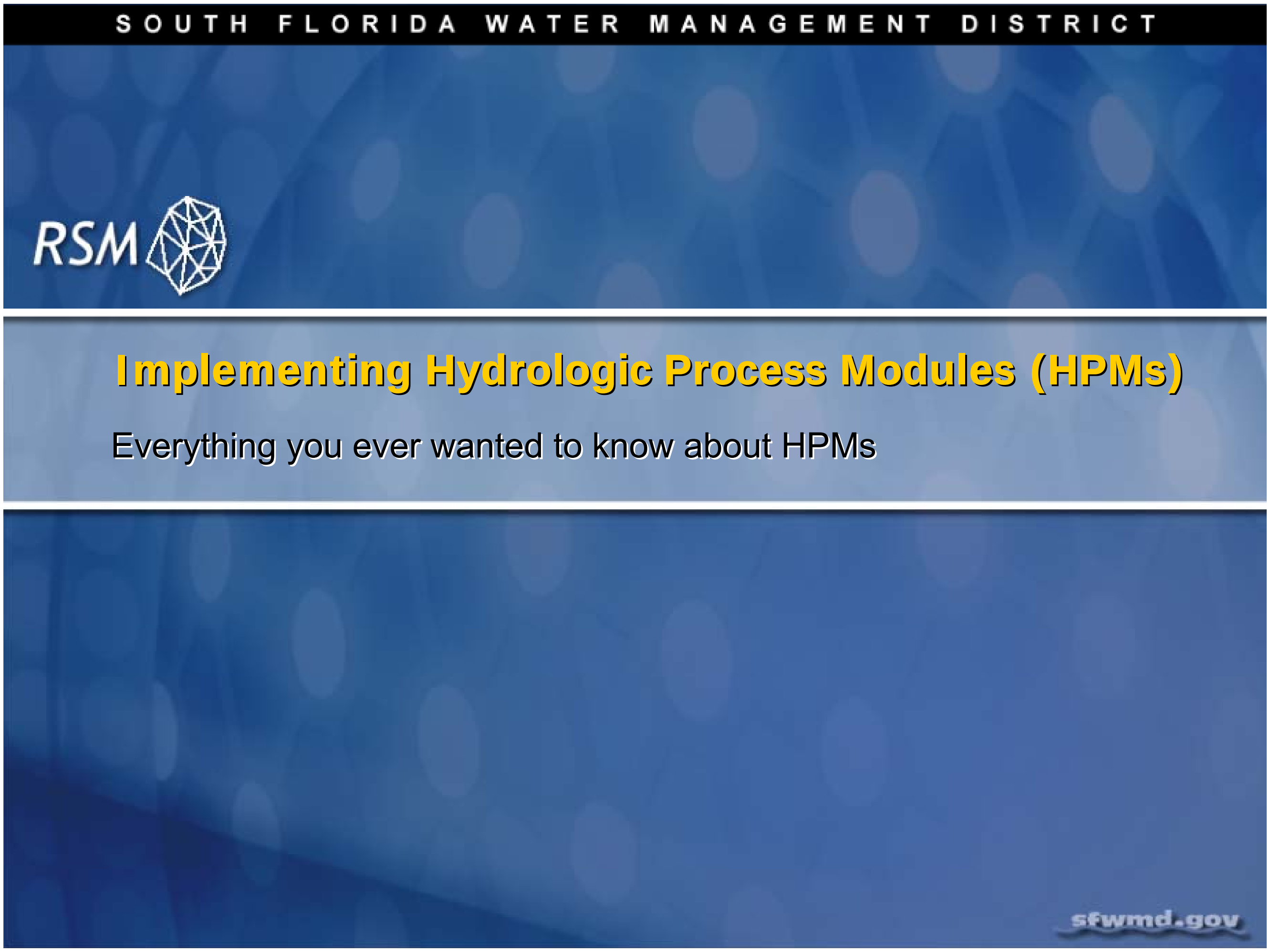


Lecture 11: Implementing Hydrologic Process Modules (HPMs)

In this session, the Hydrologic Process Modules (HPMs) are presented and three topics are covered:

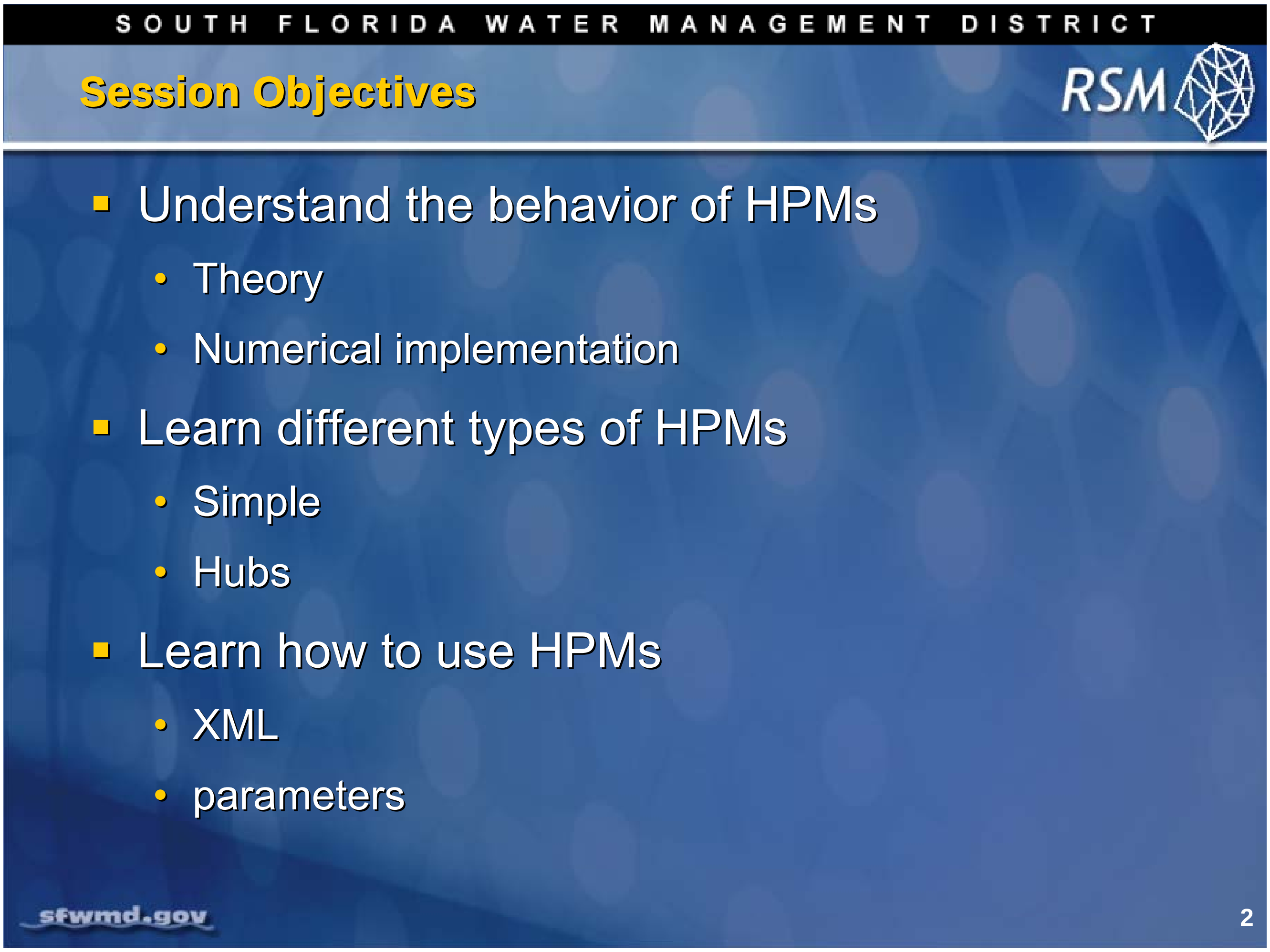
- The theory and numerical implementation of HPMs
- Different types of HPMs background, control volume, XML input and input parameters
- Implementation of HPMs in the Regional Simulation Model (RSM)

For more details about HPMs, refer to the HPM White Paper, *Hydrologic Process Modules of the Regional Simulation Model: An overview.* Flaig, E.G., Van Zee, R. and Lal, W., South Florida Water Management District, 2005.

NOTE:

Additional Resources

A number of additional HPM reference materials can be found in the `labs/lab11_hpm` directory.



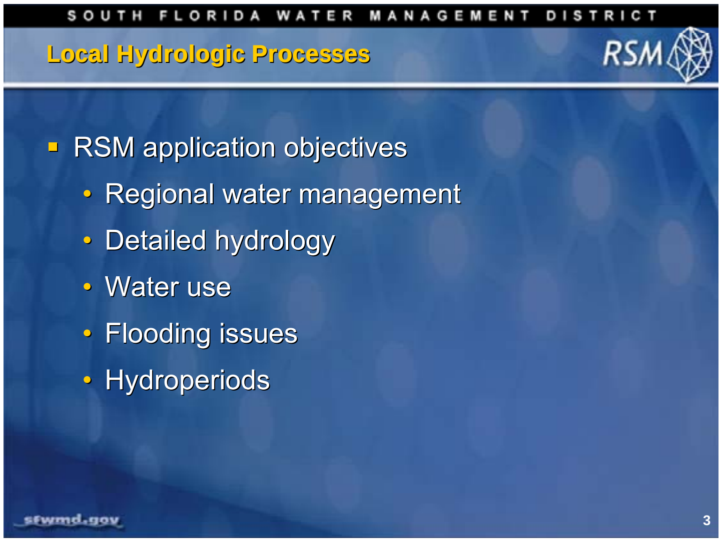
The Hydrologic Process Modules were developed to simulate local hydrology and local water management systems.

In future sessions, we will also explore Water Quality Process Modules and Ecological Process Modules that simulate local processes associated with the regional water movement.

NOTE:

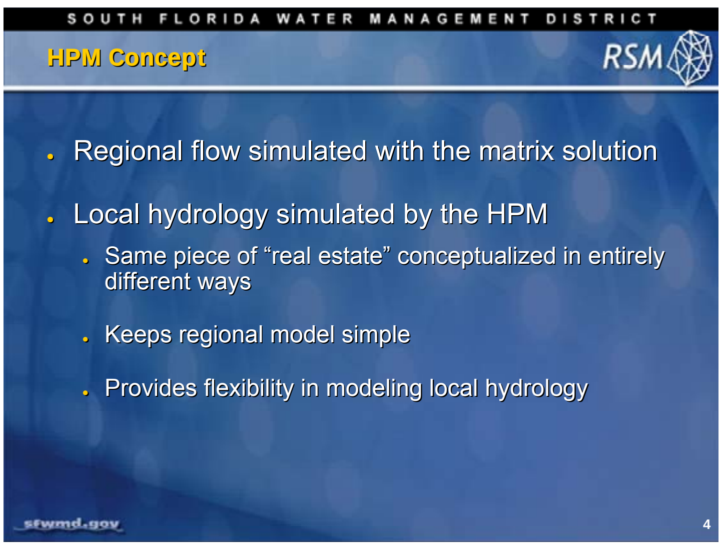
For more details on HPMs , see the HPM White Paper in the labs/lab11_hpm directory:

Flaig, E.G., R. Van Zee and W. Lal. 2005. Hydrologic process modules of the Regional Simulation Model: an overview. HESM White Paper, South Florida Water Management District.



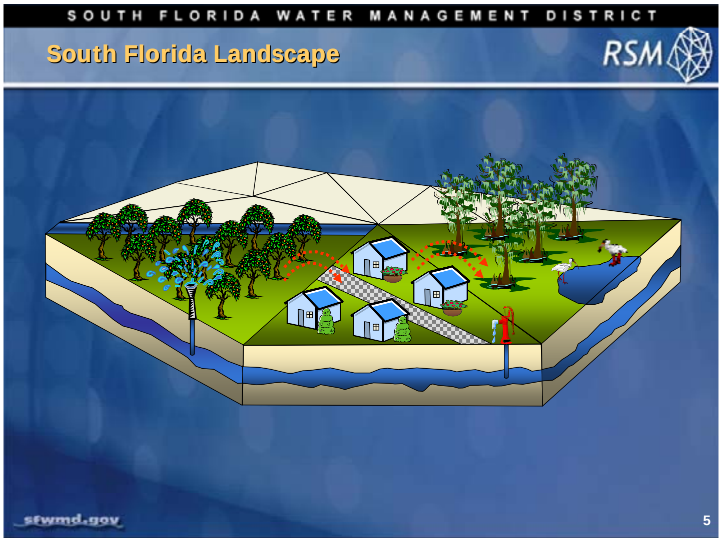
Selection and implementation of HPMs depends on the objectives of the Regional Simulation Model (RSM) application. The RSM can be applied to problems at different scales which will require different levels of hydrologic detail.

For example, it may not be necessary to model soil water movement using the Richard's equation when the objective of the model is to resolve seasonal water supply distribution.

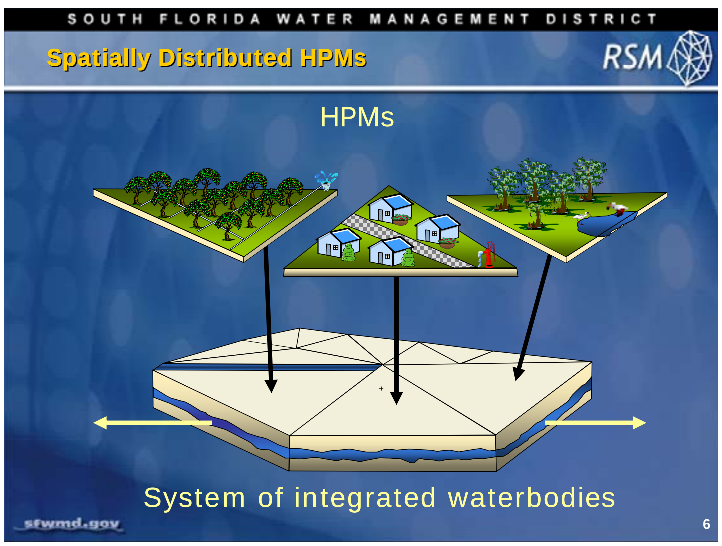


The concept of the HPM is to separate the complexity of the surface hydrology from the regional solution of the diffusive wave equation. This keeps the regional solution simple and places the complexity of the surface hydrology into the HPMs.

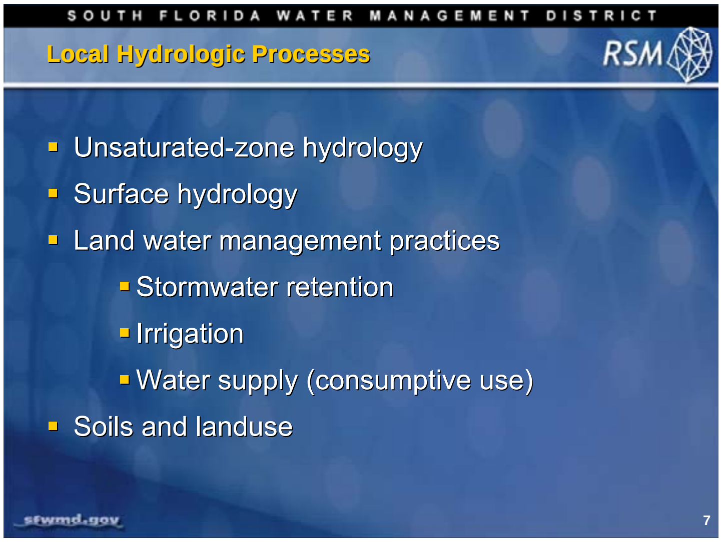
Each HPM occupies the same real estate (area and location) as the mesh cell. The HPM for each cell can be conceptualized with different processes and different parameter values compared to adjacent HPMs.



The model can be visualized as a diverse landscape underlain by a two-dimensional mesh.



The landscape is modeled by HPMs that interact with the underlying waterbodies. The 2-D flow of the groundwater and the surface water is simulated for the mesh and the canal network.



So far we have presented the regional solution of the Diffusive Wave equation for the water movement in the mesh and the network. The regional solution is good for groundwater and surface water flows, but there are local hydrologic processes that are not included in the regional solution.

These local processes include:

- Vertical processes
- Local surface hydrology
- Local water management

Vertical processes describe the movement of rainfall infiltrating into the soil and percolating to the water table. Because the vertical surface processes can be highly non-linear and spatially heterogeneous, these processes were separated from the regional solution rather than attempting to create suitably linear and differentiable vertical water movers.

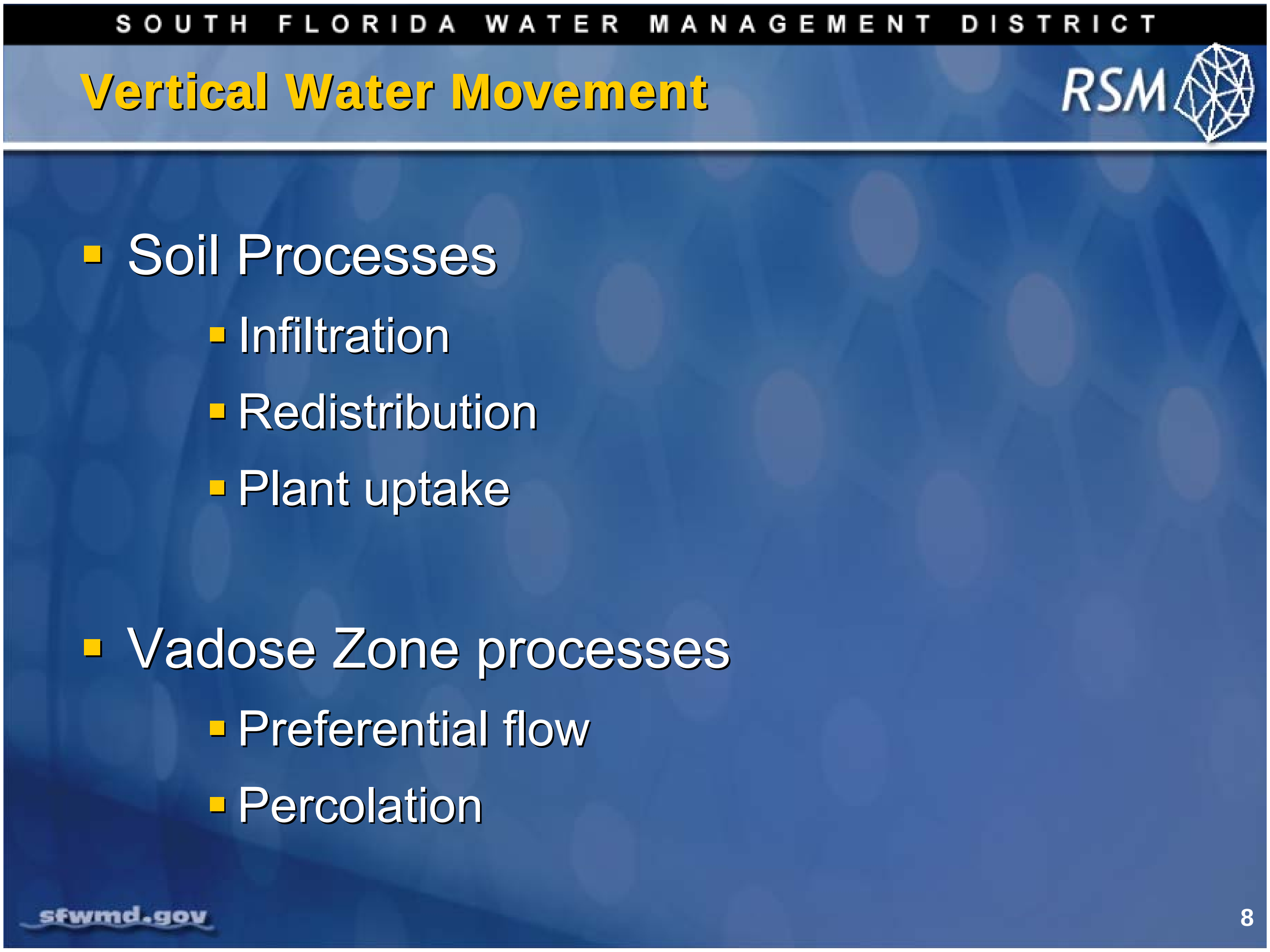
In addition to vertical solutions, different landscape types exhibit different surface hydrology with different water storage and runoff characteristics.

