EXHIBIT 17

APPENDIX D

References – Wetlands

- **D-1a Wetland Hydroperiod Analysis**
- **D-1b Chap13 Wetland Hydroperiods King Co.**

D-2 Wetland Hydroperiod Analysis –selected text and project comment

D-3 Ch 13 – selected text with highlighting and project comment

D-4 Wetland Protection Discussion

WETLAND HYDROPERIOD ANALYSIS

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ABSTRACT

Rapid urbanization can adversely impact the functional values of isolated wetlands. The hydroperiod (duration of inundation in a wetland) is one of the functional elements which must be maintained to avoid such impacts to wetlands surrounded by or adjacent to development. In the past, wetlands were typically filled in to facilitate development. Today, instead, many developments incorporate wetlands into stormwater management planning as a means to provide water quality treatment and/or attenuation. However, the hydroperiod of a wetland to be utilized in this way must be properly determined in order to avoid adverse wetland impacts. In this paper, a water budget analysis is depicted to determine the hydroperiod with special emphasis given to surface water runoff resulting from precipitation. An analytical example is included to illustrate the hydroperiod analysis.

INTRODUCTION

Hydrology is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes (Mitsch & Gosselink, 1993). Land use changes and stormwater management practices usually alter hydrology within a watershed (Azous & Homer, 1997). Within the last decade or so of rapid urbanization, the stormwater management function of natural wetlands has been recognized by those employed in land development. As a result, rather than being destroyed and replaced by mitigation projects, wetlands are being incorporated more and more into developments' stormwater management systems for water quality treatment and attenuation purposes. Given man's inability thus far to recreate nature, this may be viewed as a godsend. However, some preliminary information must be gathered prior to project design.

The objective of this paper is to evaluate the hydrological and biological functions of a wetland by considering the pre-development and post-development conditions within a wetland watershed.

Hydrologic Characteristics of Wetlands

The hydrological regimen is what distinguishes wetlands from aquatic and terrestrial systems. This characteristic creates the physicochemical conditions that make such an ecosystem unique.

Hydrology modifies or determines the structure and functioning of wetlands by controlling the composition of the plant community and thereby the animal community.

For the purpose of this paper, palustrine wetlands will be used. According to Cowardin et al. (1979) there are eight classes of palustrine wetlands, all nontidal (isolated, freshwater). In addition to physical shape and form, major factors that influence the hydrology of palustrine wetlands are precipitation, surface water inflows and outflows, groundwater exchange and evapotranspiration. These components will be further discussed under the water budget section.

Among the hydrological characteristics of wetlands described by Duever (1988), are flood hydrographs, water level fluctuations and hydroperiods.

Flood Hydrograph

A typical hydrograph is a graph or table showing the flow rate as a function of time at a given storm event in a watershed. The hydrograph is the result of physiographic aspects and meteorological occurrences in the watershed. Since wetlands are one of the physical characteristics of the watershed, the wetlands influence the response of the watershed runoff for a given storm event. The actual shape and scale of a hydrograph can vary substantially depending upon physical characteristics such as slopes, vegetation coverage and ecosystem type within a watershed. There are two types of hydrographs. The first one relates discharge to time and is called a discharge hydrograph and the second relates stage to time and are called a stage hydrograph.

Water Level Fluctuations

The fluctuations of the water level in a wetland are influenced by water inflows and outflows related to the meteorological conditions of the area. Another factor to consider that will cause different ranges in the fluctuation of the water levels is the location of wetlands within higher or lower areas of the watershed. Components which alter such fluctuations are the surface and groundwater inflows attributed to precipitation. However, the main control factor is the rise and fall of the groundwater table which is influenced by other surrounding topographic land features, soil type and vegetation cover.

Hydroperiod

Wetland hydrology may be considered in the context of the hydroperiod, defined as "the seasonal occurrence of flooding and/or soil saturation, encompassing the depth, frequency, duration, and seasonal pattern of inundation" (Azous & Homer, 1997). Wetland type varies according to frequency of inundation, which may be annual, seasonal, or in some cases a daily occurrence. In addition, the water table at times may be so low that there is no apparent soil saturation or flooding (Figure 1).

Wetlands receive water from any combination of the following: precipitation, surface water and/or groundwater. These in turn influence water depth. The duration of soil saturation determines a wetland's hydroperiod.

To determine the existing hydroperiod of a wetland to be incorporated into a stormwater management system, specific hydrological characteristics and biological indicators of the wetland must be identified or field verified. The pre-development wetland watershed must be mapped and quantified so that there is known contributing acreage. The projected post-development wetland watershed must also be mapped and quantified to determine any expected changes in contributing acreage. In addition, existing normal pool (NP) and seasonal high water elevations (SHWL) of the wetland must be identified, the vegetative community described and a wetland assessment performed.

Water Budget

It is important to understand the hydrology of a wetland system because it of its influence on chemical and biological dynamics of the wetland. For example, a significant variation especially the deficit of water associated with the hydroperiod of the wetland during the dry and/or wet seasons can result in biological changes. A major difficulty in managing wetland systems is the inability to distinguish shifis in the hydrological conditions resulting from human activities versus those caused by natural phenomena.

To understand the hydrological process based on the principles of conservation of mass and the continuity equation, the water budget reflects the net effect of all the processes that influence the hydroperiod of wetlands. The water budget for a wetland can be expressed as:

$$AS=P+SSI+SI-PR-SSO-SO-ET$$

where

AS	=	change in storage vohnne~(surface and soil);
P	5	precipitation;
SSI	=	subsurface inflow (groundwater inflow);
SI	=	surface inflow (overland flow);
PR	=	percolation;
SSO		subsurface outflow (groundwater outflow);
SO		surface ouflow (overland outflow); and
ET		evapotranspiration.

In the above equation, all the parameters represent units of depth. These parameters can either be measured or analytically calculated based on information collected at a specific site. The above components of the water budget vary significantly depending upon local topography, hydrology of the site, and wetland type.

Precipitation

Precipitation inputs to wetlands may exhibit extreme spatial variability, even over small areas during a single storm event, This variability has been synthesized and available in data sets appropriate near or within a wetland and its watershed.

For example, within the Tampa Bay area, average rainfall is 53 inches per year, much of this from June to October (the rainy season). Seasonal variation of rainfall is shown in Figure 2.

Subsurface Inflow-Oufflow

The subsurface (groundwater) inflow-outflow beneath a vegetation canopy may differ significantly from adjacent areas without a canopy. Interception of precipitation from foliage and vegetated surfaces and the re-evaporation of water can significantly reduce the amount of water reaching the water table.

In the Tampa Bay area, during the rainy season, the water table varies from zero to 2 feet below the existing ground surface, and during the dry season, the water table falls to as much as six to 8 feet below the surface.

Percolation

Gradual percolation causes a regulating effect on wetlands and its hydroperiod. Note that the percolation rate at the wetland bed would be very low because of low hydraulic conductivity due to the relatively impermeable soil characteristics underlying a wetland as shown in Figure 3 (Eggelsmann, 1972).

Surface Flow-Inflow-Outllow

In general, surface water movement in a wetland is the result of precipitation, surface water inflow and outflow, and losses through seepage, transpiration, and evaporation.

An important wetland characteristic is extended shallow water inundation - extended but not prolonged or permanent. Factors such as orientation, surrounding soil characteristics, storm characteristics, adjacent land use patterns, and man-made alterations (such as land use changes) affect wetland hydrology. During periods of high water levels, large inflows may enter a wetland, but quickly dissipate as outflows. Even several such large flood events occurring within a relatively short time span may substantially raise annual inputs, but have little significant impact on the hydrology of a wetland. However, these occasional peak flows are important to topographically isolated wetlands, which receive the majority of their inflows during storm events.

The water storage capacity of wetlands is intermediate between upland areas and aquatic systems. In a flood event, the runoff rate drastically increases when water levels exceed a system's normal barriers to flow. In other words, the rate of the water level rises and falls quickly as the runoff rates approximate the inputs. This phenomenon leads to a fairly constant year to year maximum water levels in a wetland system (Daniel, 198 1).

