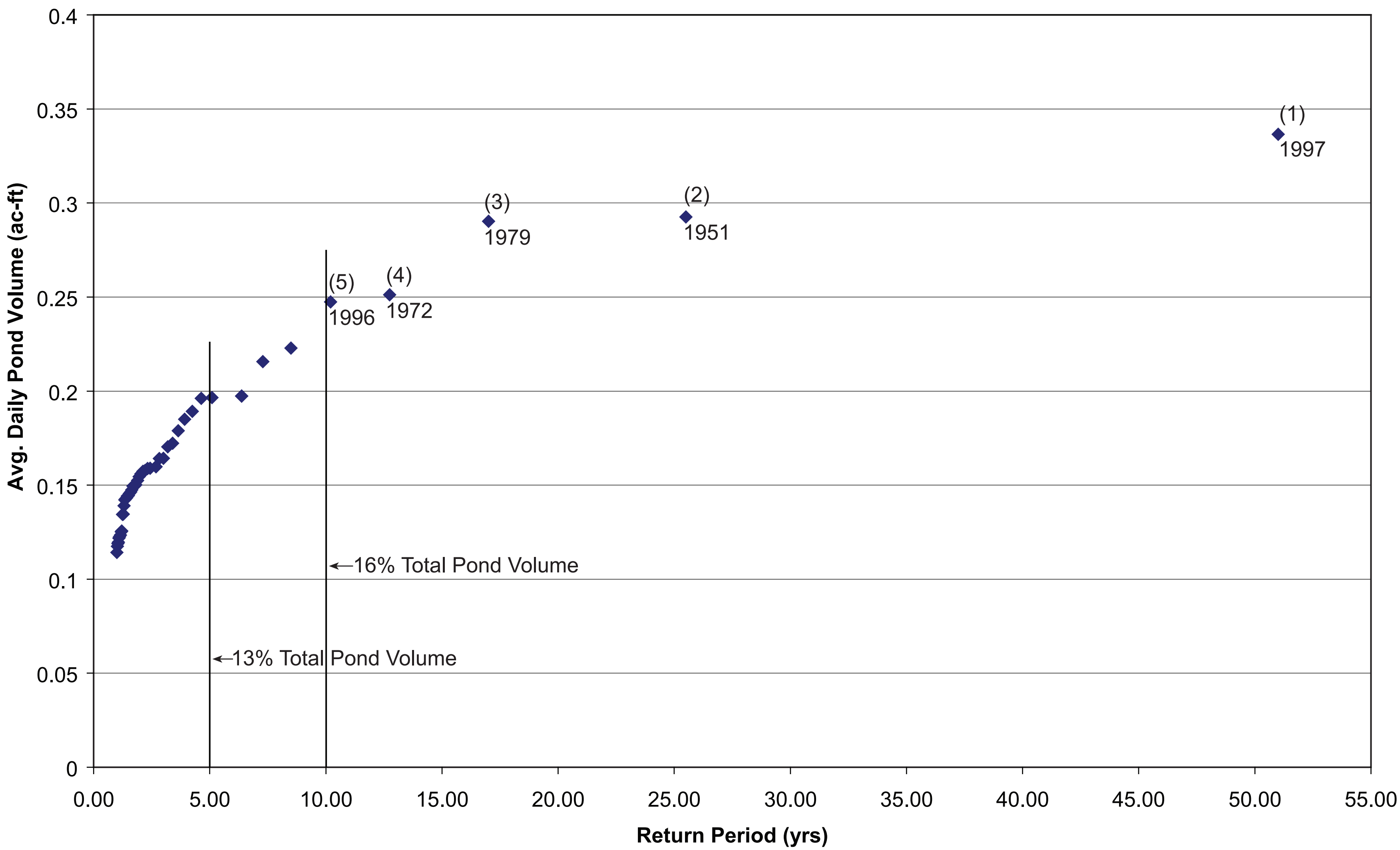
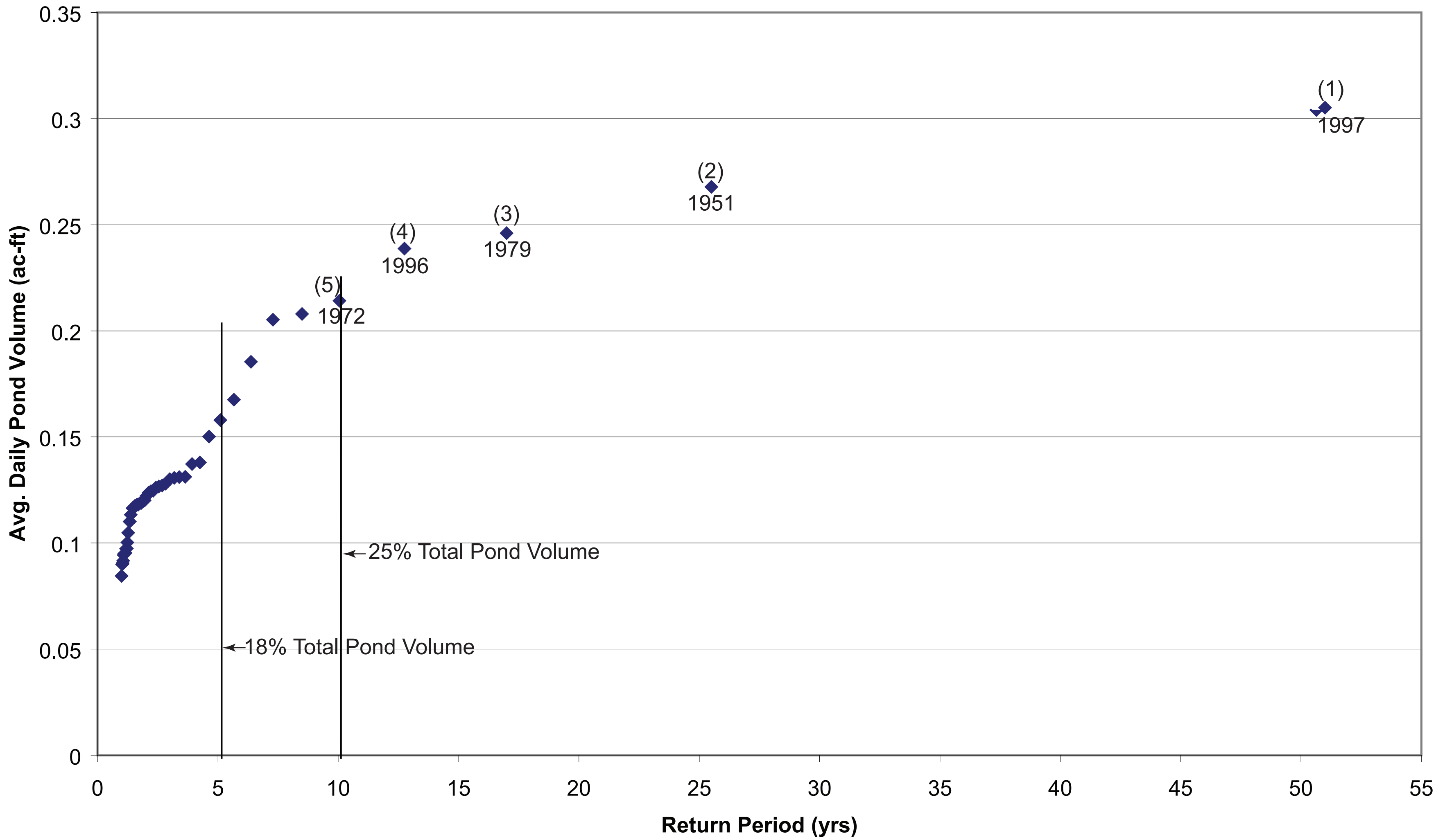
FIGURES



Parametrix 558-2535-005/AZ/AZ) 7/07 (B)

Figure 1
ARM Detention Pond 1
Return Frequency Analysis



Parametrix 558-2535-005/AZ/AZ) 7/07 (B)