The different landscapes include:

- Wetlands
- Uplands
- Agricultural and urban lands

For developed lands, there are surface water management systems that modify water storage, recharge and runoff volume and peak flow. The local hydrologic processes also include water use as irrigation and human consumptive use. These processes occur at temporal and spatial scales that are typically smaller than the regional solution.

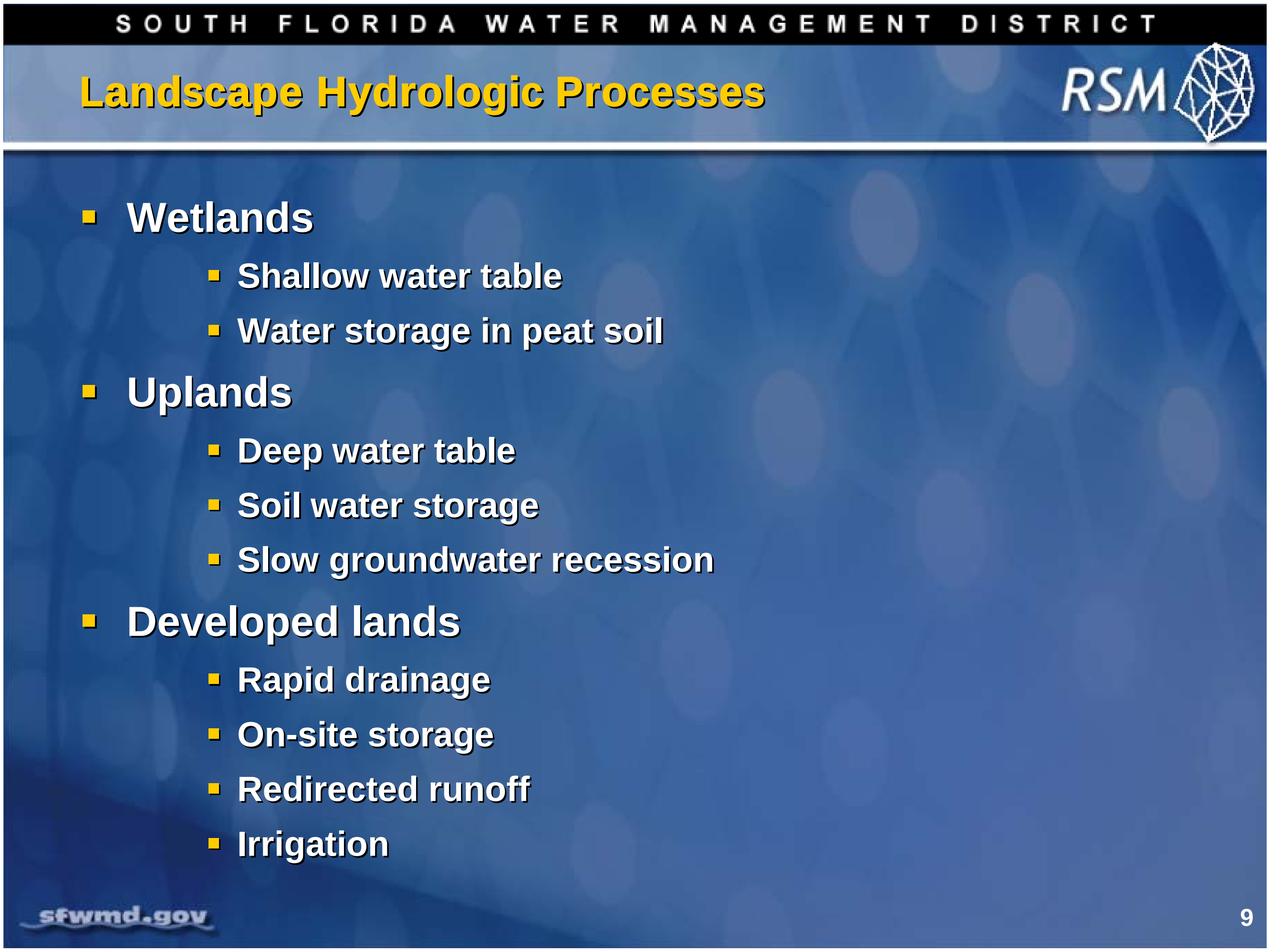
Local processes vary as a function of the soil type, landuse type and landscape. This introduces a degree of heterogeneity that can be addressed in individual Hydrologic Process Modules.



The RSM can simulate the vertical hydrologic processes that occur in the soil and the Vadose Zone. These include infiltration, redistribution, soil water storage, plant uptake from the soil, percolation, and preferential flow in the Vadose Zone.

These processes can be represented by simple mass balance, a simple analytical solution, or complete solutions based on the Richard's equation. The complexity of the selected solution depends on the objectives of the project for which RSM is being simulated as well as the selected simulation timestep and spatial discretization of the regional solution.

The complexity of the vertical solution also depends on the type of soil, substrata and landscape. In south Florida, where the soil is typically coarse, textured water infiltrates and redistributes quickly (within a day), and does not lend itself to detailed simulation modeling. Where the substrate is either impermeable, or of a similar permeability as the soil, detailed vertical simulation may not be interesting. Many landscapes in south Florida are poorly drained; the water table aquifer is shallow and is almost continually in the root zone. For these conditions, detailed vertical simulation of water movement may not provide improvement upon a simple solution.

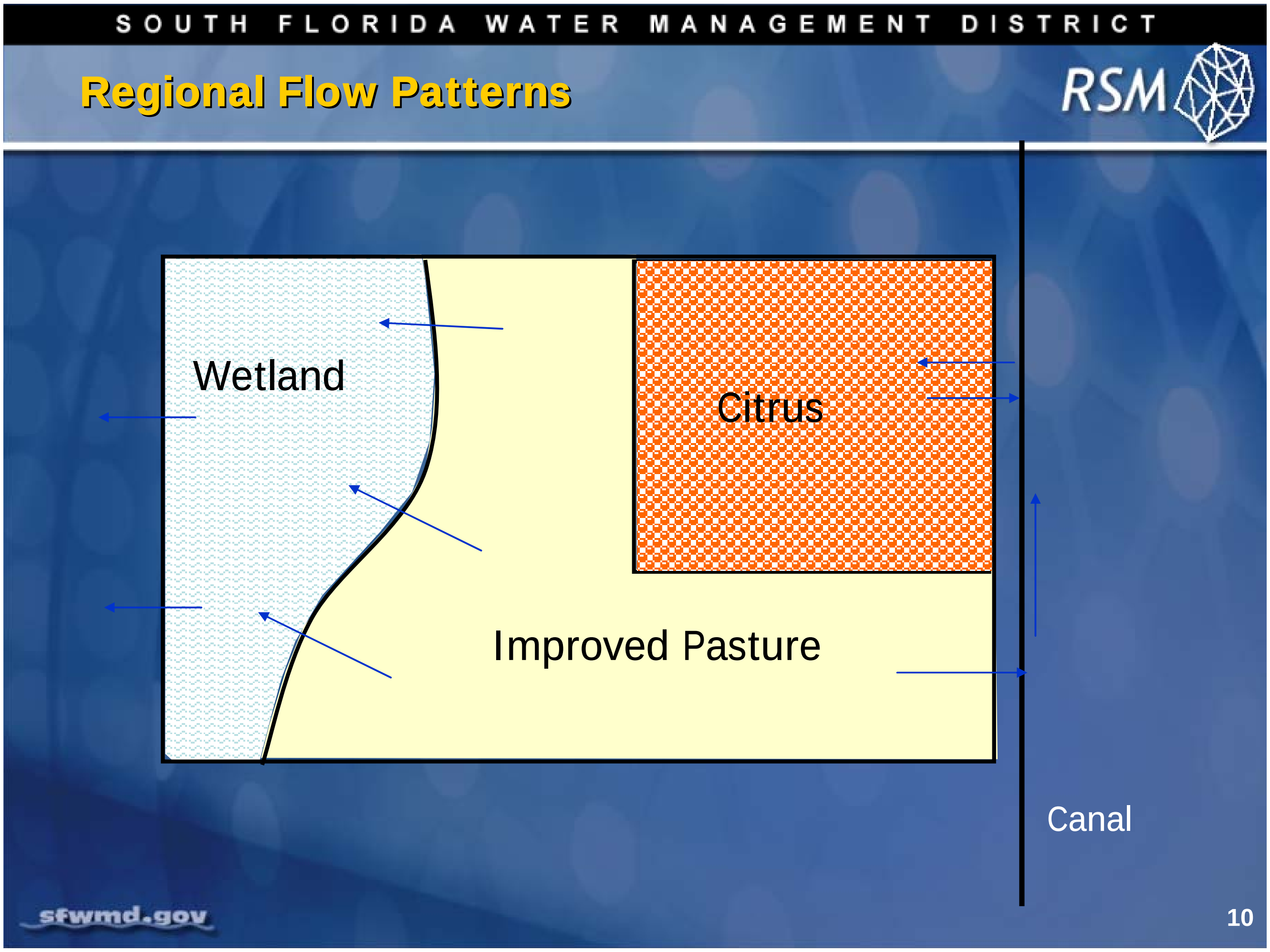


Different processes dominate the local hydrology in landscapes. Wetlands, with slow surface water flow, are dominated by evapotranspiration from the water table. There may be substantial water storage in the peat soil.

The uplands have deeper water tables that fluctuate during the year and have variable water storage.

On the sandy soils that dominate south Florida, runoff occurs when the water table, either perched or the surficial aquifer, reaches the ground surface. The upland landscapes exhibit slow groundwater table recession.

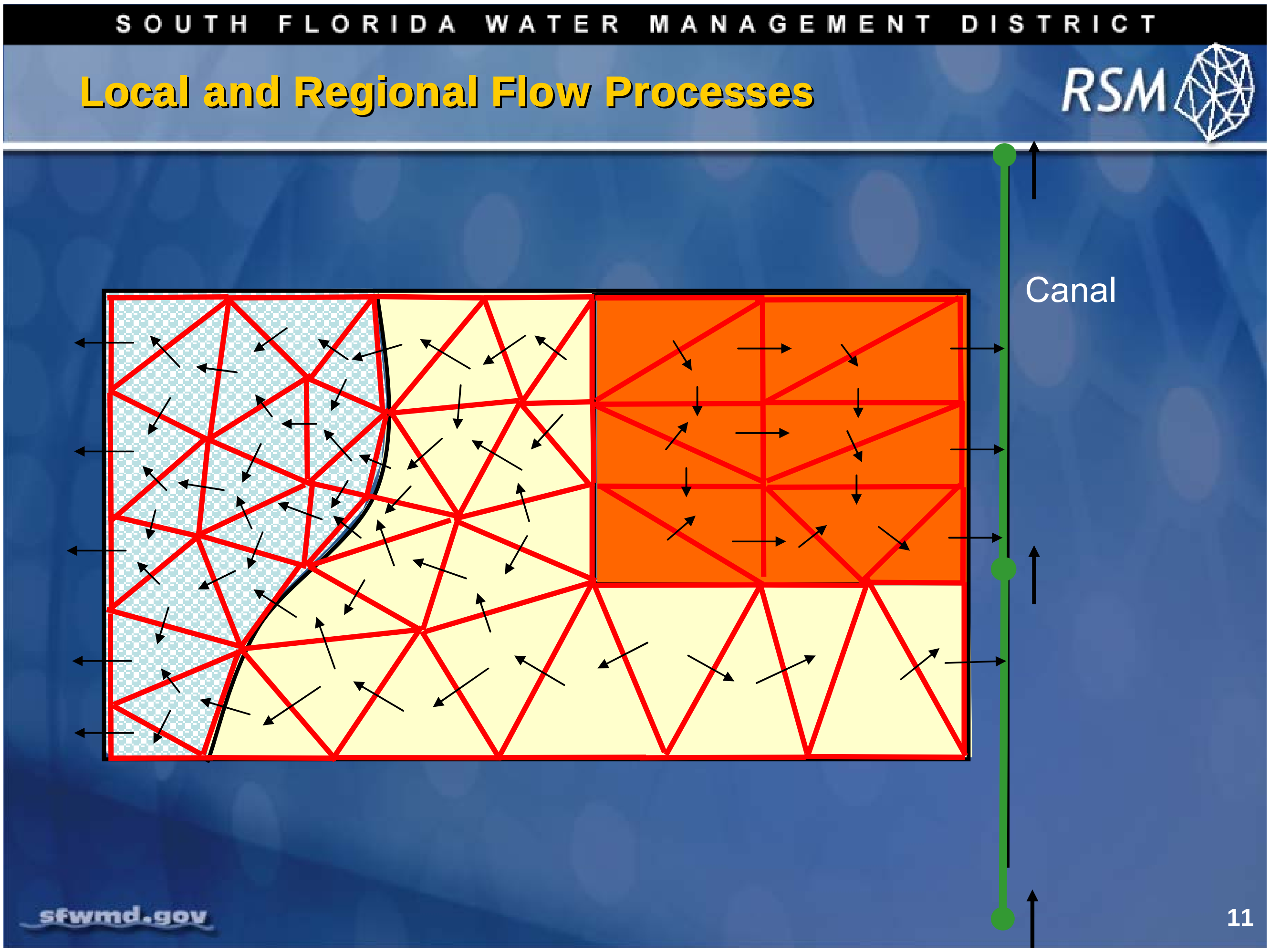
The developed landscapes are designed for rapid drainage. On sites developed within the past 20 years, there is on-site storm water detention. In many locations the runoff is directed in different flow paths from the native drainage. Most developed sites, both agricultural and urban, require irrigation from either the local water table or off-site wells.



The surface hydrology of south Florida is typically heterogeneous with native land adjacent to low intensity agricultural land and developed agricultural and urban land.

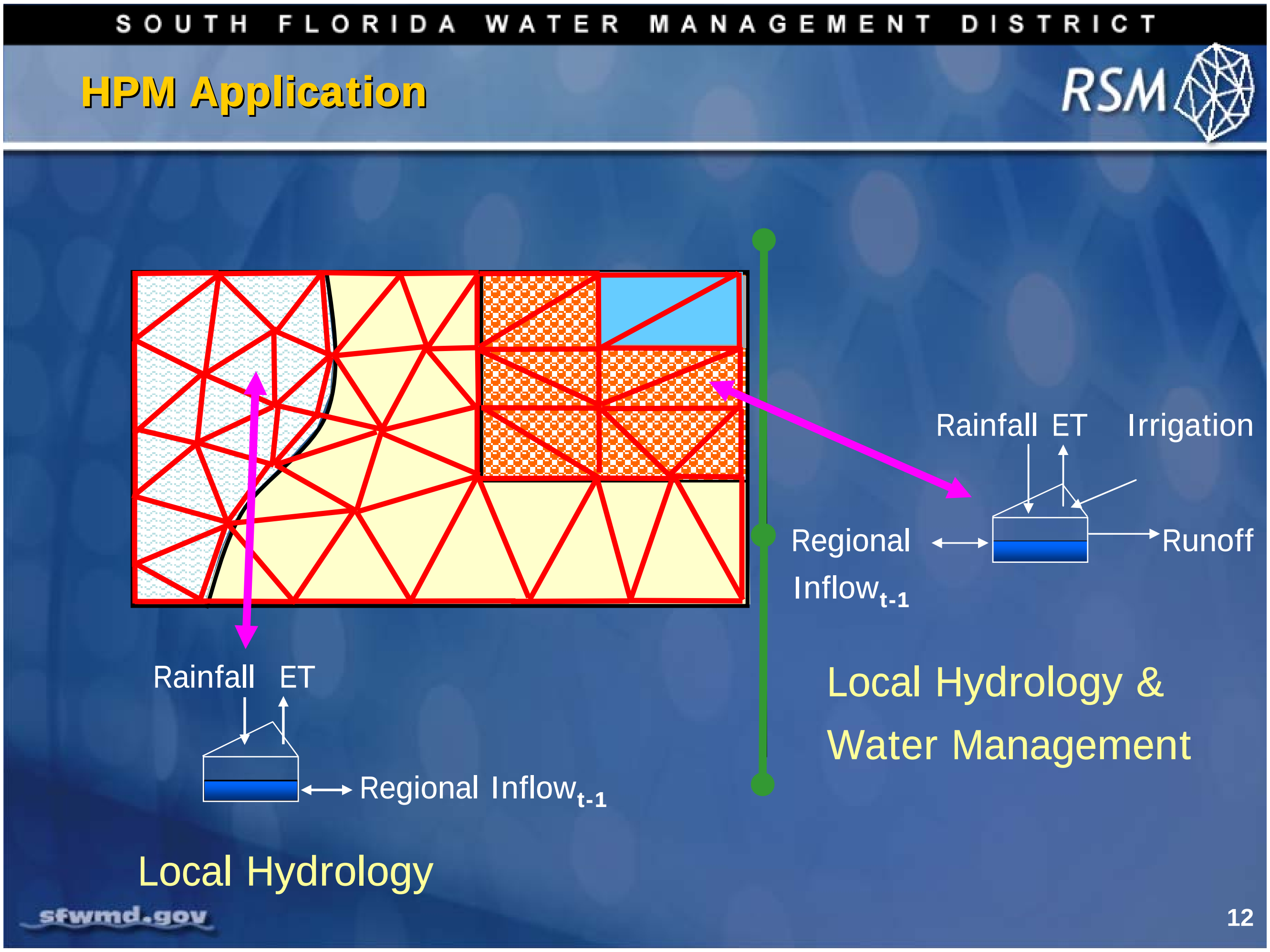
The surface hydrology of these different land uses and landscapes requires different process modules.

For example, the surface runoff is simulated using a different roughness term for wetlands compared to pastures, and surface runoff in citrus groves is either negligible on well-drained upland sites or occurs as ditch drainage on flatwoods sites.



The surface hydrology is affected by the landscape and the surface water management practices.

