New Strategies
for Impervious Surface Data Development

for the King County Water Quality and Water Quantity Groups Unit

Benjamin Gardner
Elizabeth Gould
Krystle Jumawan
University of Washington Professional Master's Program in GIS
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LIST OF ACRONYMS USED IN THIS DOCUMENT

BHT	Building Height
BMP	Best Management Practice
CIR	Color Infra-Red
DEM	Digital Elevation Model
DNRP	Department of Natural Resources and Parks
EPA	Environmental Protection Agency
Esri	Environmental Systems Research Institute
GIS	Geographic Information Systems
HSP-F	Hydrologic Simulation Program-Fortran
KC	King County
LC/LU	Land Cover/Land Use
LID	Low Impact Development
LiDAR	Light Detection And Ranging
NPDES	National Pollutant Discharge Elimination System
NVI	National Vegetation Index
RAM	Random Access Memory
SSWM	Storm and Surface Water Management
STSS	Science and Technical Support Section
SUSTAIN	System for Urban Stormwater Treatment and Analysis Integration
VHT	Vegetation Height
WLRD	Water and Land Resources Division
WRIA	Water Resource Inventory Area
WWTP	Waste Water Treatment Plant

New Strategies for Impervious Surface Data Development

I. BACKGROUND AND PROBLEM STATEMENT

BACKGROUND

Water quality and water resource management within the Puget Sound watershed are essential for the ecological restoration, management, and maintenance of the waters of Puget Sound. The Puget Sound watershed includes lands in Clallam Island, Jefferson, King, Kitsap, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom counties, Washington (U.S. Environmental Protection Agency [EPA], 2012; Jim Simmonds, Science and Technical Services Section Supervisor, King County Department of Parks and Natural Resources Water and Land Resources Division, email communication 3 July 2012). Water Resource Inventory Area (WRIA) 9, the Green/Duwamish and Central Puget Sound watershed, is the second most populated watershed in the state. It is a source of drinking water, food, and forest products, and is host to several species of federally Endangered Species Act salmonids, including Chinook, Coho, chum, and steelhead and has been identified as a conservation priority. As described in the King County (KC) Science and Technical Support Section (STSS) Business plan, stormwater is a significant stressor affecting the health of the Puget Sound Ecosystem. Efficiently and effectively managing stormwater to reduce harm to the ecosystem is a common goal of numerous local agencies and actors, ranging from special interest groups to citizens and government (King County Department of Natural Resources and Parks [KCDNRP], 2008). The KCDNRP Water and Land Resources Division (WLRD) STSS exercises a critical role in this effort, as WRIA 9 lies almost entirely within the county boundary (Figure 1), and the STSS is tasked with monitoring land and water resources, with developing and implementing management strategies for the benefit of the resources, as well as providing information and data for other departments to support them in their missions (Figure 2).

Historically, stormwater management efforts focused on concentrating and removing water from the landscape as quickly as possible, which contributed to sediment, thermal, and contaminant impacts to receiving waters. More recent efforts shifted to the development of regional and local systems to manage stormwater, through a stormwater conveyance and collection infrastructure that provides a measure of pretreatment before discharging to local waterbodies. King County is now looking forward to the next generation of stormwater management, with a focus on developing highly localized, site based stormwater treatment systems that provide maximum stormwater treatment benefit for the cost.

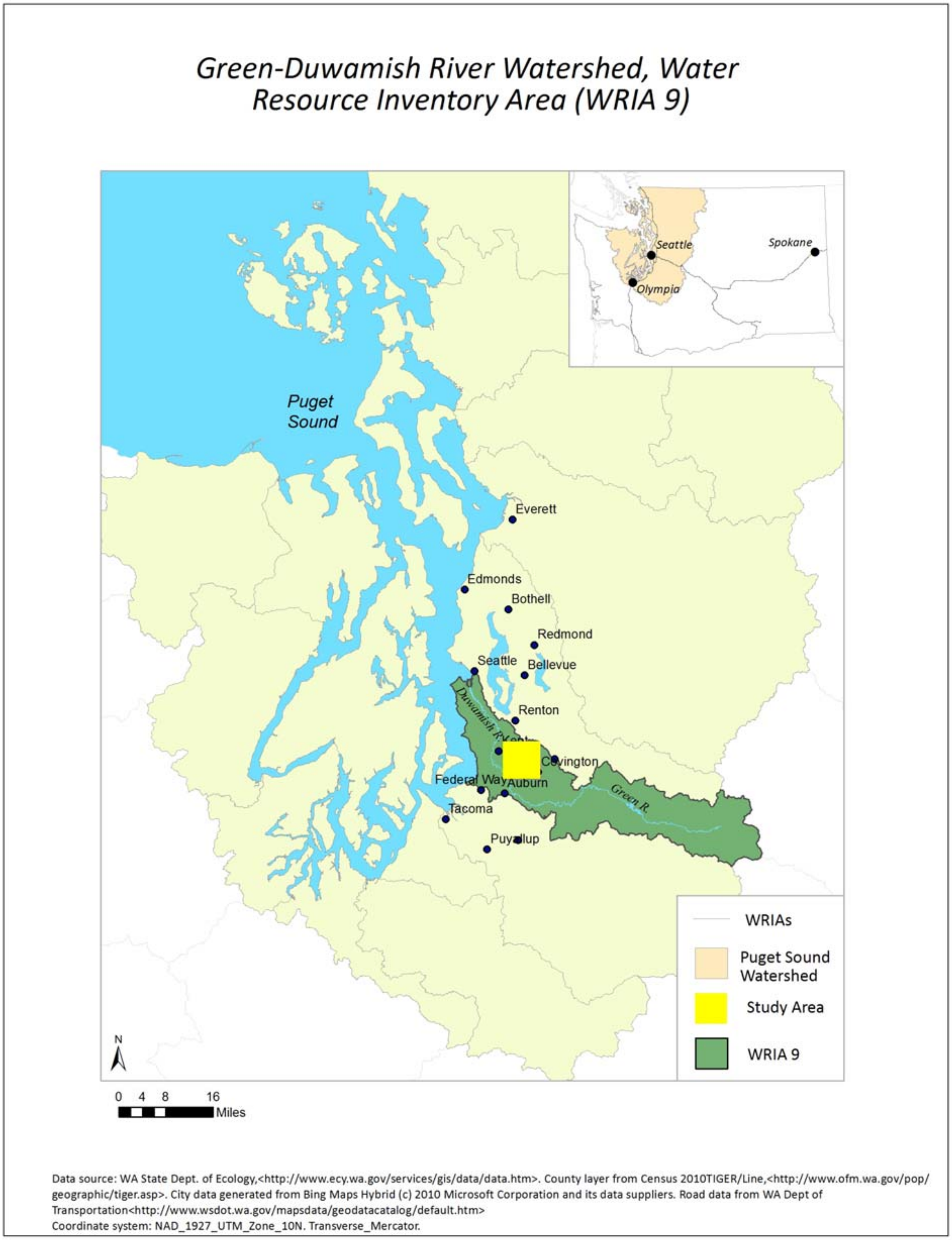

Figure 1: Project Location

King County, Water and Land Resource Division: Science and Technical Support Section Organizational Diagram

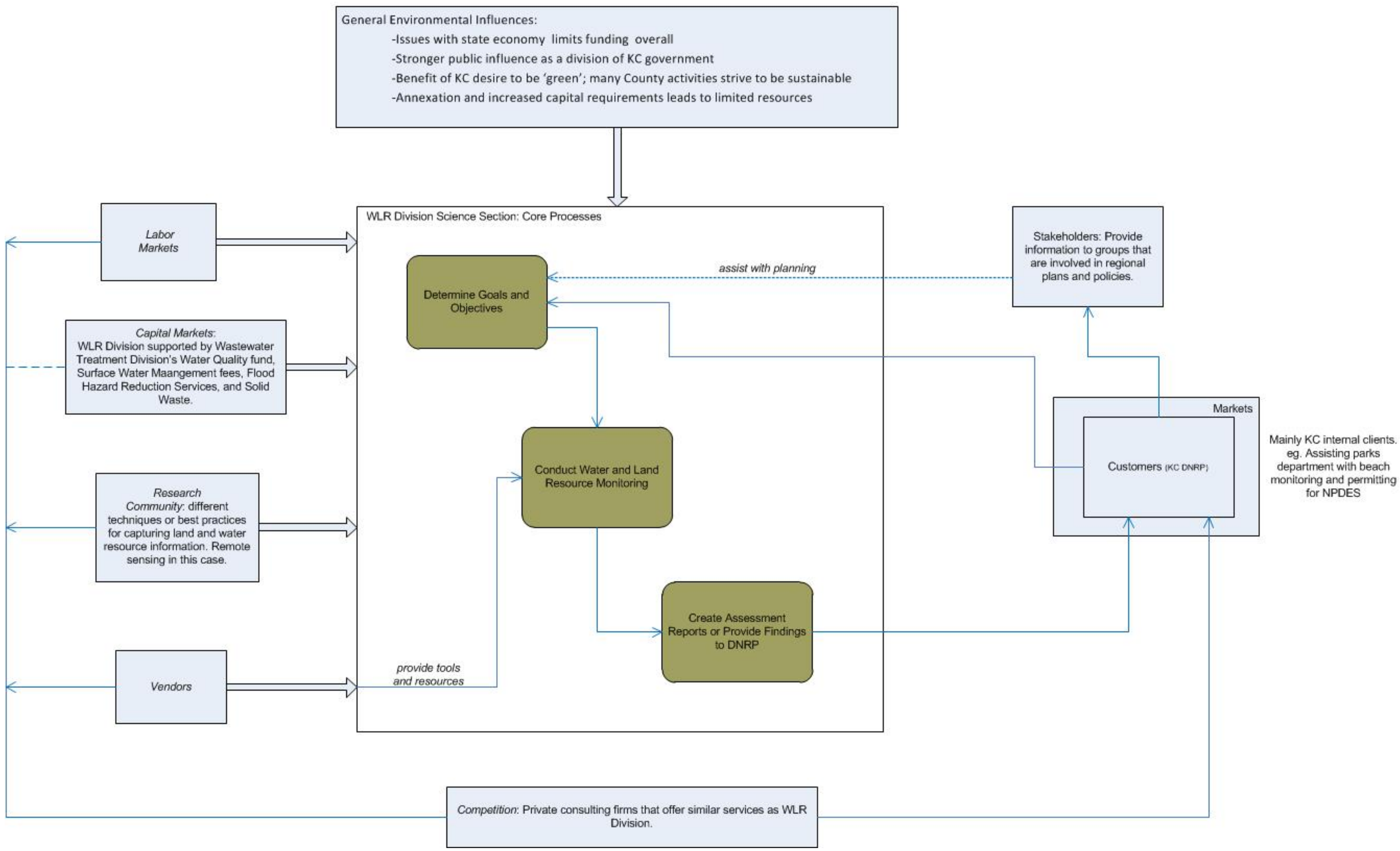

Figure 2: King County Water and Land Resources Division: Science and Technical Support Section Organizational Diagram

PROJECT GOAL

A significant area of focus for the County and the STSS is the implementation of strategies and structures to improve water quality via storm and surface water management (SSWM) (Jim Simmonds and Curtis DeGasperi, meeting notes, 27 June 2012; KCDNRP, 2008). In particular, the STSS is interested in knowing the precise locations of different types of impervious surfaces, since the type and ownership of impervious areas affects the kinds of stormwater management features that can be used to manage the associated runoff, and informs which approaches are most appropriate for funding and implementation.

OBJECTIVES

The objective for this project is to develop a tool that operates in Esri's ArcGIS and which KC GIS staff can use to automate the process of generating high resolution, fine scale, GIS-compatible vector data layers of land cover type from existing raster information. In other words, the county "needs to know" the exact location and type of impervious surface in order to plan appropriate pre-treatment strategies for a specific site. The types of impervious surface areas to be mapped automatically include:

- Commercial Parking Lots
- Commercial Roofs
- Industrial Parking Lots
- Industrial Roofs
- Multifamily Parking
- Multifamily (Buildings)
- Single Family Buildings
- Roads

An area within WRIA 9 was identified as a "sample" area to test potential methodologies. This geographic area of interest is Township 22N Range 5W--the City of Covington (Figure 1)-- which includes a mixture of developed and undeveloped land cover types.

EXISTING PROCESS WORKFLOW

DNRP executives work together to create broad strategies that address environmental health conditions of King County (Figure 3, Box 5a). (King County, 2012b) These strategies are then interpreted by the WLRD and from these strategies performance measures are established which indicate environmental health. WLRD is tasked with overseeing the STSS groups. Decisions must be made on how to delegate tasks among the STSS groups, including the Hydrology section (Figure 3, Row 2). This group conducts hydrologic monitoring and analysis to create watershed and hydrology models for KC. Hydrologic Services works with the KC GIS Center to obtain data (Figure 3, Box 1b) to assist in hydrology modeling. This information is then assessed and is used to develop specific strategies for conducting SSWM and water quality improvement projects proposed by the larger STSS (Figure 3, Box 3c). To ensure that this management is successful the STSS secure funding for projects. With the assessments made by the Hydrologic Services group and the effectiveness of SSWM improvement projects the WLRD will update their performance measures. This allows the DNRP to reevaluate their overarching strategies and goals based on these indicators. If water quality conditions in King County have not improved or are worsening then they can formulate necessary interventions (Figure 3, Box 5b).