For the Tampa Bay area, approximately 14 inches of rainfall is generated in runoff annually.

Evapotranspiration

Evapotranspiration is the combined process of evaporation from vegetation, land, water surface and transpiration by plants. Evapotranspiration for a given wetland depends on its microclimate (relative humidity, air and water temperature, wind velocity and its duration), the soil moisture content and the type and density of the vegetation. Compared to those of other ecosystems, wetlands have among the highest evapotranspiration rates.

Evapotranspiration rates for wetlands can be measured and/or calculated by a variety of techniques. Theoretical rates are established based on regional climatic data or site specific micro climatic data.

For the Tampa Bay area, annual evapotranspiration accounts for a loss of approximately 38 inches. Average seasonal evapotranspiration data are shown in Figure 2.

Stormwater Systems

Developers today face many pressures including state, local and regional regulations and above all the financial interest from shareholders. Land use policies specify what percentage of developable land needs to be set aside for other "non-income producing" usage. Stormwater management is one such use. Existing depressions in the land, or wetlands, are "natural" stormwater facilities, ideal locations for stormwater storage. Today, development plans increasingly incorporate wetlands into stormwater management systems to provide storage, water quality improvement and environmental enhancement.

The impact of quantity and quality of stormwater runoff on wetland processes has raised some concerns among researchers. Quantity of stormwater runoff is a driving force in the establishment and maintenance of wetlands. In fact, assuming adequate quality, and at the correct frequency, depth and duration, stormwater runoff maintains and may even upgrade the quality of wetlands previously altered.

Attenuation (pre- and post-development runoff rate and volume)

Variation in water level in wetlands for a typical storm under both pre- and post- development conditions can be determined by using any hydrological routing program such as EPA-SWMM, HEC-HMS or HEC-1, TR-20, etc. Water levels under pre-development conditions can be established based on biological indicators or determined by a monitoring program. Under post-development conditions, water levels will rise rapidly during and after storm events but would quickly return to its operating level @e-development level). The quick return to this operating level would be controlled by the outflow at the outlet control structure to restore the storage capacity of the wetland.

Stormwater runoff could prove to be detrimental to the wetland by causing rapid water level fluctuations and duration periods, thus altering the wetland's hydroperiod. Plant diversity, for example, is likely to be reduced if wetland hydrology is altered in this manner. Therefore, fluctuations in a wetland should be maintained at pre-development levels.

Measures should be taken to protect the integrity of a wetland during and after development. Among these should be structural and non-structural works which may include but not be limited to; sedimentation vault, erosion control, vegetation management, etc. Equally important but fewer frequently recognized, adjacent, upland buffer zones must be maintained in their natural states.

Water Quality

Urbanization and urban activities are a source of pollution in stormwater runoff. Pollutants can be removed by wetlands through a combination of: 1) incorporation into or attachment to wetland sediments or biota; 2) degradation; or 3) export to the atmosphere or groundwater. Both physical and chemical pollutant removal mechanisms occur in wetlands. These mechanisms include: sedimentation, absorption, precipitation and dissolution, filtration, biochemical interactions, infiltration, etc. These interactive mechanisms vary from wetland to wetland; therefore, the pollutant removal efficiencies also vary from wetland to wetland (Table 1).

Guidelines

Local, state and regional governmental agencies consider “wetlands” as: lands that are seasonally or permanently covered by shallow water, as well as lands where the water level is close to or at the surface. Whatever the case may be the presence of abundant water has caused the formation of hydric soil and has favored the dominance of either hydrophytic or water-tolerant plants.

In circumstances in which it is impossible to eliminate impacts from development, affected wetlands should be incorporated into stormwater management systems or as “natural facility.” enhancements.

For wetlands incorporated into stormwater management systems, government agencies, including the Southwest Florida Water Management District (SWFWMD) require pre-treatment of storm water runoff prior to discharge to a wetland. The SWFWMD (1996) allows isolated wetlands to be included in surface water management systems when it can be demonstrated that the system design will not adversely impact those wetlands. The SWFWMD requires a pre-treatment of one-fourth inch of runoff prior to release to the wetland. The SWFWMD also states that the depth, duration of frequency of inundation through changing the rate or method of discharge of water to the wetlands must be addressed to prevent adverse impacts to the functions that wetlands provide to fish and wildlife species.

The following recommendations should be considered when incorporating wetlands into designs for stormwater management facilities in new land development projects:

- Maximize natural water storage and infiltration outside of existing wetlands.
- Establish and maintain vegetative buffers in the riparian zone surrounding wetlands.
- Acquire specific management measures to avoid general urban impacts to wetlands.
- Support management of runoff water quantity by performing a hydrological assessment to estimate elements of hydropexiod and hydrodynamics under existing pre-development and anticipated post-development conditions based on the mean annual storm event.

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- Support management of runoff water quantity by performing a hydrological assessment to estimate elements of hydroperiod and hydrodynamics under existing pre-development and anticipated post-development conditions based on the mean annual storm event.

- Manage water quality (attempt to match pre-development water quality conditions by considering both source control BMP's and treatment BMP's) by providing a water quality control facility consisting of one or more treatment BMP's (i.e., pre-treatment sediment sump to control suspended sediment, skimmer/baffle to control oil and grease, overland sheet flow length with swale, if any, etc.).
- Establish plans to protect specific biological communities.

To determine the existing and future hydroperiod, a hydrological assessment (routing programs) should be used to determine the water level fluctuation due to storm event(s) prescribed by the regulations.

Water Level Fluctuation = Crest stage - Seasonal High Water Level

To maintain the hydroperiod and hydrodynamics of a wetland, and to avoid adverse impacts to its biological and hydrological functions, water level fluctuation over time should not vary significantly. If the analysis described above predicts excessive water fluctuations, stormwater management strategies should be employed to keep fluctuations within an acceptable range. Some guidelines suggest that the duration of stage excursions above the pre-development stage should not exceed 24 hours in any event in any year (Azous & Homer, 1997).

Hypothetical Example

The analytical example given shows the hydoperiod assessment of an isolated wetland. The following parameters are considered:

Pre-development conditions:

1) Isolated wetland area	= 0.9 ha at SHWL (2.0 acres)
2) Watershed area of wetland	= 12.14 ha (30.0 acres)
3) Composite curve number, CN	= 80
4) Seasonal High Water elevation	= 7.32 m (24.0' msl)
5) Normal Pool elevation	= 7.16 m (23.5' msl)
6) Time of concentration	= 66 minutes

Post-development conditions:

1) Watershed area of wetland	= 9.71 ha (24 acres)
2) Composite curve number	= 88.2
3) Time of concentration	= 18 minutes
4) Lake area	= 0.4 ha (1 .O acres) @ elevation 7.32 m (24.0' M.S.L.)

The Palustrine/ Emergent wetland consists of three distinctive vegetative zones. The outer zone is dominated by St. John's wort (Hypericum fasciculatum). A middle zone is dominated by maidencane (Panicurn hemitomon) and a core zone of pickerelweed (Pontederia cordata). The wetland is bordered by an abrupt border of saw palmetto (Serenoa repens).

Several biological indicators were identified in the field to determine the SHWL and NP of the wetland. The adventitious rooting of *H. fasciculatum* and the ground elevation at the jurisdictional line were compared and a SHWL of 7.32 m (24.0' M.S.L.) was determined. The normal pool was determined at 7.16 m (23.5' M.S.L.) by comparing ***H.** fasciculutum* indicators with the ground elevation at the apparent change of zonation where *P. hemitomon* begins to dominate. This wetland has minimal impacts and provides significant functions and values.