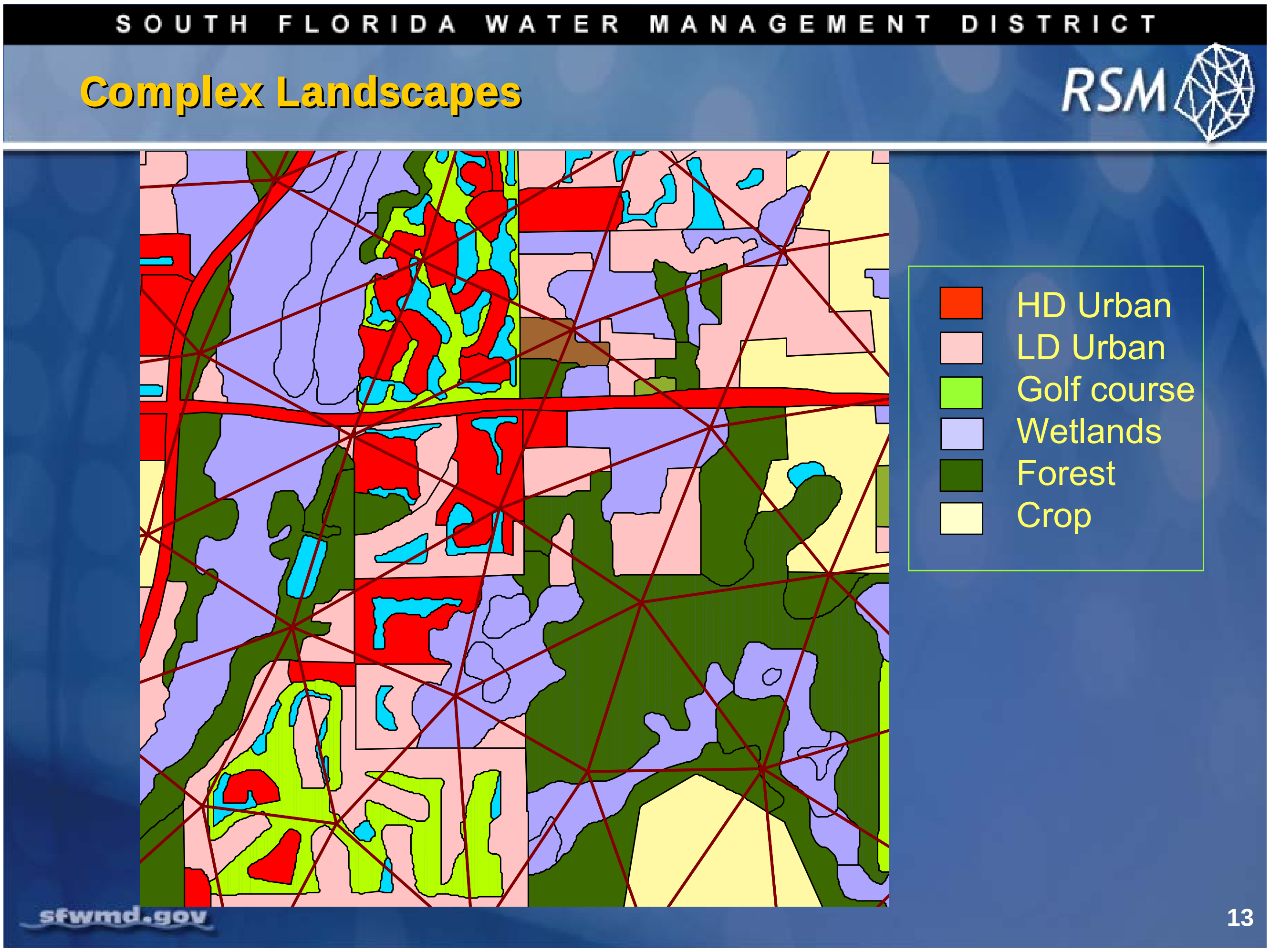
Frequently, it is appropriate to adjust the framework of the mesh for the regional model to accommodate the different landscape types and drainage patterns.



Where possible the RSM mesh framework is adjusted to accommodate the different landuse types that have different local hydrology and water management characteristics.

Each of these cells will be assigned an HPM that simulates the local hydrology.

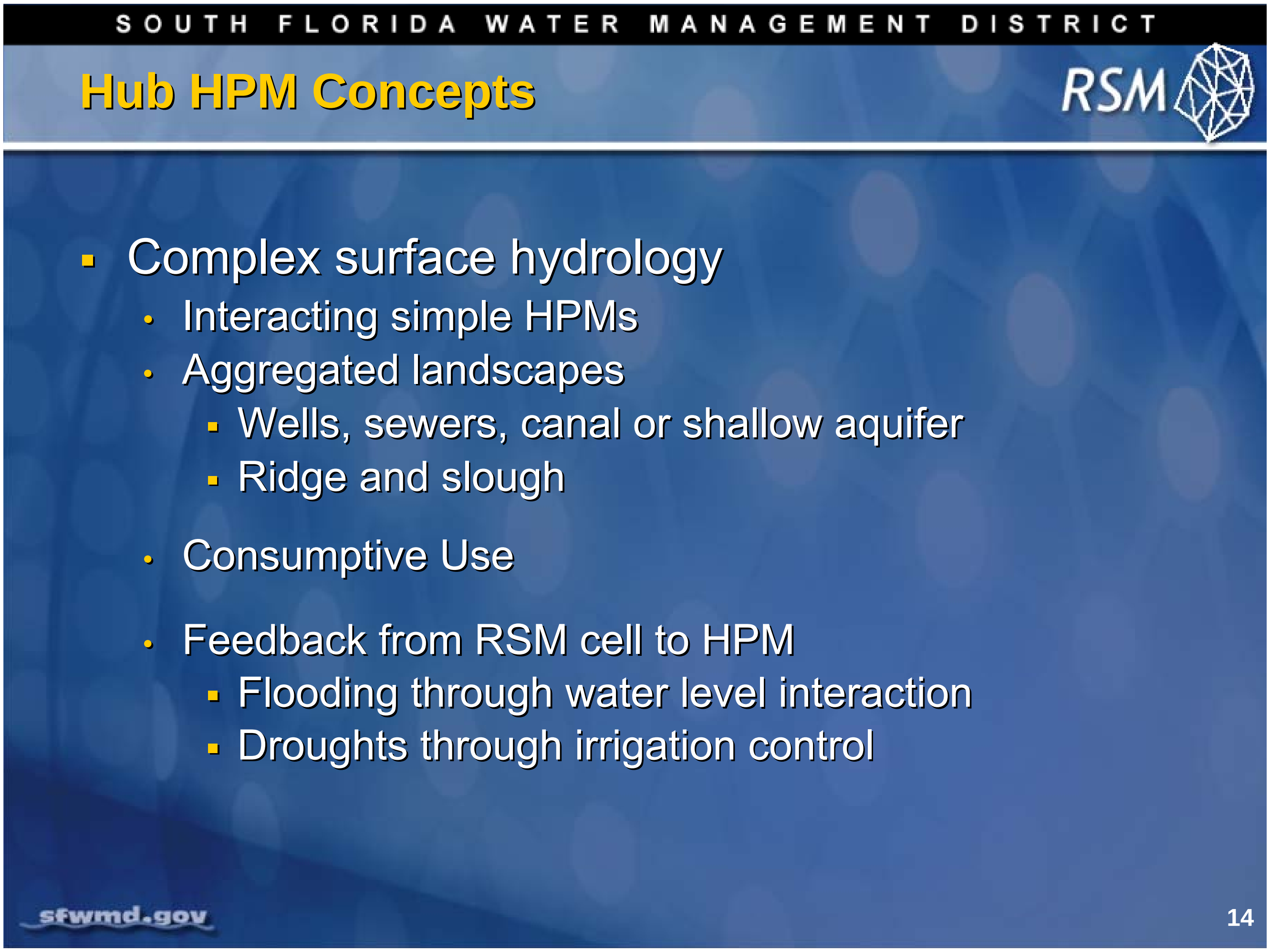
(Adjacent cells can have different HPMs).



Often the landscapes are a complex mix of different landuses and landscapes. In this example, the area is a mix of urban, agricultural, wetlands and upland forests.

The local hydrology can be simulated with a single HPM that represents either the most hydrologically significant landuse or the spatially dominant landuse type.

The local hydrology can be simulated using a "Hub" that provides a linear combination of the hydrology produced by the different landuse types.



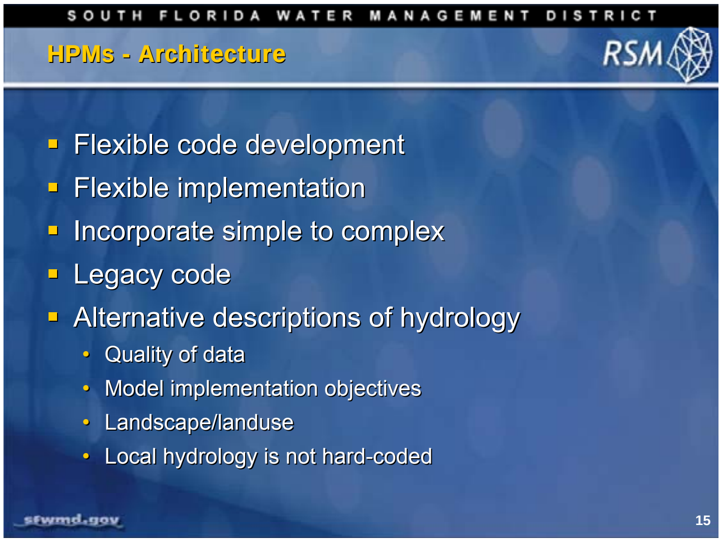
The landscape of south Florida has areas that are a complex mix of urban-commercial, urban-residential, golf courses, agricultural and native land. The urban and agricultural land can be broken down into simple landuse types that interact with each other.

Urban developments can be modeled as impervious land representing roofs, sidewalks, parking lots, and roads interacting with pervious land representing lawns and landscaping, and draining to detention ponds.

The "Hub" HPM concept allows the simulation of complex landscapes. Where the mesh cells are large it is possible to have multiple landuse and landscape types within the cell that should be modeled as different HPM types within the HPM. In this case, a HPM Hub can be constructed that includes several HPMs and the resulting hydrology (runoff, recharge and water supply) is an area-weighted combination of the included HPMs.

The Hubs provide the capability to simulate urban water consumptive use and the discharge of water to treatment plants or recycling of gray water.

With the multiple HPM types within a Hub it is possible to model on-site storage and irrigation from that storage.



Flexible code

The architecture of the HPM code was developed to provide flexibility in the development and implementation of HPMs.

The object-oriented approach to the RSM programming provides the capability to add new functionality to the RSM. Each HPM is a new class with independent methods for implementing surface hydrology. Each HPM inherits the necessary connections to the RSM through the parent HPModule class.

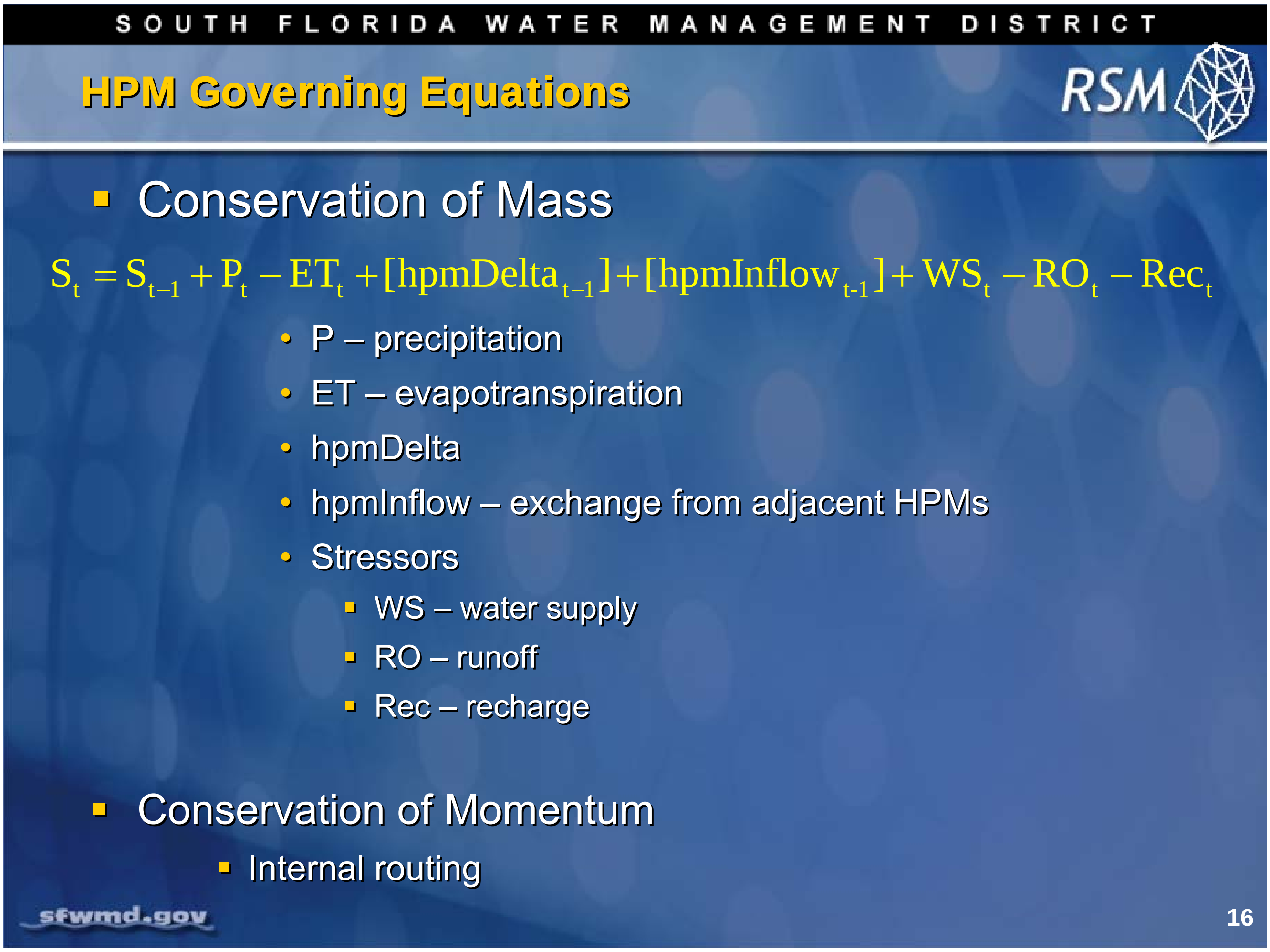
In the HPModule class, a simple interface has been developed for water exchange between the HPMs and the waterbodies. Additional HPMs can be added to the model by writing the new class with the necessary methods, writing some additional code for implementing the HPM within the RSM, and adding the necessary input formats to the XML schema in the hse.dtd. This approach for implementation of HPMs provides the flexibility to add any form of surface hydrology to the RSM.

Flexible Implementation

The use of HPMs provides the flexibility for simulating a wide range of possible surface hydrologic processes. For example, there are several methods for simulating the attenuation of storm water runoff from developed land. Each can be coded into the RSM and implemented where appropriate. Because each cell may have a unique HPM, alternative formulations can be applied to adjacent cells.

Legacy Code

The HPM structure allows for old FORTRAN code to be included in the RSM by using a C++ wrapper. The original code is not modified reducing programming time and insuring users of the integrity of the original code.



The governing equation for the HPMs is the Conservation of Mass.

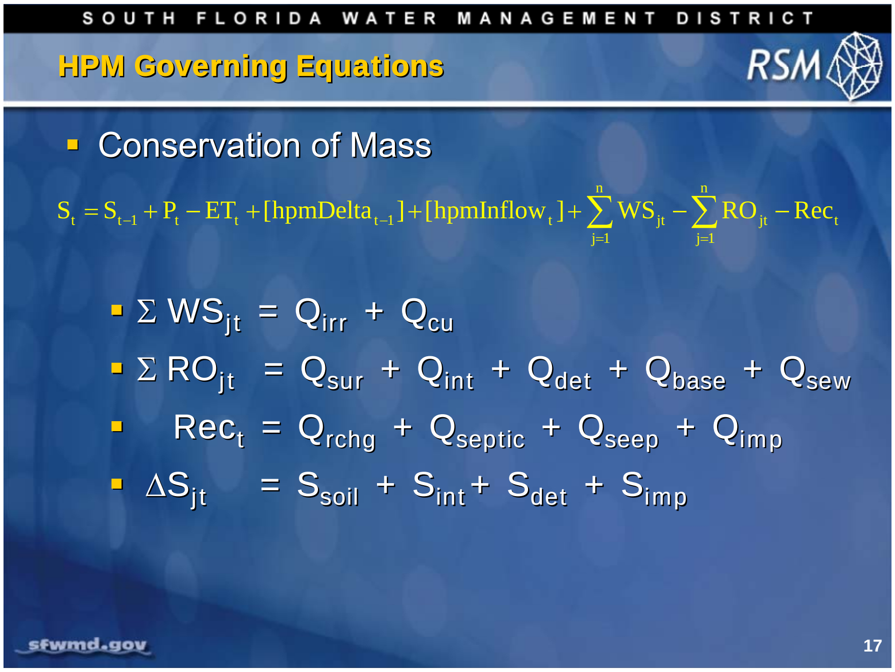
The change in water content is the sum of rain (P), evapotranspiration (ET), the contribution from the underlying mesh cell from the previous timestep (hpmDelta), the exchange of water from adjoining HPMs, water supply* requirements (WS), the sum of runoff (RO) and the loss of recharge (Rec) to the home cell.

The Mass Balance equation is solved on a depth per unit area basis for each timestep.

To accurately simulate the local hydrology it may be necessary to route storm water runoff through detention/retention impoundments or through the perched water table aquifer. In these cases the Momentum equation is solved to provide the necessary equations of flow. There is local water storage within the selected HPM and water is routed according to the timestep.

For example, for a model daily timestep, the amount of water discharged from an impoundment is calculated on 30-minute timesteps within the HPM. Shorter timesteps can be applied within other HPMs as well.

NOTE: Typically, water supply is an addition of water to the HPM.



The Water Supply, Runoff, Recharge and Storage terms may contain other components depending on the types of HPMs that are simulated. The Water Supply components include irrigation and urban consumptive use. In a Hub (to be discussed later in this lecture) there can be multiple water supply sources.

The Runoff component include:

- Surface runoff
- Sewage loss
- Base flow
- Discharge from detention ponds and impoundments
- Interflow from surface storage

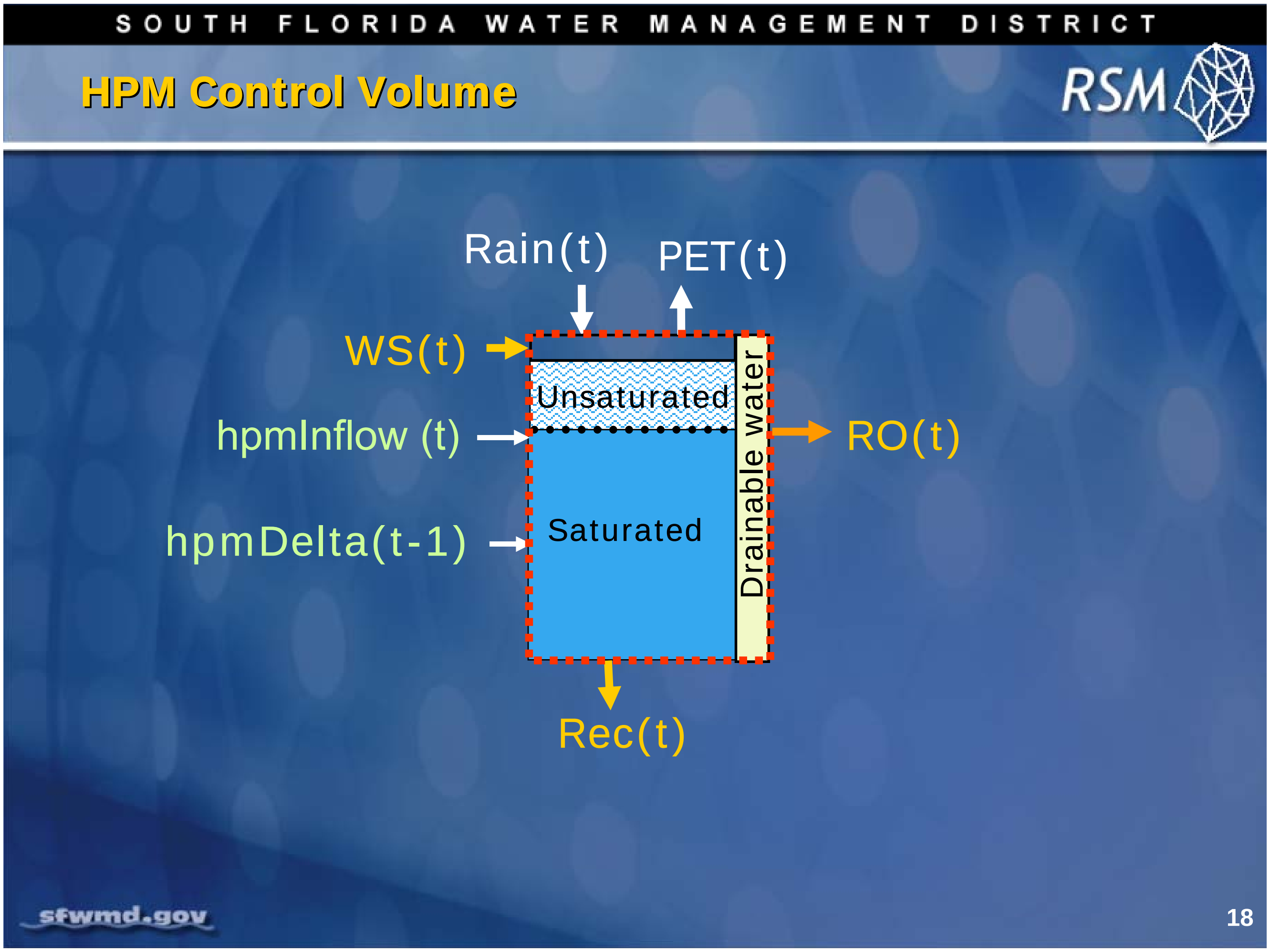
The Recharge component includes:

- Percolation
- Septic system drainfield losses
- Seepage from detention ponds, impoundments and pumped ditches

The Mass Balance equation may include any or all terms depending on the complexity of the HPM.