Figure 2
ARM Detention Pond 2
Return Frequency Analysis

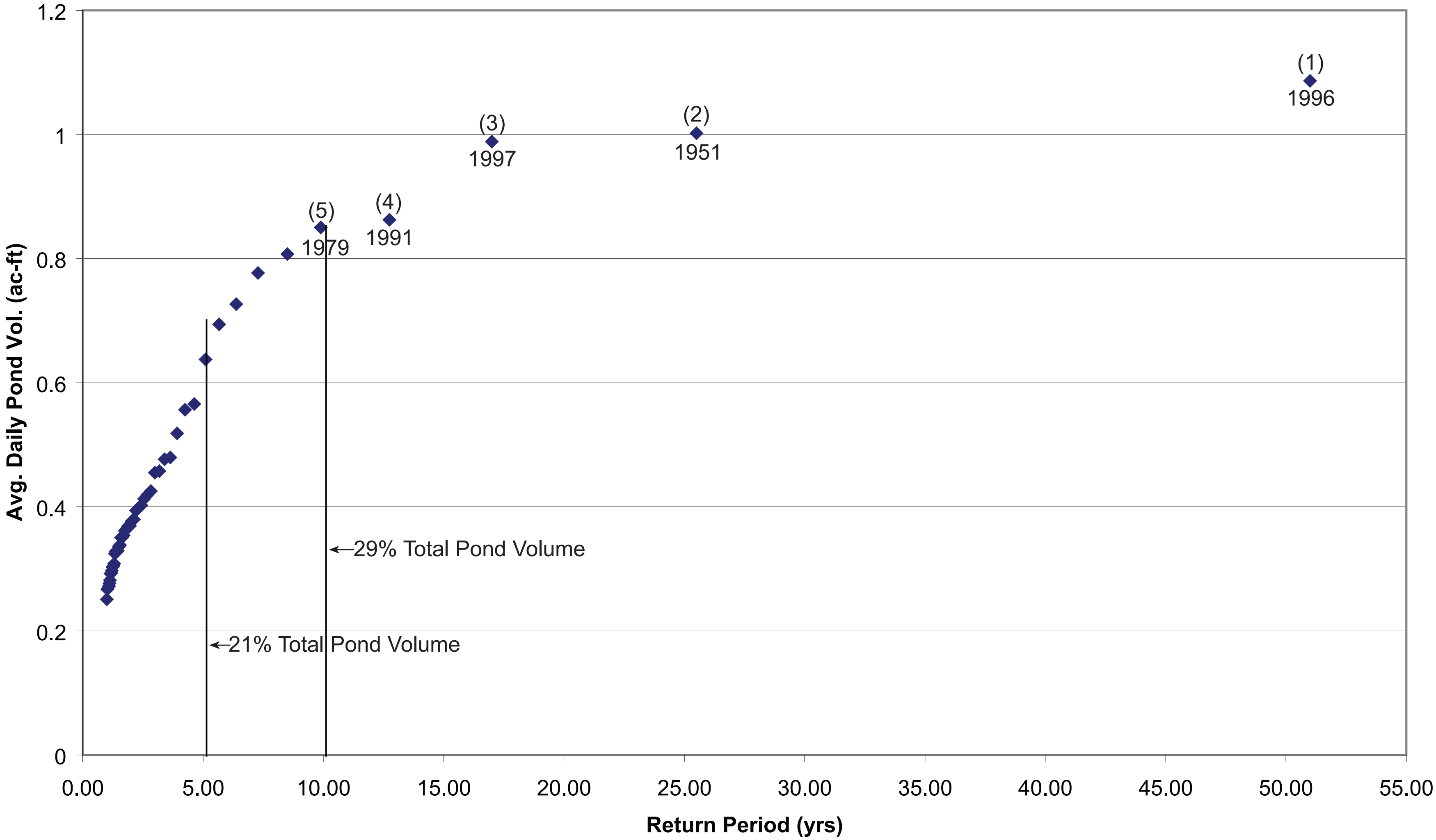


Figure 3
ARM Detention Pond 3
Return Frequency Analysis

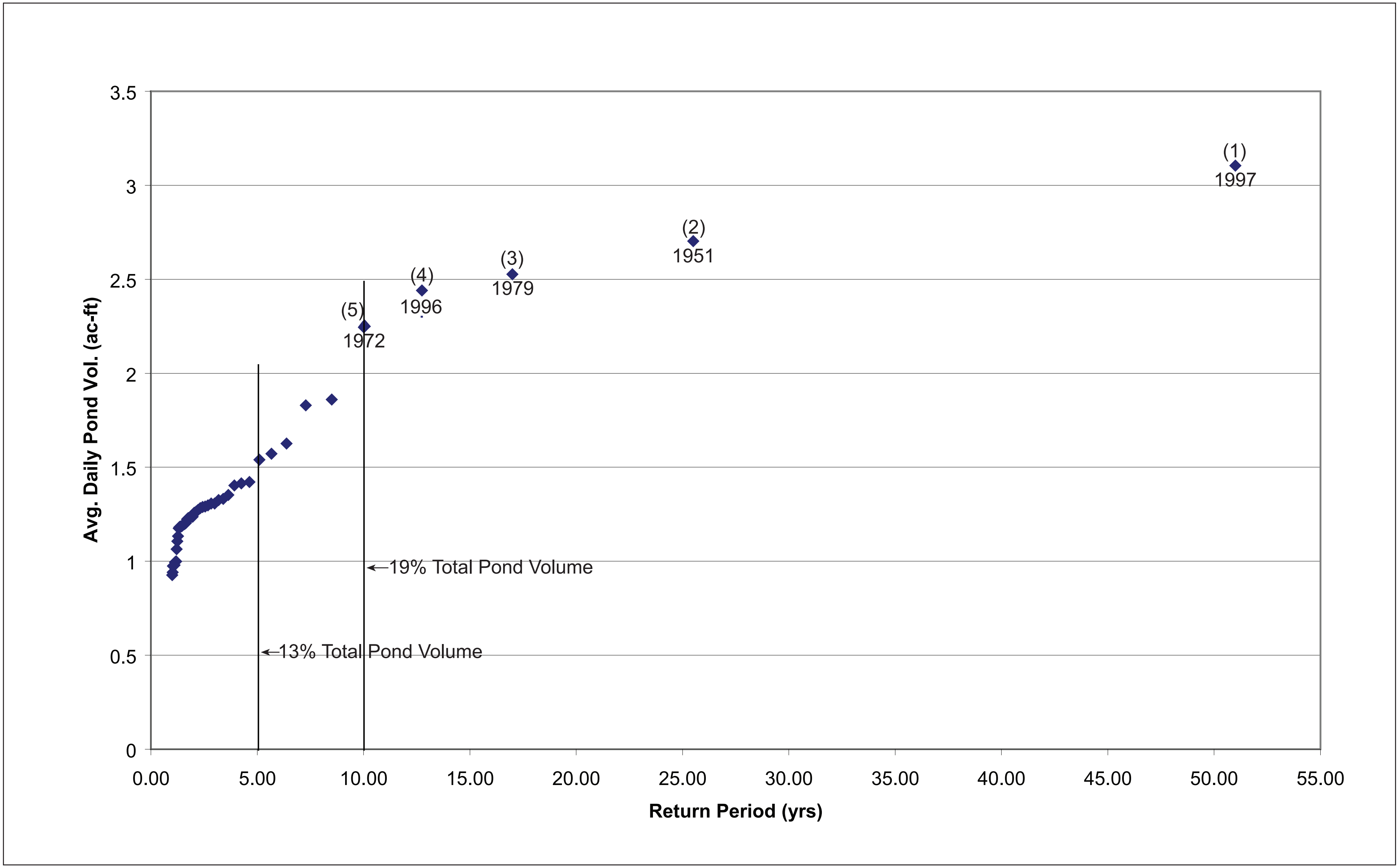


Figure 4
ARM Detention Pond 4
Return Frequency Analysis

ATTACHMENTS

POND TRIAL #1

ARMDET1.prj Detention Pond Design WWHM
Land Use predev = 5ac forest till
Land Use dev = 3ac Imp; 2ac landscape till
Infiltration rate = 0.0
L:W = 3:1; 160.8ft x 53.6ft x 6ft + 1 ft freeboard
ss=2:1

Total Pond Volume @ Riser =	1.57	ac-ft
Avg. Daily Pond Vol. Max	0.33	ac-ft
% of pnd volume	21%	

	Return Frequncy Volume		
	5-yr	**10-yr**	**max**
Avg. Daily Pond Volume (ac-ft)	0.20	0.25	0.34
% of Total Pond Volume	13%	16%	21%

POND TRIAL #2

ARMDET2.prj Detention Pond Design - WWHM
Land Use predev = 4ac forest till
Land Use dev = 1ac Imp; 3ac landscape till
Infiltration rate = 0.0
L:W = 3:1; 113.4 ft x 37.8 ft x 6 ft + 1 ft freeboard
ss=2:1

Total Pond Volume @ Riser =	0.87	ac-ft
Avg. Daily Pond Vol. Max	0.31	ac-ft
% of pnd volume	36%	

	Return Frequncy Volume		
	5-yr	**10-yr**	**max**
Pond Volume (ac-ft)	0.16	0.21	0.31
% of Total Pond Volume	18%	25%	35%

POND TRIAL #3

ARMDET3.prj Detention Pond Design - WWHM
Land Use predev = 10ac forest till
Land Use dev = 6ac Imp; 2ac landscape till; 2ac pasture till
Infiltration rate = 0.0
L:W = 3:1; 230.5 ft x 76.9 ft x 6 ft + 1 ft freeboard
ss=2:1

Total Pond Volume @ Riser =	2.98	ac-ft
Avg. Daily Pond Vol. Max	1.09	ac-ft
% of pnd volume	37%	

	Return Frequncy Volume		
	5-yr	**10-yr**	**max**
Pond Volume (ac-ft)	0.64	0.85	1.09
% of Total Pond Volume	21%	29%	37%

POND TRIAL #4

ARMDET4.prj Detention Pond Design - WWHM
Land Use predev = 40ac forest till; 10ac till grass
Land Use dev = 30ac Imp; 15ac grass till; 5ac forest
Infiltration rate = 0.0
L:W = 3:1; 485.7 ft x 161.9 ft x 6 ft + 1 ft freeboard
ss=2:1

Total Pond Volume @ Riser =	11.93	ac-ft
Avg. Daily Pond Vol. Max	3.10	ac-ft
% of pnd volume	26%	

	Return Frequncy Volume		
	5-yr	**10-yr**	**max**
Pond Volume (ac-ft)	1.54	2.24	3.10
% of Total Pond Volume	13%	19%	26%

WESTERN WASHINGTON HYDROLOGY MODEL V2
PROJECT REPORT

Project	Name:	ARMDET1				
Site	Address:					
City	:					
Report	Date	:		1/24/2007		
Gage	:	Seatac				
Data	Start	:		1948		
Data	End	:		1998		
Precip	Scale:		1.17			

PREDEVELC LAND USE

Basin	:	Basin		1		
Flows	To	:	Point	of	Compliance	
GroundWater	No					
Land	Use	Acres				
TILL	FOREST:		5			

DEVELOPEC LAND USE

Basin	:	Basin		1		
Flows	To	:	Pond		1	
GroundWater	No					
Land	Use	Acres				
TILL	GRASS:		2			
IMPERVIOUS	3					

RCHRES (POND) INFORMATION

Pond	Name:	Pond		1		
Pond	Type:	Trapezoidal	Pond			
Pond	Flows	to	:	Point	of	Compliance
Pond	Rain	/	Evap	is	not	activated.
Dimensions						
Depth:	7ft.					
Bottom	Length:	160.81ft.				
Bottom	Width	:	53.64ft.			
Side	slope	1:00		2	To	1

Side	slope		2:00	2	To	1	
Side	slope		3:00	2	To	1	
Side	slope		4:00	2	To	1	
Volume	at	Riser	Head:			1.569	acre-ft.
Discharge	Structure						
Riser	Height:		6	ft.			
Riser	Diameter:		18	in.			
NotchType	:	Rectangular					
Notch	Width	:		0.034	ft.		
Notch	Height:		2.338	ft.			
Orifice	1	Diameter:		1.307	in.	Elevati	0 ft.

