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MULTI-SCALE LIFE CYCLE IMPACT INDICATORS OF FRESHWATER RESOURCES IN THE BUILT ENVIRONMENT

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Historically, the typical practice for impact assessment of water use as a resource in life cycle assessment (LCA) was to calculate an inventory for water use on a mass or volume basis. Life cycle impact assessment (LCIA) modeling requires models that are globally applicable and can estimate the relative intensity of impact. Recent work uses concepts such as water stress which recognize the need to differentiate between consumptive and non-consumptive water use. The model developed in this work examines water use in the built environment by coupling hydrological and land-use data to determine the impact on surface and groundwater storage, and can serve as a tool for policy-makers and planners to understand the impacts of land-use change on the sustainable management of water resources.

In general terms, the built environment affects water quantity available in an ecosystem through water withdrawal from surface and ground-water, and by altering land cover and thereby changing infiltration, runoff, and evaporation and transpiration. The model uses as its boundaries the drainage basin to facilitate the water mass balance calculations and validate the results based on precipitation input and stream-flow output. The method uses parcels as the analytical unit, and estimates the effective impervious area per entity based on its land-use classification. Then, each unit's water use is modeled using a system analysis that combines water flows from building processes and the environment into the hydrological mass balance. Finally, the approach to estimating impact is to compare the changes in the water budget of the modeled hypothetical natural vegetated land cover state to the current developed state, with the ratio of both states representing the relative impact on surface water discharge and aquifer recharge at an annual basis. Conversely, the analysis can compare future land use scenarios with the current hydrological state of the selected area. Consequently, the impact indicators have been calculated at the parcel-level, at the community level, and at the sub-region hydrologic unit level.

For this study, two modeling approaches have been used. The first uses four water budget breakdowns according to land use density and its ranges of imperviousness. And it

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multiplies the given percentages per hydrologic component by measured precipitation to obtain the annual water mass balance in an expedited way. The second approach is based on the curve number method for run-off calculation and the application of the Penman-Monteith equation for evapotranspiration. The calculations were performed on a daily basis with data from the nearest climate station and aggregated by months in order to account for the effects of time lags in shallow infiltration discharge on the resulting hydrograph. The modeled discharge values have been compared with stream-gauged values. The difference between the modeled and the measured values are attributed to aquifer discharge at the point of measurement and precipitation variability due to the distance of the climate station to the area of study.

The impact model results confirmed that changes in discharge to surface water and aquifer recharge are correlated to the percentage of effective impervious surfaces within the study area. At the hydrological unit sub-regions in Florida a decrease in aquifer recharge in the developed stage was calculated in the range of 50% to 70% of expected natural vegetated land cover state volume. Also, increases in surface discharge after land development range from 80% to 120% of the predevelopment volume. However, at the parcel and community levels, water use intensity by areal unit showed greater impact on the aquifer than the hydrological response from changes in land-cover alone. At the parcel-level, the indicators for aquifer recharge showed negative values that account for a greater water use than available recharge under natural land-cover conditions. Furthermore, the indicator for surface discharge showed an increase over 200% of the predevelopment value. At the community level, aquifer recharge and surface discharge show intermediate magnitudes between the regional and parcel level values. The variability across scales is attributed to the “modifiable areal unit problem” and represents a challenge for further development of these indicators and their comparison. Nevertheless, the modeled indicators generally follow the accepted view of regional water stress in Florida.

Future work will see this model applied to the University of Florida campus, a micro watershed community. In the scenario analysis, the effects of implementations of green roofs are evaluated. The hypothesis is that upon the inclusion of green roofs acting as additional water detention facilities throughout campus will decrease the dynamic runoff quantity temporally due to retention and decrease spatially due to an increase in evapotranspiration. Conversely, water withdrawal could increase due to green roof irrigation.

In conclusion, the model provides a framework to combine the impacts of the built environment on water resources through changes in pervious surfaces and water use. Its focus on changes in the water mass balance facilitates the incorporation of LCIA beyond the industrial production chain into land use. Among the significant issues in the development of multi-scale indicators is the definition of system boundaries and the unit of analysis, be it the watershed, the community or the building within a parcel.