The Water Storage component includes:

- Storage in unsaturated soil
- Detention ponds
- Interception storage
- Impoundments

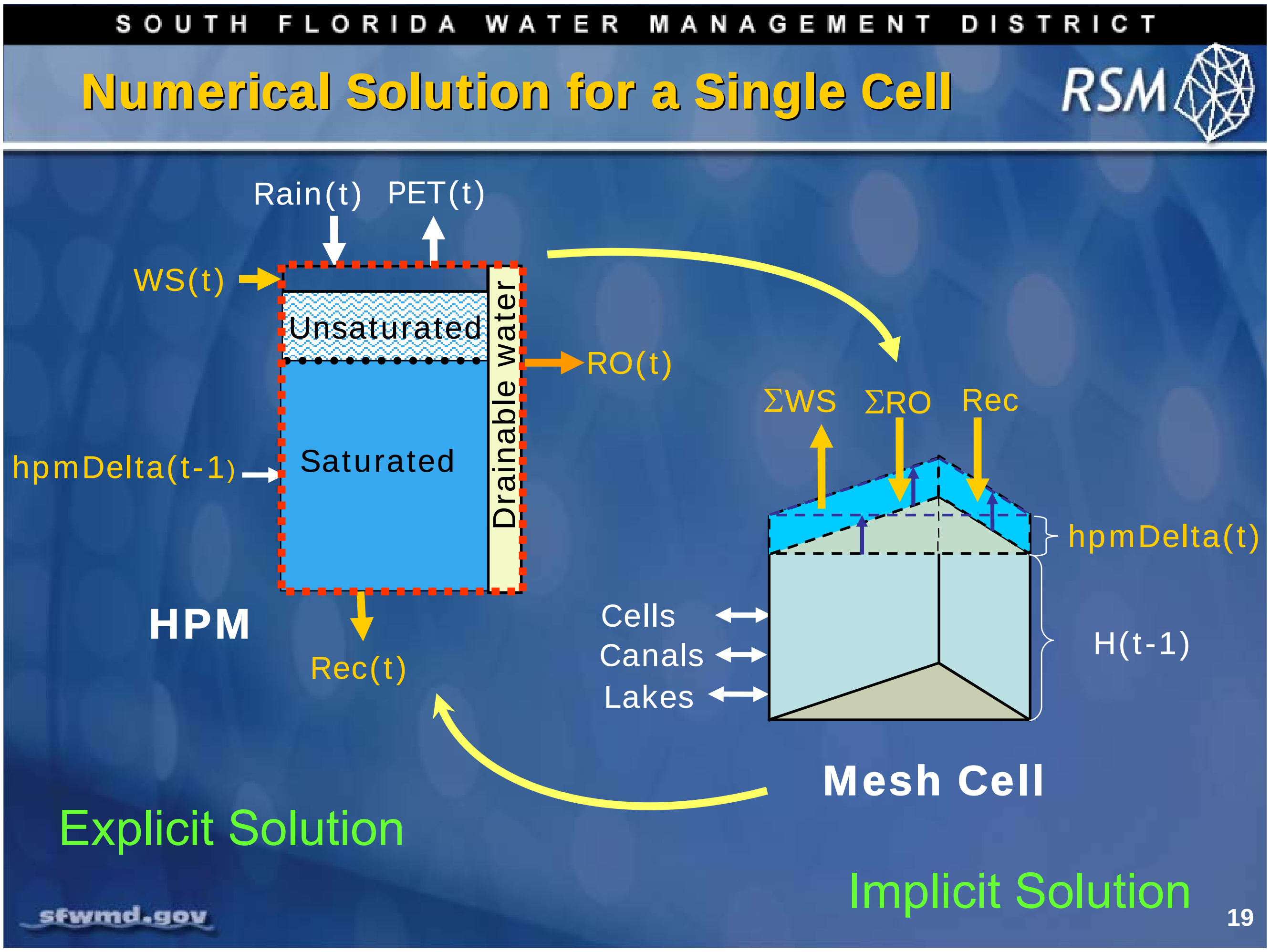


The control volume for the HPM varies with the HPM type. Generally, it includes the land surface, the unsaturated soil, part of the saturated soil and water stored in detention or retention ponds or impoundments.

The HPMs are connected to the waterbodies (cells, segments, lakes, basins and water control districts) by way of the water supply, runoff and recharge. Although the HPM may include saturated soil there is recharge to the underlying cell. Water in the saturated portion of the HPM can still interact with other surface processes.

The hpmDelta component is the term that contains the interaction with the cells. It tracks the water in the HPM that occurs due to the change in the water level in the cell as a result of the regional solution.

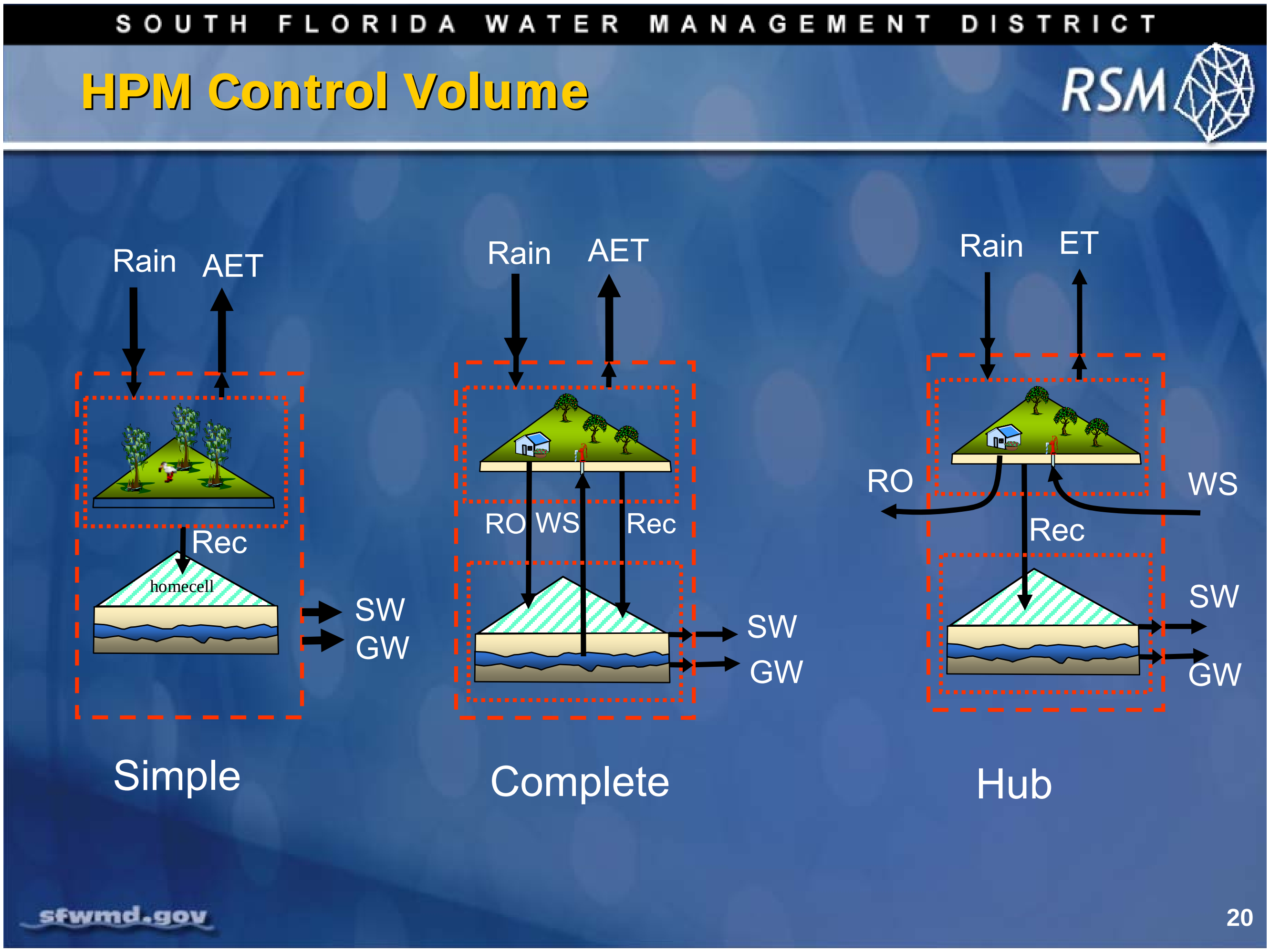
The hpmDelta is not an addition of water from the underlying cell, but a mapping of the water table into the cell. Any actual exchanges of water are made through the actual water flows: WS, RO and Rec.



The numerical solution for a single cell contains two parts: the explicit solution of the HPMs and the implicit solution for the watermovers.

First, the governing equations for the HPMs are solved using the driving functions of rain and potential evapotranspiration, and hpmDelta where appropriate. Where the HPMs are connected they are processed in a cascading order.

Then the WS, RO and Rec components are applied to “known” flows of the waterbodies. The WS is provided as a demand on the available water. This information is used in the implicit solution. Following the implicit solution information on the water table (hpmDelta), amount of available water for water supply and available capacity for flood control drainage is provided to the HPMs for the next timestep.



Application of the control volumes depends on the HPM type.

Simple HPMs

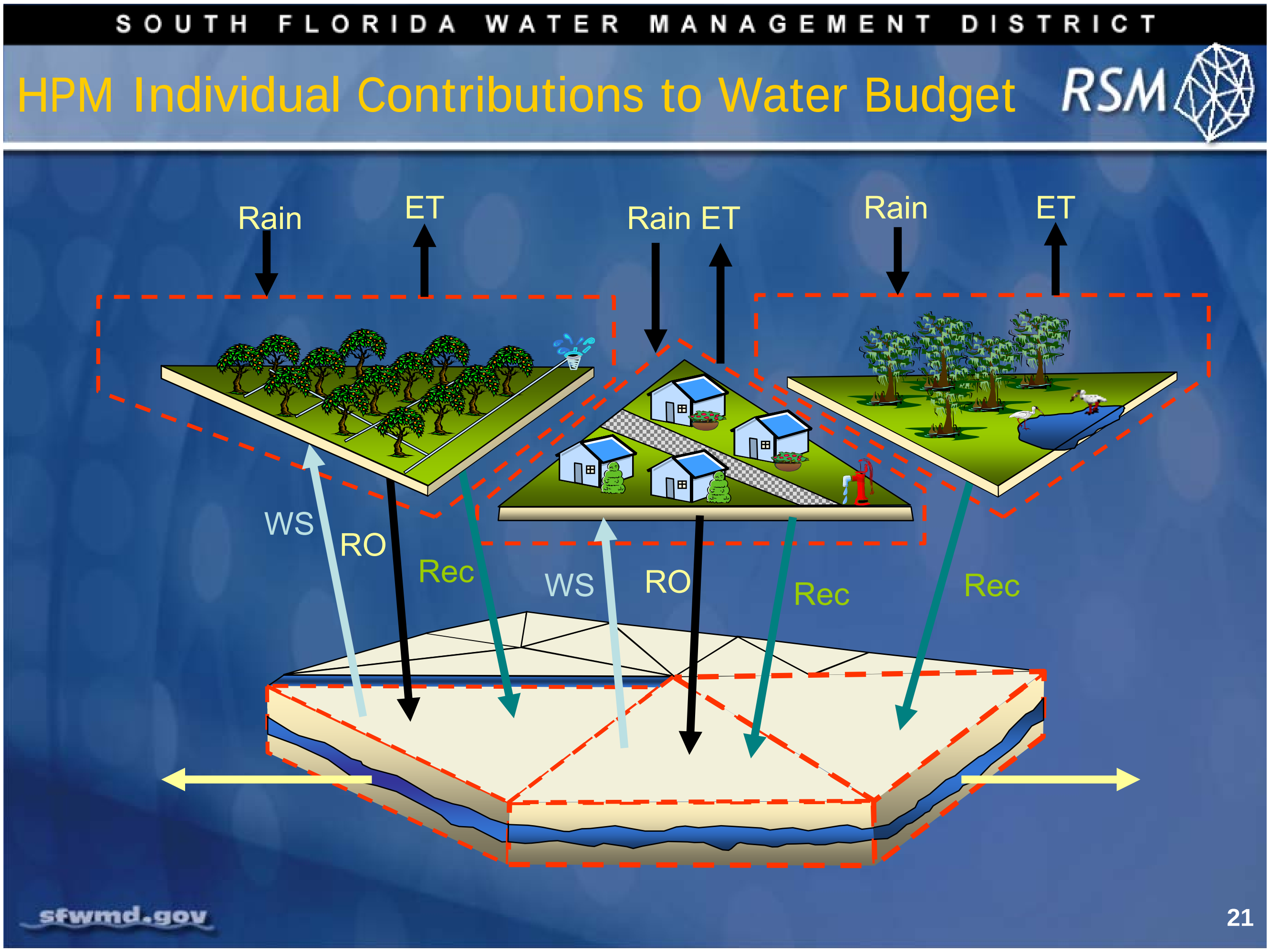
There is no separate water storage in the HPM. The HPM simply processes Rain and ET and provides the home cell with a net recharge (Rec).

Complete HPMs

There is separate water storage in the HPM. The HPM interacts with the home cell through three possible connections: WS, RO and Rec.

Hub

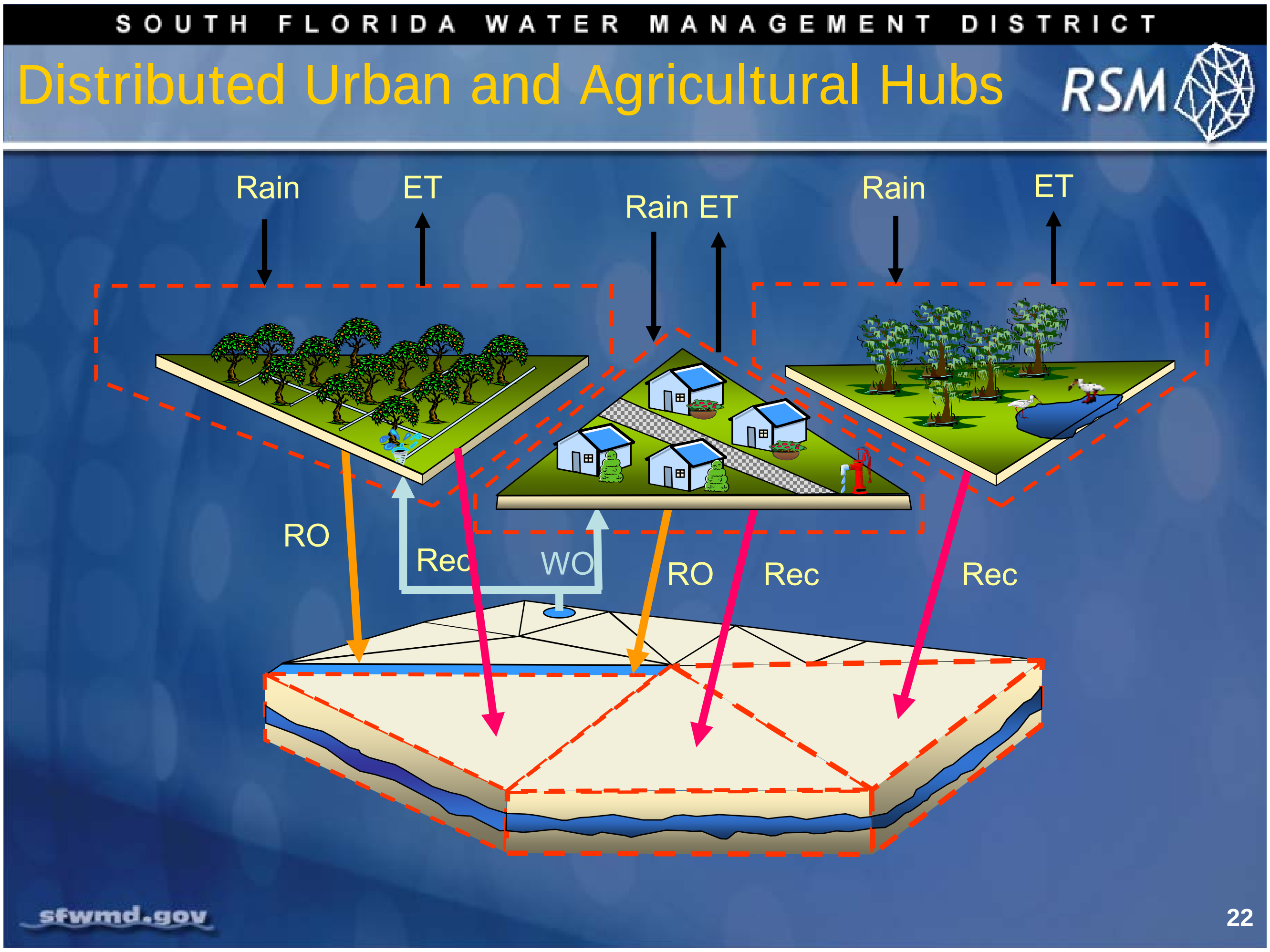
The Hub maintains one overall water storage that can have several components. The Hub can interact with different waterbodies for WS and RO.



The HPMs interact with the waterbodies through the three components:

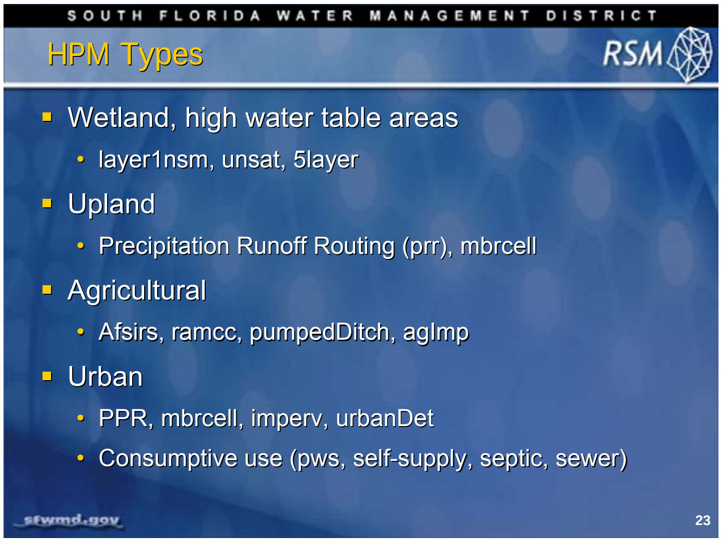
1. Water Supply (WS)
2. Runoff (RO)
3. Recharge (Rec)

In the simplest case of the native land (right side), recharge is the only interaction term. For urban and agricultural landscapes there is also water supply or runoff.



In a more complex case, the HPM may interact with adjacent waterbodies. Runoff may be directed to the nearest canal or Stormwater Treatment Area (STA). The water supply may come from a regional Public Water Supply (PWS) or the nearest canal.