Pond Stage(ft)	Hydraulic Area(acr)	Table Volume(acr-ft)	Dschrg(cfs)	Infilt(cfs)
0.00	0.20	0.00	0.00	0
0.08	0.20	0.02	0.01	0
0.16	0.20	0.03	0.02	0
0.23	0.20	0.05	0.02	0
0.31	0.20	0.06	0.03	0
0.39	0.21	0.08	0.03	0
0.47	0.21	0.10	0.03	0
0.54	0.21	0.11	0.03	0
0.62	0.21	0.13	0.04	0
0.70	0.21	0.14	0.04	0
0.78	0.21	0.16	0.04	0
0.86	0.22	0.18	0.04	0
0.93	0.22	0.19	0.04	0
1.01	0.22	0.21	0.05	0
1.09	0.22	0.23	0.05	0
1.17	0.22	0.25	0.05	0
1.24	0.22	0.26	0.05	0
1.32	0.23	0.28	0.05	0
1.40	0.23	0.297	0.05	0
1.48	0.23	0.315	0.06	0
1.56	0.23	0.33	0.06	0
1.63	0.23	0.35	0.06	0
1.71	0.23	0.37	0.06	0
1.79	0.23	0.39	0.06	0
1.87	0.24	0.41	0.06	0
1.94	0.24	0.42	0.06	0
2.02	0.24	0.44	0.06	0
2.10	0.24	0.46	0.07	0
2.18	0.24	0.48	0.07	0
2.26	0.24	0.50	0.07	0
2.33	0.25	0.52	0.07	0
2.41	0.25	0.54	0.07	0
2.49	0.25	0.56	0.07	0
2.57	0.25	0.58	0.07	0
2.64	0.25	0.60	0.07	0
2.72	0.25	0.61	0.07	0
2.80	0.26	0.63	0.075	0
2.88	0.26	0.65	0.076	0

2.96	0.26	0.67	0.077	0	
3.03	0.26	0.70	0.078	0	
3.11	0.26	0.72	0.079	0	
3.19	0.27	0.74	0.080	0	
3.27	0.27	0.76	0.081	0	
3.34	0.27	0.78	0.082	0	
3.42	0.27	0.80	0.083	0	
3.50	**0.27**	**0.82**	**0.084**	**0**	50% of Predev Q2yr
3.58	0.27	0.84	0.09	0	
3.66	0.28	0.86	0.09	0	
3.73	0.28	0.88	0.09	0	
3.81	0.28	0.90	0.09	0	
3.89	0.28	0.93	0.10	0	
3.97	0.28	0.95	0.11	0	
4.04	0.28	0.97	0.12	0	
4.12	0.29	0.99	0.12	0	
4.20	0.29	1.01	0.13	0	
4.28	0.29	1.04	0.14	0	
4.36	0.29	1.06	0.15	0	
4.43	0.29	1.08	0.16	0	
4.51	**0.29**	**1.11**	**0.17**	**0**	Predev Q2yr
4.59	0.30	1.13	0.18	0	
4.67	0.30	1.15	0.19	0	
4.74	0.30	1.17	0.20	0	
4.82	0.30	1.20	0.21	0	
4.90	0.30	1.22	0.23	0	
4.98	0.31	1.25	0.24	0	
5.06	0.31	1.27	0.25	0	
5.13	0.31	1.29	0.27	0	
5.21	0.31	1.32	0.28	0	
5.29	0.31	1.34	0.29	0	
5.37	0.31	1.37	0.31	0	
5.44	**0.32**	**1.39**	**0.32**	**0**	Predev Q10yr
5.52	0.32	1.41	0.34	0	
5.60	0.32	1.44	0.35	0	
5.68	0.32	1.46	0.37	0	
5.76	0.32	1.49	0.38	0	
5.83	0.33	1.51	0.40	0	
5.91	0.33	1.54	0.42	0	
5.99	0.33	1.57	0.43	0	
6.07	0.33	1.59	0.69	0	
6.14	0.33	1.62	1.24	0	
6.22	0.34	1.64	1.97	0	
6.30	0.34	1.67	2.84	0	
6.38	0.34	1.70	3.83	0	
6.46	0.34	1.72	4.93	0	
6.53	0.34	1.75	6.13	0	
6.61	0.34	1.78	7.42	0	
6.69	0.35	1.80	8.80	0	
6.77	0.35	1.83	10.25	0	
6.84	0.35	1.86	11.78	0	
6.92	0.35	1.88	13.38	0	

7.00	0.35	1.91	15.05	0

ANALYSIS RESULTS

Flow Return	Frequency Period	Return Flow(cfs)	Predeveloped	
2	year	0.17		0.0859835
5	year	0.27		
10	year	0.33		
25	year	0.42		
50	year	0.48		
100	year	0.54		

Flow Return	Frequency Period	Return Flow(cfs)	Developed Mitigated
2	year	0.08	
5	year	0.10	
10	year	0.12	
25	year	0.14	
50	year	0.16	
100	year	0.17	

Yearly Peaks for

Year	Predeveloped	Developed
1949	0.20	0.07
1950	0.42	0.08
1951	0.40	0.16
1952	0.13	0.06
1953	0.11	0.08
1954	0.15	0.07
1955	0.25	0.07
1956	0.23	0.11
1957	0.20	0.07
1958	0.18	0.08
1959	0.15	0.07
1960	0.29	0.12
1961	0.15	0.08
1962	0.10	0.06
1963	0.14	0.08
1964	0.15	0.08
1965	0.13	0.09
1966	0.13	0.08
1967	0.26	0.08
1968	0.15	0.07
1969	0.16	0.07
1970	0.14	0.08
1971	0.14	0.08
1972	0.33	0.13

1973	0.14	0.09
1974	0.15	0.08
1975	0.26	0.07
1976	0.15	0.07
1977	0.03	0.06
1978	0.14	0.08
1979	0.08	0.06
1980	0.22	0.15
1981	0.12	0.08
1982	0.30	0.09
1983	0.19	0.08
1984	0.12	0.06
1985	0.07	0.06
1986	0.32	0.08
1987	0.29	0.10
1988	0.12	0.07
1989	0.07	0.06
1990	0.46	0.11
1991	0.38	0.11
1992	0.14	0.08
1993	0.15	0.06
1994	0.05	0.06
1995	0.20	0.08
1996	0.38	0.14
1997	0.36	0.19
1998	0.10	0.06

Ranked Yearly Peaks for Predevelope and Developed-Mitigated

Rank	Predeveloped	Developed
1	0.4244	0.1564
2	0.3978	0.1496
3	0.3807	0.1373
4	0.3778	0.1313
5	0.362	0.115
6	0.3298	0.1134
7	0.3176	0.1092
8	0.2956	0.1055
9	0.2942	0.1005
10	0.293	0.0931
11	0.2597	0.0927
12	0.2548	0.0877
13	0.2479	0.0837
14	0.2258	0.0836
15	0.2164	0.0819
16	0.1977	0.0814
17	0.1957	0.0812
18	0.1953	0.0809
19	0.1916	0.0803
20	0.1806	0.0803
21	0.159	0.0798
22	0.1543	0.0786

23	0.1538	0.0774
24	0.1503	0.0772
25	0.1502	0.0766
26	0.1492	0.0761
27	0.147	0.0756
28	0.1467	0.0755
29	0.1464	0.0748
30	0.1421	0.0736
31	0.141	0.0734
32	0.1408	0.073
33	0.1389	0.0729
34	0.1388	0.072
35	0.1385	0.0697
36	0.133	0.0688
37	0.1288	0.0684
38	0.1262	0.0683
39	0.1242	0.068
40	0.1226	0.0639
41	0.116	0.0634
42	0.1078	0.0632
43	0.0956	0.062
44	0.0949	0.0616
45	0.0781	0.0614
46	0.069	0.0611
47	0.0682	0.0597
48	0.0481	0.0566
49	0.0328	0.0548

1/2 2-year to the 50-year

Flow(CFS)	Predev	Final	Percentage	Pass/Fail
0.086	4286	3855	89	Pass
0.09	3859	2793	72	Pass
0.0939	3501	2459	70	Pass
0.0979	3186	2169	68	Pass
0.1019	2928	1978	67	Pass
0.1058	2679	1799	67	Pass
0.1098	2426	1651	68	Pass
0.1138	2217	1517	68	Pass
0.1177	2045	1395	68	Pass
0.1217	1897	1293	68	Pass
0.1257	1732	1209	69	Pass
0.1297	1581	1142	72	Pass
0.1336	1457	1065	73	Pass
0.1376	1355	994	73	Pass
0.1416	1247	933	74	Pass
0.1455	1156	873	75	Pass
0.1495	1071	823	76	Pass
0.1535	1005	771	76	Pass
0.1574	931	723	77	Pass
0.1614	868	683	78	Pass

0.1654	813	650	79	Pass
0.1694	758	611	80	Pass
0.1733	708	572	80	Pass
0.1773	665	529	79	Pass
0.1813	623	498	79	Pass
0.1852	583	472	80	Pass
0.1892	554	437	78	Pass
0.1932	511	409	80	Pass
0.1971	473	397	83	Pass
0.2011	439	373	84	Pass
0.2051	408	352	86	Pass
0.2091	386	339	87	Pass
0.213	368	323	87	Pass
0.217	349	314	89	Pass
0.221	330	304	92	Pass
0.2249	309	293	94	Pass
0.2289	283	278	98	Pass
0.2329	264	270	102	Pass
0.2368	252	254	100	Pass
0.2408	235	238	101	Pass
0.2448	224	224	100	Pass
0.2488	211	213	100	Pass
0.2527	202	195	96	Pass
0.2567	192	176	91	Pass
0.2607	183	162	88	Pass
0.2646	174	150	86	Pass
0.2686	167	134	80	Pass
0.2726	160	124	77	Pass
0.2765	151	113	74	Pass
0.2805	138	103	74	Pass
0.2845	129	93	72	Pass
0.2885	119	81	68	Pass
0.2924	112	76	67	Pass
0.2964	99	68	68	Pass
0.3004	92	66	71	Pass
0.3043	82	60	73	Pass
0.3083	76	57	75	Pass
0.3123	67	52	77	Pass
0.3162	64	45	70	Pass
0.3202	56	42	75	Pass
0.3242	54	34	62	Pass
0.3282	49	32	65	Pass
0.3321	41	30	73	Pass
0.3361	37	29	78	Pass
0.3401	33	26	78	Pass
0.344	31	24	77	Pass
0.348	27	23	85	Pass
0.352	26	23	88	Pass
0.3559	24	20	83	Pass
0.3599	21	17	80	Pass
0.3639	19	15	78	Pass
0.3679	19	11	57	Pass