EXISTING ACTIVITY WORKFLOW

While current regulations require that the creation of new impervious surface areas include adequate storm and surface water management treatment methods, existing or older impervious surface areas often do not have adequate existing stormwater infrastructure. Stormwater maintenance and improvements are currently funded via the stormwater management fee paid by KC property owners.

This generates $1-2 million annually (Figure 4 Box 3b) , which is enough revenue to cover emergency repairs to infrastructure within the stormwater management "train", and to address violations that contribute to water quality degradation, such as erosion, but is not sufficient to cover the cost of routine maintenance or upgrades (Figure 4, Box 3c). While KC has investigated the possibility of increasing the fees and expanding the capital improvement program, the ten-fold or more increase that is necessary to fully fund needed improvements and maintenance is politically untenable, and the County remains limited to managing only emergencies and violations. The Science section group supervisor leads this process, with input from the lead hydrologist and data and processing support from KC GIS center (Figure 4, Boxes 1a -d, 2a-c)

PROPOSED ACTIVITY WORKFLOW

As part of the effort to further refine King County's SSWM efforts into a highly localized treatment system, members of the KCDNRP WLRD received EPA funding to develop models that will prioritize areas in WRIA 9 where stormwater infrastructure installation will provide maximum benefit to water quality (Figure 5). The modeling effort is a two-stage process, executed by the hydrologists at KC DNRP WLRD. The first phase (Figure 5, Box 2b) uses the Hydrologic Simulation Program-Fortran (HSP-F) to develop time series data of flow and water quality at catchment pour-points for subbasins within the watershed. Data input into this model includes land cover, Digital Elevation Model (DEM) information, weather, geologic information, soils, hydrologic features including stream channel morphology, incision, and depth, and the locations and types of existing stormwater facilities (Figure 5, Box 1b). Desired additional information to input into this model includes highly detailed information about the types and locations of impervious surface within the model area (Figure 5, Box 1d).

The output from the HSPF model is then input into the EPA's SUSTAIN model (System for Urban Stormwater Treatment and Analysis Integration) (Figure 5 Box 2c). SUSTAIN is a powerful, flexible, and complex modeling software with the capability of outputting very specific information about the size, types, numbers, and locations of Best Management Practices (BMPs) and Low Impact Development (LID) strategies that will provide the maximum benefit to watershed water quality for the cost (Figure 5, Box 2a) . Once this information is available, implementation and retrofitting of the new stormwater treatment infrastructure can be accomplished via several approaches (Figure 5 Box 3g). When existing sites are redeveloped, permitting under the National Pollutant Discharge Elimination System (NPDES) requires implementation of appropriate metrics and measures to eliminate discharge. For existing properties, the ability to customize existing stormwater fees based on the site contribution may serve as incentive for property owners to retrofit. Finally, government programs exist that can fund stormwater management improvements on public lands; in addition to minimizing impacts arising from these lands, stormwater treatments on these lands may be planned and designed in such a way as to treat or mitigate from adjacent private lands (personal communications, Jim Simmonds and Victor High, meeting 11 July 2012).

However, to effectively implement this strategy, the SSTS needs to know the locations of impervious surface at as fine a scale as possible, and to be able to distinguish the type and ownership of impervious, as different types require different treatment strategies, and the ownership type affects which implementation strategies are appropriate. Typically this has been accomplished via manually digitizing vector data layers from satellite imagery (Sterr and Yui Lau, 2012). However, this process was found to be extremely labor intensive and expensive given the geographic scope of the study area, often too coarse in scale, and not necessarily comparable through time (Simmonds, 2012; Harmon, 2007). (Figure 5, boxes 6a-e, Boxes 3b-c)

INFORMATION PRODUCTS

The information products include fine scale vector data layers that represent the location of specific types of impervious surface, within a 6' horizontal accuracy. Specifically, the data products include vector layers of roof tops and pavement, organized according whether the associated land use is single family homes, multiple-family dwellings, commercial, or industrial. The products also include a "blueprint" for the method for generating the data, so that KC can refine and additionally develop outputs as needed, including potential future development of a tool to map vegetative cover type. The method for creating the vector data layers will also be captured as a tool coded in Python and executable within ArcGIS vers. 10.1.