In a complex landscape each cell can have an HPM that is unique and different from the adjacent HPMs.



Currently, there are 12 single HPM types. These cover the four different landscape types.

Wetlands

Within wetlands, or other landscapes where the water table is always within the root zone, there are three HPMs:

1. <layer1nsm> for homogenous soils
2. <unsat> for homogenous soil with significant soil water storage
3. <5layer> for soils with significant development of different soil layers.

Uplands

Both the <prr> and the <mbrcell> HPMs were developed to provide shallow groundwater routing for uplands that have a significant Vadose Zone storage capacity.

Agricultural

The <afsirs> and <ramcc> HPMs are used to estimate irrigation requirements and drainage for agricultural crops. The <afsirs> HPM is a simple soil water model that estimates optimal irrigation requirements. The <ramcc> HPM is a complete soil water model that estimates actual irrigation requirements. The <pumpedDitch> and <agImp> HPMs simulate storm water management systems.

Urban

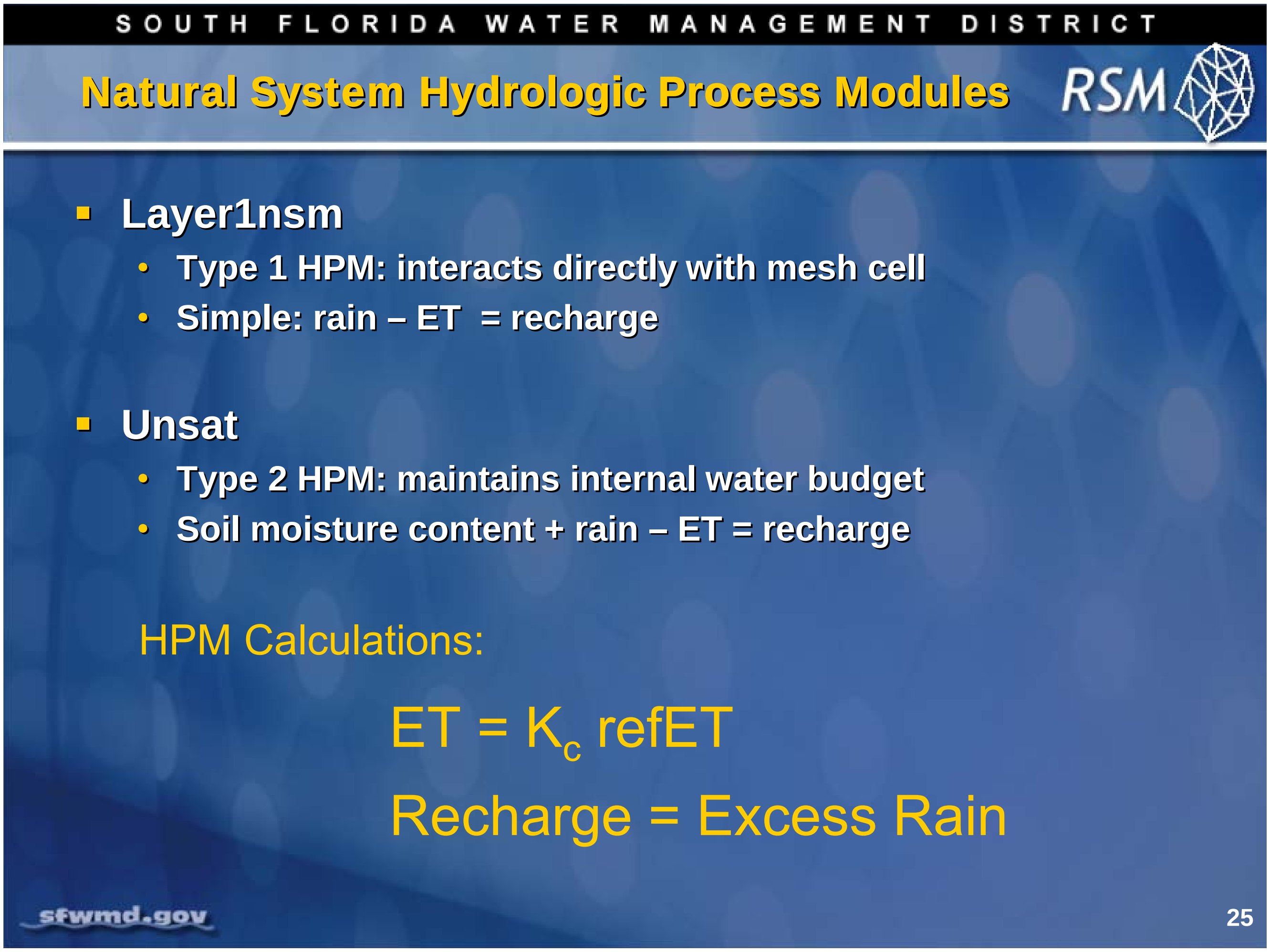
The <ppr> and <mbrcell> are used to model urban land with significant Vadose Zone storage. The <imperv> HPMs simulates the effect of impervious land and <urbanDet> simulates urban storm water detention systems. Consumptive use <CU> can be used to simulate water use within Hubs.

The natural systems are simulated using the five HPMs listed in the slide above. The first two HPMs, <layer1nsm> and <unsat> are used primarily for wetland soils. The <layer1nsm> provides reasonable results (surface and groundwater heads and flows) for all non-irrigated sites as a first approximation.

The <layer5> HPM is used occasionally for soils with distinctly different soil horizons. In the future the <layer5> will be extended to provide for water movement through unlimited soil layers.

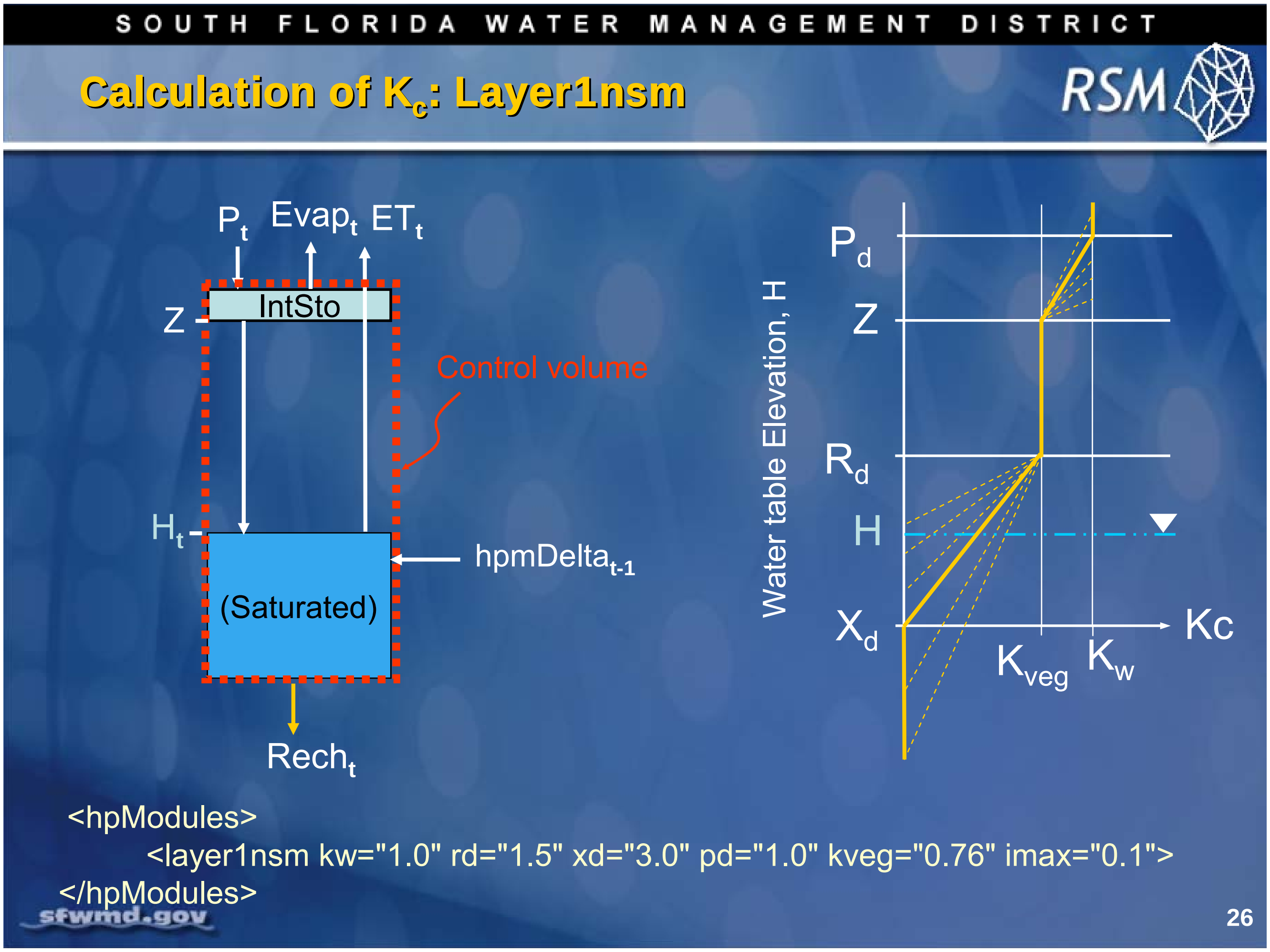
The <prr> HPM was developed based on the DHI NAM Surface Hydrologic Simulation Module to model surface runoff as well as the shallow water table contribution to interflow and base flow to create a typical runoff hydrograph from uplands.

The no action HPM, <layerpc>, is used where there is no upper boundary condition. It is used during testing of a mesh or in areas of a model when it is necessary to separate out different surface water components. The <layerpc> HPM is also used in multilayer models where a HPM is required for every cell and the HPMs for lower aquifer layers are inactive.



The One Layer Natural Wetland System <layer1nsm> HPM and Unsaturated Soil <unsat> HPM provide two methods for estimating the vegetation evapotranspiration (ET) from the reference vegetation evapotranspiration (refET). In the <layer1nsm> HPM, rain and ET interact directly with the underlying mesh cell, so the HPM does not maintain a separate soil storage. The <unsat> HPM maintains a separate water budget from the cell. This is important for finer textured soils and upland landscapes.

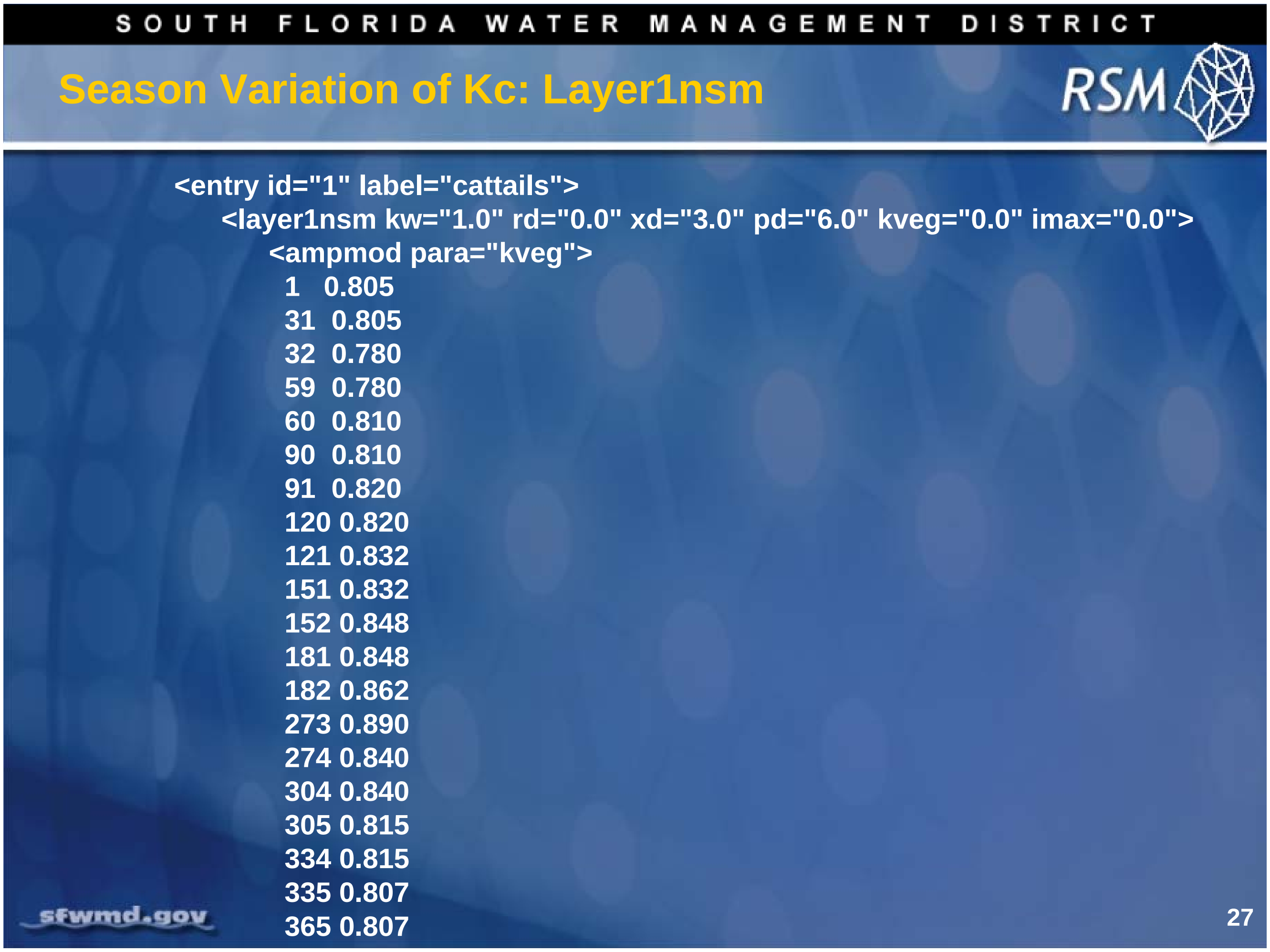
Actual ET is calculated using the reference crop ET adjustment coefficient, Kc, which is commonly known as the crop coefficient. The natural system HPMs calculate recharge as the rainfall in excess of ET.



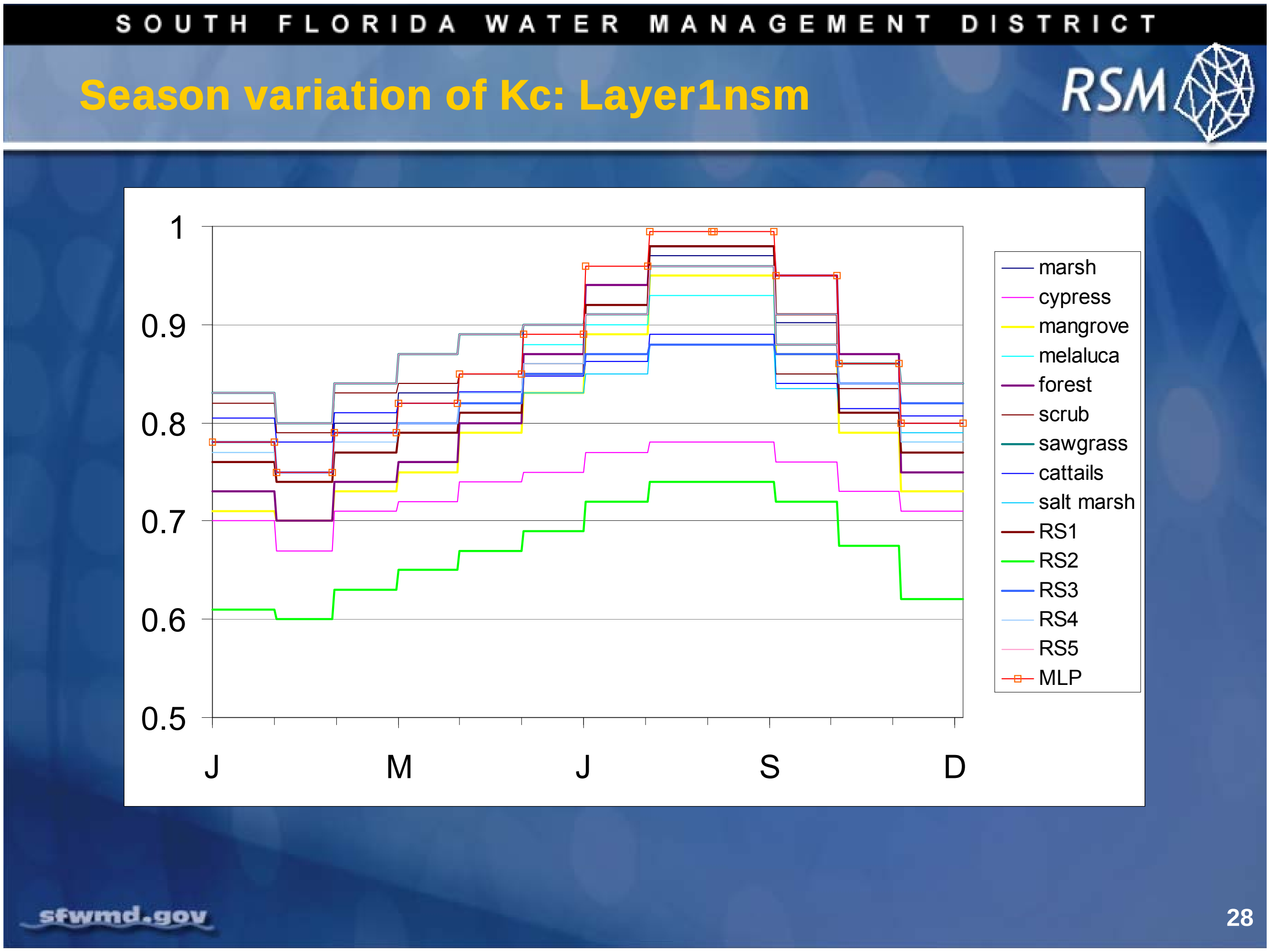
To estimate recharge we need to calculate actual ET. This requires us to calculate the Kc. The Kc value follows the typical curve. The slope of the Kc curve above Z and below Rd is critical to obtain the correct ET predictions. The values of Rd are from the literature. The values of Pd and Xd are generally determined through calibration.

The <layer1nsm> HPM simulates the effect of rainfall and evapotranspiration on the water table in a wetland. The effect of soil water content on cell head (Ht) is considered negligible. With a shallow water table, the soil is considered near saturation for fine-textured soil and thus the unsaturated soil water content will change little while the water table changes, or for coarse-textured soils there is a small unsaturated zone storage and the rainfall percolates directly to the water table.