0.3718	18	10	55	Pass
0.3758	14	8	57	Pass
0.3798	10	8	80	Pass
0.3837	8	6	75	Pass
0.3877	8	4	50	Pass
0.3917	6	3	50	Pass
0.3956	6	2	33	Pass
0.3996	5	0	0	Pass
0.4036	5	0	0	Pass
0.4076	5	0	0	Pass
0.4115	5	0	0	Pass
0.4155	5	0	0	Pass
0.4195	4	0	0	Pass
0.4234	4	0	0	Pass
0.4274	3	0	0	Pass
0.4314	3	0	0	Pass
0.4353	2	0	0	Pass
0.4393	2	0	0	Pass
0.4433	2	0	0	Pass
0.4473	2	0	0	Pass
0.4512	2	0	0	Pass
0.4552	1	0	0	Pass
0.4592	0	0	0	Pass
0.4631	0	0	0	Pass
0.4671	0	0	0	Pass
0.4711	0	0	0	Pass
0.475	0	0	0	Pass
0.479	0	0	0	Pass

WESTERN WASHINGTON HYDROLOGY MODEL V2
PROJECT REPORT

Project Name: ARMDET2
Site Address:
City :
Report Date : 1/24/2007
Gage : Seatac
Data Start : 1948
Data End : 1998
Precip Scale: 1.17

PREDEVELOPED LAND USE

Basin : Basin 1
Flows To : Point of Compliance
GroundWater: No

Land Use	Acres
TILL FOREST:	4

DEVELOPED LAND USE
Basin : Basin 1
Flows To : Pond 1
GroundWater: No

Land Use	Acres
TILL GRASS:	3
IMPERVIOUS:	1

RCHRES (POND) INFORMATION
Pond Name: Pond 1
Pond Type: Trapezoidal Pond
Pond Flows to : Point of Compliance
Pond Rain / Evap is not activated.
Dimensions
Depth: 7ft.
Bottom Length: 113.36ft.
Bottom Width : 37.8ft.
Side slope 1: 2 To 1

Side slope 2: 2 To 1
Side slope 3: 2 To 1
Side slope 4: 2 To 1
Volume at Riser Head: 0.867 acre-ft.
Discharge Structure
Riser Height: 6 ft.
Riser Diameter: 18 in.
NotchType : Rectangular
Notch Width : 0.012 ft.
Notch Height: 2.301 ft.
Orifice 1 Diameter: 1.166 in. Elevation: 0 ft.

Pond Hydraulic Table

Stage(ft)	Area(acr)	Volume(acr-ft)	Dschrg(cfs)	Infilt(cfs)
0.00	0.10	0.00	0.00	0.00
0.08	0.10	0.01	0.01	0.00
0.16	0.10	0.02	0.01	0.00
0.23	0.10	0.02	0.02	0.00
0.31	0.10	0.03	0.02	0.00
0.39	0.10	0.04	0.02	0.00
0.47	0.11	0.05	0.02	0.00
0.54	0.11	0.06	0.03	0.00
0.62	0.11	0.06	0.03	0.00
0.70	0.11	0.07	0.03	0.00
0.78	0.11	0.08	0.03	0.00
0.86	0.11	0.09	0.03	0.00
0.93	0.11	0.10	0.03	0.00
1.01	0.11	0.11	0.04	0.00
1.09	0.11	0.12	0.04	0.00
1.17	0.12	0.12	0.04	0.00
1.24	0.12	0.13	0.04	0.00
1.32	0.12	0.14	0.04	0.00
1.40	0.12	0.15	0.04	0.00
1.48	0.12	0.16	0.04	0.00
1.56	0.12	0.17	0.05	0.00
1.63	0.12	0.18	0.05	0.00
1.71	0.12	0.19	0.05	0.00
1.79	0.12	0.20	0.05	0.00
1.87	0.13	0.21	0.05	0.00
1.94	0.13	0.22	0.05	0.00
2.02	0.13	0.23	0.05	0.00
2.10	0.13	0.24	0.05	0.00
2.18	0.13	0.25	0.05	0.00
2.26	0.13	0.26	0.05	0.00
2.33	0.13	0.27	0.06	0.00
2.41	0.13	0.28	0.06	0.00
2.49	0.14	0.29	0.06	0.00
2.57	0.14	0.30	0.06	0.00
2.64	0.14	0.31	0.06	0.00
2.72	0.14	0.32	0.06	0.00
2.80	0.14	0.33	0.06	0.00
2.88	0.14	0.34	0.06	0.00

2.96	0.14	0.36	0.06	0.00	
3.03	0.14	0.37	0.06	0.00	
3.11	0.15	0.38	0.06	0.00	
3.19	0.15	0.39	0.06	0.00	
3.27	0.15	0.40	0.065	0.00	
3.34	0.15	0.41	0.065	0.00	
3.42	0.15	0.42	0.066	0.00	
3.50	0.15	0.44	0.067	0.00	
3.58	0.15	0.45	0.068	0.00	
3.66	0.15	0.46	0.068	0.00	
3.73	0.16	0.47	0.069	0.00	
3.81	**0.16**	**0.48**	**0.071**	**0.00**	**50% 2-year Predev Q2**
3.89	0.16	0.50	0.074	0.00	
3.97	0.16	0.51	0.08	0.00	
4.04	0.16	0.52	0.08	0.00	
4.12	0.16	0.53	0.08	0.00	
4.20	0.16	0.55	0.09	0.00	
4.28	0.16	0.56	0.09	0.00	
4.36	0.17	0.57	0.09	0.00	
4.43	0.17	0.58	0.10	0.00	
4.51	0.17	0.60	0.10	0.00	
4.59	0.17	0.61	0.10	0.00	
4.67	0.17	0.62	0.11	0.00	
4.74	0.17	0.64	0.11	0.00	
4.82	0.17	0.65	0.12	0.00	
4.90	0.18	0.66	0.12	0.00	
4.98	0.18	0.68	0.13	0.00	
5.06	0.18	0.69	0.13	0.00	
5.13	0.18	0.70	0.136	0.00	
5.21	**0.18**	**0.72**	**0.141**	**0.00**	**2-yr Predev Q**
5.29	0.18	0.73	0.15	0.00	
5.37	0.18	0.75	0.15	0.00	
5.44	0.19	0.76	0.16	0.00	
5.52	0.19	0.78	0.16	0.00	
5.60	0.19	0.79	0.17	0.00	
5.68	0.19	0.81	0.17	0.00	
5.76	0.19	0.82	0.18	0.00	
5.83	0.19	0.83	0.19	0.00	
5.91	0.19	0.85	0.19	0.00	
5.99	0.20	0.86	0.20	0.00	
6.07	0.20	0.88	0.45	0.00	
6.14	0.20	0.90	1.00	0.00	
6.22	0.20	0.91	1.73	0.00	
6.30	0.20	0.93	2.60	0.00	
6.38	0.20	0.94	3.59	0.00	
6.46	0.20	0.96	4.69	0.00	
6.53	0.21	0.97	5.89	0.00	
6.61	0.21	0.99	7.18	0.00	
6.69	0.21	1.01	8.56	0.00	
6.77	0.21	1.02	10.01	0.00	
6.84	0.21	1.04	11.54	0.00	
6.92	0.21	1.05	13.14	0.00	

7.00	0.21	1.07	14.81	0.00

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped

Return Period	Flow(cfs)	
2	year	0.14
5	year	0.22
10	year	0.27
25	year	0.33
50	year	0.38
100	year	0.43

Flow Frequency Return Periods for Developed Mitigated

Return Period	Flow(cfs)	
2	year	0.06
5	year	0.08
10	year	0.10
25	year	0.12
50	year	0.14
100	year	0.16

Yearly Peaks for Predeveloped and Developed-Mitigated

Year	Predeveloped	Developed
1949	0.16	0.05
1950	0.34	0.07
1951	0.32	0.14
1952	0.11	0.05
1953	0.09	0.06
1954	0.12	0.06
1955	0.20	0.06
1956	0.18	0.08
1957	0.16	0.06
1958	0.15	0.06
1959	0.12	0.05
1960	0.23	0.11
1961	0.12	0.07
1962	0.08	0.05
1963	0.11	0.06
1964	0.12	0.06
1965	0.10	0.07
1966	0.10	0.06
1967	0.21	0.06
1968	0.12	0.06
1969	0.13	0.06
1970	0.11	0.06
1971	0.11	0.06
1972	0.26	0.11
1973	0.11	0.07
1974	0.12	0.06
1975	0.20	0.06

1976	0.12	0.06
1977	0.03	0.04
1978	0.11	0.06
1979	0.06	0.04
1980	0.17	0.13
1981	0.10	0.06
1982	0.24	0.08
1983	0.15	0.06
1984	0.10	0.05
1985	0.06	0.05
1986	0.25	0.07
1987	0.24	0.09
1988	0.09	0.05
1989	0.06	0.05
1990	0.37	0.10
1991	0.30	0.09
1992	0.11	0.07
1993	0.12	0.05
1994	0.04	0.04
1995	0.16	0.07
1996	0.31	0.13
1997	0.29	0.16
1998	0.08	0.05