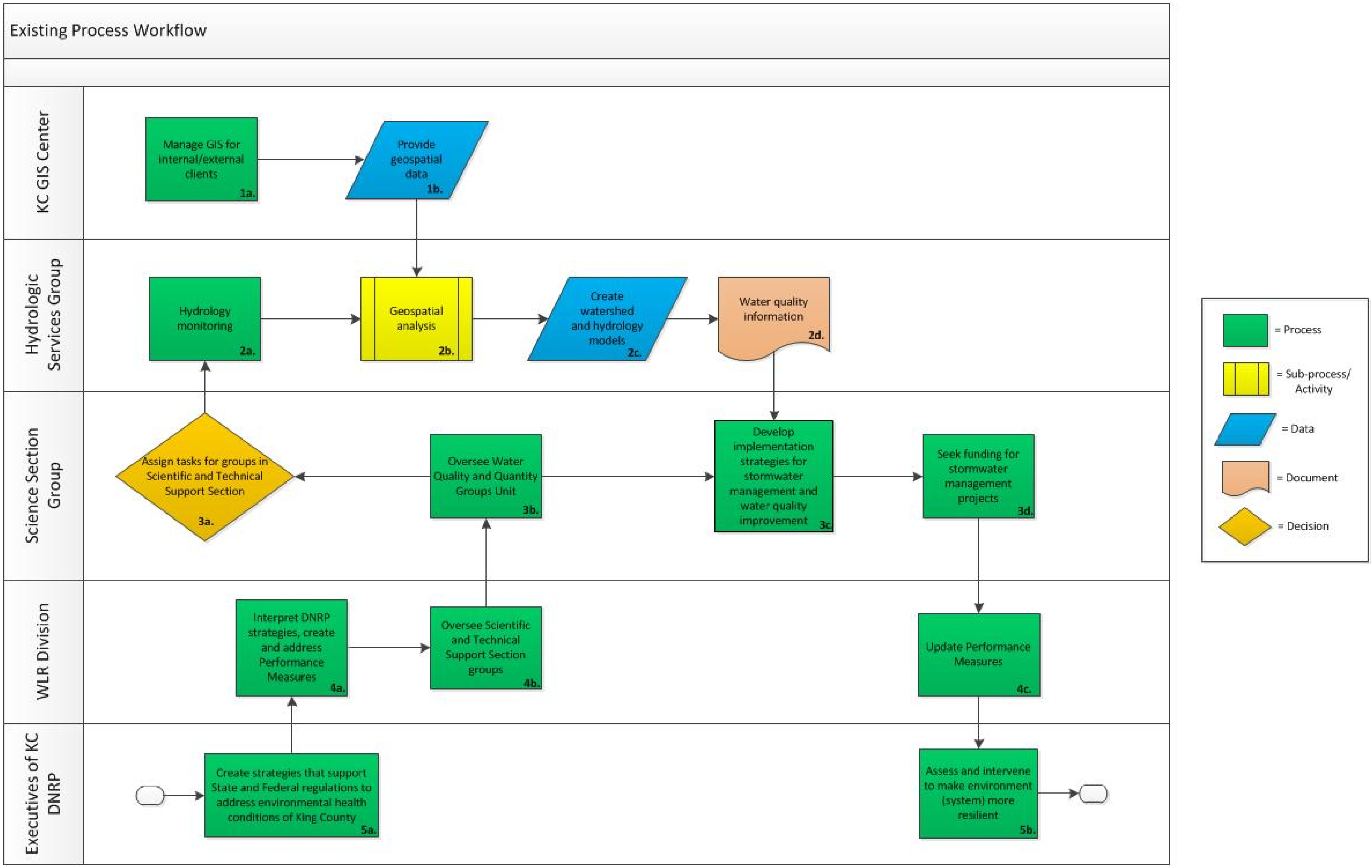

Figure 3: Existing Process Workflow

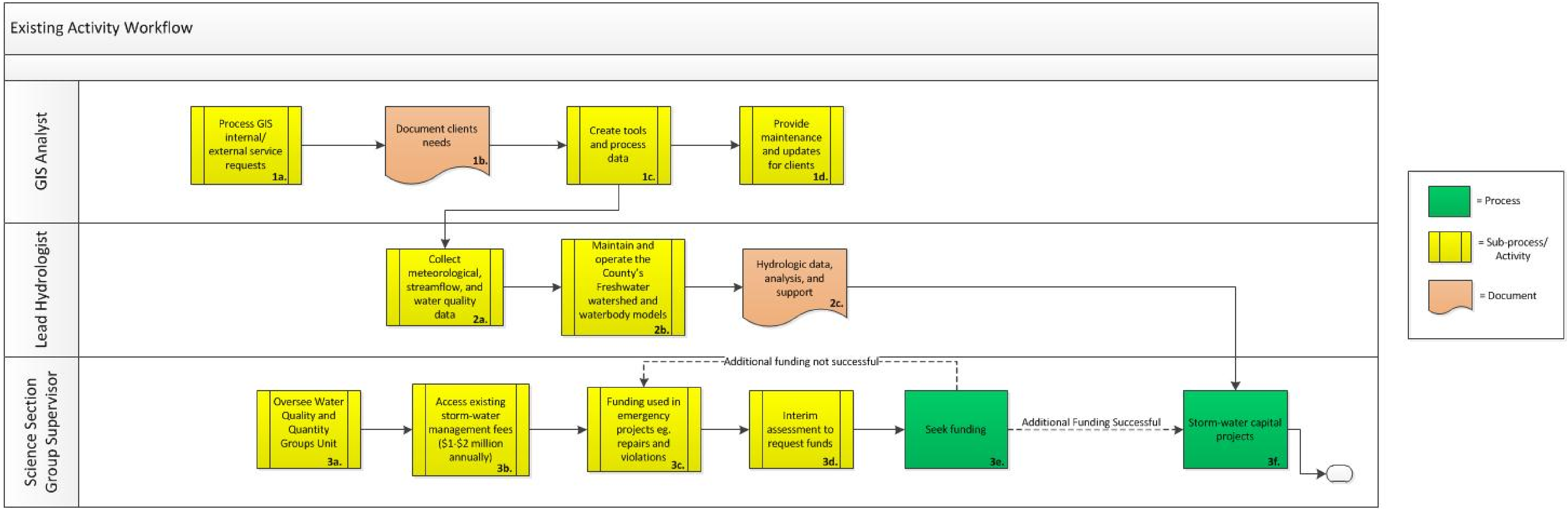

Figure 4: Existing Activity Workflow

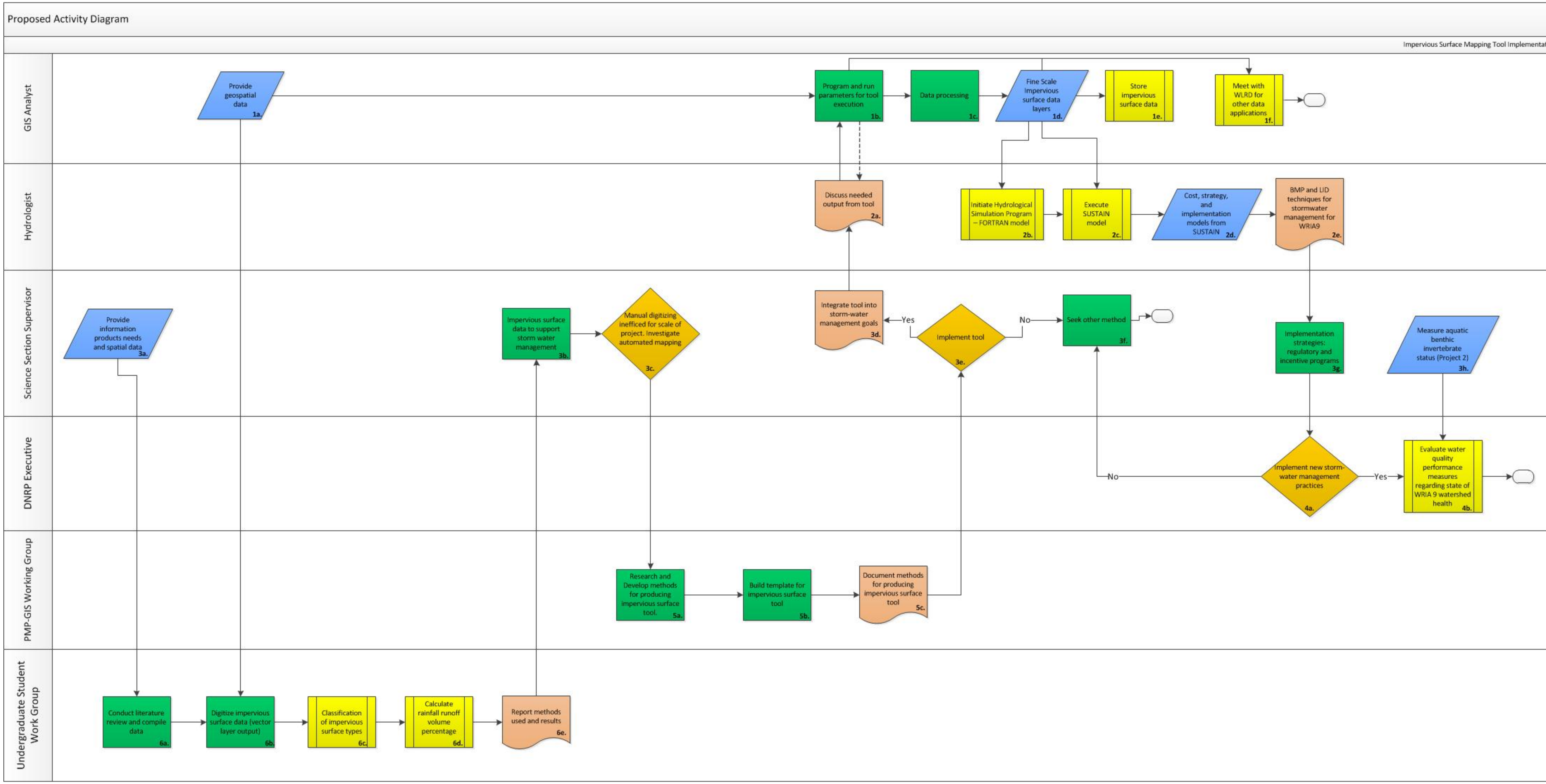

Figure 5: Proposed Activity Workflow

PROJECT BENEFITS

When developed to completion, the project will benefit water quality within WRIA 9 and Puget Sound by allowing a very focused, directed application of stormwater management strategies within the watershed. Because generating the data by hand is extremely labor intensive and thus very costly, having a tool that automates the process will present a cost savings to the SSTS and KC (see Section V) and also will make it possible to generate impervious cover data far more frequently, as well as with greater accuracy.

While the immediate benefit of the impervious surface tool is the stormwater treatment analysis that will be output from the SUSTAIN model, this fine scale mapping of impervious has various other applications that will benefit water quality within the implementation area.

In addition to the funding challenges that the county faces in stormwater management, there are practical challenges that arise naturally when working in an area with a varied and long history. One of these is the lack of adequate information about the location --or existence--of all connections between commercial, industrial, and multifamily units and the existing stormwater infrastructure. This makes planning and implementing maintenance of these connections impossible (Jim Simmonds, 26 July 2012). When overlaid with the stormwater infrastructure data in GIS, the fine scale impervious data output will facilitate the identification of locations where these connections are likely to occur.

Other challenges to water quality protection include the fact that, at the time when the City of Seattle's original stormwater conveyance system was constructed, it was standard practice to design stormwater systems such that any stormwater overflow resulting from heavy precipitation events was diverted to the sanitary sewer and ultimately to the waste water treatment plants (WWTPs). This can drive up treatment costs at the WWTP and has the potential to overwhelm the WWTP capacity, resulting in the discharge of untreated water into receiving waterbodies. In some cases, cities with this design have been able to separate the storm water and wastewater infrastructure into two different pipe systems, however in Seattle this is both cost-prohibitive and impractical, as it would require digging up every street to make the necessary changes. Instead, King County and the City of Seattle are taking a two-pronged approach: 1. prevent stormwater from entering the system in the first place and 2. incurring significant costs to increase the capacity of the WWTP to reduce the potential for an overflow event. The SUSTAIN model process will allow SSTS to identify, with a much higher degree of accuracy, those areas within the watershed that contribute a disproportionately high level of runoff into the storm sewer system. Prioritizing these areas for stormwater rate and volume control will have significant benefit in reducing both operations costs at WWTP during runoff events and in reducing the risk of untreated discharge from the WWTP.

II. SYSTEM REQUIREMENTS

SOFTWARE AND NETWORKING REQUIREMENTs

The tool is designed to run on ArcGIS vers. 10.1, using either a standard laptop or desktop configuration. A summary of the specifications used during development, available at KCGIS, and the recommended configuration is provided in Table 1. Note that faster processing speeds and greater RAM will significantly improve data handling and processing performance during tool execution.

Table 1: System Configuration

	Tool Development	Current KCGIS	Recommended Hardware (Minimum Requirements from Esri)
Hardware	HP Pavilion dv6 Notebook PC	Unknown	2.2 GHz
Processor	Intel(R) Core(TM) i7-	Duel processors, Dell Intel	Intel Pentium 4, Intel

	3610QM CPU @ 2.30 GHz	Xeon E5640 @2.67 GHz and 2.66 GHz	Core Duo, or Xeon Processors; SSE2 (or greater)
System type	64 bit	64 bit	
RAM	16.0 GB	12 GB	2GB
Operating System	Microsoft Windows 7, Service Pack 1	Windows 7 Professional	Windows 7 Professional
Software	ArcGIS version 10.1	ArcGIS version 10.1	ArcGIS version 10.1

While the tool was developed using ArcGIS vers.10.1, it may not run on earlier versions of ArcGIS, since ArcToolbox varies among different versions of ArcGIS. However, the fundamental process outlined in the model remains accurate.

PERSONNEL AND TIME REQUIREMENTS

Running tools in ArcGIS with larger raster data inputs can be time consuming, but once the tool is operational, initiating execution will be straightforward. Processing the data and outputs for a 36 square mile area takes several minutes; the processing time will increase somewhat proportionally as the study area increases, and will be affected by variables including the complexity of land cover. In highly developed areas, the high levels of impervious cover will require more time to process. In rural areas, where there is less impervious, processing time may be shorter.

King County anticipates that this detailed land cover data would only need to be generated every few years (Simmonds, 2012); the data could be updated when new LiDAR or new Land cover/Land use (LC/LU) data becomes available, and when the county needs updated information about the detailed location of impervious cover types. The tool is designed so that it can be executed by one person and has the potential to be generated at a local desktop or workstation. However, the recommended "best practice" for management and use of the tool output data is that the tool and output be maintained by

KCGIS, and that KC STSS staff coordinate with the KCGIS for data use; this coordination will require minimal time.

OTHER CONSIDERATIONS

In the event of significant changes or upgrades to the ArcGIS software, it may be necessary to implement some changes in how the tool is programmed, although the workflow process executed by the tool will remain valid. Similarly, the impervious surface tool uses some functions and tools that are already pre-installed in the GIS "toolbox", and the impervious surface tool design assumes that those pre-installed tools are unaltered and are stored in the default location. If Esri changes where the pre-installed tools are stored in a future version of the software, the coding in the impervious surface tool will need to be updated so that the sub-processes are initiated from the correct location.

III. DATA ACQUISITION

DATA DESIGN

Several sources and types of data were used to generate the final vector layers of impervious surface types. These are summarized in Table 2. Essential data includes the "BHT" layer created by King County GIS. "BHT" is a DEM layer that represents the heights of buildings and pavement--in other words, impervious surfaces. ("VHT" is a corresponding DEM layer that represents the heights of vegetated surfaces.) These data layers were generated by KCGIS using the 2002 6 foot resolution LiDAR and 2009 Color InfraRed (CIR) aerial imagery, using the following process (Victor High, meeting, 11 July 2012) (see also Figure 6):

1. Create a DEM file of feature heights: obtained by subtracting ground elevation LiDAR from surface elevations, using 2002 6' resolution LiDAR.
2. Separate pervious and impervious cover types:

(a) Create a "mask" of vegetated vs. non-vegetated cover, using spectral signatures in the 2009 Color InfraRed (CIR) aerial photos and calculations from the National Vegetation Index (NVI)

(b) Several cover types, including water, bare earth, and recent clearcuts, will read as "impervious" using this methodology. The King County water layer was used to subtract water features from the impervious layer that was output in step 2a. Then, the data was reviewed against the aerial photos and any remaining non-impervious areas were manually removed.

3. The resulting layer of impervious cover was used to clip the feature height LiDAR from step 1 into a "vegetation height" layer (VHT) and an "impervious height" layer (BHT).

Data Processing for BHT & VHT layers

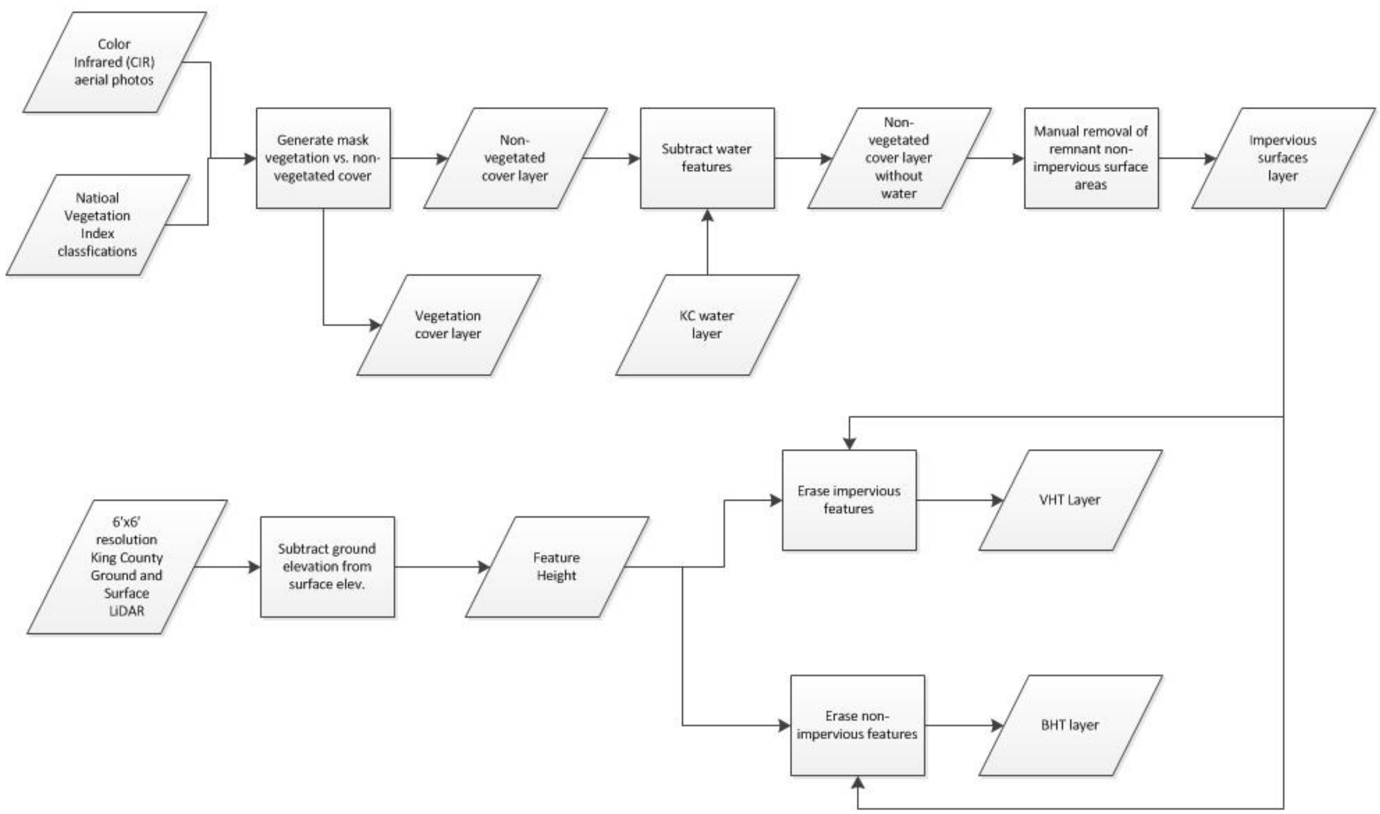

Figure 6: Process for Creating the BHT and VHT DEM files

Table 2: Input Data , Fitness for Use, Application, and Sources

Information Needed	Source[1]	Purpose/Use	Feature Class Name or Attribute Selected	Type
Building heights	KCGIS	Shows height of most impervious surface data	t22r05_bht006 ("BHT")	Raster
Vegetation heights	KCGIS	Shows height of most vegetation data	t22r05_vht006 ("VHT")	Raster
Orthophoto	KCGIS	Used as reference to determine whether the proper values are selected for each Land Cover type.	t22r05_10n050.sid	Raster
Parcel	KCGIS	Used to distinguish the roads from drive ways	parcel	Shape file
Landuse	WSGP	To help determine commercial buildings and parking lots from building height raster	Commercial	Shape file
Landuse	WSGP	To help determine industrial buildings and parking lots from building height raster	Industrial	Shape file
Landuse	WSGP	To help determine multifamily buildings, parking lots, and drive ways	MultiFamily	Shape file
Landuse	WSGP	To help determine single family buildings and driveways	SingleFamily	Shape file

[1] KCGIS: King County Geographic Information Center
WSGP: Washington State Geospatial Portal

DATA CHARACTERISTICS

Relevant data characteristics include resolution, projection, and temporal.