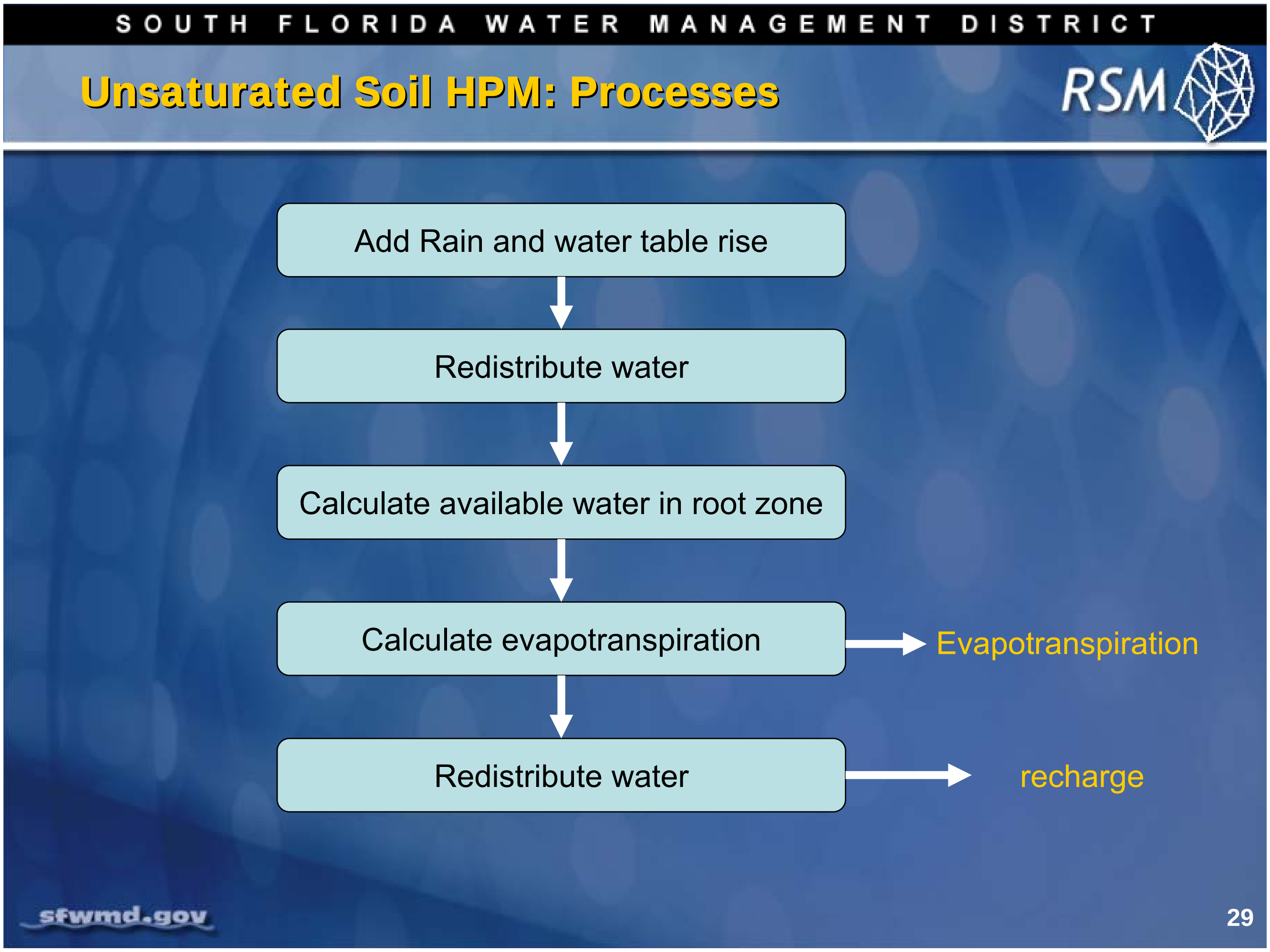
In <layer1nsm>, ET is extracted directly from the water table and the crop-specific reference crop ET coefficient is a function of the depth of the water table, rooting depth (Rd), ponding depth (Pd) and extinction depth (Xd) (right hand graph). The extinction depth is the depth at which ET goes to zero. Typically, this depth is set below the depth the water table will ever reach so that the ET rates become small but never zero. There can be interception storage where evaporation can occur from dew or rain. It has been shown that evaporation from interception storage can substantially affect the change in the water table elevation as a result of evapotranspiration.



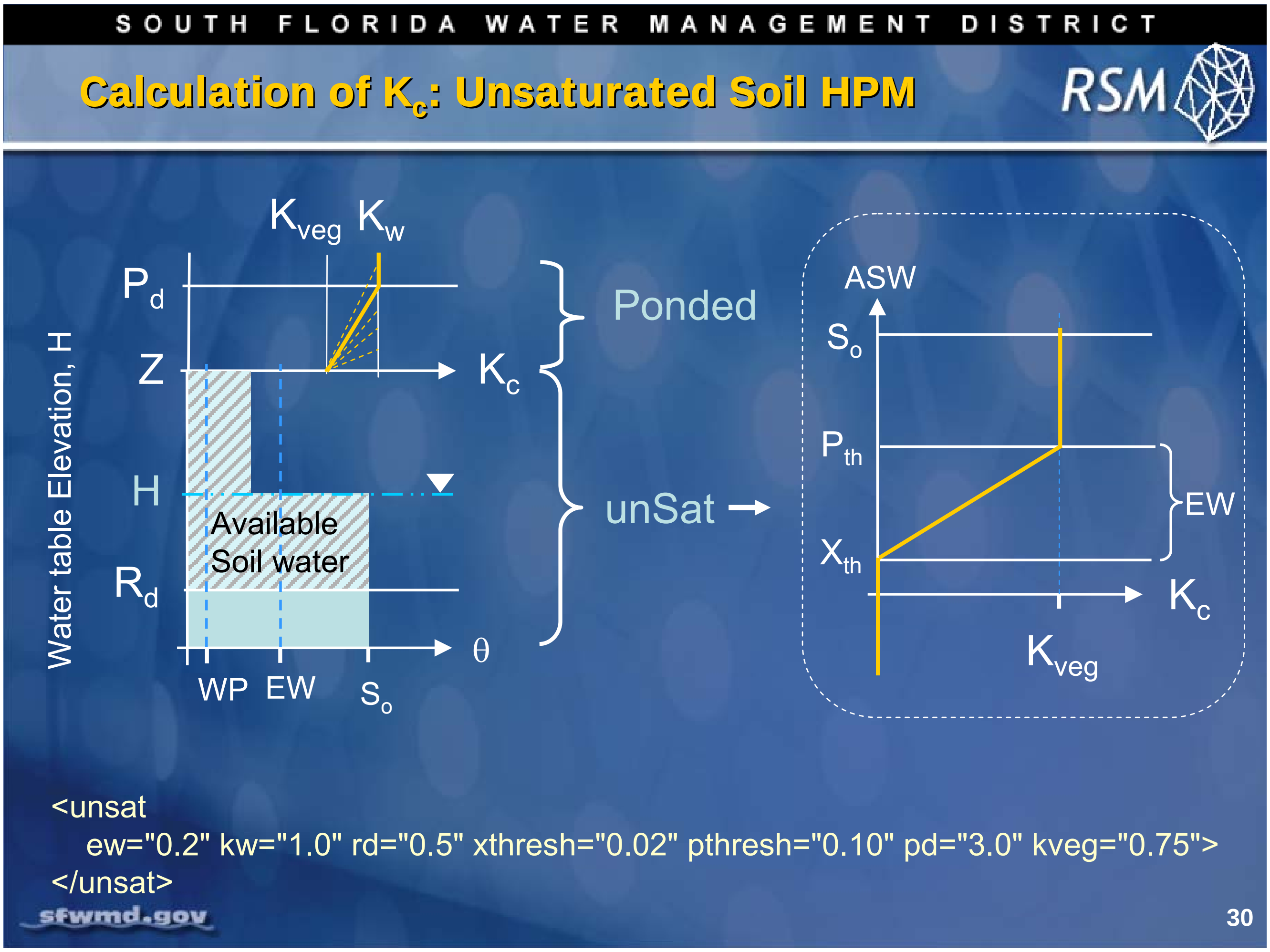
Using an <ampmod> element for the <layer1nsm> HPM, it is possible to apply adjustments to the Kc value on a 365-day cycle. In this example, there are 12 monthly crop adjustment coefficients which change on the last day of the month.



The seasonal values for the vegetation cover correction coefficient for reference crop evapotranspiration are shown in the slide above.



The process for calculating ET and recharge is different for the Unsaturated Soil <unsat> HPM. First the inflowing water is redistributed between saturated and unsaturated soil, then ET is calculated, and finally the remaining water is redistributed.

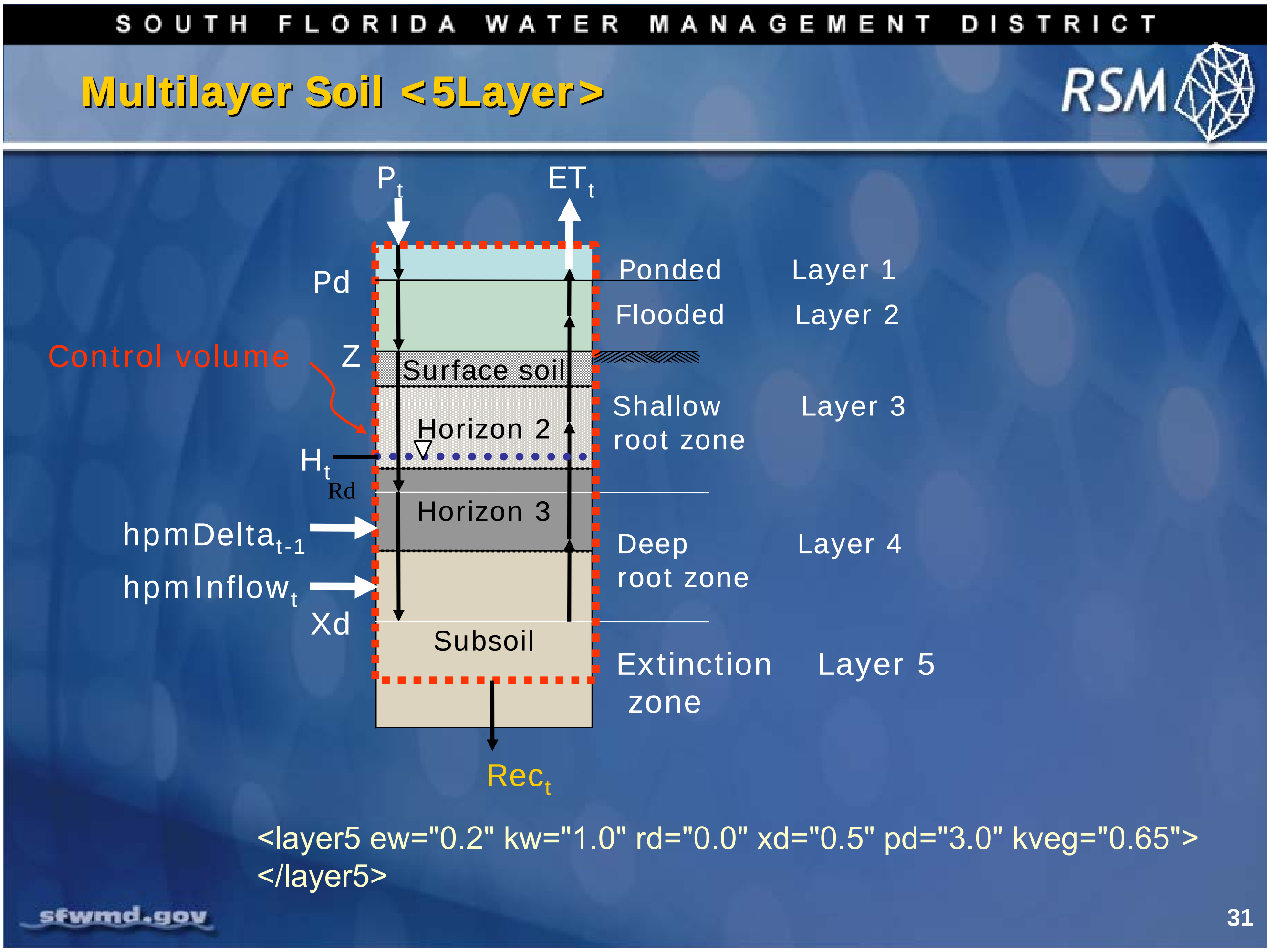


The Unsaturated Soil <unsat> HPM was developed as an enhancement to the <layer1nsm> HPM where there is significant soil water storage.

The control volume is defined as the portion of the soil above the saturated zone. The thickness of the control volume varies with the depth of the water table. In the unsaturated zone, the available soil water (ASW) ranges from the wilting point (WP) to saturation (So). The extractable water (EW) is the amount of water between WP and field capacity. The water in the soil above field capacity will drain to the water table.

The evapotranspiration function of <unsat> is similar to <layer1nsm> with the exception that water is first withdrawn from unsaturated soil and then from the water table. When the soil water content is greater than “pthresh” (P_{th}) the ET will occur at the rate of Kveg. When water content falls below “cthresh” (X_{th}), water is transpired from the water table.

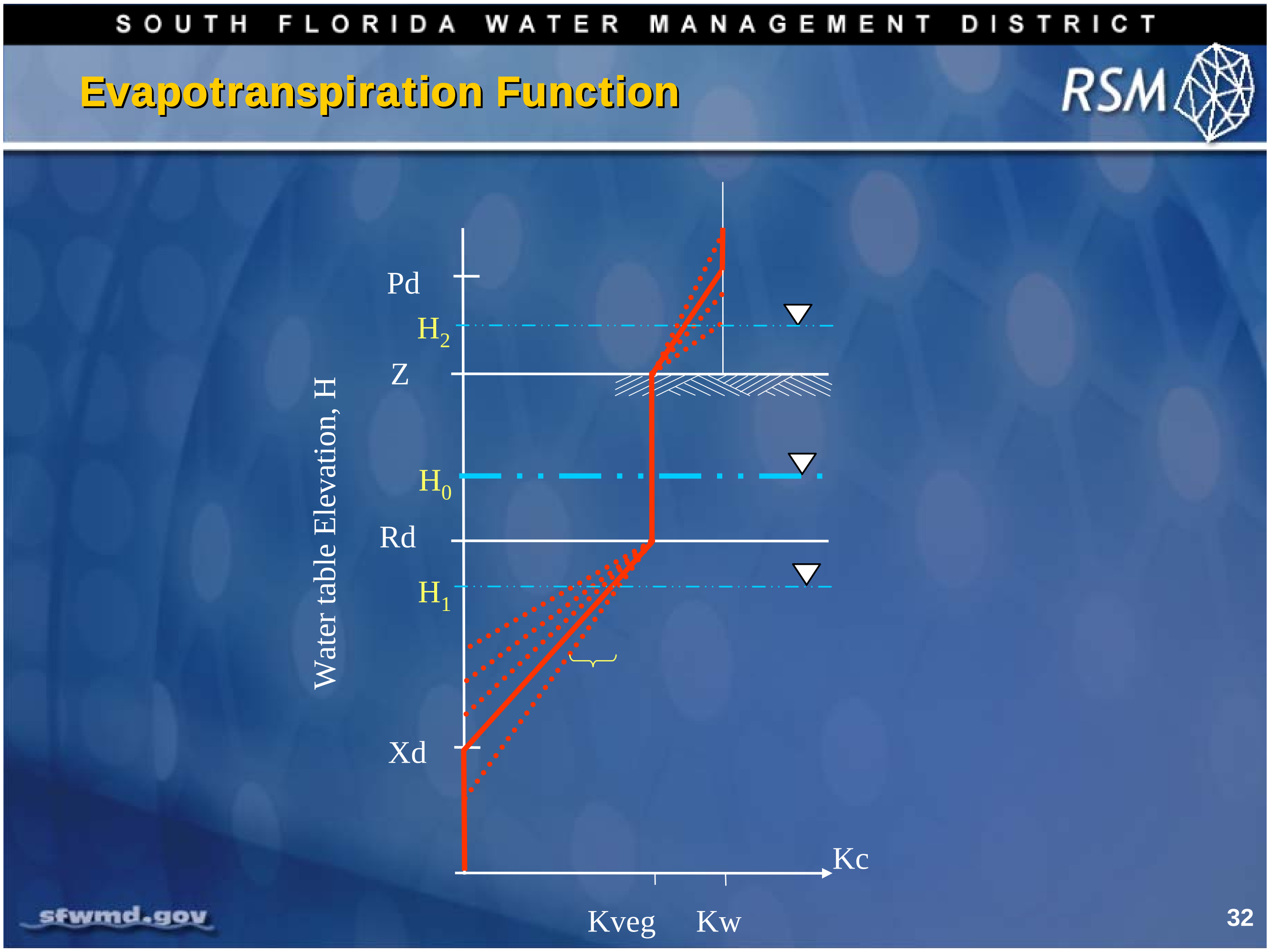
For ponded conditions, Kc is a function of head. For conditions where the water table is below the ground, Kc is a function of the available soil water.



For multilayer soils, the <layer5> HPM is used to model water movement and evapotranspiration. The different layers, 1 to 5, have different soil water storage capacities and different thicknesses.

Evapotranspiration from the <layer5> profile is determined by the water table depth, which determines the value of the cover vegetation reference-crop correction coefficient.

The control volume contains the water from the top of any ponded water, down to 3 meters below the extinction depth. This includes the saturated and unsaturated zone water.



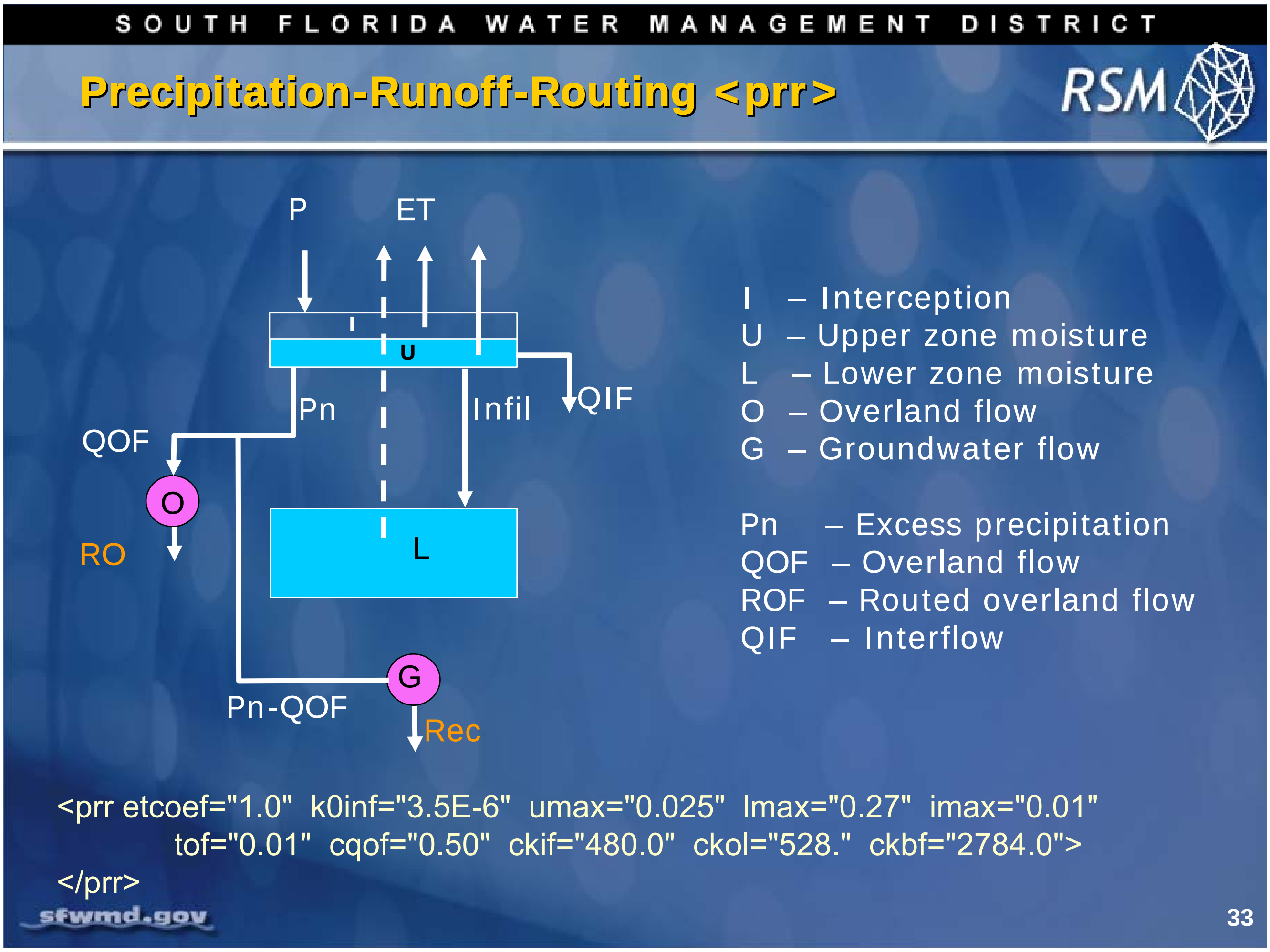
The Evapotranspiration (ET) function determines the value of the vegetation specific correction factor for the reference cover vegetation evapotranspiration (refET). The reference cover type, typically used in south Florida, is a healthy wetland with the water table near the ground surface.