Ranked Yearly Peaks for Predeveloped and Developed-Mitigated

Rank	Predeveloped	Developed
1	0.34	0.14
2	0.32	0.13
3	0.30	0.13
4	0.30	0.11
5	0.29	0.11
6	0.26	0.10
7	0.25	0.09
8	0.24	0.09
9	0.24	0.08
10	0.23	0.08
11	0.21	0.07
12	0.20	0.07
13	0.20	0.07
14	0.18	0.07
15	0.17	0.07
16	0.16	0.07
17	0.16	0.07
18	0.16	0.06
19	0.15	0.06
20	0.14	0.06
21	0.13	0.06
22	0.12	0.06
23	0.12	0.06
24	0.12	0.06
25	0.12	0.06

26	0.12	0.06
27	0.12	0.06
28	0.12	0.06
29	0.12	0.06
30	0.11	0.06
31	0.11	0.06
32	0.11	0.06
33	0.11	0.06
34	0.11	0.06
35	0.11	0.06
36	0.11	0.06
37	0.10	0.05
38	0.10	0.05
39	0.10	0.05
40	0.10	0.05
41	0.09	0.05
42	0.09	0.05
43	0.08	0.05
44	0.08	0.05
45	0.06	0.05
46	0.06	0.05
47	0.05	0.04
48	0.04	0.04
49	0.03	0.04

1/2 2 year to 50 year

Flow(CFS)	Predev	Final	Percentage	Pass/Fail
0.0688	4286	4093	95.0	Pass
0.0720	3883	3331	85.0	Pass
0.0751	3432	2760	80.0	Pass
0.0783	3155	2430	77.0	Pass
0.0815	2911	2131	73.0	Pass
0.0847	2679	1861	69.0	Pass
0.0878	2441	1681	68.0	Pass
0.0910	2182	1451	66.0	Pass
0.0942	2025	1319	65.0	Pass
0.0974	1885	1213	64.0	Pass
0.1005	1732	1116	64.0	Pass
0.1037	1590	1039	65.0	Pass
0.1069	1473	956	64.0	Pass
0.1101	1335	853	63.0	Pass
0.1133	1237	781	63.0	Pass
0.1164	1156	740	64.0	Pass
0.1196	1075	705	65.0	Pass
0.1228	1010	659	65.0	Pass
0.1260	946	620	65.0	Pass
0.1291	864	565	65.0	Pass
0.1323	813	524	64.0	Pass
0.1355	760	468	61.0	Pass
0.1387	717	438	61.0	Pass
0.1418	668	409	61.0	Pass

0.1450	622	359	57.0	Pass
0.1482	583	344	59.0	Pass
0.1514	556	325	58.0	Pass
0.1545	517	311	60.0	Pass
0.1577	480	292	60.0	Pass
0.1609	447	276	61.0	Pass
0.1641	408	250	61.0	Pass
0.1672	389	228	58.0	Pass
0.1704	372	201	54.0	Pass
0.1736	348	176	50.0	Pass
0.1768	330	151	45.0	Pass
0.1799	310	131	42.0	Pass
0.1831	278	115	41.0	Pass
0.1863	263	101	38.0	Pass
0.1895	251	87	34.0	Pass
0.1927	235	67	28.0	Pass
0.1958	224	49	21.0	Pass
0.1990	209	31	14.0	Pass
0.2022	201	29	14.0	Pass
0.2054	192	28	14.0	Pass
0.2085	183	27	14.0	Pass
0.2117	175	25	14.0	Pass
0.2149	169	24	14.0	Pass
0.2181	159	21	13.0	Pass
0.2212	149	21	14.0	Pass
0.2244	138	21	15.0	Pass
0.2276	129	20	15.0	Pass
0.2308	120	19	15.0	Pass
0.2339	113	19	16.0	Pass
0.2371	98	19	19.0	Pass
0.2403	92	18	19.0	Pass
0.2435	82	17	20.0	Pass
0.2466	76	17	22.0	Pass
0.2498	68	16	23.0	Pass
0.2530	66	15	22.0	Pass
0.2562	56	14	25.0	Pass
0.2593	54	12	22.0	Pass
0.2625	49	11	22.0	Pass
0.2657	41	11	26.0	Pass
0.2689	39	11	28.0	Pass
0.2721	33	10	30.0	Pass
0.2752	31	10	32.0	Pass
0.2784	29	10	34.0	Pass
0.2816	26	9	34.0	Pass
0.2848	24	9	37.0	Pass
0.2879	21	9	42.0	Pass
0.2911	19	7	36.0	Pass
0.2943	19	7	36.0	Pass
0.2975	17	6	35.0	Pass
0.3006	14	6	42.0	Pass
0.3038	10	6	60.0	Pass
0.3070	8	6	75.0	Pass

0.3102	8	5	62.0	Pass
0.3133	6	5	83.0	Pass
0.3165	6	5	83.0	Pass
0.3197	5	5	100.0	Pass
0.3229	5	5	100.0	Pass
0.3260	5	5	100.0	Pass
0.3292	5	4	80.0	Pass
0.3324	5	4	80.0	Pass
0.3356	4	4	100.0	Pass
0.3387	4	4	100.0	Pass
0.3419	3	3	100.0	Pass
0.3451	3	2	66.0	Pass
0.3483	2	2	100.0	Pass
0.3515	2	2	100.0	Pass
0.3546	2	2	100.0	Pass
0.3578	2	2	100.0	Pass
0.3610	2	2	100.0	Pass
0.3642	1	0	.0	Pass
0.3673	0	0	.0	Pass
0.3705	0	0	.0	Pass
0.3737	0	0	.0	Pass
0.3769	0	0	.0	Pass
0.3800	0	0	.0	Pass
0.3832	0	0	.0	Pass

WESTERN WASHINGTON HYDROLOGY MODEL V2
PROJECT REPORT

Project Name: ARMDET3
Site Address:
City :
Report Date : 1/24/2007
Gage : Seatac
Data Start : 1948
Data End : 1998
Precip Scale: 1.17

PREDEVELOPED LAND USE

Basin : Basin 1
Flows To : Point of Compliance
GroundWater: No

Land Use	Acres
TILL FOREST:	10

DEVELOPED LAND USE
Basin : Basin 1
Flows To : Pond 1
GroundWater: No

Land Use	Acres
TILL PASTURE:	2
TILL GRASS:	2
IMPERVIOUS:	6

RCHRES (POND) INFORMATION
Pond Name: Pond 1
Pond Type: Trapezoidal Pond
Pond Flows to : Point of Compliance
Pond Rain / Evap is not activated.
Dimensions
Depth: 7ft.
Bottom Length: 230.55ft.
Bottom Width : 76.85ft.

Side slope 1: 2 To 1
Side slope 2: 2 To 1
Side slope 3: 2 To 1
Side slope 4: 2 To 1
Volume at Riser Head: 2.975 acre-ft.
Discharge Structure
Riser Height: 6 ft.
Riser Diameter: 18 in.
NotchType : Rectangular
Notch Width : 0.035 ft.
Notch Height: 2.498 ft.
Orifice 1 Diameter: 1.87 in. Elevation: 0 ft.

Pond Hydraulic Table

Stage(ft)	Area(acr)	Volume(acr-ft)	Dschrg(cfs)	Infilt(cfs)
0.0	0.41	0.00	0.00	0.00
0.1	0.41	0.03	0.03	0.00
0.2	0.41	0.06	0.04	0.00
0.2	0.41	0.10	0.04	0.00
0.3	0.42	0.13	0.05	0.00
0.4	0.42	0.16	0.06	0.00
0.5	0.42	0.19	0.06	0.00
0.5	0.42	0.23	0.07	0.00
0.6	0.42	0.26	0.07	0.00
0.7	0.43	0.29	0.08	0.00
0.8	0.43	0.33	0.08	0.00
0.9	0.43	0.36	0.09	0.00
0.9	0.43	0.39	0.09	0.00
1.0	0.44	0.43	0.09	0.00
1.1	0.44	0.46	0.10	0.00
1.2	0.44	0.49	0.10	0.00
1.2	0.44	0.53	0.10	0.00
1.3	0.45	0.56	0.11	0.00
1.4	0.45	0.60	0.11	0.00
1.5	0.45	0.63	0.11	0.00
1.6	0.45	0.67	0.12	0.00
1.6	0.45	0.70	0.12	0.00
1.7	0.46	0.74	0.12	0.00
1.8	0.46	0.77	0.12	0.00
1.9	0.46	0.81	0.13	0.00
1.9	0.46	0.85	0.13	0.00
2.0	0.47	0.88	0.13	0.00
2.1	0.47	0.92	0.13	0.00
2.2	0.47	0.95	0.14	0.00
2.3	0.47	0.99	0.14	0.00
2.3	0.48	1.03	0.14	0.00
2.4	0.48	1.06	0.14	0.00
2.5	0.48	1.10	0.15	0.00
2.6	0.48	1.14	0.15	0.00
2.6	0.48	1.18	0.15	0.00
2.7	0.49	1.21	0.15	0.00
2.8	0.49	1.25	0.15	0.00

