PROJECT MEMO

To:

FROM: Glenn Hume

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PROJECT: Low Impact Development

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SUBJECT: WWHM Comparison Analysis

AHBL
CIVIL & STRUCTURAL
ENGINEERS▲PLANNERS

The purpose of this analysis was to provide general comparisons for the total volume of stormwater storage required for a conventional residential development versus a low impact development (LID) design by utilizing the new Department of Ecology (DOE) standards. Kensington Estates, a residential development in Pierce County on a 23.92-acre site approximately 4 miles south of Puyallup, was used as the case study site. The Western Washington Hydrology Model (WWHM) developed by the DOE was utilized as the design tool in sizing conceptual stormwater facilities. The WWHM is an continuous model based on HSPF developed by DOE to provide a tool to design and analyze a storm facility's ability to meet the new DOE requirements of matching pre-developed and developed peak flows and also matching flow durations from half the 2-year storm to the 50-year design storm. This new quantity control requirement, established in the *Stormwater Management Manual for Western Washington*, August 2001, is similar to the King County requirements for Level 2 quantity control. Following is a list of the assumptions and input used to compare the stormwater storage requirement for conventional development versus Low impact development. The resulting volumes are provided in the attached table for comparison (see Attachment #1).

General Assumptions:

1. The total site area is 23.92 acres.
2. Soils are predominately Type C soils, modeled as till soils in the WWHM.
3. There is an existing wetland located near the south portion of the property line.
4. Existing conditions are predominately forested (pre-developed conditions of forest are required by the WWHM unless there is historical evidence that the property was pasture prior to the influence of man.)

Conventional Development Assumptions:

1. Area input values for conventional development analysis were obtained from the *Pierce County Low Impact Development Study* by CH2MHILL, dated April 11, 2001.
2. All roof drains are tight-lined to closed-pipe conveyance system located in the road network.

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3. Roads consists of asphalt concrete pavement with curb and gutter and sidewalk. Stormwater conveyance is through a network of catch basins and closed pipe discharging directly to the quantity control facility.

4. The developed site was modeled as a single basin.

5. Existing wetland and wetland buffer area was not included in the basin input for pre-developed or developed basins.

6. The conventional design utilizes a single detention facility. The detention design was evaluated using the WWHM and the new DOE standards.

7. Stormwater quality requirements are met via a wetpond. The required wetpond volume was calculated utilizing the Waterworks program. Waterworks is an event-based program that utilizes the Santa Barbara Urban Hydrograph (SBUH) method with Type a 1A rainfall event to determine total volume of stormwater runoff for design events. The treatment design event used to size the wetpond was the 6-month, 24-hour storm event with a total precipitation of 1.28 inches.

Low Impact Development Assumptions:

1. Basin area values are based on the Low Impact Site Plan developed by AHBL.

2. All roof drainage and road runoff is routed through a network of swales and rain gardens with a total flow length of greater than 50-feet prior to discharge to detention ponds.

3. The rain gardens provided and grassed swales meet the minimum requirement for runoff treatment.

4. Due to flow length through vegetated areas, all roof area is modeled as grass.

5. Open space retained on the site is in forested conditions.

Method of Analysis

6. The site is divided into four basins (see Attachment #2). Each basin has its own stormwater quantity control facility.

    a. Basin B1 is the northern portion of the site. This basin sheet flows towards the west. The western portion of this basin has been left undisturbed to allow for dissipation of stormwater runoff into the natural forest. This basin does not meet the DOE requirement for full dispersion. To obtain the full dispersion credit, eliminating the need for quantity control ponds, the basin must be 65-percent undeveloped and the total impervious area must be less than 10 percent of the basin area. Currently, as shown, Basin B1 is 55-percent undisturbed. This does not meet DOE requirements, therefore; a stormwater detention pond was developed for this basin.

b. Basin B2 is the southwest portion of the site. This basin sheet flows across the southwest corner of the site and is partially intercepted by the ditch adjacent to 152 Street E.

c. Basin B3 is the wetland and buffer area and the portion of the site directly tributary to the wetland through sheet flow. It was assumed that this basin in the developed conditions would be allowed to discharge directly to the wetland because we have reduced the area tributary to the wetland and the developed area tributary to the wetland consists of lots and undisturbed open space. All roof runoff will be sheet flowed or flow in swales for a minimum of 50-feet prior to discharge to the wetland buffer.

d. Basin B4 is the southeast portion of the site. This basin sheet flows across the eastern property line.