The ponding depth and extinction depth are the principal calibration parameters.

The ponding depth adjusts for the presence of emergent macrophytes in wetlands and wetland forests that may increase the ET under ponded conditions or adjust for the limiting impact of ponding on upland vegetation.

The extinction depth includes the maximum depth of roots, spatial variability of the water table and impact of upflux from the water table.

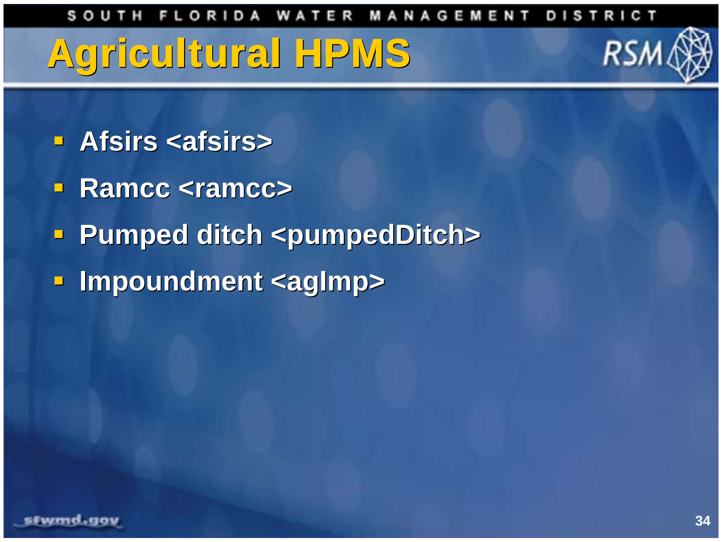
Setting Xd deep allows for a smooth decrease in the ET as the water table recedes. The actual value of Xd is often set to obtain the best decrease in ET as the water table recedes rather than a specific depth at which ET ceases since the water table rarely recedes that deep.



The Precipitation-Runoff-Routing <prr> HPM was adapted from the NAM process used by the Danish Hydraulic Institute in the MikeSHE model. This HPM is useful in upland sites where the soil water storage and routing are important. The <prr> HPM provides three different storage types:

- Interception
- Upper zone
- Lower zone

Linear reservoir routing is the method used to simulate the surface runoff, interflow and base flow components of a storm water hydrograph.

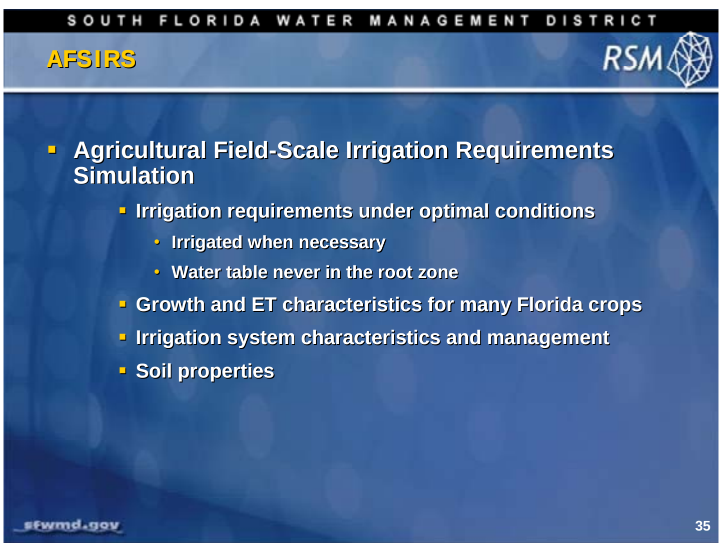


There are four agricultural HPMs. The <afsirs> HPM and the <ramcc> HPM simulate agricultural fields.

The <afsirs> HPM is based on the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS), a commonly used program for estimating irrigation requirements under optimal growing conditions.

The Regional Agricultural Module <ramcc> HPM is an improved version of <afsirs> that corrects for deficiencies in <afsirs> when it is used for continuous simulation in non-optimal conditions.

The Pumped Ditch <pumpedDitch> HPM and Impoundment <agImp> HPM simulate stormwater management systems.

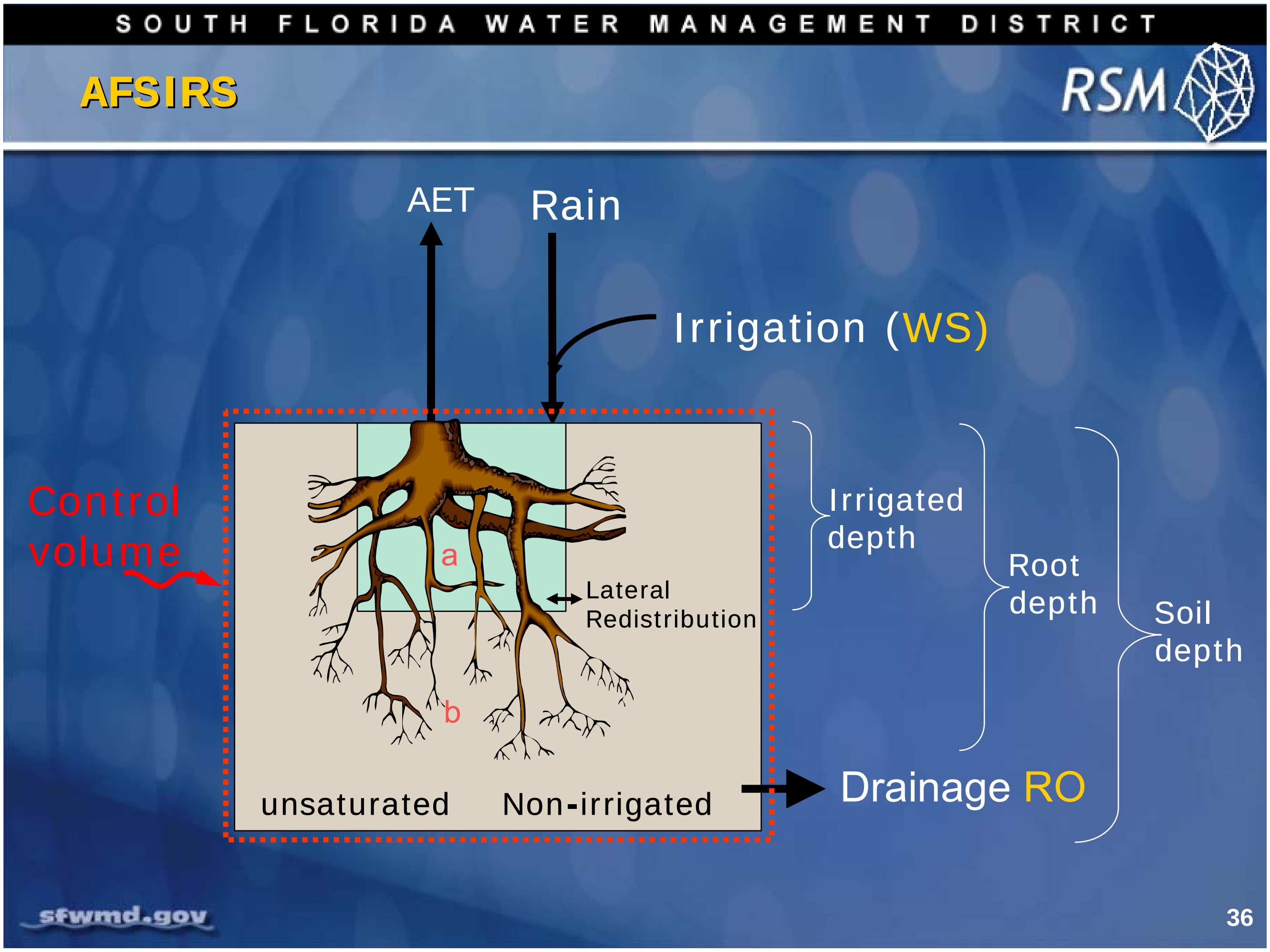


The Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) was developed by the University of Florida for use by water management districts to estimate irrigation requirements of crops.

The AFSIRS model accounts for different soil and crop types, irrigation systems and management practices in the simulation of crop irrigation requirements. The St. Johns River Water Management District and Southwest Florida Water Management District MD and SWFWMD use AFSIRS to regulate agricultural water use.

The AFSIRS model was coded in FORTRAN and is incorporated into the RSM with a C++ wrapper around the FORTRAN legacy code, so modelers can see the algorithms as implemented, as well as modifications made to the original code.

Although AFSIRS works well for crops under optimal conditions, which is appropriate for setting permit requirements, the model does not predict irrigation under realistic operating conditions of variable water availability, high water tables and less than optimal irrigation management.



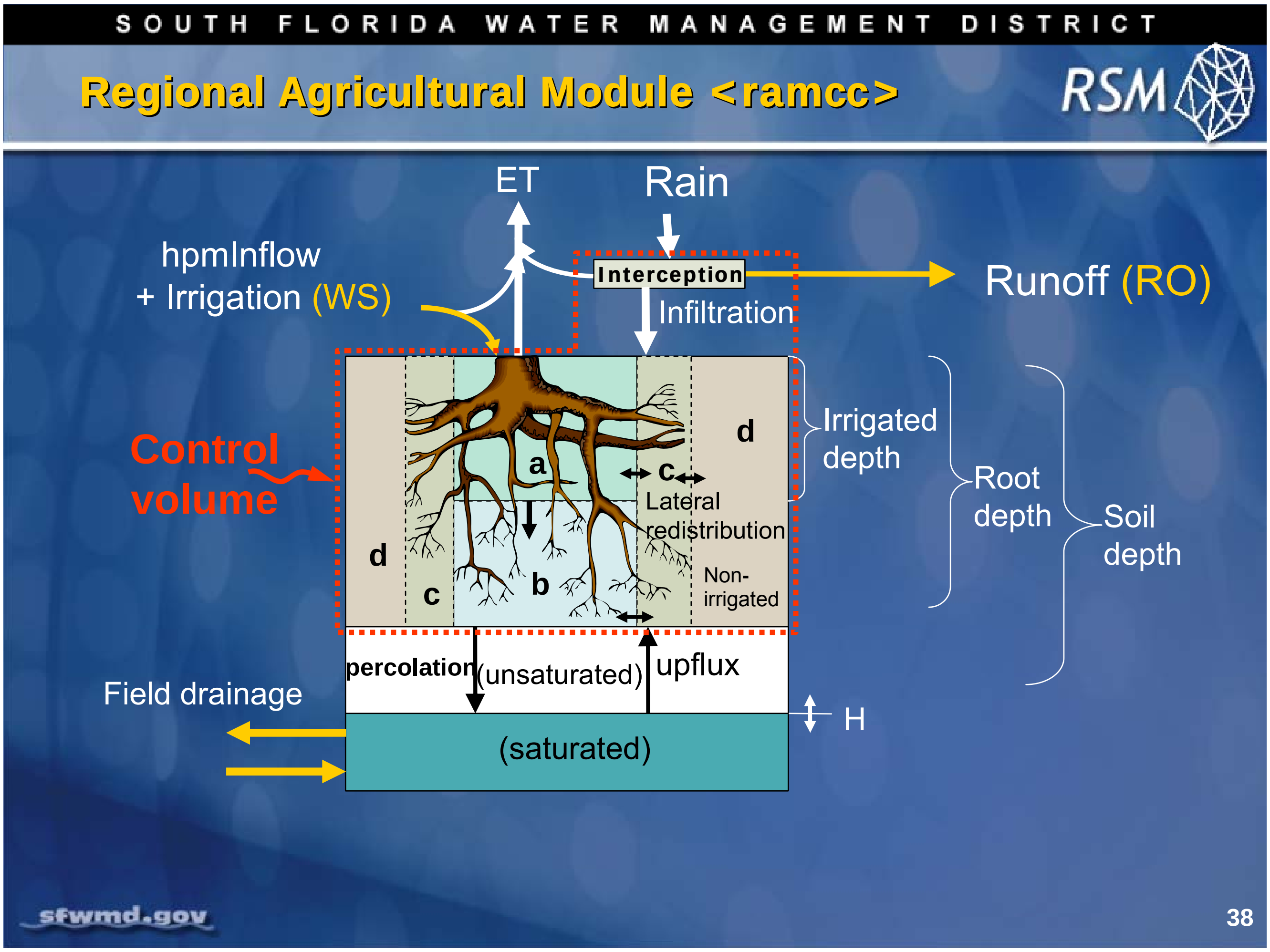
The AFSIRS model has a simple control volume. It includes an irrigated zone and a non-irrigated zone. The non-irrigated zone includes land area that is not irrigated and deep soil that does not receive irrigation. The user determines the extent of both volumes of soil.

The model processes an irrigation demand and a drainage term that lumps together runoff and seepage.

The input variables for AFSIRS are displayed in the slide above. These inputs include the crop characteristics, irrigation method, irrigation management and soils data.

NOTE:

Refer to Smajstrla (1990) in the training class folder for details on AFSIRS: $RSM/labs/lab11_hpm/Afsirs.pdf



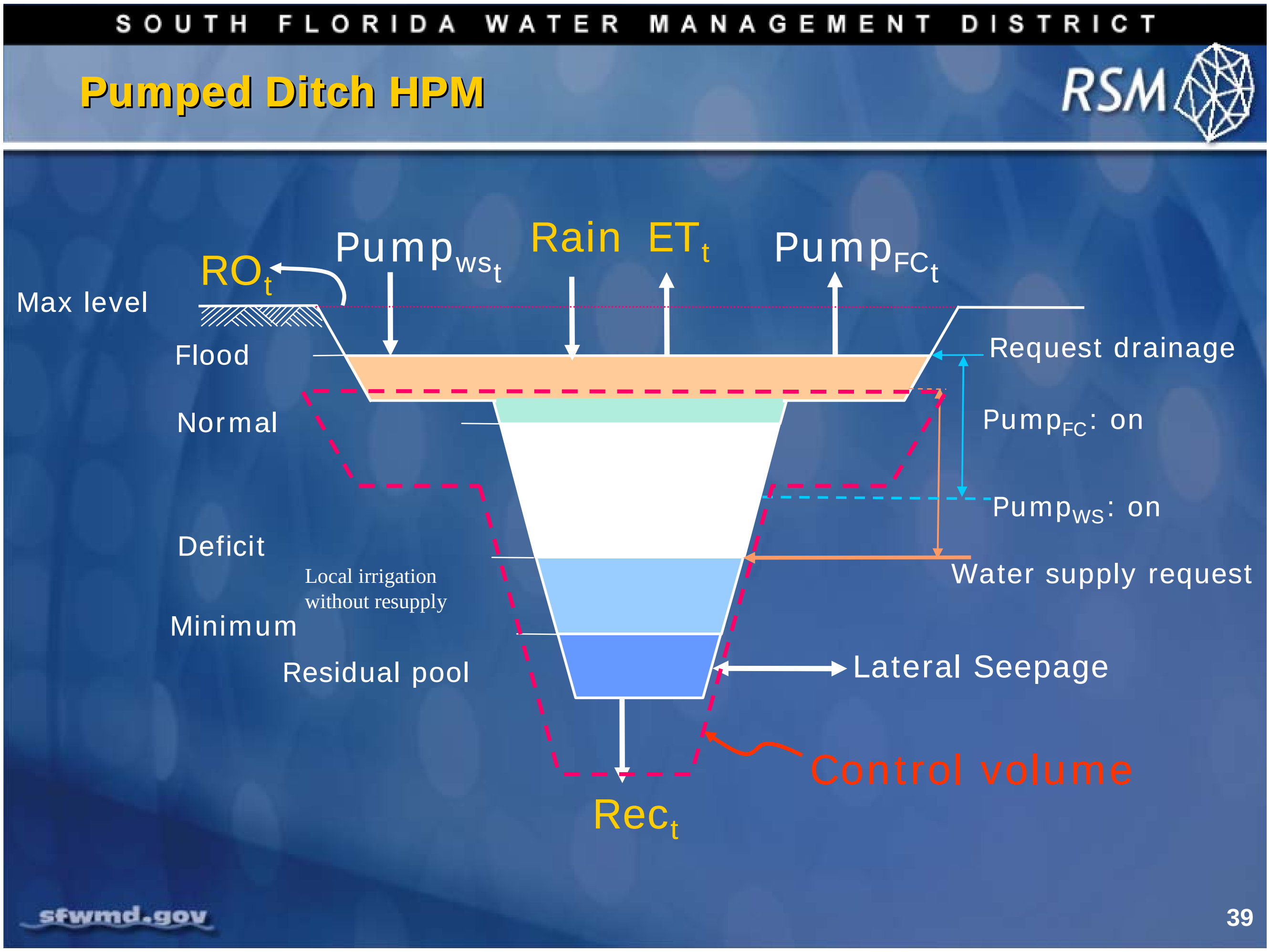
The Regional Agricultural Module <ramcc> HPM corrects several problems with <afsirs> while maintaining the same soil water mass balance approach.

The soil is divided into four components based on irrigation and root location. The rooted soil interacts with the groundwater via percolation, upflux, field drainage and subsurface irrigation. These last two processes are important for sites with perched water tables on impermeable layers.

The water table can move up into the root zone, decreasing the volume of aerated soil. Soil water is redistributed between the irrigated and non-irrigated soil, and there is better tracking of the water content of soil water outside the root zone.

The <ramcc> HPM includes rainfall interception.

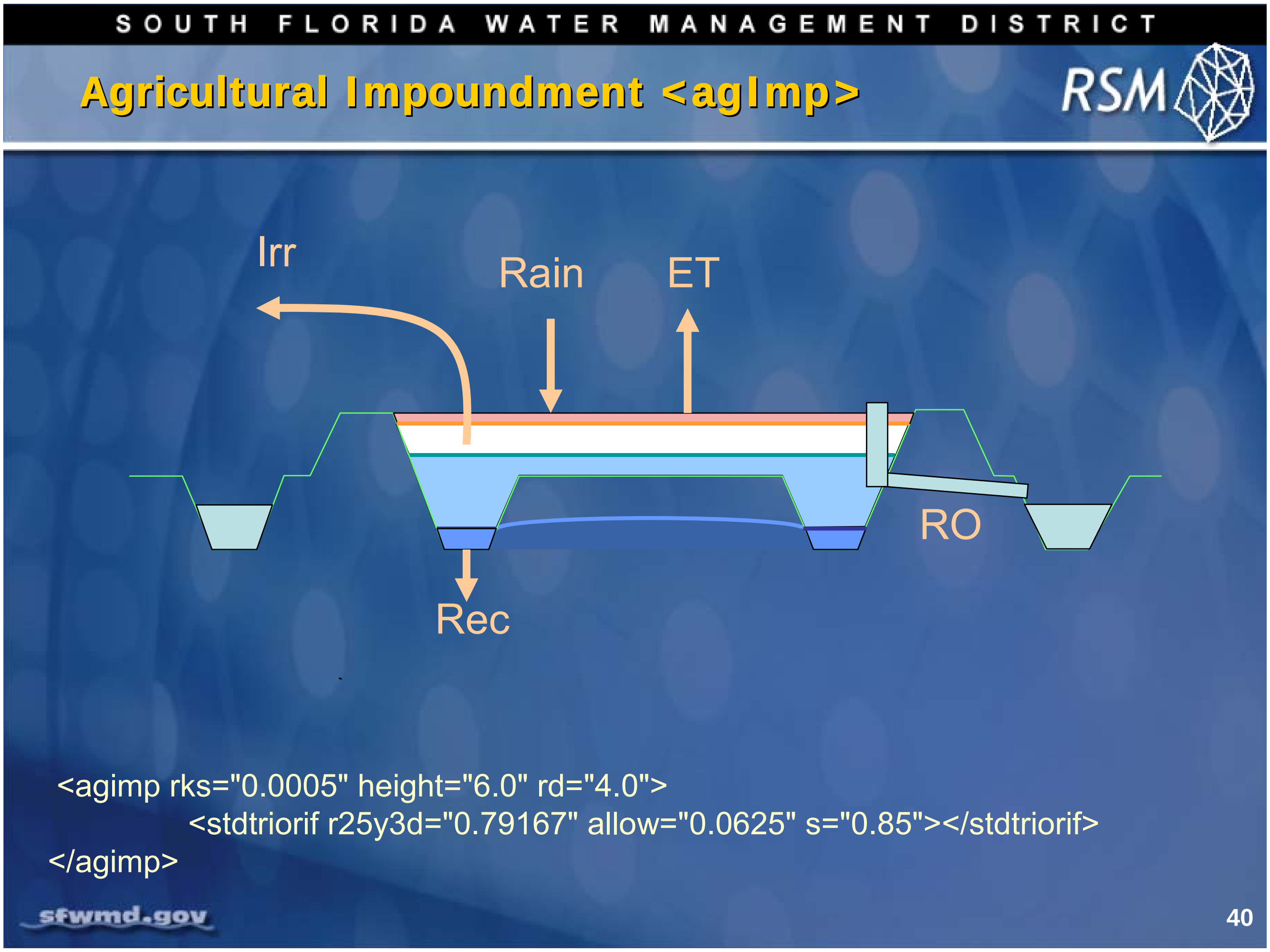
Ramcc was developed for RSM with a daily timestep; rain and irrigation are assumed to complete redistribution within a day.