Resolution is important, because the finer the resolution, the more accurately the final output data can be used to model optimal location for siting stormwater treatment features. Data resolution is determined by the resolution at which the LiDAR data was processed when creating the BHT and VHT layer, which in this case was 6 feet. King County has expressed an interest in repeating the processing at a resolution of 3 feet at a future date. (Jim Simmonds and Victor High, personal communication, 11 July 2012).

Projection: to maintain compatibility with KCGIS data standards, data were generated in the projection used by King County GIS: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet.

Temporal: currently, the base data (BHT and VHT data layers) reflect a "hybrid" point in time, because the base data used to derive these files is from different time points. The LiDAR is from 2003, whereas the Color Infrared used to separate the vegetation and impervious surfaces dates from 2009. It may be possible to generate the fine-scale impervious and fine-scale land cover mapping for a particular time point if appropriate base data becomes available.

DATABASES

The tool will operate in ArcGIS 10, running on Windows 7 Operating System, and a current version of Microsoft Word will be used to document the metadata. The eventual data output includes raster data and vector data (layer files). Metadata will follow KC GIS Center Metadata standards (FGDC-1998 standards), and will be generated by KC GIS after executing the tool and creating county-wide coverage of the data. Tool output will also conform to KC GIS center data standards.

LOGICAL DATABASE MODEL

The database model for this project is object-relational, which allows for integration with Esri's ArcGIS Object Model. This also allows for the use of relational table primary keys to provide for data interaction, coded domains for generating data attributes, and database integrity rules. This model is consistent with existing KC GIS protocol and standards.

The proposed database structure is illustrated in Figure 7. The elements of the database are not very interconnected because this database is used solely to present basic data output from the Impervious Surface Mapping tool. As a result of data table attributes not being a major component of the project's data needs there are not many parts that describe the behavior of the data. As illustrated, the database contains one dataset to hold impervious shapefiles and also includes individual datasets for the raster data. The database stores metadata and data layer information as well.

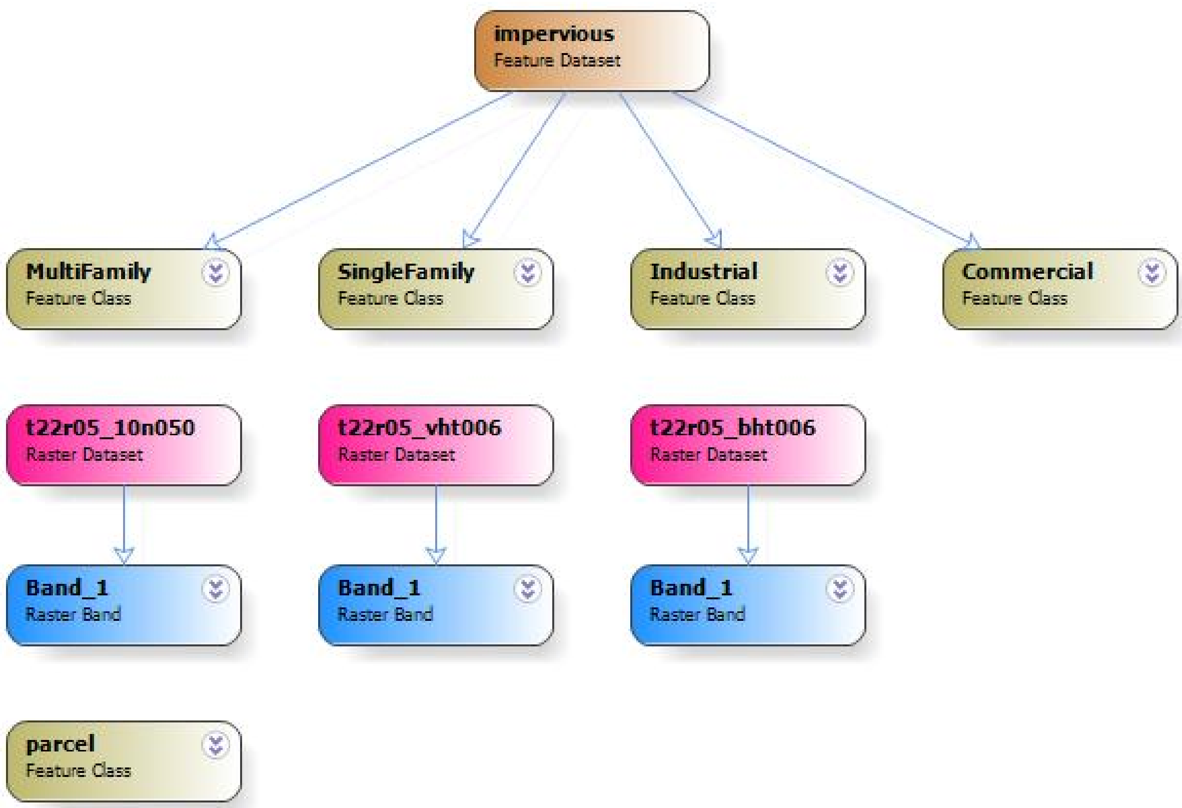

Figure 7: Proposed Database Structure

FUTURE DATABASE DEVELOPMENT

In terms of the larger project --developing the stormwater infrastructure placements--additional refinement of the existing data will be required. KC GIS will need to revisit some of the data processing steps that were conducted outside of this immediate project to develop a more refined--and more current- layer for BHT and VHT to capture more current conditions, and at a finer resolution.

As the larger stormwater project evolves and takes form, it may make sense for the project geodatabase to hold additional information and attributes, according to the input needed for the stormwater model. This will be evaluated as the project progresses.

IV: DATA ANALYSIS, INFORMATION PRODUCTS, AND FINDINGS

INPUT DATA

There are several feature layers that were input into the data processing. The first one is the "man-made feature height", or BHT data developed by King County GIS. This is a continuous raster data set which stores a single value representing a general height of impervious features relative to ground elevation. The King County parcel data and subsets of the King County land cover data were also input (Table 2).

DATA ANALYSIS

The data analysis process involves using various layers to mask and extract different subsets of information from the BHT file. The premise behind the analysis is to first separate building from roads using the parcel data. The parcel data was used as the first mask, as it allowed the separation of roads, which are not captured in the parcel layer, and driveways and parking lots, which are included in the parcel layer. Next, the resulting output data was masked using specific subsets of the land cover data. Finally, buildings and pavement output were distinguished based on feature height. The result is a raster layer representing specific types of impervious cover. The last step is conversion of the raster output into a vector data layer.

Early during the planning process, the STSS identified a number of types of impervious surface to isolate via this tool. As part of the tool design process, these impervious surface categories were matched with corresponding LU/LC categories as defined in the LU/LC data layer provided by KC (Table 3). The result of this process has allowed the automated creation of raster and vector data for:

- Commercial Parking Lots
- Commercial Roofs
- Industrial Parking Lots
- Industrial Roofs
- Multifamily Parking
- Multifamily Roofs
- Single Family Paved areas
- Single Family Roofs
- Roads

The full workflow for each of these processes is depicted in Appendix A. Once each vector layer has been created, we recommend combing the separate layers into a single GIS file, and separating the cover types within the attribute table. Since the final GIS layer will likely be posted on the KC GIS data center, combining the layers into one file will helps ensure that end-users have the full data set, rather than partial data, and reduces the potential for errors of omission by subsequent users (Jim Simmonds, meeting, 26 July 2012).

Table 3: KC DNRP WLRD Impervious Categories and Corresponding Land Use/Land Cover Attribute Values

KC Impervious Surface Category	Corresponding Land Use/Land Cover Value
Single family residential roof	Household, single family units Mobile home parks or courts
Single family residential driveways	Household, single family units Mobile home parks or courts
Multifamily parking lots	Household, 2-4 units -Household, multi-units (5 or more) Residential condominiums Automobile parking
Multifamily roofs	-Household, 2-4 units -Household, multi-units (5 or more) Residential condominiums
Industrial roofs	Food and kindred products Utilities Miscellaneous manufacturing
Industrial parking lots	Automobile parking Food and kindred products Utilities Miscellaneous manufacturing
Commercial roofs	Business services Cultural activities Cultural activities and nature exhibitions Finance, insurance, and real estate services Governmental services Hotels/motels Institutional lodging Miscellaneous services Other cultural, entertainment, recreational, church, cemetery Other retail trade Personal services Public assembly Retail trade - automotive, marine craft, aircraft, and accessories Retail trade - eating and drinking Retail trade - food Retail trade - general merchandise Wholesale trade
Commercial parking lots	Automobile parking

	Business services Cultural activities Cultural activities and nature exhibitions Finance, insurance, and real estate services Governmental services Hotels/motels Institutional lodging Miscellaneous services Other cultural, entertainment, recreational, church, cemetery Other retail trade Personal services Public assembly Retail trade - automotive, marine craft, aircraft, and accessories Retail trade - eating and drinking Retail trade - food Retail trade - general merchandise Wholesale trade

INFORMATION PRODUCTS

There are two significant products of this project. The first is a "blueprint" for a methodology to for automating the creation of vector impervious cover type data from existing, LiDAR derived rasters. The second product is the data output itself. Samples of the data output for the City of Covington--the study area-- are available in Appendix C.

V. FINANCIAL & STRATEGIC ANALYSIS

FINANCIAL ANALYSIS

An important consideration when evaluating whether to implement a new technology or technique is cost: will the new approach provide a cost savings over the existing or conventional strategies? How does the cost savings compare to the cost of implementation? To address these questions, a detailed, step-by-step financial analysis was conducted (Lerner, 2007). The full analysis is presented in Appendix D, and summarized here.

As outlined in the proposed activity workflow diagram (Figure 5) there are only a few positions involved with implementing the impervious surface mapping tool: a GIS analyst, a hydrologist, and STSS supervisor. The GIS analyst will work to integrate the tool within the King County GIS Center, and will coordinate with the hydrologist on analysis extent and the formatting of input data prior to tool execution. The GIS analyst will also execute the tool and assume responsibility for processing the output data and maintaining the final dataset within the KCGIS data library. The hydrologist will work closely with the GIS analyst and provide specifications for the tool output. The STSS supervisor will work closely with the hydrologist and provide overall guidance and direction.

Since the WLRD has already decided to conduct new stormwater modeling using HSP-F and SUSTAIN to determine the optimal location and types of stormwater treatment methods, the financial analysis focuses on the two options considered as methods for generating the impervious surface data: hand digitizing and automated digitizing (Figure 5, boxes 6a-e, and boxes 3c, 5a-c). At current labor costs and using entry level staff, the STSS supervisor estimates that it would take 6-8 months to manually digitize, field verify, and complete a data quality check on impervious data for the approximately 570 square miles in WRIA 9. This would likely be done by entry-level analysts and technicians, with an estimated cost of $40,000-$60,000 for salary, benefits, and overhead, or $70 - $105/square mile. Once the data is finalized, the STSS supervisor estimates that it would take another 240 hours for a senior hydrologist to develop and automate a method to process the data into the format necessary for input into the hydrologic models. The estimated total cost for the senior hydrologist's effort is an additional $15,000. This represents a total cost of $55,000 - $75,000 to generate the impervious data for WRIA 9, or $97 to $131 per square mile. While there will be some additional savings when the method is implemented in other WRIAs because some of the processes will be automated, the per mile cost will remain high. In addition, the same costs will be incurred each time the data needs to be updated. Finally, funding availability has the potential to limit the frequency with which the data is updated and the extent of quality review, and may place the county in a position of using dated information in future analysis. (Jim Simmonds, email communication, 6 August 2012).

Automating the process of impervious surface mapping significantly reduces the cost per square mile. We estimate that it will require a GIS analyst a maximum of 40 hours to set up and integrate the impervious surface tool within the existing KC GIS system and prepare the input data for processing. In preliminary tests, the tool was able to generate the necessary vector data at a rate of 36 square miles in 3 minutes, which predicts less than an hour of effort for WRIA 9. Additional post processing will be required to combine the multiple outputs into a single layer file. In all, we estimate that generating a single vector data layer representing the impervious cover types for WRIA 9 will take less than 50 hours, and should require minimal additional time from the senior hydrologist prior to input into the hydrologic models. This reflects a total estimated cost of $3,000, or approximately $5 per square mile. As well, if the original tool design and the input data are accurate, the resultant output data is less susceptible to mapping error when compared to manual mapping, and costs are low enough that repeating the mapping when new input data become available is a much more affordable process.

STRATEGIC ANALYSIS

The costs included in this analysis represent tool implementation costs including labor, tool updates, and maintenance, but does not consider other costs needed for developing specialized impervious surface layers for other groups or departments within KC. One of the indirect benefits gained by KC as a result of the impervious surface tool is the ability for KC GIS to offer additional support to these other groups, and for the LWRD Water Quality /Water Quantity Groups Unit to additionally refine and prioritize expenditures to maximize benefit to the existing system, by focusing water quality management strategies in areas where connections to the existing stormwater system may be damaged or absent.

One of the most significant ancillary cost savings and environmental benefit may result from the prioritization of stormwater management projects that reduce or eliminate the potential for high volume storm events to overflow the storm water system and impact the wastewater system, including WWTPS (see Project Benefits section).