7. The four Basins were analyzed for ten scenarios, each using a different combination of low impact development concepts. The model scenarios are described below: (the scenario numbers correspond to row numbers listed on Attachment 1)

   a. Scenario #1 – In Scenario #1 it was assumed that all roads would be 24-feet wide with asphalt concrete surfacing. Runoff is collected in a network of vegetated swales and conveyed to a stormwater quantity control facility. Rain gardens are provided for each lot or two lots share a common rain garden. By use of rain gardens and vegetated swales, it was assumed that the house roof area may be modeled as grass and not impervious surface. As stated earlier, undisturbed areas are assumed to be in a forested condition.

   b. Scenario #2 – Scenario #2 is set up the same as #1 except the roads are 20-feet wide.

   c. Scenario #3 – Scenario #3 is set up the same as #1 except the 24-foot roads are constructed of a pervious pavement system. The credit for pervious pavement is equal to the maximum credit allowed by the WWHM.

   d. Scenario #4 – Scenario #4 is the same as #1 with the addition of Pin Foundation systems. Based on the analysis by Rick Gagliano of Pin Foundations Inc., it was assumed that on average 47.7 percent of the undisturbed soil profile under a house would be 'activated' by the use of pin foundations. Pin foundation systems are constructed so that the majority of the natural soil profile is maintained under the house. Runoff from the house's roof is directed onto the lot and is allowed to flow through the soil profile under the house. The term 'activated' refers to the portion of the soil profile that is left undisturbed to which runoff from downspouts can be directed. The percent of activated soil under the house if a function of site topography, house configuration, and downspout location. It was assumed that the 'activated' soil profile could be modeled as pasture. Therefore, in the scenarios where pin foundations are utilized, it is assumed that 47.4-percent of the roof area may be modeled as pasture. In Scenario #4 the remaining

52.3-percent of the roof area was modeled as grass through the use of rain gardens and vegetated swales.

e. Scenario #5 – Scenario #5 is the same as Scenario #4 except that the 24-foot roads are constructed of a pervious pavement system.

f. Scenario #6 – Scenario #6 is the same as #4 except that 47.7-percent of the roof area is modeled as pasture because of the Pin Foundation system and the remainder of the roof area (52.3-percent) is modeled as impervious.

g. Scenario #7 – Scenario #7 assumes that the roof systems are directly connected to the main storm conveyance system and are therefore modeled as impervious surfaces. The road widths are 24-feet wide and constructed of impervious pavement. The total required detention volume for this scenario is approximately 121,000 cubic feet. This is compared to the required volume of 270,000 cubic feet for the conventional design. A comparison of these numbers shows that the greatest affect of low impact development is the reduction of the development's footprint.

h. Scenario #8 – Scenario #8 is the same as #3 except that the pervious pavement was modeled as grass instead of using the WWHM's standard credit for pervious pavement. The assumption that pervious pavement can be modeled as grass is based on the "University of Washington Permeable Pavement Demonstration Project".

i. Scenario #9 – Scenario #9 assumes the roads are 20-feet wide and constructed of a pervious pavement system. The standard WWHM credit for pervious pavement was used. Pin foundation systems and rain gardens are also utilized. Therefore, the roof area is modeled as 47.7-percent pasture and 52.3-percent grass.

j. Scenario #10 – Scenario #10 is the same as #9 except that the pervious pavement was models as grass instead of using the standard WWHM credit.

8. Basins B1, B2, and B3 were each analyzed to compute the required volume for Scenario #1. These volumes were compared to obtain a relationship between the volumes obtain for Basin B2 compared to volumes in B1 and B4. The volume required for Basin B1 is 117.5-percent of B2's volume while Basin B3's volume is only 0.75-percent of B2's. Basin B2 was analyzed using the WWHM for the remaining nine scenarios. Volume values for the remainder of the scenarios for Basins B1 and B4 were computed based on the percentages calculated above and the required volume for Basin B2. The values that are calculated via percentages are shaded in the table (Attachment #1).

Results

The total stormwater storage volume required for all four LID Basins are compared against the total volume required for the conventional development basin. The total LID volume required for the scenarios analyzed ranges from approximately 43,500 ft^3 to 121,000 ft^3; the total conventional volume required is 270,000 ft^3. The total difference is between 226,500 ft^3 and 149,000 ft^3.