2.9	0.49	1.29	0.16	0.00	
3.0	0.49	1.33	0.16	0.00	
3.0	0.50	1.37	0.16	0.00	
3.1	0.50	1.41	0.16	0.00	
3.2	0.50	1.45	0.16	0.00	
3.3	0.50	1.48	0.166	0.00	
3.3	0.51	1.52	0.168	0.00	
3.4	**0.51**	**1.56**	**0.170**	**0.00**	**50% 2-yr Predev Q**
3.5	0.51	1.60	0.172	0.00	
3.6	0.51	1.64	0.18	0.00	
3.7	0.52	1.68	0.18	0.00	
3.7	0.52	1.72	0.19	0.00	
3.8	0.52	1.76	0.20	0.00	
3.9	0.52	1.80	0.21	0.00	
4.0	0.52	1.84	0.22	0.00	
4.0	0.53	1.88	0.23	0.00	
4.1	0.53	1.93	0.24	0.00	
4.2	0.53	1.97	0.25	0.00	
4.3	0.53	2.01	0.26	0.00	
4.4	0.54	2.05	0.27	0.00	
4.4	0.54	2.09	0.28	0.00	
4.5	0.54	2.13	0.29	0.00	
4.6	0.54	2.18	0.30	0.00	
4.7	0.55	2.22	0.32	0.00	
4.7	0.55	2.26	0.33	0.00	
4.8	**0.55**	**2.30**	**0.34**	**0.00**	**2-yr Predev Q**
4.9	0.55	2.35	0.36	0.00	
5.0	0.56	2.39	0.37	0.00	
5.1	0.56	2.43	0.39	0.00	
5.1	0.56	2.48	0.40	0.00	
5.2	0.56	2.52	0.42	0.00	
5.3	0.57	2.56	0.43	0.00	
5.4	0.57	2.61	0.45	0.00	
5.4	0.57	2.65	0.47	0.00	
5.5	0.57	2.70	0.48	0.00	
5.6	0.58	2.74	0.50	0.00	
5.7	0.58	2.79	0.52	0.00	
5.8	0.58	2.83	0.54	0.00	
5.8	0.58	2.88	0.55	0.00	
5.9	0.59	2.92	0.57	0.00	
6.0	**0.59**	**2.97**	**0.59**	**0.00**	**10-yr Predev Q**
6.1	0.59	3.01	0.85	0.00	
6.1	0.59	3.06	1.40	0.00	
6.2	0.60	3.11	2.13	0.00	
6.3	0.60	3.15	3.00	0.00	
6.4	0.60	3.20	3.99	0.00	
6.5	0.60	3.25	5.09	0.00	
6.5	0.61	3.29	6.29	0.00	
6.6	0.61	3.34	7.58	0.00	
6.7	0.61	3.39	8.96	0.00	
6.8	0.62	3.44	10.41	0.00	
6.8	0.62	3.48	11.94	0.00	

6.9	0.62	3.53	13.55	0.00
7.0	0.62	3.58	15.22	0.00

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped

Return Period		Flow(cfs)
2	year	0.34
5	year	0.54
10	year	0.67
25	year	0.84
50	year	0.96
100	year	1.08

Flow Frequency Return Periods for Developed Mitigated

Return Period		Flow(cfs)
2	year	0.16
5	year	0.21
10	year	0.25
25	year	0.30
50	year	0.34
100	year	0.38

Yearly Peaks for Predeveloped and Developed-Mitigated

Year	Predeveloped	Developed
1949	0.40	0.14
1950	0.85	0.16
1951	0.80	0.34
1952	0.27	0.12
1953	0.22	0.16
1954	0.30	0.15
1955	0.50	0.14
1956	0.45	0.21
1957	0.39	0.15
1958	0.36	0.16
1959	0.29	0.14
1960	0.59	0.24
1961	0.29	0.17
1962	0.19	0.12
1963	0.28	0.15
1964	0.30	0.16
1965	0.26	0.18
1966	0.25	0.15
1967	0.52	0.16
1968	0.31	0.15
1969	0.32	0.15
1970	0.28	0.16
1971	0.28	0.15

1972	0.66	0.29
1973	0.28	0.19
1974	0.30	0.15
1975	0.51	0.14
1976	0.31	0.15
1977	0.07	0.12
1978	0.28	0.16
1979	0.16	0.11
1980	0.43	0.32
1981	0.25	0.15
1982	0.59	0.19
1983	0.38	0.15
1984	0.25	0.12
1985	0.14	0.13
1986	0.64	0.16
1987	0.59	0.21
1988	0.23	0.13
1989	0.14	0.12
1990	0.92	0.25
1991	0.76	0.22
1992	0.28	0.16
1993	0.29	0.12
1994	0.10	0.11
1995	0.39	0.17
1996	0.76	0.31
1997	0.72	0.41
1998	0.19	0.13

Ranked Yearly Peaks for Predeveloped and Developed-Mitigated

Rank	Predeveloped	Developed
1	0.8488	0.3433
2	0.7955	0.3218
3	0.7614	0.3052
4	0.7556	0.2862
5	0.7240	0.2454
6	0.6595	0.2431
7	0.6352	0.2237
8	0.5912	0.2128
9	0.5885	0.2070
10	0.5859	0.1870
11	0.5195	0.1854
12	0.5096	0.1775
13	0.4959	0.1678
14	0.4516	0.1670
15	0.4327	0.1636
16	0.3953	0.1635
17	0.3914	0.1628
18	0.3907	0.1619
19	0.3831	0.1614
20	0.3612	0.1607
21	0.3180	0.1569

22	0.3086	0.1568
23	0.3076	0.1563
24	0.3006	0.1544
25	0.3004	0.1535
26	0.2984	0.1535
27	0.2941	0.1517
28	0.2934	0.1514
29	0.2927	0.1484
30	0.2842	0.1475
31	0.2820	0.1471
32	0.2816	0.1471
33	0.2779	0.1470
34	0.2777	0.1455
35	0.2771	0.1418
36	0.2660	0.1372
37	0.2577	0.1371
38	0.2524	0.1366
39	0.2484	0.1330
40	0.2452	0.1255
41	0.2321	0.1248
42	0.2157	0.1244
43	0.1913	0.1242
44	0.1899	0.1233
45	0.1561	0.1225
46	0.1380	0.1210
47	0.1365	0.1203
48	0.0961	0.1134
49	0.0656	0.1094

1/2 2 year to 50 year

Flow(CFS)	Predev	Final	Percentage	Pass/Fail
0.1720	4231	3839	90.0	Pass
0.1799	3812	3000	78.0	Pass
0.1878	3457	2563	74.0	Pass
0.1958	3155	2228	70.0	Pass
0.2037	2899	1969	67.0	Pass
0.2117	2641	1760	66.0	Pass
0.2196	2396	1570	65.0	Pass
0.2275	2194	1433	65.0	Pass
0.2355	2025	1314	64.0	Pass
0.2434	1876	1202	64.0	Pass
0.2514	1714	1095	63.0	Pass
0.2593	1565	1000	63.0	Pass
0.2672	1440	917	63.0	Pass
0.2752	1335	839	62.0	Pass
0.2831	1229	772	62.0	Pass
0.2911	1144	718	62.0	Pass
0.2990	1065	650	61.0	Pass
0.3069	1005	613	60.0	Pass
0.3149	931	579	62.0	Pass
0.3228	868	548	63.0	Pass

0.3308	813	520	63.0	Pass
0.3387	758	491	64.0	Pass
0.3466	708	464	65.0	Pass
0.3546	665	439	66.0	Pass
0.3625	623	418	67.0	Pass
0.3705	583	386	66.0	Pass
0.3784	554	356	64.0	Pass
0.3863	511	333	65.0	Pass
0.3943	473	312	65.0	Pass
0.4022	439	287	65.0	Pass
0.4102	408	266	65.0	Pass
0.4181	386	247	63.0	Pass
0.4260	368	231	62.0	Pass
0.4340	346	209	60.0	Pass
0.4419	329	195	59.0	Pass
0.4499	307	177	57.0	Pass
0.4578	280	159	56.0	Pass
0.4657	263	146	55.0	Pass
0.4737	251	132	52.0	Pass
0.4816	234	113	48.0	Pass
0.4896	223	96	43.0	Pass
0.4975	209	81	38.0	Pass
0.5054	201	72	35.0	Pass
0.5134	190	59	31.0	Pass
0.5213	182	51	28.0	Pass
0.5293	173	45	26.0	Pass
0.5372	166	36	21.0	Pass
0.5451	159	30	18.0	Pass
0.5531	145	24	16.0	Pass
0.5610	138	22	15.0	Pass
0.5690	129	18	13.0	Pass
0.5769	119	15	12.0	Pass
0.5848	112	12	10.0	Pass
0.5928	99	10	10.0	Pass
0.6007	92	9	9.0	Pass
0.6087	82	9	10.0	Pass
0.6166	76	9	11.0	Pass
0.6245	67	9	13.0	Pass
0.6325	64	8	12.0	Pass
0.6404	56	7	12.0	Pass
0.6484	54	7	12.0	Pass
0.6563	49	7	14.0	Pass
0.6642	41	7	17.0	Pass
0.6722	37	7	18.0	Pass
0.6801	33	7	21.0	Pass
0.6881	31	6	19.0	Pass
0.6960	27	6	22.0	Pass
0.7039	26	6	23.0	Pass
0.7119	23	6	26.0	Pass
0.7198	21	5	23.0	Pass
0.7278	19	5	26.0	Pass
0.7357	19	3	15.0	Pass

0.7436	17	3	17.0	Pass
0.7516	14	3	21.0	Pass
0.7595	10	3	30.0	Pass
0.7675	8	3	37.0	Pass
0.7754	8	3	37.0	Pass
0.7833	6	3	50.0	Pass
0.7913	6	3	50.0	Pass
0.7992	5	3	60.0	Pass
0.8072	5	2	40.0	Pass
0.8151	5	2	40.0	Pass
0.8230	5	2	40.0	Pass
0.8310	5	2	40.0	Pass
0.8389	4	2	50.0	Pass
0.8469	4	1	25.0	Pass
0.8548	3	0	.0	Pass
0.8627	3	0	.0	Pass
0.8707	2	0	.0	Pass
0.8786	2	0	.0	Pass
0.8866	2	0	.0	Pass
0.8945	2	0	.0	Pass
0.9024	2	0	.0	Pass
0.9104	1	0	.0	Pass
0.9183	0	0	.0	Pass
0.9263	0	0	.0	Pass
0.9342	0	0	.0	Pass
0.9421	0	0	.0	Pass
0.9501	0	0	.0	Pass
0.9580	0	0	.0	Pass

WESTERN WASHINGTON HYDROLOGY MODEL V2
PROJECT REPORT

Project Name: armdet4
Site Address:
City :
Report Date : 1/30/2007
Gage : Seatac
Data Start : 1948
Data End : 1998
Precip Scale: 1.00

PREDEVELOPED LAND USE

Basin : Basin 1
Flows To : Point of Compliance
GroundWater: No

Land Use	Acres
TILL FOREST:	40
TILL GRASS:	10

DEVELOPED LAND USE
Basin : Basin 1
Flows To : DET4
GroundWater: No

Land Use	Acres
TILL FOREST:	5
TILL GRASS:	15
IMPERVIOUS:	30

RCHRES (POND) INFORMATION
Pond Name: DET4
Pond Type: Trapezoidal Pond
Pond Flows to : Point of Compliance
Pond Rain / Evap is not activated.
Dimensions
Depth: 7ft.
Bottom Length: 485.68ft.