Increased support for related projects is thus an ancillary benefit of this impervious surface mapping tool. WLRD performance measures are influenced by many separate groups, but many of these groups will be able to work together on the water management projects that require information on impervious surfaces of King County. Finally, KC may also want to consider how the new impervious surface information created by this tool can benefit outside agencies and organizations in the Puget Sound region.

RECOMMENDED COURSE OF ACTION

The proposed course of action is to implement the impervious surface mapping tool within the KCs enterprise GIS using the methods outlined here. This will result in substantial benefit to KC, both in terms of cost savings and in terms of a significant increase in data accuracy, and a concomitant increase in modeling and planning accuracy.

VI. FUTURE DIRECTIONS

The effort thus far has focused on isolating different types of impervious cover. There are a variety of potential directions both for next steps, and for future efforts.

1. Implement the tool and generate the detailed impervious surface data for WRIA 9 and potentially for Bear Creek. While WRIA 9 is the current focus for KC SSWM and modeling efforts, studies in the Bear Creek watershed will begin in 2013. Eventually the goal is to generate this information for all of KC, so that it can be used more widely for a variety of stormwater

management studies and implementation projects, ranging from improving maintenance and repair of the existing system or preventing high volume runoff from impacting Seattle's WWTPs (see Project Benefits section), as well as potential uses as yet undefined. While the tool outputs individual vector data files, we recommend that KCGIS merge all of the output files into a single file, and distinguish the impervious cover type via attributes. Since the final GIS layer will likely be posted on the KCGIS data center, combining the layers into one file will helps ensure that end-users have the full data set, rather than partial data, and reduces the potential for errors of omission by subsequent users (Jim Simmonds, meeting, 26 July 2012).

2. To generate a finer detail for impervious surface mapping, resample the LiDAR data that was used to create the BHT DEM files at a 3' resolution rather than 6', and re-run the tool.

3. Evaluate how a similar process could be used for mapping pervious/vegetated cover types. King County is interested in automatically generating detailed vector information about vegetation cover types, as well as impervious. The methods developed during this project may help to lay the groundwork for developing a similar tool for mapping types of vegetated cover.

4. For the most accurate and current impervious surface input into the hydrologic modeling sequence, re-create the BHT and VHT DEM files using current LiDAR and current CIR imagery.

The information created by this tool will be used by KC to support the STSS's hydrology modeling efforts. This, in turn, assists in implementing storm water management efforts that will minimize or eliminate negative water quality impacts to Puget Sound. The information generated by this tool will provide significant support for the WLRD in their decision making efforts, for the benefit of the health of the Puget Sound aquatic ecosystem and tributary waterways.

The goal of WLRD STSS is to implement best practices for the sustainable management of the region's water resources. Using sustainability-focused science and sustainability -focused management practices is an effective strategy for moving the Puget Sound ecosystem towards a more healthy balance or trajectory. Given this, the data generated by the impervious surface tool, and more significantly, the extensive analysis and modeling conducted by the WLRD can be considered as an expression of "sustainability information science"--a detailed, data based analysis of an existing system, with the express intent of how to modify that system so that it functions within a state of resilience and equilibrium.

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APPENDICES

APPENDIX A: ENVIRONMENT SETTINGS

Setting the Environment in ArcMap

Before doing any processing, we need to set up the ArcMap environment. Establishing the environment parameters provides for consistency in coordinates, spatial extent, cell size, and file saving in the data processing output products, as illustrated in Figure A-1 and described below.

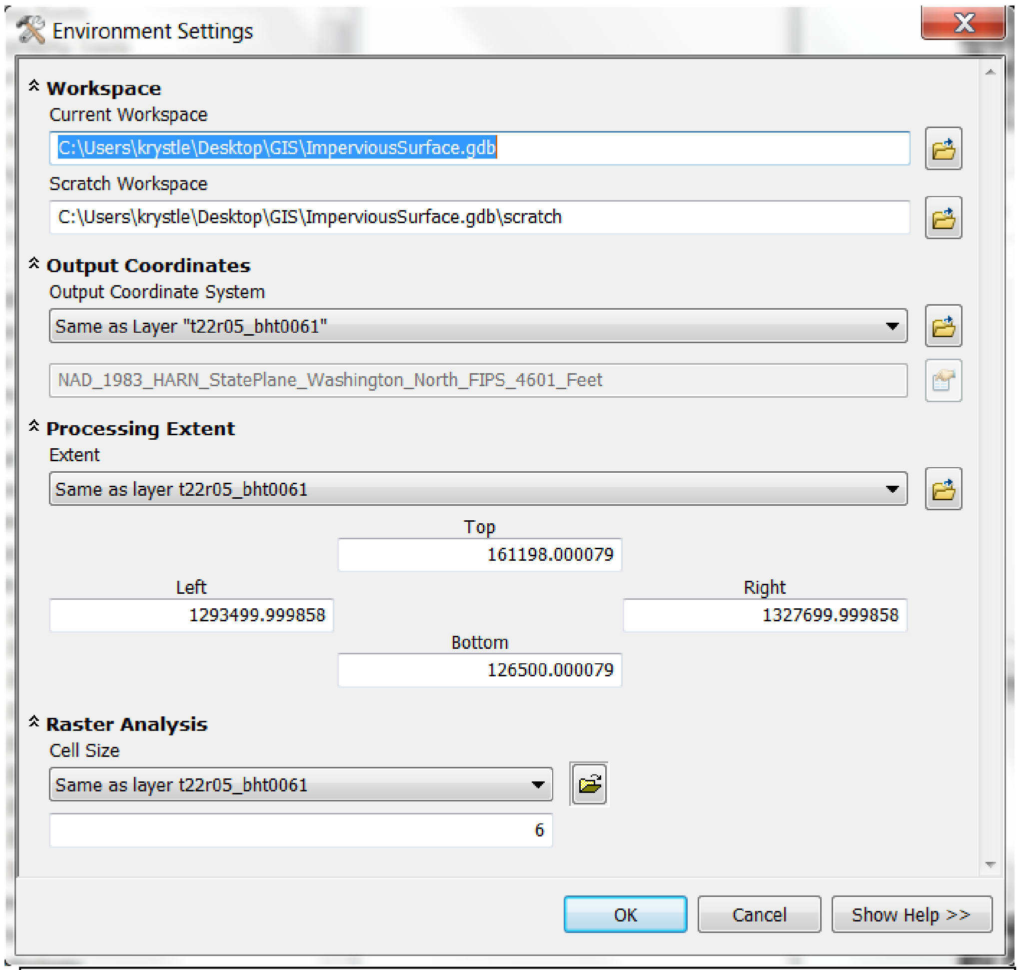


Figure A-1: ArcGIS Environment Settings Used

Workspace

The current workspace is where the outputs will be automatically saved. We set the current workspace to the geodatabase that was created specifically for this project.

The Scratch Workspace is where the intermediate rasters and shapefiles are stored. These are files that are not needed in the final product, but are intermediate steps in the processing analysis. The scratch workspace is within the geodatabase.

Output Coordinates

The Output Coordinate System is used to set the coordinate system of each output dataset. For this project, the output coordinate system was set to match the t22r05_bht006 raster, because this raster was the basis for most of the processing in this process.

Processing Extent

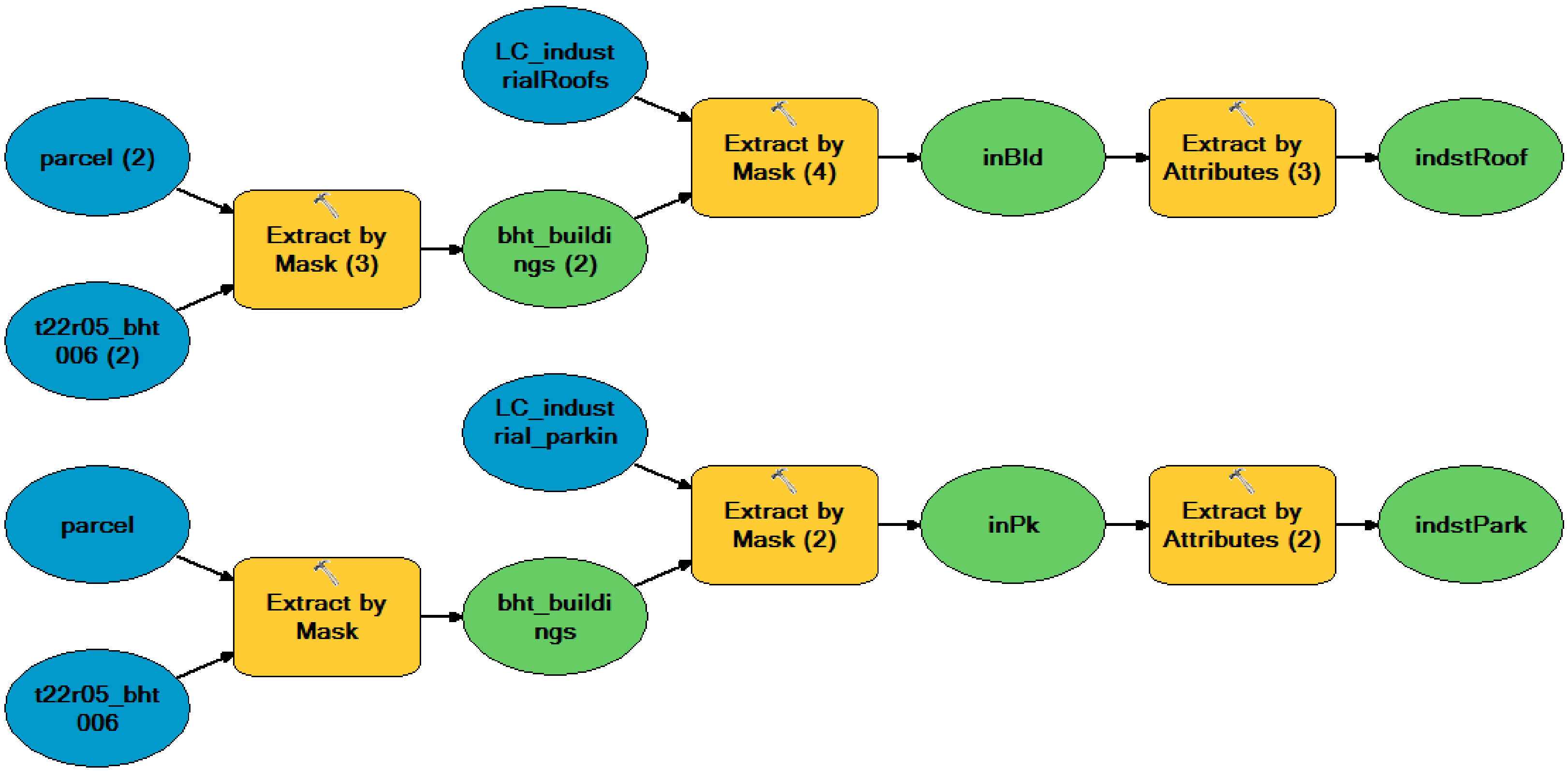
The Extent defines the geographic extent of the areas that will be processed during execution of the tool; areas outside of this extent are excluded from analysis. We set the extent to match the t22r05_bht006 raster because that defines our study area. This will need to be reset/redefined each time KCGIS chooses to run the tool for a new area.

Raster Analysis

The cell size is where we set the cell size of all of the rasters that are processed or produced. We set the cell size to the same as t22r05_bht006 because our final output is extracted from t22r05_bht006, therefore the resolution of that raster defines the finest resolution obtainable from any subsidiary raster datasets.

APPENDIX B: WORKFLOW FOR IMPERVIOUS SURFACE EXTRACTION PROCESSES

Industrial workflow



Industrial Roof

Goal: to create a new raster that only includes the buildings that are used for industrial purposes from the t22r05_bht 006 raster file. Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

Use the extract by mask on bht_buildings to obtain a raster data output that represents industrial roofs.

Input: bht_building

Input Mask: LC_industrialRoofs

Output: inBld

Select the roofs of industrial buildings from inBld by using select by values tool.

Input: inBld

Where clause: "Values" > 14 (we select anything higher than 14' because the maximum height freights can be is 14')

Output: industRoof

Industrial Parking

Goal: to create a new raster that only includes the buildings from the t22r05_bht 006 raster file. Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

Use the extract by mask tool on bht_buildings to a obtain a raster data output that represents the industrial parking area.