The hydrologic analysis demonstrates that the required detention storage volume can be substantially reduced by the use of LID elements. The main intent of the stormwater design for the LID version of Kensington Estates was to manage rainfall runoff as close to the source to emulate existing hydrology as much as feasible. Whereas, the common practice in conventional development is to convey, typically through a closed-pipe system, all the runoff produced in a development to one large detention facility. The detention facility then flows from the development at a single discharge point. In the LID layout, the site is divided into four separate drainage basins each with its own discharge point.

Basin B1 is configured to leave a large undisturbed area downstream of the proposed development. Although the basin does not meet the DOE requirements for full dispersion, the open area does provide for greater stormwater attenuation. The design concept for this basin would be to provide long, linear detention ponds following the existing contours of the site. Discharge from the ponds would be through a level-spreader device that would allow the pond discharge to sheet flow across approximately 200 feet of undisturbed forest prior to discharge from the site. The DOE manual encourages this practice, however; there is currently no credit for the use of the undisturbed area because the basin does not meet the threshold requirements of 65-percent undisturbed area.

Basins B2 and B4 would have a more concentrated point discharge, but the peak discharge rate is greatly reduced from the rates of a single discharge point expected in convectional design.

In each basin there are rectangular open spaces created by the road circulation pattern. These areas can be used to provide some community parking. They can also be utilized as convex open areas. These open areas average approximately 60 feet by 160 feet. With 5:1 transition slopes and a 6-inch total depth, these areas can provide approximately 3750 cubic feet of temporary storage. The runoff collected in these depressions would receive treatment through uptake by vegetation. Additionally, the shallow pool with a large surface area will encourage infiltration into the soil and evaporation. This analysis did not account for the storage area available in these convex open spaces, primarily due to the limitations of the WWHM. Specifically, the model currently does not provide a means of routing runoff information through multiply facilities. The next version of the model is expected to have this ability. This will assist in the analysis of the multiple facility concept utilized in LID.

Discussion Items

The new DOE manual encourages the use of LID concepts, however; there are limited credits available for their use. As discussed earlier, the largest affect of LID is the reduced development footprint. Other LID elements contribute to a lower runoff rate and volume from the developed project but the credit given by the DOE manual for these elements is limited or not clearly defined. The following LID elements need to be discussed to determine if greater credit shall be given for their use:

1. The threshold for full dispersion is 65-percent of the development (or threshold discharge area on the site) and a 100 foot flow length through natural vegetation to

property lines or drainage channels. There is no dispersal credit for Basin B2 despite the fact that a 55-percent open space and a 200-foot flow length are provided. A chart based on the functions of basin percent disturbed/impervious versus undisturbed flow length could be developed to provide incremental credit instead of one firm threshold.

2. The full dispersal BMP states that the runoff shall be directed through native vegetation for a minimum flow length of 100 lineal feet. In the case where development is occurring on a site that has been previously converted from forest to pasture or other non-native use, is re-forestation an option for the open areas to meet this requirement? If so, what are the standards for re-forestation?

3. Related to item #2, assume the site being development has been previously converted from forest to pasture or other non-native vegetation. If the development proposes to leave a large open space in its current conditions (pasture), is mitigation required for this area because the DOE manual requires that all pre-developed conditions be modeled as forest? If so, is there a threshold for when the requirement would become affective. For example, if a corner of a 20-acre parcel that has been previously converted from forest is being developed for commercial use and the developed area is 5-acres. When the detention system is designed, is it required to be sized for just the 5-acre disturbed area, or does it also have to mitigate for the 15-acre undisturbed area because it had been previously converted from forest to pasture?

4. The individual roof dispersal is geared towards large (22,000 square foot) lots. Rain gardens are described in BMP T5.34 Multiple Small Basins, but it does not clearly state the credit provided by their use. The assumption was made that by utilizing rain gardens to temporarily store roof runoff that the roof area could be modeled as grass. The manual could develop guidelines for the minimum size/volume of a rain garden per square foot of projected roof area. If the minimum volume is provided, the roof area could be modeled as grass. Otherwise, the engineer would be required to analyze each rain garden as an individual detention basin that flows are routed through prior to discharge to a main stormwater control facility. This is a cumbersome task for a 100-lot development. Especially considering that the current version of the WWHM does not support analysis of a series of small basins.

5. Soil amendments and increased soil restoration depths are encouraged but no credit is given for improving the soil characteristics.

6. Based on studies performed by the University of Washington, larger credits may be appropriate for the use of pervious pavement systems.

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