DISCUSSION

As indicated by the example, based on the mean annual storm event (2.33 year - 24 hour storm), the wetland water level fluctuates from a seasonal high water elevation (SHWL) of 7.32 m to 7.4 m (+/-) (24.0 to 24.3 feet (+/-)) at hour eight to approximately hour 40 (i.e., it takes approximately 32 hours to return to the pre-development seasonal high water level). While in the post-development condition it takes about 50 hours to return to the pre-development level (i.e., there is approximately 18 hours longer inundation time).

During a flood storm event (25 year - 24 hour storm), the wetland water level fluctuates from 7.32 m to 7.5 m (+/-) (24.00 to 24.6 feet (+/-)) and takes approximately 35 hours to return to the pre-development SHWL elevation. While in the post-development conditions it takes about 50 hours (i.e., there is an approximate15 hour longer inundation time).

Since the wetland will be used for the treatment and attenuation of runoff, a pre-treatment lake has been proposed. The pre-treatment lake provides removal of sediment, oils and greases prior to discharge to the wetland. To prevent oils and greases, a structure would be set at the seasonal high water elevation with a skimmer which will function as a positive/negative flow from and to the wetland from the lake. The top of the skimmer and berm elevation around wetland were considered as the routed post-development design high water level for the 25 year - 24 hour storm event.

In both storm events, the stage excursion for the wetland was under the 24 hour guideline proposed by Azous and Homer (1997). Using the proposed guideline and limited literature available concerning the tolerance of emergent vegetative species from prolonged and/or frequent inundations, the example suggests that no adverse wetland impacts would occur; however, it is strongly recommended that each wetland hydroperiod be analyzed, as in the example, on a case by case basis. If the proposed design exceeds the range of the pre-development staging, and adverse wetland impacts are anticipated, a stormwater management design modification or a monitoring plan for the wetland may be necessary.

CONCLUSIONS

In summary, the following statements provide reasonable assurance that when wetlands are incorporated into stormwater management systems, the hydroperiod of the wetland will be maintained or may improve in the case of previously altered wetlands and if used for water quality treatment, will not cause adverse impacts to the functions and values provided by the wetland.

The hydroperiod of isolated wetlands can be determined by using the water budget analysis.

2. Wetlands can be incorporated into the stormwater management system (i.e., attenuation and treatment) provided that all necessary criteria of the govemmental agencies requirements/guidelines/policies including pre-treatment (removal of sediment, oils and greases) of runoff have been met.

3. The depth, duration or frequency of inundation should be analyzed by using a mean annual storm event (2.33 year - 24 hour storm) and at least one flood storm event such as a 25 year - 24 hour or a 100 year - 24 hour storm event.

4. The duration of inundation of stage excursions above the pre-treatment stage should be limited to 24 hours in any storm event (i.e., the difference between the pre- and post-development stage hydrographs (stage versus time) should not exceed 24 hours at the SHWL stage.

5, If the wetland is used for the treatment of stormwater runoff, a water quality recovery structure(s) between the wetland and the proposed stormwater system (dry and/or wet detention) should be considered. The top elevation of the structure(s) should be established between the SHWL and NP elevations depending upon the treatment volume provided in the wetland.

6. If the overland sheet flow from the rear yard is designed to directly discharge into the wetland, a minimum of 80 to 100 feet vegetative (grassed) filter strip including the wetland's buffer should be considered.

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Section 4 Management of Freshwater Wetlands in the Central Puget Sound Basin

CHAPTER 13 MANAGING WETLAND HYDROPERIOD: ISSUES AND CONCERNS

by Amanda L. Azous, Lorin E. Reinelt and Jeff Burkey

INTRODUCTION

Land use changes and stormwater management practices usually alter hydrology within a watershed. A major finding of our study was that hydrologic changes were having more immediate and greater effects on the composition of vegetation and amphibian communities than other environmental conditions we monitored. Early study results showed wetland hydroperiod, which refers to the depth, duration, frequency and pattern of wetland inundation to be a key factor in determining biological responses.

Continuous recording gages were unavailable for the study, but we were able to monitor hydroperiod in the wetlands with instantaneous staff and crest stage gages. From these measurements a metric was developed called water level fluctuation (WLF) which showed statistically significant relationships with several measures of biological health (Azous 1991a). WLF is measured as the average difference between the maximum depth and average instantaneous or base depth in a time period (Taylor 1993, Taylor, Ludwa and Horner 1995).

Consistently we observed reduced numbers of plant and amphibian species when WLF was high in wetland areas (Azous 1991b, Cooke and Azous 1993, Richter and Azous 1995). As a result, substantial attention was given to understanding WLF and developing management guidelines for protecting wetland plants and animals.

A local jurisdiction, King County Surface Water Management (KCSWM) expressed an interest in developing wetland management guidelines that could be used in continuous flow event simulation computer models. In addition, only a few of the wetlands in the original 19 study wetlands showed extreme water level changes and we wanted to measure more plant and amphibian communities with high WLF conditions. We undertook a cooperative study to monitor the hydroperiods of six wetlands with continuous recording gages, and measure the plant and amphibian communities, in order to better understand the relationship between biological diversity, WLF, and the pattern of water depth, duration and frequency of inundation in wetlands.

This paper will discuss the methods and results of this study. The information has significant implications for evaluating the level of protection afforded wetlands from changing hydroperiod.

METHODS

Continuous recording gages were installed in six wetlands in late 1994 and early 1995. The gages were programmed to record water surface elevations at 15-minute increments. Two of the wetlands we monitored were in relatively undisturbed watersheds and were already experimental controls in our ongoing study. The remaining four were recommended by KCSWM field staff as wetlands known to experience large changes in water depth throughout the year.

Water levels in all six wetlands were monitored over one year, however due to unexpected seasonable differences in rainfall and some losses of data due to malfunctioning equipment, there was only a partial water year for all the wetlands. The hydroperiod data was used to calculate WLF and to calibrate the computer model Hydrologic Simulation Program- FORTRAN (HSPF), a continuous event model with the ability to simulate hydrologic processes in a watershed. The model is used to predict rainfall runoff from different watershed conditions and is more accurate when field measurements are used to adjust runoff from simulated rainfall events with the outflows and stages resulting from actual events.

Of the six wetlands, two control wetlands were not calibrated nor modeled. The complexity of the wetlands' hydraulics were beyond the scope of this project. The remaining four wetlands all had well defined outlets, hydraulics and bethymetry which allowed reasonably accurate stage-storage-discharge relationships to be developed. Based on the margin of errors in the spatial distribution of precipitation represented by nearby gages and the length of the field record, the accuracy of the model's simulated wetland water levels to recorded water levels was limited to plus or minus 0.5 ft. (15 cm).

Emergent (PEM), scrub-shrub (PSS) and forested (PFO) wetland zones were surveyed and evaluated for plant species richness and the presence and dominance of exotic invasive species using the protocols for vegetation field work documented in Cooke et al. (Cooke et al. 1989). Disturbed commodities were those sample stations found to be dominated (>60%) by a weedy species. Amphibians were sampled during the fall and spring breeding seasons using methods described in Richter and Azous (1995).

The condition of plant and amphibian communities were compared with the observed and predicted water depths, the duration of storm events and the frequency of storm events for the whole season and the early growing season (March 1 through May 15). . We analyzed the emergent, scrub-shrub and forested zones to determine if there were significant differences in community composition related to hydroperiod regimes .

The six special study wetlands were also added to the larger database of 19 wetlands and all the data analyzed for differences corresponding to WLF conditions. All sample stations that were inundated at least once during the year were included in the analysis of water level fluctuation. The data was analyzed using StatView (Abacus Concepts Inc. 1993) statistical applications program. The plant richness data were not normal; therefore the non-parametric Kruskal-Wallace (KW) and Mann-Whitney (MW) tests were used to compare the distributions among categories, depending on the number of variables in the category being compared. Both tests indicate whether the underlying distributions for different groups are the same. Both use ranked data and are resistant to outliers.