Input: bht_building

Input Mask: LC_industrial_Parking

Output: inPk

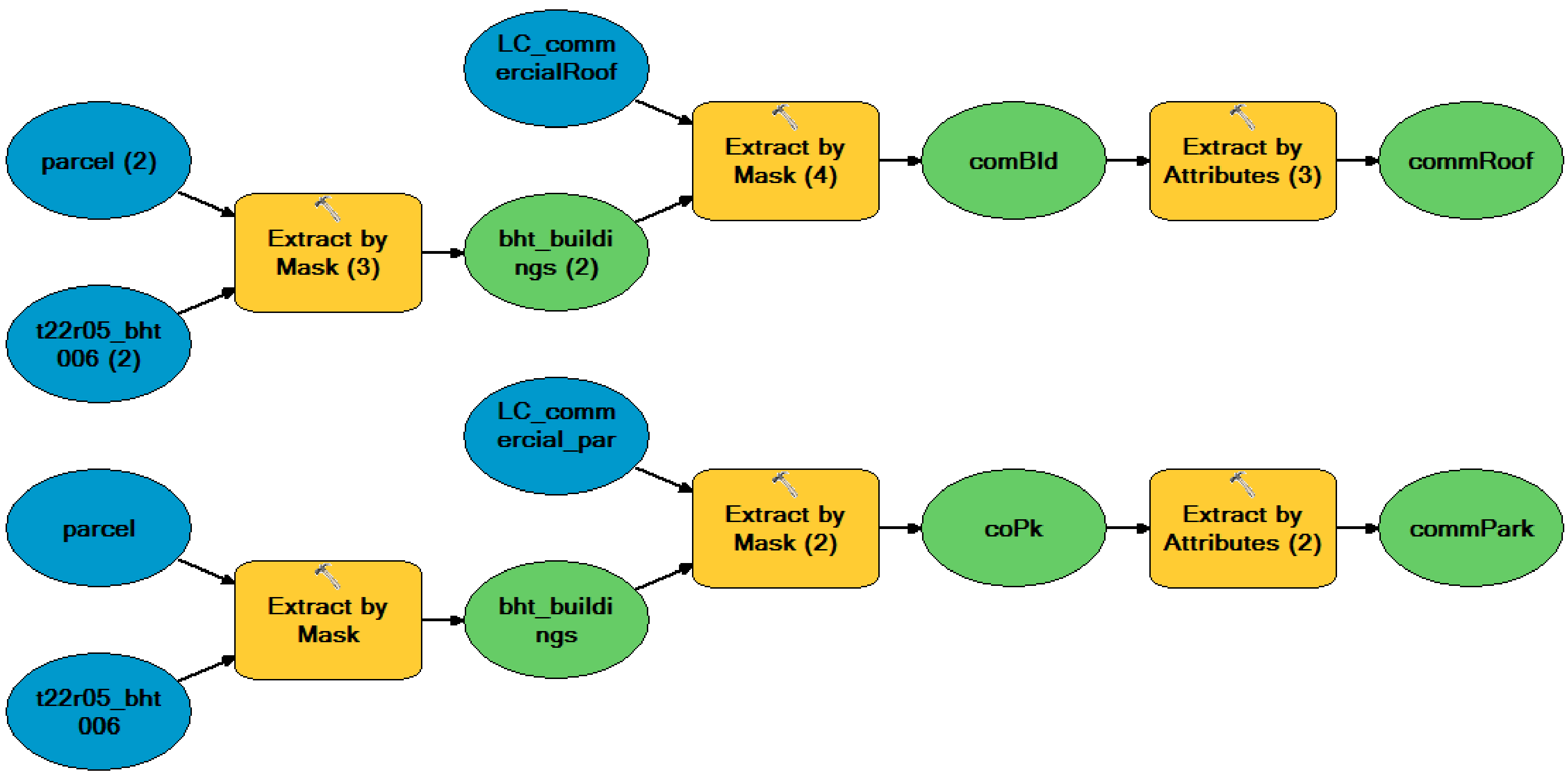
Select the parking areas of all the industrial buildings from inPk by using select by values tool.

Input: inPk

Where clause: “Values” <= 14 (we select anything lower to or equal to 14’ because freight trucks and semi-trailers may have a maximum height of 14'. Similarly, roof elevations in industrial areas tend to be taller. By setting the elevation threshold at 14' , areas where trucks are parked are mapped as pavement rather than as buildings/roofs.)

Output: industPark

Commercial Workflow



Commercial Roof

Goal: Create a new raster that only includes commercial buildings from the t22r05_bht 006 raster file.

Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

Use the extract by mask tool on bht_buildings to obtain a raster data output that represents the commercial roof areas.

Input: bht_building

Input Mask: LC_CommercialRoofs

Output: comBld

Select the roofs for all the commercial buildings from comBld by using select by values.

Input: comBld

Where clause: “Values” > 10 (we select all cells where the elevation greater than 10', representing roofs)

Output: commRoof

Commercial Parking

Goal: Create a new raster that only includes the commercial buildings from the t22r05_bht 006 raster file.

Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

Use the extract by mask tool on bht_buildings to obtain a raster data output that represents commercial parking area.

Input: bht_building

Input Mask: LC_commerical_Parking

Output: coPk

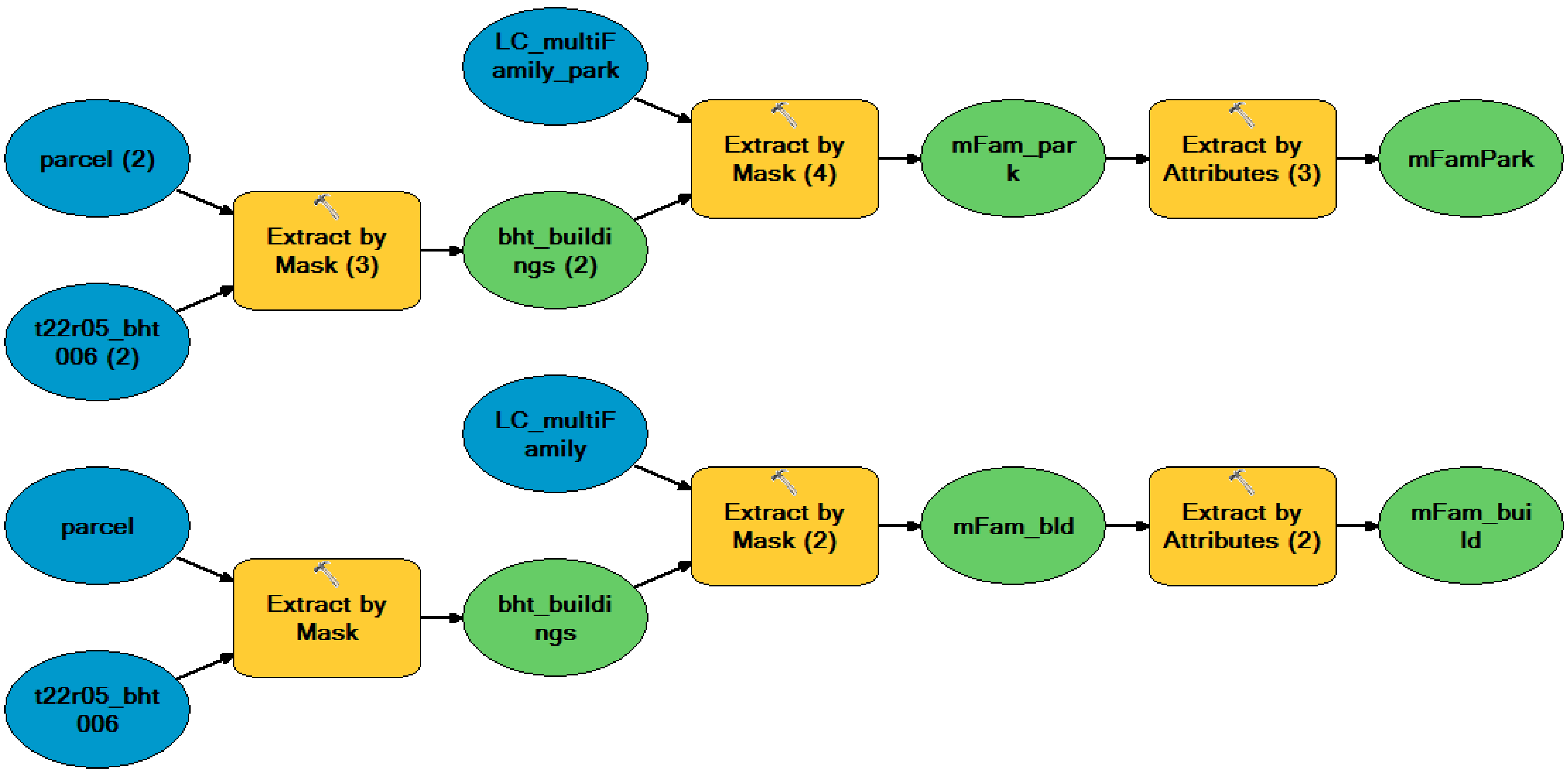
Select the parking areas of all the commercial areas from coPk by using select by values.

Input: coPk

Where clause: “Values” <= 10 (we select all cells where the elevation is less than 10', representing parking lots/pavement.)

Output: commPark

MultiFamily Workflow



MultiFamily Roof

Create a new raster that only includes the buildings from the t22r05_bht 006 raster file. Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

Extract by mask on bht_buildings to obtain a raster data output that represents MultiFamily roofs areas.

Input: bht_building

Input Mask: LC_multiFamily

Output: mFam_bld

We are then going to try and select the roofs of all the MultiFamily buildings from comBld by using select by values.

Input: mFam_bld

Where clause: “Values” > 6   (we we select all cells where the elevation is greater than or equal to 6', representing roofs; the 6' threshold captures low-hanging eaves.)

Output: mFam_build

MultiFamily Parking

Create a new raster that only includes the buildings from the t22r05_bht 006 raster file.

Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

Extract by mask on bht_buildings obtain a raster data output that represents multifamily parking area.

Input: bht_building

Input Mask: LC_multiFamily_park

Output: mFam_park

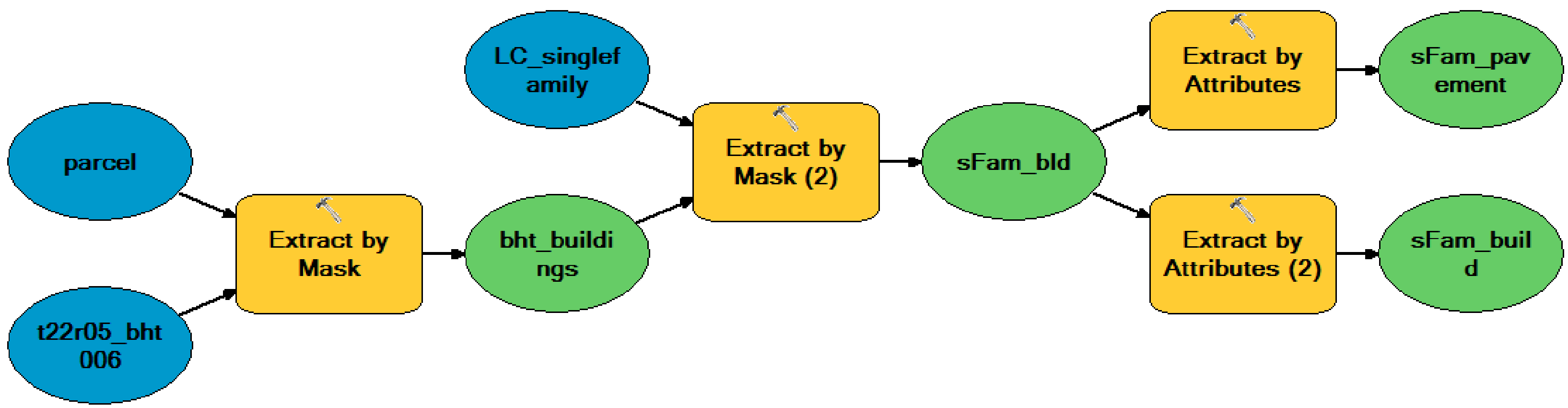
We then select the parking areas of all the multi family areas from mfPk by using select by values.

Input: mFam_park

Where clause: “Values” <= 6 (we select all cells where the elevation is less than or equal to 6’.)

Output: mFamPark

Single Family Workflow



Goal: Create a new raster that only includes the buildings from the t22r05_bht 006 raster file. Using the extract by mask tool the raster is clipped to parcel shapefile to exclude roads.

Input: t22r05_bht006

Input Mask: parcel.shp

Output: bht_buildings

We are going to extract by mask on bht_buildings to obtain a raster data output that represents MultiFamily roofs areas.

Input: bht_building

Input Mask: LC_multiFamily

single family area.

Input: bht_building

Input Mask: LC_singlefamily

Output: sFam_bld

We then select the pavement areas of all the single family areas by using select by values.

Input: sFam_bld

Where clause: “Values” <= 6 (we select anything where the elevation is less than or equal to 6’ to represent pavement.)

Output: sFam_pavment

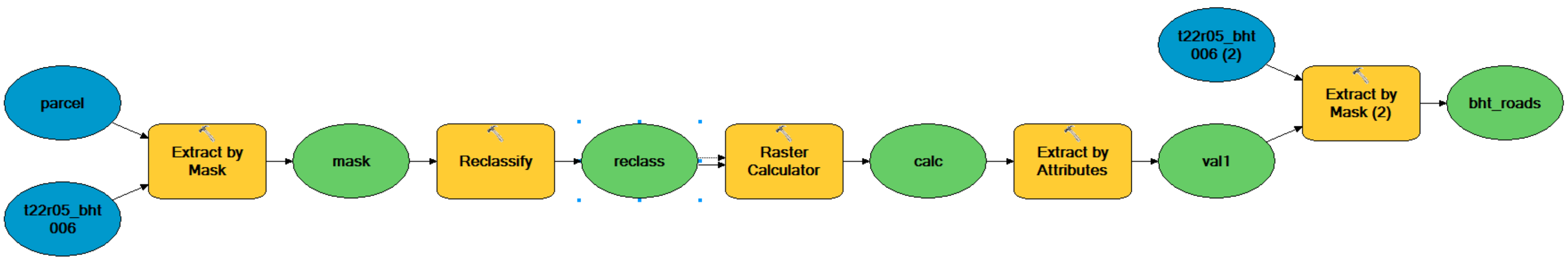
We then select the building areas of all the single family areas by using select by values.