Bottom Width : 161.92ft.
Side slope 1: 2 To 1
Side slope 2: 2 To 1
Side slope 3: 2 To 1
Side slope 4: 2 To 1
Volume at Riser Head: 11.929 acre-ft.
Discharge Structure
Riser Height: 6 ft.
Riser Diameter: 18 in.
NotchType : Rectangular
Notch Width : 0.226 ft.
Notch Height: 2.462 ft.
Orifice 1 Diameter: 3.824 in. Elevation: 0 ft.

Pond Hydraulic Table

Stage(ft)	Area(acr)	Volume(acr-ft)	Dschrg(cfs)	Infilt(cfs)
0.000	1.805	0.000	0.000	0.000
0.078	1.810	0.141	0.107	0.000
0.156	1.815	0.282	0.151	0.000
0.233	1.819	0.423	0.186	0.000
0.311	1.824	0.565	0.214	0.000
0.389	1.829	0.707	0.240	0.000
0.467	1.833	0.849	0.262	0.000
0.544	1.838	0.992	0.283	0.000
0.622	1.843	1.135	0.303	0.000
0.700	1.847	1.278	0.321	0.000
0.778	1.852	1.422	0.339	0.000
0.856	1.857	1.566	0.355	0.000
0.933	1.861	1.711	0.371	0.000
1.011	1.866	1.856	0.386	0.000
1.089	1.871	2.001	0.401	0.000
1.167	1.875	2.147	0.415	0.000
1.244	1.880	2.293	0.428	0.000
1.322	1.885	2.439	0.442	0.000
1.400	1.889	2.586	0.454	0.000
1.478	1.894	2.733	0.467	0.000
1.556	1.899	2.881	0.479	0.000
1.633	1.903	3.029	0.491	0.000
1.711	1.908	3.177	0.502	0.000
1.789	1.913	3.325	0.514	0.000
1.867	1.918	3.474	0.525	0.000
1.944	1.922	3.624	0.536	0.000
2.022	1.927	3.773	0.546	0.000
2.100	1.932	3.924	0.557	0.000
2.178	1.937	4.074	0.567	0.000
2.256	1.941	4.225	0.577	0.000
2.333	1.946	4.376	0.587	0.000
2.411	1.951	4.527	0.596	0.000
2.489	1.956	4.679	0.606	0.000
2.567	1.960	4.832	0.615	0.000
2.644	1.965	4.984	0.625	0.000
2.722	1.970	5.137	0.634	0.000

2.800	1.975	5.291	0.643	0.000
2.878	1.980	5.445	0.652	0.000
2.956	1.984	5.599	0.660	0.000
3.033	1.989	5.753	0.669	0.000
3.111	1.994	5.908	0.677	0.000
3.189	1.999	6.063	0.686	0.000
3.267	2.004	6.219	0.694	0.000
3.344	2.008	6.375	0.702	0.000
3.422	2.013	6.531	0.710	0.000
3.500	2.018	6.688	0.719	0.000
3.578	2.023	6.845	0.732	0.000
3.656	2.028	7.003	0.764	0.000
3.733	2.032	7.161	0.804	0.000
3.811	2.037	7.319	0.851	0.000
3.889	2.042	7.478	0.903	0.000
3.967	2.047	7.637	0.958	0.000
4.044	2.052	7.796	1.016	0.000
4.122	2.057	7.956	1.077	0.000
4.200	2.062	8.116	1.139	0.000
4.278	2.066	8.277	1.203	0.000
4.356	2.071	8.438	1.267	0.000
4.433	2.076	8.599	1.332	0.000
4.511	2.081	8.760	1.398	0.000
4.589	2.086	8.923	1.472	0.000
4.667	2.091	9.085	1.552	0.000
4.744	2.096	9.248	1.635	0.000
4.822	2.101	9.411	1.720	0.000
4.900	2.106	9.575	1.808	0.000
4.978	2.110	9.739	1.898	0.000
5.056	2.115	9.903	1.990	0.000
5.133	2.120	10.07	2.084	0.000
5.211	2.125	10.23	2.181	0.000
5.289	2.130	10.40	2.279	0.000
5.367	2.135	10.56	2.380	0.000
5.444	2.140	10.73	2.483	0.000
5.522	2.145	10.90	2.587	0.000
5.600	2.150	11.06	2.693	0.000
5.678	2.155	11.23	2.802	0.000
5.756	2.160	11.40	2.912	0.000
5.833	2.165	11.57	3.023	0.000
5.911	2.170	11.74	3.137	0.000
5.989	2.175	11.90	3.252	0.000
6.067	2.180	12.07	3.526	0.000
6.144	2.185	12.24	4.082	0.000
6.222	2.190	12.41	4.817	0.000
6.300	2.195	12.58	5.693	0.000
6.378	2.200	12.76	6.690	0.000
6.456	2.205	12.93	7.796	0.000
6.533	2.210	13.10	9.000	0.000
6.611	2.215	13.27	10.29	0.000
6.689	2.220	13.44	11.67	0.000
6.767	2.225	13.62	13.13	0.000

6.844	2.230	13.79	14.67	0.000
6.922	2.235	13.96	16.28	0.000
7.000	2.240	14.14	17.95	0.000

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped

Return Period	Flow(cfs)
2 year	1.445288
5 year	2.324012
10 year	2.931093
25 year	3.709506
50 year	4.291359
100 year	4.871527

Flow Frequency Return Periods for Developed Mitigated

Return Period	Flow(cfs)
2 year	0.650784
5 year	0.855746
10 year	1.008362
25 year	1.221237
50 year	1.394998
100 year	1.582343

Yearly Peaks for Predeveloped and Developed-Mitigated

Year	Predeveloped	Developed
1949	1.763	0.562
1950	4.139	0.673
1951	3.342	1.453
1952	1.154	0.507
1953	0.868	0.648
1954	1.215	0.601
1955	2.083	0.577
1956	2.023	0.877
1957	1.708	0.592
1958	1.468	0.639
1959	1.212	0.563
1960	2.341	0.965
1961	1.219	0.681
1962	0.747	0.493
1963	1.139	0.629
1964	1.296	0.664
1965	0.987	0.712
1966	1.116	0.609
1967	2.354	0.665
1968	1.334	0.602
1969	1.334	0.604
1970	1.178	0.644

1971	1.125	0.618
1972	2.911	1.199
1973	1.148	0.733
1974	1.272	0.632
1975	2.287	0.560
1976	1.326	0.602
1977	0.277	0.489
1978	1.153	0.659
1979	0.614	0.459
1980	1.725	1.323
1981	1.084	0.619
1982	2.514	0.722
1983	1.612	0.627
1984	1.116	0.500
1985	0.550	0.512
1986	2.700	0.670
1987	2.446	0.827
1988	0.907	0.546
1989	0.533	0.508
1990	4.169	0.971
1991	3.504	0.896
1992	1.214	0.667
1993	1.192	0.499
1994	0.345	0.441
1995	1.637	0.691
1996	3.333	1.268
1997	2.946	1.767
1998	0.703	0.513

Ranked Yearly Peaks for Predeveloped and Developed-Mitigated

Rank	Predeveloped	Developed
1	4.1395	1.4527
2	3.5043	1.3234
3	3.3425	1.2678
4	3.3335	1.1987
5	2.9461	0.9713
6	2.9106	0.9651
7	2.6998	0.8956
8	2.5139	0.8768
9	2.4456	0.8271
10	2.3543	0.7333
11	2.3414	0.7222
12	2.2866	0.7118
13	2.0828	0.6914
14	2.0231	0.6811
15	1.7632	0.6735
16	1.7250	0.6695
17	1.7082	0.6669
18	1.6370	0.6648
19	1.6117	0.6641
20	1.4681	0.6586

21	1.3344	0.6477
22	1.3341	0.6444
23	1.3263	0.6394
24	1.2965	0.6320
25	1.2722	0.6287
26	1.2191	0.6273
27	1.2147	0.6188
28	1.2141	0.6179
29	1.2118	0.6094
30	1.1923	0.6041
31	1.1784	0.6025
32	1.1540	0.6024
33	1.1535	0.6013
34	1.1475	0.5919
35	1.1388	0.5772
36	1.1249	0.5627
37	1.1158	0.5616
38	1.1157	0.5595
39	1.0842	0.5458
40	0.9874	0.5125
41	0.9066	0.5117
42	0.8679	0.5079
43	0.7470	0.5074
44	0.7034	0.5002
45	0.6144	0.4988
46	0.5496	0.4929
47	0.5334	0.4885
48	0.3451	0.4594
49	0.2774	0.4408

1/2 2 year to 50 year

Flow(CFS)	Predev	Final	Percentage	Pass/Fail
0.7226	3659	3265	89.0	Pass
0.7587	3312	2632	79.0	Pass
0.7947	3005	2273	75.0	Pass
0.8308	2741	1999	72.0	Pass
0.8668	2477	1795	72.0	Pass
0.9029	2238	1625	72.0	Pass
0.9389	2051	1481	72.0	Pass
0.9750	1888	1354	71.0	Pass
1.0110	1738	1235	71.0	Pass
1.0471	1577	1145	72.0	Pass
1.0831	1453	1070	73.0	Pass
1.1192	1328	992	74.0	Pass
1.1552	1220	921	75.0	Pass
1.1913	1128	843	74.0	Pass
1.2273	1041	779	74.0	Pass
1.2634	969	738	76.0	Pass
1.2994	896	705	78.0	Pass
1.3355	838	667	79.0	Pass
1.3715	787	624	79.0	Pass