Much of the data was categorized to provide more statistical rigor given the small data set and the 0.5 ft. (15 cm.) margin of error. Categories were based on frequency distributions of the data and a very limited sensitivity analysis of statistically significant breaks in the data.

We measured frequency of storm events in a hydroperiod by defining an event as an excursion which we define as a water level increase above the monthly average depth of more than 0.5 ft. (15 cm.). Duration was defined as the time period of an excursion. In a stepwise regression, we looked at the statistical relationship between WLF, frequency and duration. Table 1 shows the categories used in the analysis.

Table 13-1. Category Definitions for Water Depth and Excursion Duration.

Frequency of Excursions	Water Depth*	Duration of Excursions
less than 6 per year	Greater than 2.0 ft. depth (>60 cm.)	less than 3 days
more than 6 per year	2 ft. to 0 ft. depth (-60 to 0 cm.)	3 to 6 days
	0 to 2.0 feet above water surface. (0 to +60 cm.)	more than 6 days

*Negative numbers are under water.

RESULTS

Plant richness in the sample stations ranged from three to 31 species in the POW zones, three to 22 in the PSS zones and 17 to 25 in the forested areas. Very few invasive weedy species were found and were dominant in only a few localized areas.

Frequency and Duration and Plant Richness

Plant richness was found to be significantly lower if water depths were usually deeper than 2 feet (60 cm.) (KW, $p < 0.0001$). To control for this, frequency and duration were evaluated separately for different water depths. The test for differences in duration and frequency showed that, in general, plant communities in areas subjected to more than six hydrologic excursions per year tended to have lower richness. In both the greater than 2.0 feet range and zero to 2.0 feet range the difference is statistically significant (MW, $p \leq 0.004$). It was not significant for the -2.0 to zero range (Figure 13-1).

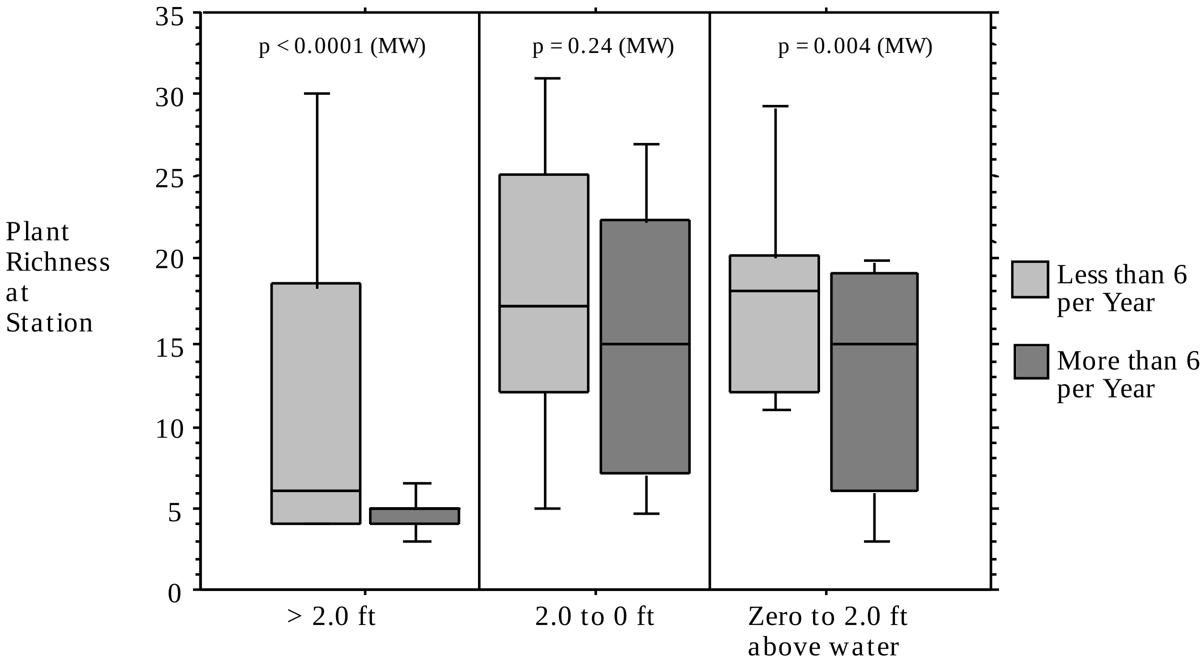

Figure 13-1. Plant richness, water depth and frequency of excursions.

The duration of excursions was compared to plant richness and water depth. Duration alone was a significant factor only in the deepest zones of -8.0 to -2.0 feet (KW, $p < 0.001$) (Figure 13-2). From -2.0 feet to 2.0 feet, increased duration did not significantly contribute to the variability of plant richness.

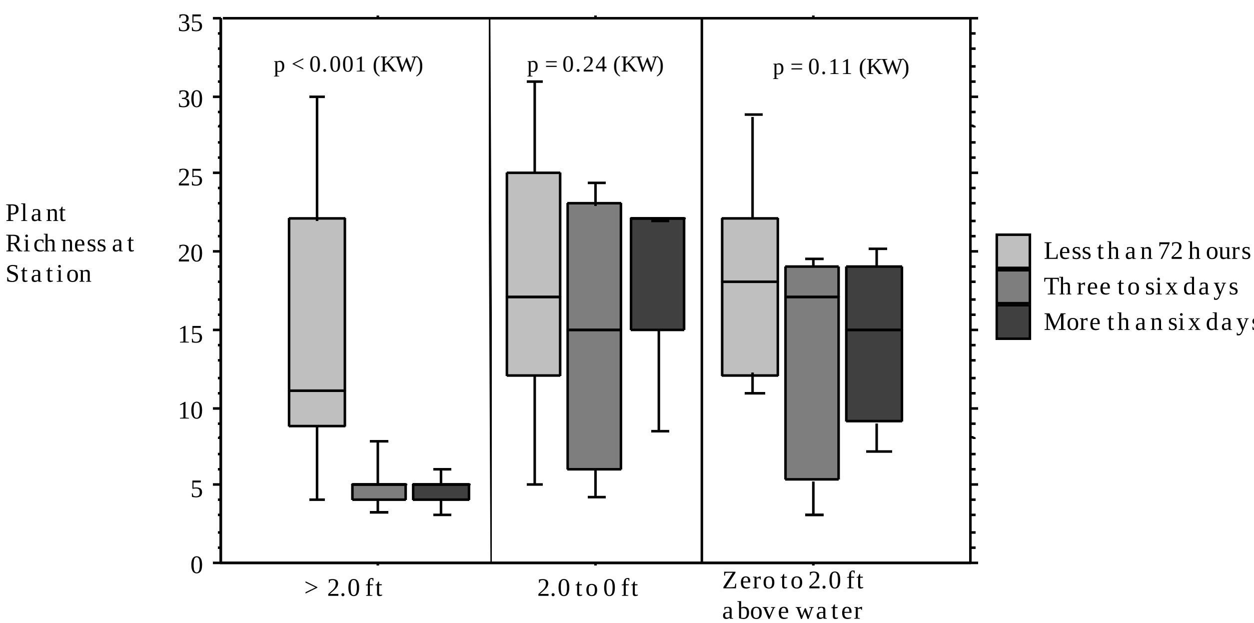

Figure 13-2. Plant richness, water depth and duration of excursions.

When the effects of excursion frequency and duration were combined, the relationship with plant richness was much stronger. Plant richness was found to decrease significantly with excursions longer than six days duration even with frequencies of less than six per year (KW, $p < 0.0001$). For excursion frequencies greater than six per year, richness dropped significantly when duration' exceeded three days per month (KW, $p < 0.0001$) (Figure 13-3)

These results were significant for both emergent and scrub-shrub zones and indicate that the average monthly duration of inundation can be significant to plant species richness, when the frequency of inundation is greater than six times per year on average or when the length of inundation exceeds three days per month. The frequency of excursions did not account for variability in species richness until excursion durations exceeded three days per month. There were an insufficient number of forested zones in the wetlands where frequency and duration were measured to adequately test for differences in the forested conditions and open water.