Input: sFam_bld

Where clause: “Values” > 6 (we we select all cells where the elevation is greater than or equal to 6', representing roofs; the 6' threshold captures low-hanging eaves.)

Output: sFam_build

Roads Workflow



Essentially we want obtain the areas of t22r05_bht006 that are not covered by the parcel shapefile, to get the roads.

We start by extracting all the parts of the t22r05_bht006 raster that are covered by the parcel polygon

Spatial Analyst Tools → Extraction → Extract by mask

Input: t22r05_bht006

Mask: parcel

Output: mask

After extracting all the parts from t22r05_bht006 that are covered by the parcel polygon, we want to give the entire raster one value. In this case we selected a value of "1".

Spatial Analyst Tools → Reclass → Reclassify
Input: Mask
Reclass Field: Value
Classify…
Method: Equal Interval
Classes: 1
Reclassification
New Values: 1
Output: Reclass

Once we set all the values to 1, we create another raster that will convert all the values of 1 to 0, and all the null values within the extent of t22r05_bht006 will turn into 1. We change the values in reclass (raster created from the last step) from 1 to 0 because we are not interested in the areas of the t22r05_bht006 that are covered by the parcel shapefile. We change all the null values in the extent of t22r05_bht006 because that represents the areas we are interested in-- in other words, those areas not covered by the parcel polygon).

Spatial Analyst Tools → Map Algebra → Raster Calculator
Expression: IsNull("reclass")
Output: Calc

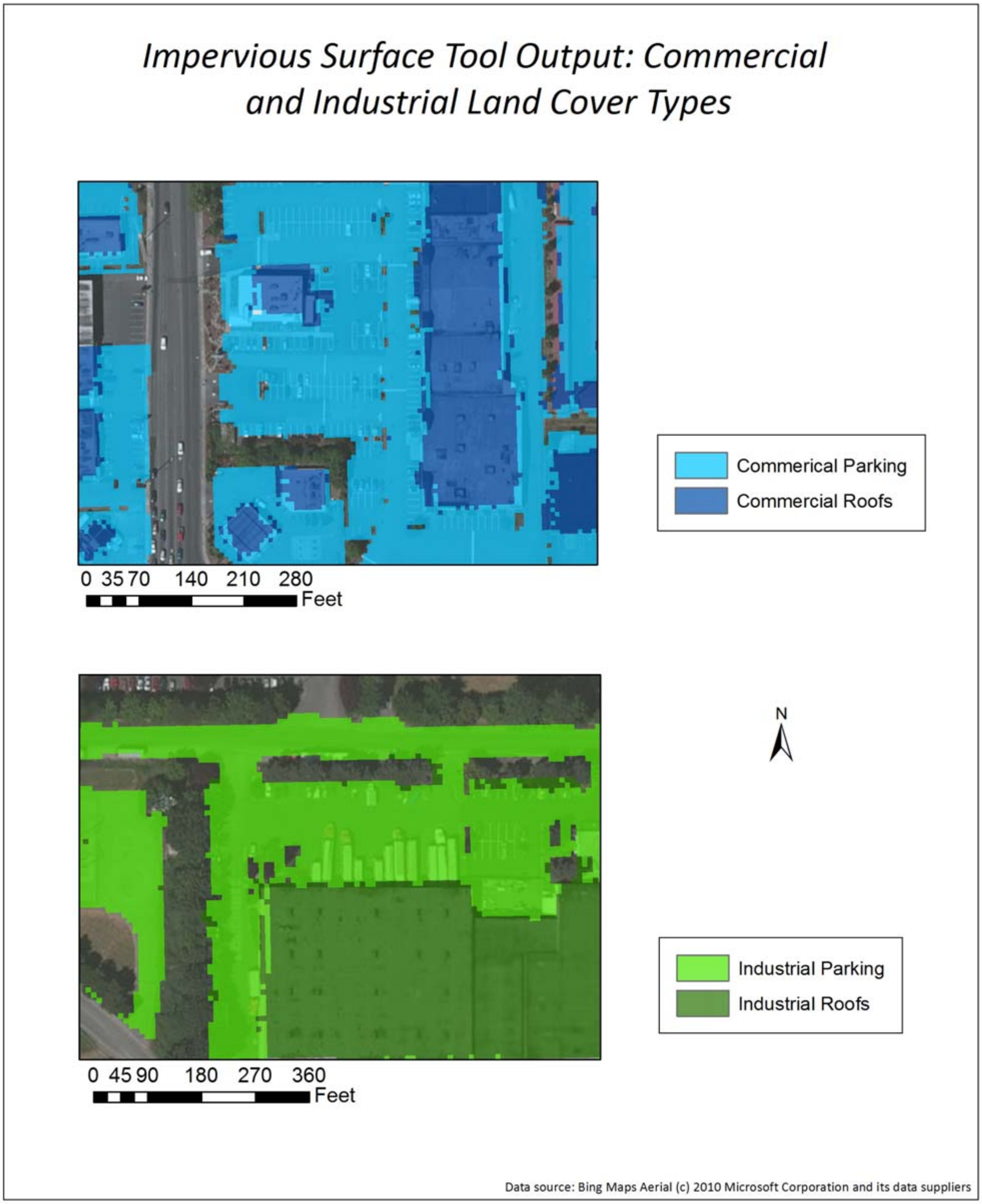
We extract all the values of 1 to serve as a mask in the following step.

Spatial Analyst Tools → Extraction → Extract by Attributes
Input Raster: calc
Expression: "VALUE" = 1
Output: val1

Now we can extract the areas that are not covered by the parcel polygon by using val1 (raster created from the previous step) as the mask. The output of this process will create a new raster of all the roads within the study area.

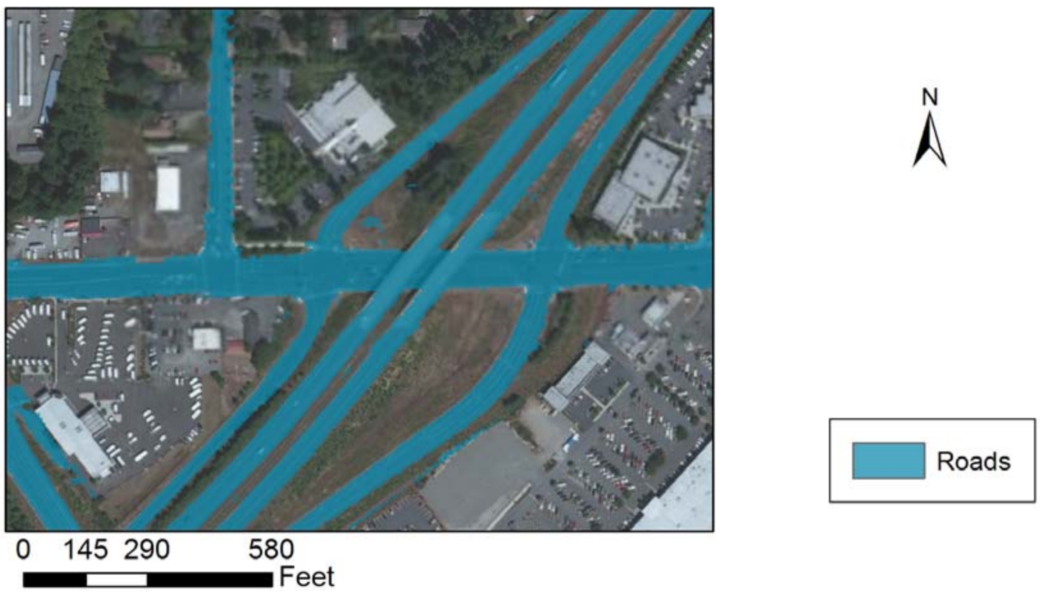
Spatial Analyst Tools → Extraction → Extract by Mask
Input: t22r05_bht006
Mask: val1
Output: bht_roads

APPENDIX C: MAPS OF IMPERVIOUS SURFACE DATA OUTPUT



Impervious Surface Tool Output: Single-Family and Multi-Family Land Cover Types

Impervious Surface Tool Output: Road Land Cover Type



Data source: Bing Maps Aerial (c) 2010 Microsoft Corporation and its data suppliers

APPENDIX D: DETAILED FINANCIAL AND RISK ANALYSIS

FINANCIAL ANALYSIS

The financial analysis was conducted using the Financial Detail worksheets provided in Lerner *et al*'s Building a Business Case for Geospatial Information Technology: A Practitioner's Guide to Financial and Strategic Analysis. These worksheets act as a template and include eleven variables of which many are automated based on functions included in each cell. All of these variables were factored into each year for the next 10 years of the project.

1. Inflation rate
2. Opportunity cost of capital
3. Job categories and descriptions
4. Average hourly rates for employees
5. Fringe rates
6. Avg. annual regular hours
7. Valuation method
8. FTEs dedicated to project in each project year
9. Contract and procurement costs
10. Productivity benefits per job category
11. Other benefits

The inflation rate used is 2.5% is the default provided in the worksheet and is comparable to Bureau of Labor Statistics 2012 rates (http://www.bls.gov/data/). The second variable is opportunity costs of capital at 5% which is a percentage that represents forgone investments by the project sponsor. The analysis also includes job categories and descriptions. Three positions were identified in this analysis which is a GIS programmer, hydrologist (environmental engineer) and supervisor. These categories are used to provide details for labor costs for current and future employees that will spend efforts on project development, but also any individuals that will benefit from the project. Job descriptions are assessed to determine the hours or FTEs spent by employees for the tasks needed for project implementation. In this case labor costs include annual salary which influences many other sub-variables among these is the valuation method which in this case per FTE. Fringe rates, or the burden rate, include the cost of taxes, insurance and related overhead items for each employee. A rate of30% was used which is based on estimates provided by the project sponsor. (Lerner et al, Appendix A, 2007). Contract and procurement costs include items such as software and hardware upgrades or staff development and training.

Ultimately the majority of the sponsor's costs are determined by time needed for implementation which includes a pilot project. The pilot project consists of the labor costs of the WLRD Science Section integrating mapping tool output with their current water quality and storm-water management models.

Benefits are the avoided labor or FTEs saved by implementing the mapping tool. Other benefits could include new services that can be offered using the output of this tool, but those were not included in the analysis.

The worksheets include Common Financial metrics such as net present value (NPV), the sum of present values of all future cash flows, annualized return on investment (ROI), breakeven point and payback period (Lerner et al, 2007). NPV is used at the key metric in this analysis because it is more straightforward compared to other metrics. ROI can be somewhat deceptive and cannot be used in comparing mutually exclusive investments. Another concern with ROI is that when subjective assumptions are made in a financial analysis such as consolidating workload it can result in an inaccurate ROI. Internal Rate of Return (IRR) is another important metric, but a high NPV does not always correspond with a low IRR which becomes an issue when comparing two alternative projects or conducting a sensitivity analysis as was done here. A sensitivity analysis was conducted by calculating costs for a pilot project that focuses on WRIA 9 and then changing the hours to reflect the costs if the pilot project focused on all of King County. The majority of the financial and strategic analysis will focus on the resources need to complete the project for WRIA 9.

For WRIA 9:

Project Name:	Impervious Surface Mapping Tool
Date Analyzed:	7/25/2012
Net Present Value (Net Benefits):	$27,881
Annualized Return on Investment:	16.87%
Breakeven Point:	This Year
Payback Period (in Years):	0
Inflation Rate:	2.50%
Opportunity Cost of Capital:	5.00%
Project Life (Number of Years):	10
Method for Determining Future Years' Cost of Labor: Derived by Applying Inflation Rate to Current Costs	

STRATEGIC ANALYSIS

There are only a few individuals involved with the outset of implementing the mapping tool. These include a member of the KC GIS Center staff, a hydrologist modeler from the WLRD Science Section and Science Section supervisor. The GIS staff will work to develop and integrate the tool with the GIS Center in the beginning stages. However, implementation of the tool will be influenced by a pilot project coordinated by the Science Section staff. The hydrologist modeler will work closely with the GIS person and provide specifications for the mapping tools test case with the Science Section group. These two individuals represent the main factor of costs in this analysis in addition to the Science Section supervisor that will work closely with the hydrologist. A ten year financial analysis was conducted and includes cost and benefit estimates for first year and subsequent years 5 and 10. These periods were chosen because the Science Section will revisit with the GIS Center when new mapping tool input data such as LiDAR data becomes available. This data can then be used to process new impervious surface data. So the costs identified in the first year are then repeated every five year period as this new data becomes available. While the tool will be fully implemented in the County's GIS before these later years there will be additional labor costs required for tool updates. These updates are associated with tool modification necessary for its functionality with new hardware and software, such as newer versions of ArcGIS.