1.4075	728	588	80.0	Pass
1.4436	670	553	82.0	Pass
1.4796	627	513	81.0	Pass
1.5157	590	473	80.0	Pass
1.5517	553	445	80.0	Pass
1.5878	511	419	81.0	Pass
1.6238	473	399	84.0	Pass
1.6599	441	380	86.0	Pass
1.6959	410	353	86.0	Pass
1.7320	378	333	88.0	Pass
1.7680	348	319	91.0	Pass
1.8041	326	307	94.0	Pass
1.8401	304	295	97.0	Pass
1.8762	279	287	102.0	Pass
1.9122	263	272	103.0	Pass
1.9483	247	260	105.0	Pass
1.9843	231	250	108.0	Pass
2.0204	220	236	107.0	Pass
2.0564	206	223	108.0	Pass
2.0925	191	197	103.0	Pass
2.1285	183	179	97.0	Pass
2.1645	172	167	97.0	Pass
2.2006	165	152	92.0	Pass
2.2366	158	138	87.0	Pass
2.2727	148	125	84.0	Pass
2.3087	139	113	81.0	Pass
2.3448	128	98	76.0	Pass
2.3808	118	90	76.0	Pass
2.4169	104	83	79.0	Pass
2.4529	97	81	83.0	Pass
2.4890	86	72	83.0	Pass
2.5250	75	67	89.0	Pass
2.5611	68	60	88.0	Pass
2.5971	65	52	80.0	Pass
2.6332	60	50	83.0	Pass
2.6692	53	40	75.0	Pass
2.7053	48	37	77.0	Pass
2.7413	43	33	76.0	Pass
2.7774	37	32	86.0	Pass
2.8134	34	30	88.0	Pass
2.8495	31	28	90.0	Pass
2.8855	30	26	86.0	Pass
2.9215	26	22	84.0	Pass
2.9576	23	20	86.0	Pass
2.9936	22	16	72.0	Pass
3.0297	21	15	71.0	Pass
3.0657	20	13	65.0	Pass
3.1018	18	13	72.0	Pass
3.1378	16	11	68.0	Pass
3.1739	15	9	60.0	Pass
3.2099	12	8	66.0	Pass
3.2460	9	8	88.0	Pass

3.2820	9	7	77.0	Pass
3.3181	8	6	75.0	Pass
3.3541	6	5	83.0	Pass
3.3902	6	5	83.0	Pass
3.4262	6	2	33.0	Pass
3.4623	6	2	33.0	Pass
3.4983	6	2	33.0	Pass
3.5344	5	2	40.0	Pass
3.5704	5	2	40.0	Pass
3.6065	5	2	40.0	Pass
3.6425	5	1	20.0	Pass
3.6785	5	0	.0	Pass
3.7146	5	0	.0	Pass
3.7506	5	0	.0	Pass
3.7867	5	0	.0	Pass
3.8227	5	0	.0	Pass
3.8588	5	0	.0	Pass
3.8948	5	0	.0	Pass
3.9309	5	0	.0	Pass
3.9669	4	0	.0	Pass
4.0030	4	0	.0	Pass
4.0390	3	0	.0	Pass
4.0751	2	0	.0	Pass
4.1111	2	0	.0	Pass
4.1472	1	0	.0	Pass
4.1832	0	0	.0	Pass
4.2193	0	0	.0	Pass
4.2553	0	0	.0	Pass
4.2914	0	0	.0	Pass

Detention Pond Design - WWHM
Land Use predev = 5ac forest till
Land Use dev = 3ac Imp; 2ac landscape till
Infiltration rate = 0.0

Year	Hours Inundated	Days Inundated	Consecutive Hours Inundated	Consecutive Days Inundated
1948	4,446	185.3	1480	61.7
1949	5,902	245.9	3577	149.0
1950	5,405	225.2	3138	130.8
1951	5,390	224.6	1288	53.7
1952	5,186	216.1	2073	86.4
1953	6,371	265.5	2403	100.1
1954	6,277	261.5	2439	101.6
1955	5,878	244.9	2439	101.6
1956	6,071	253.0	1136	47.3
1957	5,671	236.3	1413	58.9
1958	6,671	278.0	3291	137.1
1959	6,126	255.3	1303	54.3
1960	5,998	249.9	1695	70.6
1961	5,856	244.0	948	39.5
1962	5,856	244.0	1261	52.5
1963	7,027	292.8	3058	127.4
1964	5,622	234.3	1349	56.2
1965	6,335	264.0	2341	97.5
1966	5,739	239.1	2748	114.5
1967	6,948	289.5	1279	53.3
1968	6,123	255.1	1889	78.7
1969	5,924	246.8	766	31.9
1970	6,714	279.8	2348	97.8
1971	6,943	289.3	4077	169.9
1972	5,504	229.3	1833	76.4
1973	6,316	263.2	2316	96.5
1974	5,996	249.8	2169	90.4
1975	6,602	275.1	3001	125.0
1976	5,385	224.4	631	26.3
1977	6,989	291.2	2121	88.4
1978	5,484	228.5	798	33.3
1979	6,450	268.8	1092	45.5
1980	6,728	280.3	1763	73.5
1981	5,981	249.2	1420	59.2
1982	7,169	298.7	1128	47.0
1983	6,119	255.0	1632	68.0
1984	5,848	243.7	1802	75.1
1985	5,932	247.2	1136	47.3
1986	5,463	227.6	1372	57.2
1987	5,857	244.0	793	33.0
1988	5,802	241.8	2412	100.5
1989	6,353	264.7	1514	63.1
1990	6,270	261.3	2234	93.1
1991	5,718	238.3	2029	84.5
1992	5,858	244.1	1498	62.4

Detention Pond Design - WWHM
Land Use predev = 5ac forest till
Land Use dev = 3ac Imp; 2ac landscape till
Infiltration rate = 0.0

Year	Hours Inundated	Days Inundated	Consecutive Hours Inundated	Consecutive Days Inundated
1993	5,584	232.7	1074	44.8
1994	6,155	256.5	2193	91.4
1995	6,450	268.8	1918	79.9
1996	7,232	301.3	5312	221.3
1997	5,370	223.8	1264	52.7
AVG		**252.6**		**80.2**

POND TRIAL #1
Infiltration Pond Design - WWHM
Land Use predev = 5ac forest till
Land Use dev = 3ac Imp; 2ac landscape till
Infiltration rate = 1.0 in/hr w/ 4 SF
L:W = 4:1
ss=3:1

Year	Hours Inundated	Days Inundated	Consecutive Hours Inundated
1948	150	6.3	
1949	295	12.3	7
1950	288	12.0	12
1951	144	6.0	7
1952	211	8.8	12
1953	253	10.5	14
1954	170	7.1	15
1955	295	12.3	18
1956	194	8.1	13
1957	172	7.2	13
1958	265	11.0	13
1959	214	8.9	33
1960	269	11.2	16
1961	122	5.1	7
1962	195	8.1	15
1963	255	10.6	14
1964	212	8.8	22
1965	188	7.8	11
1966	222	9.3	14
1967	282	11.8	17
1968	231	9.6	15
1969	195	8.1	14
1970	231	9.6	14
1971	281	11.7	23
1972	153	6.4	17
1973	263	11.0	11
1974	196	8.2	20
1975	240	10.0	21
1976	88	3.7	8
1977	182	7.6	13
1978	123	5.1	11
1979	212	8.8	21
1980	175	7.3	9
1981	201	8.4	17
1982	225	9.4	25
1983	192	8.0	12
1984	149	6.2	14
1985	162	6.8	20
1986	202	8.4	29
1987	157	6.5	14
1988	149	6.2	6
1989	211	8.8	17
1990	250	10.4	39
1991	163	6.8	14
1992	158	6.6	20
1993	94	3.9	6
1994	215	9.0	16
1995	311	13.0	21
1996	305	12.7	30
1997	172	7.2	11
Average	**206**	**8.6**	**15.9**
Maximum	**311**	**13.0**	**39**
Minimum	**88**	**3.7**	**6**
Number of years with > 48 hrs			**0**

POND TRIAL #2
Infiltration Pond Design - WWHM
Land Use predev = 5ac forest till
Land Use dev = 3ac Imp; 2ac landscape till
Infiltration rate = 0.5 in/hr w/ 4 SF
L:W = 4:1
ss=3:1

Year	Hours Inundated	Days Inundated	Consecutive Hours Inundated
1948	357	14.9	18
1949	595	24.8	31
1950	568	23.7	72
1951	346	14.4	19
1952	438	18.3	22
1953	536	22.3	43
1954	377	15.7	32
1955	642	26.8	25
1956	423	17.6	23
1957	402	16.8	23
1958	583	24.3	27
1959	484	20.2	48
1960	560	23.3	33
1961	309	12.9	22
1962	440	18.3	41
1963	542	22.6	28
1964	442	18.4	23
1965	438	18.3	22
1966	485	20.2	37
1967	547	22.8	36
1968	523	21.8	24
1969	374	15.6	31
1970	521	21.7	52
1971	631	26.3	60
1972	336	14.0	20
1973	580	24.2	18
1974	426	17.8	25
1975	512	21.3	29
1976	210	8.8	23
1977	423	17.6	22
1978	238	9.9	21
1979	465	19.4	43
1980	425	17.7	18
1981	492	20.5	40
1982	517	21.5	31
1983	417	17.4	23
1984	316	13.2	29
1985	371	15.5	35
1986	415	17.3	45
1987	327	13.6	28
1988	402	16.8	19
1989	407	17.0	36
1990	534	22.3	54
1991	360	15.0	19
1992	362	15.1	28
1993	225	9.4	12
1994	455	19.0	33
1995	622	25.9	60
1996	574	23.9	77
1997	419	17.5	25
Average	**448**	**18.7**	**32.1**
Maximum	**642**	**26.8**	**77**
Minimum	**210**	**8.8**	**12**
Number of years with > 48 hrs			**6**