Water Level Fluctuation and Plant Richness

We looked at the relationship of water level fluctuation to plant richness in different zones of the wetlands. We examined all sample stations inundated at any time of the year and found richness was lower in wetlands with high WLF hydroperiods in the emergent and scrub-shrub zones but not the forested zones. There were not enough aquatic bed zones for adequate evaluation. Emergent zones subject to mean WLFs greater than 0.8 ft. (24 cm.) ranked significantly lower in the number of plant species present (MW, $U \geq 55$, $P \leq 0.003$) than emergent areas with mean WLF less than 0.8 ft. (24 cm.). This relationship was even more significant when richness was compared with water level fluctuation during the early growing season (Figure 13-4). Shrub-scrub zones also showed a significant difference in plant richness related to annual and early growing season water level fluctuation (MW, $U \geq 55$ $p < 0.0001$) (Figure 13-5). Forested zones showed no differences in richness accounted for by WLF.

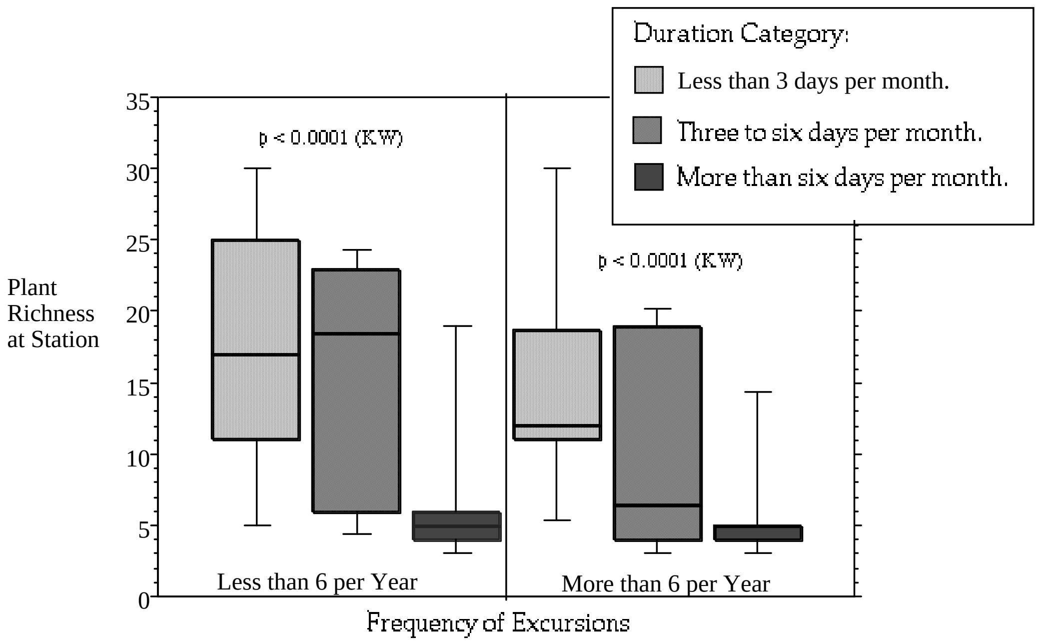

Figure 13-3. Plant richness, frequency and duration of excursions.

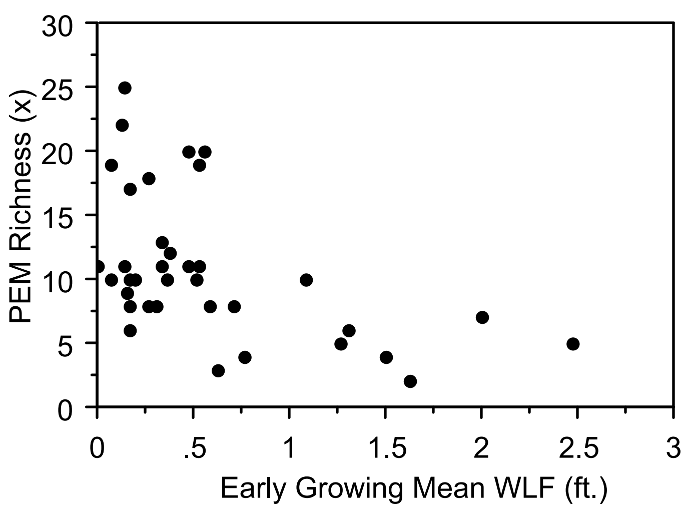

Figure 13-4. Plant rchness in the emergent zones in relation to mean WLF.

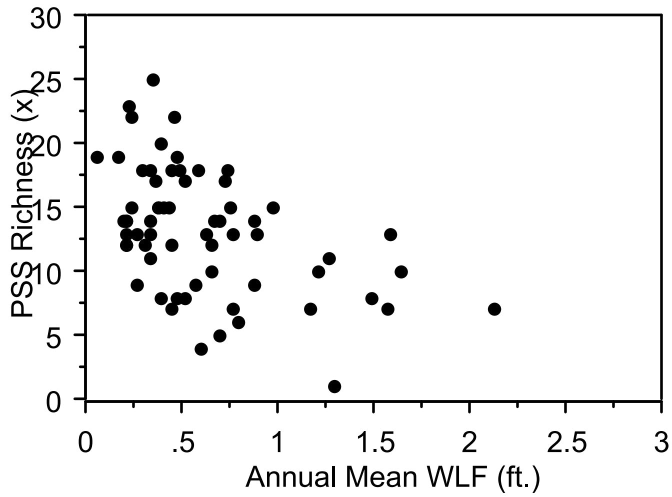

Figure 13-5. Plant richness in the scrub-shrub zones in relation to mean WLF.

Amphibian Results

Our study of amphibians left us with an incomplete picture. All of the wetlands in this study as well as the PSWSRP study had far fewer amphibian species in 1995 than collected in previously years. For example, seven species were collected in a rural wetland, BBC24, in 1989 and only three in 1995. Five species were collected in the urban surrounded wetland, LPS9, in 1989, compared with none in 1995. Eight were captured in SR24 in 1989 and again none were captured in 1995. Figure 13-6 shows amphibian richness for each wetland for both 1989 and 1995 trapping years. The lack of captures prevented analysis of frequency and duration effects for this study's wetlands.

Nevertheless, we were able to measure WLF relationships between amphibian communities over all years and all wetlands using the PSWSMRP wetlands database. The richness of amphibian communities was found to be lower in wetlands with WLF less than 0.8 ft. (24 cm). Wetlands with greater WLF were significantly more likely to have low amphibian richness with three or fewer different species present (*FE*, P = 0.046) as compared with four to eight.

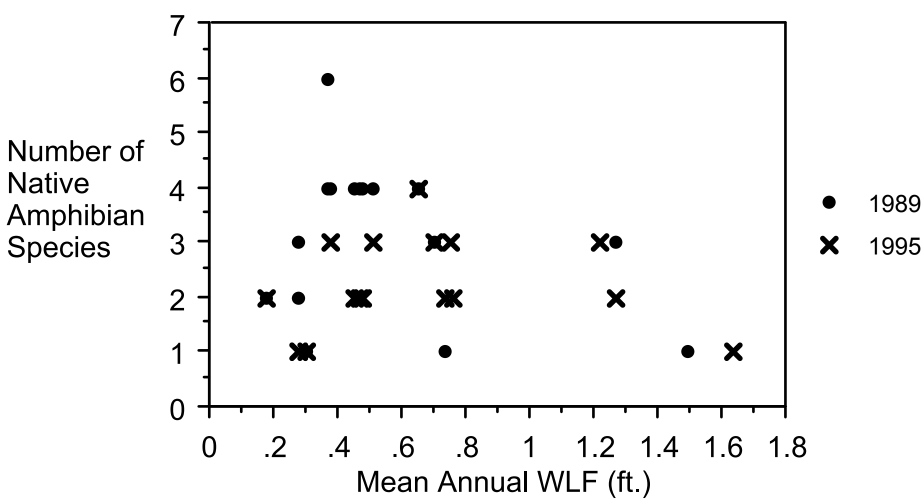

Figure 13-6. Amphibian richness as a function of mean WLF.