The costs included in this analysis represent tool implementation costs such as upfront labor costs and tool updates and maintenance, but does not consider other costs needed for developing specialized impervious surface layers for other groups or departments within KC. One of the intangible benefits gained by KC is the GIS Center's ability to offer a new service to these other groups. *(insert text on the other applications described by Jim in last meeting? Or is that somewhere else?)*

An increase in interrelated projects then becomes an intangible benefit of this mapping tool. WRLD performance measures are influenced by many separate groups, but many of these groups will be able to work together on the water management projects that require information on impervious surfaces of King County. Finally, KC may also want to consider how the new impervious surface information created by this tool can benefit outside agencies and organizations in the Puget Sound region.

<u>Project Risks</u>

Seven factors were adopted to highlight potential risks involved in implementing the tool. These include technology, organizational interactions, constraints, stakeholders, overall complexity, project planning project management and project resources. Described below is how each of these could negatively impact the project's success as well as ways of mitigating these effects. (Tomlinson, 2011)

Technology

There will be no additional hardware or software needed to implement the mapping tool and software bugs or flaws should not be an issue for the first year. This may depend on the data used to operate the tool because if the data is not in the correct format the tool will not function. This is unknown in later applications of this tool as King County purchases new hardware and Esri releases new version of ArcGIS.

Current KC technology should be adequate but there is a risk that computer processing may be slow, however it is not expected that the project sponsor will have to contract out because of this. This can be mitigated by purchasing a small hardware upgrade such as increasing RAM.

Organizational Interactions

It is expected that there will be increased interaction between the KC GIS center and the WLRD: Science Section, but sharing information is not an issue between departments. Because the information produced by this tool has multiple applications KC GIS Center workload will increase for a short period of time while they setup the tool and coordinate with different groups in the DNRP. Once the tool is programmed is will only require a small number of minor changes to meet the needs of these other groups.

Constraints

Surface water management fees generate $1 - $2 million annually, which KC DNRP LWR uses to fund both modeling and implementation of stormwater management activities. It is not expected that there will be any risks regarding budget. The time needed for initial discussion regarding to the tool, tool development and generating the desired data will not be substantial. Time spent by the GIS Programmer position the first year could be as much as 150 hours or about three and half weeks. 140 hours is needed by the Science Section Hydrologist and 10 hours by the Science Section Supervisor. It is important to note that out of the 140 hours spent by the Hydrologist 120 hours is spent on integrating impervious surface layers with SUSTAIN and HSPF models which is something not directly related to the development of the tool. However, if testing is necessary this task could be included as a pilot project for the tool.

Stakeholders

Stakeholder's outside of the DNRP are not considered an immediate risk to the implementation of the tool in this report. Interactions with organization, other government entities or the public will not take place during tool development, however these groups may see value in the tool or the data layers produced from the tool and ask the DNRP for information. Stakeholder involvement is somewhat unforeseen at the moment and will depend on how the tool is applied and what sections of King County will utilize it.

Overall complexity

As it exists now developing this tool and generating output is not complex in terms of time and funding resources needed. Stakeholder involvement will be limited, there should be no violation of state or federal regulations and vendors will not be used at least for the first year. However, it is expected that this tool will be used every few years when new input data is acquired. Depending on how King County obtains input data they may be required to contract with outside organization. Time associated with this activity is factored into updating/maintenance work included in the time table for years 5 and 10.

Project Planning

The planning is sufficient for implementing this tool into KC's GIS environment. But the tool is developed for ArcGIS version 10.1 so it will not function in earlier versions such as ArcGIS 9.3. Employees within the Science Section group are currently using version 9.3, but they will not have an issue with viewing impervious surface data layers in this layer

Project Management The project management methods are adopted from Professor Robert Aguirre of the University of Washington, Roger Tomlinson's book Thinking About GIS: Geographic information System Planning for Managers and Paul Harmon's book Business Process Change: A Guide for Business Managers and BPM and Six Sigma Professionals which are both proven resources. Development of the tool and future implementation is majorly contributed to the author's knowledge and experiences as well as to the methods and functions in Esri's ArcGIS software which have been tested and used for several years. Use of ArcGIS software provides built-in accountability and quality control.

Project Resources

Trained staff at King County is not an issue as the tasks to be completed during project implementation are within the abilities of the County. The employees of KC GIS Center have experience with Esri ArcGIS and have the skills necessary to implement tool development and maintenance.

Other risks can include changes in the organization, such as departmental functions, but this should not be a major concern. Responsibilities may increase for the DNRP such as assessing SWM fees per parcel. Another risk could be project scheduling problems such as reasonable deadlines or developing reachable milestones.

Overall the risks will not be too burdensome for the first year if King County implements the mapping tool as outlined. Each of the risk identified above should be considered, but they are present in any project and seem insignificant if compared to the benefits. There may be issues with updating the mapping tool to generate new impervious surface data every few years. During times of use the tool will need to be altered to function with new hardware and software that is adopted over those few years.

Values in the Labor Costs table below (Table D.1) were derived from the annual gross pay of KC employees for each job category. The average gross pay of GIS programmer was determined by averaging the salaries of the three employees in this position at KC.

(http://www.thenewstribune.com/soundinfo/kingsalaries/?appSeession=343203812510513&cbSearchAgain=true) The fringe rate was determined by dividing the sum of 2011 annual gross pay salary wage, taxes, insurance, and related overhead items for Curtis DeGasperi , Hydrologist/Environmental Engineer for Surface Water Management Group, by their 2011 annual gross pay salary wage.

($120,000 / $91,974) – 1 = 30% fringe rate

This was applied to all positions in the Labor Costs worksheet. The assumption is that positions are full-time equivalent (FTE) The benefit of labor costs saved was calculated with the assumption that it would take a hydrologist at KC 100 hours per 200 acres for modeling a fully developed landscape using SUSTAIN and 50 hours per 200 acres in a suburban landscape. Employee labor savings were estimated at 0.1 FTE per year or 10% of the hydrologist's workload.

Detailed Financial Analysis Tables for WRIA 9

See Tables D.1and D.2 for estimated time requirements for years 1 and 10.

Table D.1: Estimated Time Requirements for Year 1

	Tasks	***Hours***
GIS Programmer	*Emails, phone calls, meetings, etc.*	*10*
	Tool setup	*20*
	Data processing	*60*
Subtotal:		***90***
Science Section Hydrologist	*Emails, phone calls, meetings, etc.*	*20*
	Integrate layers with Sustain/HSPF models	*60*
Subtotal:		***80***
Science Section Supervisor	*Emails, phone calls, meetings, etc.*	*10*
Subtotal:		***10***

Table D.2: Estimated Time Requirements for Year 10

	Tasks	***Hours***

GIS Programmer	*Emails, phone calls, meetings, etc.*	*10*
	Tool setup	*20*
	Data processing	*60*
	Updating/maintenance	*10*
Subtotal:		***100***
Science Section Hydrologist	*Emails, phone calls, meetings, etc.*	*20*
	Integrate layers with Sustain/HSPF models	*60*
Subtotal:		***80***
Science Section Supervisor	*Emails, phone calls, meetings, etc.*	*10*
Subtotal:		***10***

Table D.3: Detailed Financial Sheet

	This Year	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Future Cash Flows										
Internal Labor Costs	($7,892)	$0	$0	$0	$0	$0	$0	$0	$0	($10,732)
Contract/Procurement Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Productivity Benefits	$15,245	$0	$0	$0	$0	$0	$0	$0	$0	$0
Other Benefits	$29,167	$0	$0	$0	$0	$0	$0	$0	$0	$0
Present Value Multiplier:	*100.0%*	*97.6%*	*95.3%*	*93.0%*	*90.8%*	*88.6%*	*86.5%*	*84.5%*	*82.5%*	*80.5%*
Present Values										
Internal Labor Costs	($7,892)	$0	$0	$0	$0	$0	$0	$0	$0	($8,640)
Contract/Procurement Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Annual Costs	*($7,892)*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*($8,640)*
Cumulative Costs	*($7,892)*	*($7,892)*	*($7,892)*	*($7,892)*	*($7,892)*	*($7,892)*	*($7,892)*	*($7,892)*	*($7,892)*	*($16,531)*
Productivity Benefits	$15,245	$0	$0	$0	$0	$0	$0	$0	$0	$0
Other Benefits	$29,167	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Annual Benefits	*$44,412*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Cumulative Benefits	*$44,412*	*$44,412*	*$44,412*	*$44,412*	*$44,412*	*$44,412*	*$44,412*	*$44,412*	*$44,412*	*$44,412*
Cumulative Net Benefits	**$36,520**	**$36,520**	**$36,520**	**$36,520**	**$36,520**	**$36,520**	**$36,520**	**$36,520**	**$36,520**	**$27,881**

Breakeven Year:	This Year	
Payback Period (in Years):	0	
Net Present Value:	$27,881	
Present Value of Costs:	$16,531	
Return on Investment:	16.87%	*(Annualized)*

Labor Rates

Job Category	Current Average Hourly Rate ($/Hour)	Fringe	Burdened Hourly Rate	Average Annual Regular Hours	Average Annual Cost Before Overtime	Average Annual Overtime Hours	Average Overtime Multiplier	Average Annual Cost of Position
Hydrologist, Environmental Engineer	$47.90	30.00%	$62.27	2080	$129,583.87			$129,583.87
GIS Programmer	$53.95	30.00%	$70.14	2080	$145,950.94			$145,950.94
Science Section Supervisor	$56.41	30.00%	$73.33	2080	$152,605.97			$152,605.97

Labor Cost Multipliers[1]

	Current	Current	Valuation Method	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Job Category	Average Hourly Rate	Average Annual Cost/FTE		Labor Cost	Labor Cost	Labor Cost	Labor Cost	Labor Cost	Labor Cost	Labor Cost	Labor Cost	Labor Cost	Labor Cost
Hydrologist, Environmental Engineer	$62.27	$129,584	per FTE	$129,583.87	$132,823.47	$136,144.05	$139,547.65	$143,036.35	$146,612.25	$150,277.56	$154,034.50	$157,885.36	$161,832.50
GIS Programmer	$70.14	$145,951	per FTE	$145,950.94	$149,599.71	$153,339.70	$157,173.19	$161,102.52	$165,130.09	$169,258.34	$173,489.80	$177,827.04	$182,272.72
Science Section Supervisor	$73.33	$152,606	per FTE	$152,605.97	$156,421.12	$160,331.65	$164,339.94	$168,448.44	$172,659.65	$176,976.14	$181,400.55	$185,935.56	$190,583.95
Valuation Method Options	Description												

[1]Future Years' Labor cost derived by Applying Inflation Rate to Current Costs

Internal Labor Usage

Job Category	**Valuation Method**	**Nature of Work**	**Year 1 Hrs or FTEs**	**Year 2 Hrs or FTEs**	**Year 3 Hrs or FTEs**	**Year 4 Hrs or FTEs**	**Year 5 Hrs or FTEs**	**Year 6 Hrs or FTEs**	**Year 7 Hrs or FTEs**	**Year 8 Hrs or FTEs**	**Year 9 Hrs or FTEs**	**Year 10 Hrs or FTEs**
Hydrologist, Environmental Engineer	*per FTE*	Provide GIS Programmer with parameters; overlay/integrate tool output with HSPF and SUSTAIN models; provided reports on information found	0.03846	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03846
GIS Programmer	*per FTE*	Coordinate with Hydrologist/other departments; run processes in ArcMap; provide impervious surface layers based on requests	0.01490	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.019712
Science Section Supervisor	*per FTE*	Oversee Hydrologist/Science Section group; coordinate with Hydrologist on reports; review	0.00480	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00480

Internal Labor Costs

(in future year dollars) Job Category	This Year Labor Cost	Year 2 Labor Cost	Year 3 Labor Cost	Year 4 Labor Cost	Year 5 Labor Cost	Year 6 Labor Cost	Year 7 Labor Cost	Year 8 Labor Cost	Year 9 Labor Cost	Year 10 Labor Cost
Hydrologist, Environmental Engineer	$4,984	$0	$0	$0	$0	$0	$0	$0	$0	$6,224
GIS Programmer	$2,175	$0	$0	$0	$0	$0	$0	$0	$0	$3,593
Science Section Supervisor	$733	$0	$0	$0	$0	$0	$0	$0	$0	$915
Total Internal Labor Costs	$7,892	$0	$0	$0	$0	$0	$0	$0	$0	$10,732

Total Internal Labor Investment	**$18,624**

Productivity Benefits

(in future year dollars) Job Category	Valuation Method	This Year Savings
Hydrologist, Environmental Engineer	*per FTE*	$15,245
GIS Programmer	*per FTE*	$0
Science Section Supervisor	*per FTE*	$0
Total Productivity Benefits		$15,245

(in future year dollars) Specific Other Benefits	This Year Benefits
Initial entry-level analysts labor cost savings	$29,166.67
Total Other Benefits	$29,167