The reasons for the amphibian decline in 1995 are not understood. Amphibians sometimes breed in alternate years, hence in one year, populations could be much lower than the next. But we don't know if that phenomenon occurs across a population or just to particular individuals. The fact that low numbers were found in all wetlands suggests that it may be rainfall or climate related and 1995 was a drier spring than usual, but we are speculating.

WLF was found to be statistically related to excursion duration and frequency. Forty-one percent of the variation in WLF can be explained by the duration of events. Adding the effect of excursion frequency can explain as much as 53% of the variability in WLF ($p<0.0001$).

APPLICATION OF RESEARCH RESULTS

These results show that increasing the duration of storm events can be a significant factor in reducing wetland plant diversity. The frequency of storm peaks is also a factor and compounds the duration impact. Decreasing richness in the emergent and scrub-shrub zones and increasing frequency and duration are also associated with high mean water level fluctuation, annually, but particularly during the early spring growing season and amphibian breeding seasons.

Current stormwater protection measures primarily rely on stormwater detention for protecting wetlands. Detention acts to increase the duration of a storm event in order to reduce the peak depth. Water is captured, stored and released after the storm over a longer period of time. It was a management tool designed primarily for controlling floods and erosion in streams, however, it may operate counter to management goals as a tool for wetland protection.

The result of these findings has been to recommend for there to be limits on the durations of storm events as well as the frequency of excursions, when wetlands will be affected by changes in hydroperiod. The recommendations are that the frequency of water levels greater than 15 cm. (.5 ft.) above pre-development levels be limited to an annual average of six or less per year and that the durations of water levels greater than 15 cm. (.5 ft.) above or below pre-development levels be limited to less than three days per excursion.

The data set we analyzed was limited, as were time and funding and some questions remain about the potential for trading flood frequency and flood duration. For example, it might be possible to extend the durations of storm flows in wetlands if the frequency of those events is reduced. Similarly, it may also be possible to reduce durations in trade for allowing greater frequency. These areas of refinement remain largely unexplored.

Irrespective of any further results, it will be difficult for urbanizing jurisdictions to meet such standards in all areas. It is also not likely to happen if detention is the primary management tool. Achieving real resource protection of high value wetlands will require a more comprehensive approach.

Early in the research the PSWSRP learned that wetland management must be holistic, that wetlands are part of a system in a larger landscape and should be managed accordingly. This view has a number of implications for management:

- It is necessary to consider incidental effects on wetlands of activities in their watersheds, along with any engineering performed on the wetland itself for stormwater management purposes;
- Wetland response and management depend on a host of landscape factors, including retention of forest and other natural cover, maintenance of natural storage reservoirs and drainage corridors; the separation of human activities from wetlands; and public awareness.
- Wetland protection means finding root cause solutions e.g. source control practices that prevent or minimize quantities of runoff and release of pollutants, with downstream retention/detention for quantity control and treatment for pollutant capture regarded as secondary back-up measures where source controls alone can not ensure resource protection.
- Potential runoff infiltration opportunities should be explored and those that are found to be workable hydrogeologically and not threaten groundwater quality should be explored.

The experience of King County in its attempts to meet the PSWSRP recom-mendations is noteworthy and affords a view of some alternative approaches to detention.

The PSWSRP guidelines have been used in King County in both the basin and master drainage planning processes. Most of the applications have focused on minimizing water level fluctuation, as it was identified as the most direct effect on wetland functioning, vegetation communities, and habitat for breeding amphibians. Regulations governing factors that affect WLF have been targeted at new development on the urban side of the Urban Growth Boundary (UGB), where the most significant impacts are likely to occur. The general information on construction impacts generated by the Wetlands Research Program has also led to the application of seasonal clearing limits in the drainage areas of Class 1 wetlands.

Basin Planning

The basin planning process was developed by King County to address the significant and rapid land use changes occurring in the county that have an impact on water resources, including flooding, habitat, and water quality. The outcome of the basin planning process is a way of developing a comprehensive set of management recommendations that involve development regulations, capital improvement projects, education programs, improved maintenance practices, and monitoring.

The East Lake Sammamish Basin Plan (King County Surface Water Management Division (KCSWM) 1992) is an example where the results of the Wetlands Research Program were directly applied to management solutions. The East Lake Sammamish basin encompasses about 16 square miles east of Lake Sammamish. Since 1980, the basin has experienced rapid development, converting from low-density residential and forested land uses to higher density residential and some commercial uses. The diversity of the basin's more than 40 inventoried wetlands is as great as anywhere in King County, with nine wetlands ranked as unique and outstanding (Class 1 rating). As one of the prime resources in the basin, wetlands received significant attention for protection from the County and the citizenry.

Wetland Management Areas

Prior to adoption of the basin plan, wetland protection in King County was achieved primarily through the Sensitive Areas Ordinance (SAO). The wetland protection in the SAO provides for discrete buffer widths as a function of assigned rating (e. g., 100 feet for Class 1 wetlands). Although these buffers confer some protection to wetlands, they are inadequate to protect other functions influenced by the broader watershed and surrounding landscape. To address these issues, King County developed wetland management areas (WMA) focused on watershed-based controls to protect the nine Class 1 wetlands. The intent of these controls was to minimize the stormwater-related impacts on wetlands by minimizing impervious surfaces, retaining forests, clustering, and providing constructed infiltration systems, where feasible.

A major component of the wetland management strategy was the limitation of total impervious area in the catchment to eight percent, where allowed by zoning. From the Wetlands Research Program data, it was clear that there were significant increases in WLF between wetlands with watersheds less than 4 percent and those with watersheds greater than 12 percent impervious surface (Taylor 1993; Taylor, Ludwa, and Horner 1995). It was difficult to define this more precisely, because of the absence of impervious surfaces between 4 and 12 percent. Booth and Reinelt (1994) summarized several data sets showing loss of aquatic system function with impervious surface areas above about 10 percent, as measured by changes in channel morphology, fish and amphibian populations, habitat, and water chemistry. While the precise threshold will vary by watershed and the effectiveness of mitigation strategies, 8-10 percent impervious surface appears to be an appropriate threshold.

A requirement for 50 percent forest retention was also imposed in the catchments of some wetlands. This limitation is consistent with King County's reserve tract requirements associated with clustering and growth-reserve zoning. Taylor (1993) found a correlation between forest retention and reduced WLF, but no specific threshold was identified in this work. Clustering of development away from hydrologic source areas (landscape features transmitting water to wetlands during the wet season) was also recommended. An additional requirement in one wetland watershed was the use of constructed infiltration systems to reduce increases in stormwater volumes. This was feasible given the extensive glacial outwash soils in this watershed that were amenable to substantial infiltration. Finally, seasonal clearing limits for construction activities were imposed in eight of the nine watersheds. This limitation prevents clearing and grading during the wet season (October-April) when up to 88 percent of erosion occurs (KCSWM 1992).

King County has continued this approach of wetland management areas for protection of Class 1 wetlands in the Cedar River Basin Plan currently under development. Four Class 1 wetlands in the Cedar basin that are on the urban side of the UGB or that receive runoff from urban areas have been targeted.

Master Drainage Planning and Guidelines

King County uses the Master Drainage Planning (MDP) process for large or complex development sites to assess the potential impacts of development on aquatic resources (KCSWM 1993). The MDP process is required for Urban Plan Developments (UPD), for subdivisions with more than 100 single-family residences, and for projects which clear 500 acres or more within a subbasin. In addition, there are lower thresholds for development in the drainage areas of Class 1 wetlands, regionally significant resource streams, or over sole source aquifers. For Class 1 wetlands, an MDP is required if a project seeks to convert more than 10 percent of the wetland's total watershed area to impervious surface.

The updated guidelines for MDP monitoring and studies (KCSWM 1993), supported in part by results of the Wetlands Research Program, require monitoring for purposes of: (1) assessing wetland functions in storing and releasing stormwater, (2) determining baseline WLF in relation to vegetation and amphibian communities, and (3) establishing baseline conditions from which to measure potential post-development changes. Specific concerns potentially resulting from development are: (1) loss of live storage and infiltration functions of wetlands, (2) stability of outlet control conditions, (3) the effects of increases in flow rates and volumes, (4) changes in spring WLF and resultant habitat changes, and (5) changes in groundwater and interflow.

For purposes of assessing wetland impacts, the MDP guidelines require determination of the following: bathymetry (morphometry) of the wetland; outlet control description and measurement; stage-discharge volume relationships; surface area of open water, including ordinary high water levels; and the dead and live storage maximum elevation and volume. Specific monitoring requirements are: (1) monthly instantaneous and crest water levels to determine WLF in the permanent pool area of the wetland; (2) inflow and outflow rates of the wetland; and (3) the duration of summer drying, if applicable.

For the North Fork Issaquah Creek Wetland 7 Management Area and Grand Ridge MDP, the East Sammamish Community Plan limited development in the drainage area tributary to North Fork Issaquah Creek Wetland 7 (NFIC-7), a Class 1 wetland, to no more than eight percent impervious surfaces and 65 percent forest retention. This condition applies to all development proposals submitted prior to adoption of the Issaquah Basin Plan (KCSWM 1994) and for all developments not going through the MDP process. In the basin plan, impervious surfaces are limited to a maximum of eight percent for all new subdivisions, short subdivision, and UPDs.

The proposed Grand Ridge development in the North and East Fork Issaquah Creek basins involved two development options: rural estates at a density of one unit per 5 acres and an urban proposal consisting of 580 acres of urban development and 1400 acres of permanent open space. In a study of potential development scenarios carried out using the Wetlands Research Program guidelines and a model developed by Taylor (1993), it was possible to examine the development impacts on the water level fluctuation of wetland NFIC-7. Based on the results of that analysis, mitigations were proposed that focused on maintaining greater forested area and utilizing infiltration to reduce stormwater volumes.

CONCLUSION

Fundamentally managing stormwater to protect wetland ecosystems must operate holistically within context of the hydrologic cycle. That requires that we consider infiltration and evapotranspiration in addition to storage, when we think about strategies. Controls focused on minimizing impervious surfaces and maximizing forest retention are likely to be the most widely usable effective strategies; however, additional mitigations that reduce stormwater volumes through infiltration are highly recommended when hydrogeological conditions permit.

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WETLAND HYDROPERIOD ANALYSIS

- Selected text and comment

Reference:

WETLAND HYDROPERIOD ANALYSIS

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Sixth Biennial Stormwater Research & Watershed Management Conference
September 14-l 7, 1999

Selected text:

Surface Flow-Inflow-Outllow

In general, surface water movement in a wetland is the result of precipitation, surface water inflow and outflow, and losses through seepage, transpiration, and evaporation. An important wetland characteristic is extended shallow water inundation - extended but not prolonged or permanent. Factors such as orientation, surrounding soil characteristics, storm characteristics, adjacent land use patterns, and man-made alterations (such as land use changes) affect wetland hydrology. During periods of high water levels, large inflows may enter a wetland, but quickly dissipate as outflows. Even several such large flood events occurring within a relatively short time span may substantially raise annual inputs, but have little significant impact on the hydrology of a wetland. However, these occasional peak flows are important to topographically isolated wetlands, which receive the majority of their inflows during storm events.

The water storage capacity of wetlands is intermediate between upland areas and aquatic systems. In a flood event, the runoff rate drastically increases when water levels exceed a system's normal barriers to flow. In other words, the rate of the water level rises and falls quickly as the runoff rates approximate the inputs. This phenomenon leads to a fairly constant year to year maximum water levels in a wetland system (Daniel, 1981).

Information applicable to this site:

Since the wetlands on this property are not topographically isolated, the following statements appply.

1) During periods of high water levels, large inflows may enter a wetland, but quickly dissipate as outflows.
2) Even several such large flood events occurring within a relatively short time span may substantially raise annual inputs, but have little significant impact on the hydrology of a wetland.

WETLAND HYDROPERIOD ANALYSIS
- Selected text and comment

3) The rate of the water level rises and falls quickly… This phenomenon leads to a fairly constant year to year maximum water levels in a wetland system.

Stormwater Systems
Developers today face many pressures including state, local and regional regulations and above all the financial interest from shareholders. Land use policies specify what percentage of developable land needs to be set aside for other "non-income producing" usage. Stormwater management is one such use. Existing depressions in the land, or wetlands, are "natural" stormwater facilities, ideal locations for stormwater storage. Today, development plans increasingly incorporate wetlands into stormwater management systems to provide storage, water quality improvement and environmental enhancement.

The impact of quantity and quality of stormwater runoff on wetland processes has raised some concerns among researchers. Quantity of stormwater runoff is a driving force in the establishment and maintenance of wetlands. In fact, assuming adequate quality, and at the correct frequency, depth and duration, stormwater runoff maintains and may even upgrade the quality of wetlands previously altered. '

Attenuation (pre- and post-development)

… Stormwater runoff could prove to be detrimental to the wetland by causing rapid water level fluctuations and duration periods, thus altering the wetland's hydroperiod. Plant diversity, for example, is likely to be reduced if wetland hydrology is altered in this manner. Therefore, fluctuations in a wetland should be maintained at pre-development levels.

Fluctuation level does not appear to be detrimentally affected based on preliminary crsory analysis. See Appendix ???????????

Portion of:

Section 4 Management of Freshwater Wetlands in the Central Puget Sound Basin
CHAPTER 13 MANAGING WETLAND HYDROPERIOD: ISSUES AND CONCERNS

Hydroperiod

Refers to the depth, duration, frequency and pattern of wetland inundation

- has been determined to be a key factor in determining biological responses

Water Level Fluctuation

WLF is measured as the average difference between the maximum depth and average instantaneous or base depth in a time period (Taylor 1993, Taylor, Ludwa and Horner 1995).

Excursion

Frequency of storm events in a hydroperiod that develop a water level increase above the monthly average depth of more than 0.5 ft.

Duration

Defined as the time period of an excursion.

Selected Text from: – highlighting and underlining added by GME

Section 4 Management of Freshwater Wetlands in the Central Puget Sound Basin
CHAPTER 13 MANAGING WETLAND HYDROPERIOD: ISSUES AND CONCERNS

by Amanda L. Azous, Lorin E. Reinelt and Jeff Burkey

Consistently we observed reduced numbers of plant and amphibian species when WLF was high in wetland areas (Azous 1991b, Cooke and Azous 1993, Richter and Azous 1995). As a result, substantial attention was given to understanding WLF and developing management guidelines for protecting wetland plants and animals.

The complexity of the wetlands' hydraulics were beyond the scope of this project. The remaining four wetlands all had well defined outlets, hydraulics and bethymetry which allowed reasonably accurate stage-storage-discharge relationships to be developed.

We measured frequency of storm events in a hydroperiod by defining an event as an excursion which we define as a water level increase above the monthly average depth of more than 0.5 ft. (15 cm.). Duration was defined as the time period of an excursion. In a stepwise regression, we looked at the statistical relationship between WLF, frequency and duration. Table 1 shows the categories used in the analysis.

Table 13-1. Category Definitions for Water Depth and Excursion Duration.

Frequency of Excursions	Water Depth*	Duration of Excursions
less than 6 per year	Greater than 2.0 ft. depth (>60 cm.)	less than 3 days
more than 6 per year	2 ft. to 0 ft. depth (-60 to 0 cm.)	3 to 6 days
	0 to 2.0 feet above water surface. (0 to +60 cm.)	more than 6 days

*Negative numbers are under water.

RESULTS

Plant richness in the sample stations ranged from three to 31 species in the POW zones, three to 22 in the PSS zones and 17 to 25 in the forested areas. Very few invasive weedy species were found and were dominant in only a few localized areas.

Frequency and Duration and Plant Richness

Plant richness was found to be significantly lower if water depths were usually deeper than 2 feet (60 cm.) (KW, $p < 0.0001$). To control for this, frequency and duration were evaluated separately for different water depths. The test for differences in duration and frequency showed that, in general, plant communities in areas subjected to more than six hydrologic excursions per year tended to have lower richness. In both the greater than 2.0 feet range and zero to 2.0 feet range the difference is statistically significant (MW, $p \leq 0.004$). It was not significant for the -2.0 to zero range (Figure 13-1).

APPLICATION OF RESEARCH RESULTS

These results show that

- increasing the duration of storm events can be a significant factor in reducing wetland plant diversity. The frequency of storm peaks is also a factor and compounds the duration impact.
- Decreasing richness in the emergent and scrub-shrub zones and increasing frequency and duration are also associated with high mean water level fluctuation, annually, but particularly during the early spring growing season and amphibian breeding seasons.

Current stormwater protection measures primarily rely on stormwater detention for protecting wetlands. Detention acts to increase the duration of a storm event in order to reduce the peak depth. Water is captured, stored and released after the storm over a longer period of time. It was a management tool designed primarily for controlling floods and erosion in streams, however, it may operate counter to management goals as a tool for wetland protection.

The result of these findings has been to recommend for there to be limits on the durations of storm events as well as the frequency of excursions, when wetlands will be affected by changes in hydroperiod.

- The recommendations are that the frequency of water levels greater than 15 cm. (0.5 ft.) above pre-development levels be limited to an annual average of six or less per year and that the durations of water levels greater than 15 cm. (0.5 ft.) above or below pre-development levels be limited to less than three days per excursion.

The data set we analyzed was limited, as were time and funding and some questions remain about the potential for trading flood frequency and flood duration. For example, it might be possible to extend the durations of storm flows in wetlands if the frequency of those events is reduced. Similarly, it may also be possible to reduce durations in trade for allowing greater frequency. These areas of refinement remain largely unexplored.

Irrespective of any further results, it will be difficult for urbanizing jurisdictions to meet such standards in all areas. It is also not likely to happen if detention is the primary management tool. Achieving real resource protection of high value wetlands will require a more comprehensive approach.
Early in the research the PSWSRP learned that wetland management must be holistic, that wetlands are part of a system in a larger landscape and should be managed accordingly. This view has a number of implications for management:

CONCLUSION

Fundamentally managing stormwater to protect wetland ecosystems must operate holistically within context of the hydrologic cycle. That requires that we consider infiltration and evapotranspiration in addition to storage, when we think about strategies. Controls focused on minimizing impervious surfaces and maximizing forest retention are likely to be the most widely usable effective strategies; however, additional mitigations that reduce stormwater volumes through infiltration are highly recommended when hydrogeological conditions permit.

D-4 Parklands Executive Residential and Parklands Business Park at Camas Meadows Golf Course – Wetland Protection Discussion

2.5.8 Minimum Requirement #8: Wetlands Protection

Applicability

The requirements below apply only to projects whose stormwater discharges into a wetland, either directly or indirectly through a conveyance system. These requirements must be met in addition to meeting Minimum Requirement #6, Runoff Treatment.

Thresholds

The thresholds identified in Minimum Requirement #6 – Runoff Treatment, and Minimum Requirement #7 – Flow Control shall also be applied for discharges to wetlands.

- **Runoff treatment is being met by several different BMP approaches. <u>This project discharges to a Flow Control - exempt receiving water</u>. See comments that proceed this section.**

Standard Requirement

Discharges to wetlands shall maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated uses. The hydrologic analysis shall use the existing land cover condition to determine the existing hydrologic conditions unless directed otherwise by a regulatory agency with jurisdiction. A wetland can be considered for hydrologic modification and/or stormwater treatment in accordance with Guide Sheet 1B in Appendix I-D.

- **The portions of wetlands on this site (part of larger complex) historically have received runoff from a larger drainage area than presently exists. Approximately 12 to 14 acres west of the present development was diverted as part of the Payne Road project. Another 11 acres seem to have been diverted when Larkspur Road and Larkspur Subdivsion was developed.**

- **The proposed stormwater management plan is proposing measures to reduce runoff impact in two specific manners.**
  1) **Apply soil amendment and flow dispersion to reduce runoff volume.**
  2) **Design for lots along buffer to continue to flow overland to and through the buffer and into the wetland.**
- **The wetland does have gradient for flow to and through the wetland. The large surface area involved allows for hydraulic flow movement with little fluctuation in water depth or velocity.**

- **This site has three separate wetlands hydraulically connected with existing culverts. Therefore it seems advisable and prudent to utilize these structures to continue to manage inflow/outflow from one wetland to another. Even though the required**

treatment is provided onsite for the conveyance systems, further treatment if needed will be naturally accomplished.

- **Optional – only pursued by City approval: In particular, by allowing a bit of storage attenuation in the smaller wetland, the timing of outflow to the larger wetland can be delayed and 'spread out' over time to reduce the impact to the larger wetland. It appears that this design approach can be considered appropriate for hydrologic modification and/or stormwater treatment in accordance with Guide Sheet 1B in Appendix I-D.**

Additional Requirements

The standard requirement does not excuse any discharge from the obligation to apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC, or state ground water standards, Chapter 173-200 WAC. Additional treatment requirements to meet those standards may be required by federal, state, or local governments.

Stormwater treatment and flow control facilities shall not be built within a natural vegetated buffer, except for:

• necessary conveyance systems as approved by the local government; or
• as allowed in wetlands approved for hydrologic modification and/or treatment in accordance with Guidesheet 1B.

- **This design approach (optional – see above) is applicable for this site. However, a number of trees might need to be removed, and the approval process seems cumbersome because of concerns about the wetland.**
- **The overflow water would enter the wetlands in a non-erodible manner.**

An adopted and implemented basin plan (Minimum Requirement #9),or a Total Maximum Daily Load (TMDL, also known as a Water2-36 Volume I – Minimum Technical Requirements February 2005

Clean-up Plan) may be used to develop requirements for wetlands that are tailored to a specific basin.

Objective

To ensure that wetlands receive the same level of protection as any other waters of the state. Wetlands are extremely important natural resources which provide multiple stormwater benefits, including ground water recharge, flood control, and stream channel erosion protection. They are easily impacted by development unless careful planning and management are conducted. Wetlands can be severely degraded by stormwater discharges from urban development due to pollutants in the runoff and also due to disruption of natural hydrologic functioning of the *wetland system. Changes in water levels and the frequency and duration of inundations are of particular concern.*

Supplemental Guidelines
Appendix I-D, "Wetlands and Stormwater Management Guidelines" is an amended version of Chapter 14 of the publication, "Wetlands and Urbanization, Implications for the Future", the final report of the Puget Sound Wetland and Stormwater Management Research Program, 1997.

- **This document is being used as guidance for this project.**

It should be used for discharges to natural wetlands and wetlands constructed as mitigation. The amendments were added to Guidesheets 1A, 2B, and 2C to improve clarity of intent and to make them compatible with the updated manual. While it is always necessary to pre-treat stormwater prior to discharge to a wetland, there are limited circumstances where wetlands may be used for additional treatment and detention of stormwater. These situations are considered in Guide Sheet 1B of the guidelines.

- **See comments on separate document related to these guidelines.**

Note that if selective runoff bypass is an alternative being considered to maintain the hydroperiod, the hydrologic analysis must consider the impacts of the bypassed flow. For instance, if the bypassed flow is eventually directed to a stream, the flow duration standard,

Minimum
Requirement #7, applies to the bypass.

- **Selective runoff bypass is not being proposed.**