The <pumpedDitch> represents a typical agricultural water management system in south Florida. The agricultural fields are surrounded by a perimeter levee with an internal borrow ditch that serves the purpose of storm water collection and interim storage. Irrigation water is obtained from the ditch and irrigation water is pumped into the ditch from a groundwater well or neighboring secondary canal.

The input parameters for the HPM describe the pumping behavior and seepage.

```
<pumpedditch rks="0.001" fcPump="25" wsPump="25" bottom="52.0" biDirSeep="0">
    <maxLevel     name="max Level">      <const value="63.0" /> </maxLevel>
    <fcPumpOn     name="fc pump ON">     <const value="62.0" /> </fcPumpOn>
    <fcPumpOff    name="fc pump OFF">    <const value="61.5" /> </fcPumpOff>
    <wsPumpOff    name="ws pump OFF">    <const value="58.5" /> </wsPumpOff>
    <wsPumpOn     name="ws pump ON">     <const value="58.0" /> </wsPumpOn>
    <minLevel     name="min Level">      <const value="56.0" /> </minLevel>
</pumpedditch>
```

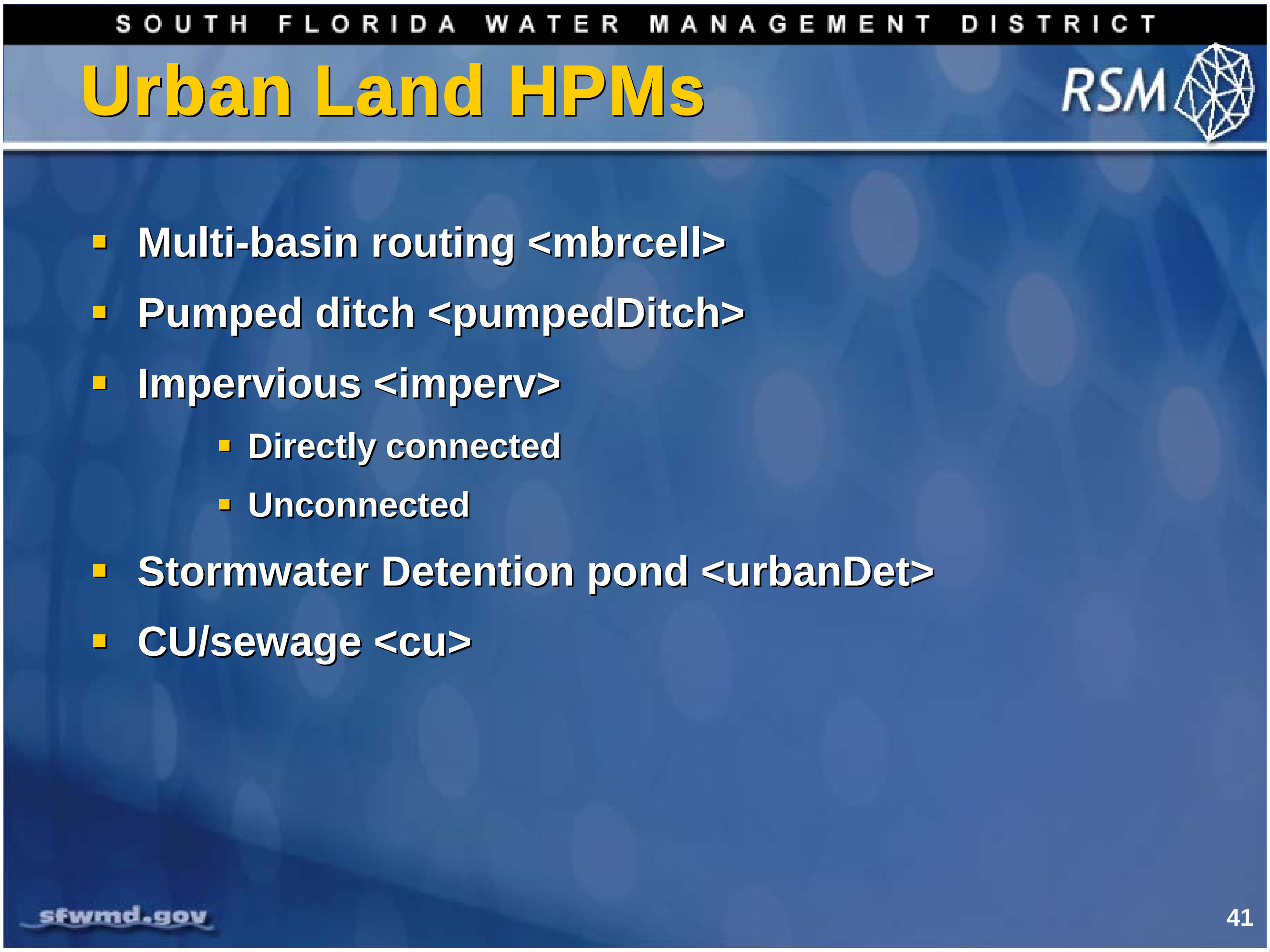


The Agricultural Impoundment <agImp> HPM is based on the South Florida Water Management District's rules for designing agricultural impoundments. It applies to agricultural permits issued after 1985, where agricultural developments are required, to restrict storm water runoff to be no greater than pre-development peak runoff.

Key attributes include the 25-year, 3-day rainfall depth, allowable discharge based on the capacity of the primary canals and the storage of the system, the height of the impoundment and the seepage rate.

The <agImp> HPM determines the size of the impoundment based on the area of the underlying cell necessary to detain storm water and creates an appropriate sized v-notch weir. The <agImp> HPM may be used as an irrigation source for other HPMs.

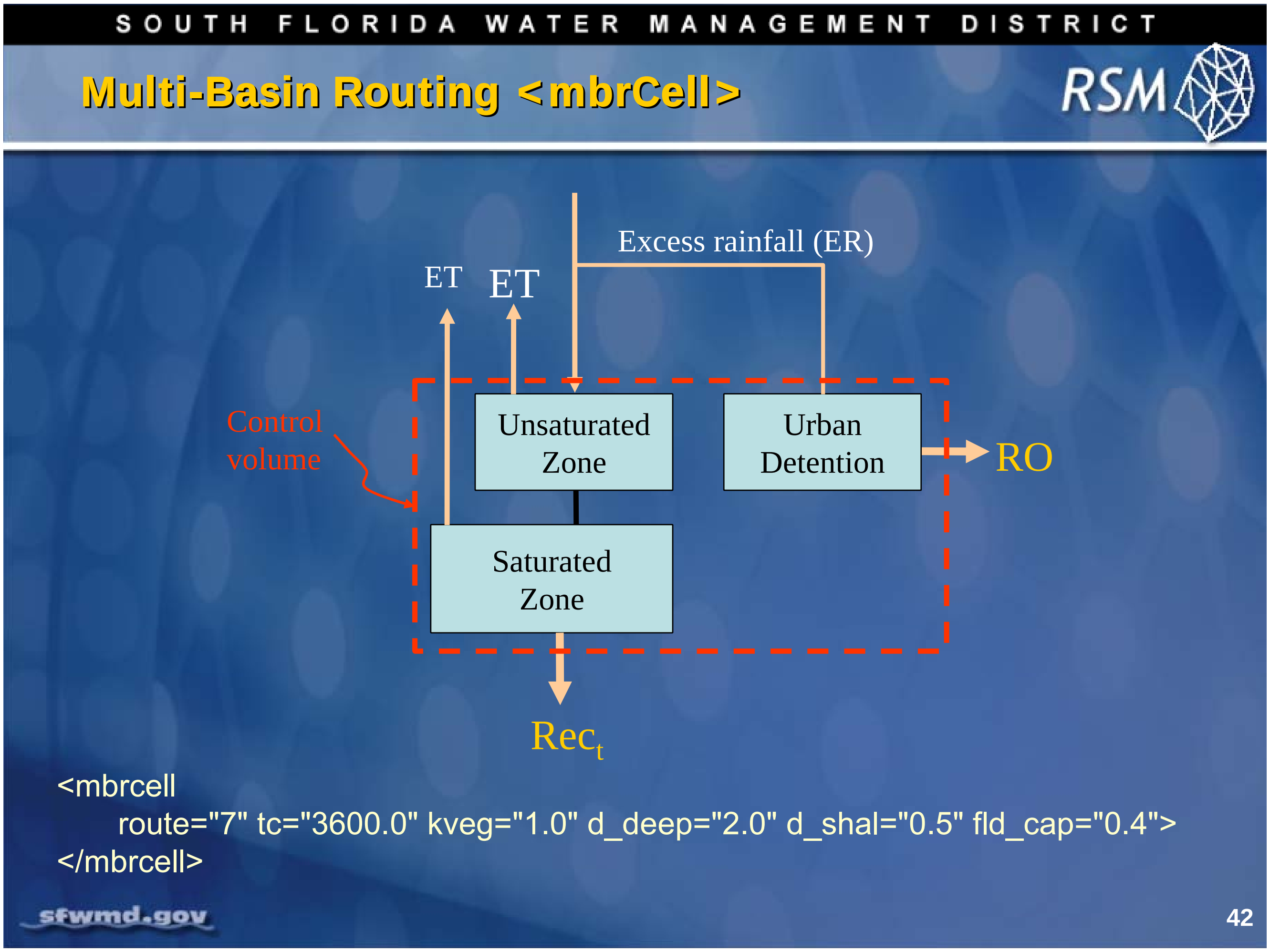
Agricultural impoundments are typically created aboveground for a water depth of no more than four feet. The embankments are created from borrow ditches located either inside or outside of the impoundment. During the dry season they will dry out with the exception of the internal borrow ditches.



There are several HPMs available for modeling urban land. Choice of an Urban Land HPM depends upon the objectives of the RSM application. Urban land is a mix of pervious and impervious land, with or without storm water retention/detention.

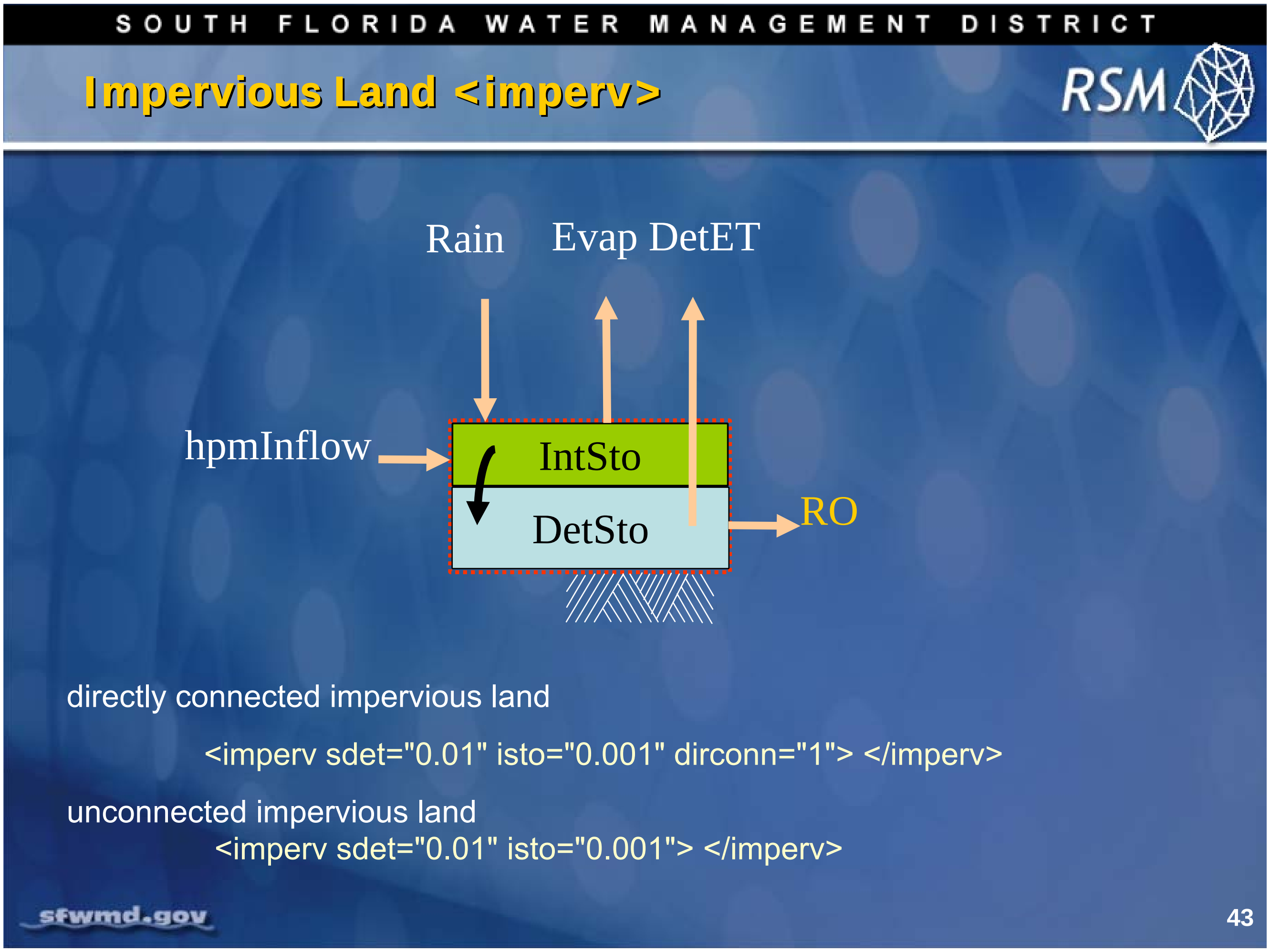
The <afsirs> HPM or <ramcc> HPM are used for pervious land; and, the <imperv> HPM is used for impervious land. Although the <layer1nsm> HPM has been used for impervious land, it lacks the appropriate runoff characteristics.

Where urban water supply issues are a concern, the Consumptive Use <cu> HPM can be implemented to track water use and provide the appropriate flows for gray-water reuse.



The <mbrcell> HPM is used to mimic a simple urban hydrology. It provides a simple module where detailed hydrology is not required.

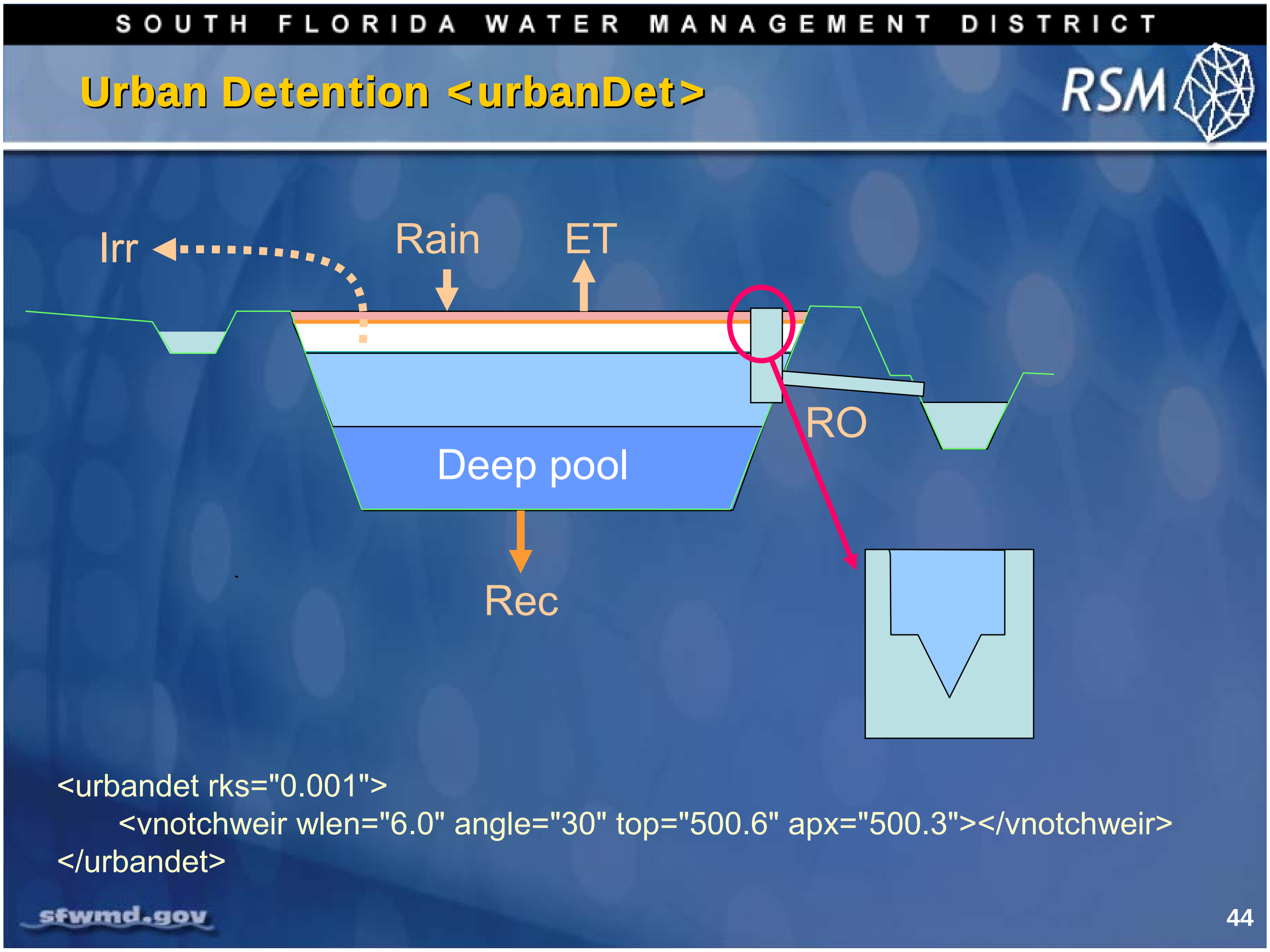
The <mbrcell> HPM is similar to some generic urban storm water models. The runoff is modeled using a curve number approach with linear reservoir routing. The degree of routing is determined by the Time of Concentration (tc) variable.



The Impervious Land <imperv> HPM is used to simulate directly-connected impervious land, such as roads and parking lots; and unconnected impervious land, such as roofs and sidewalks.

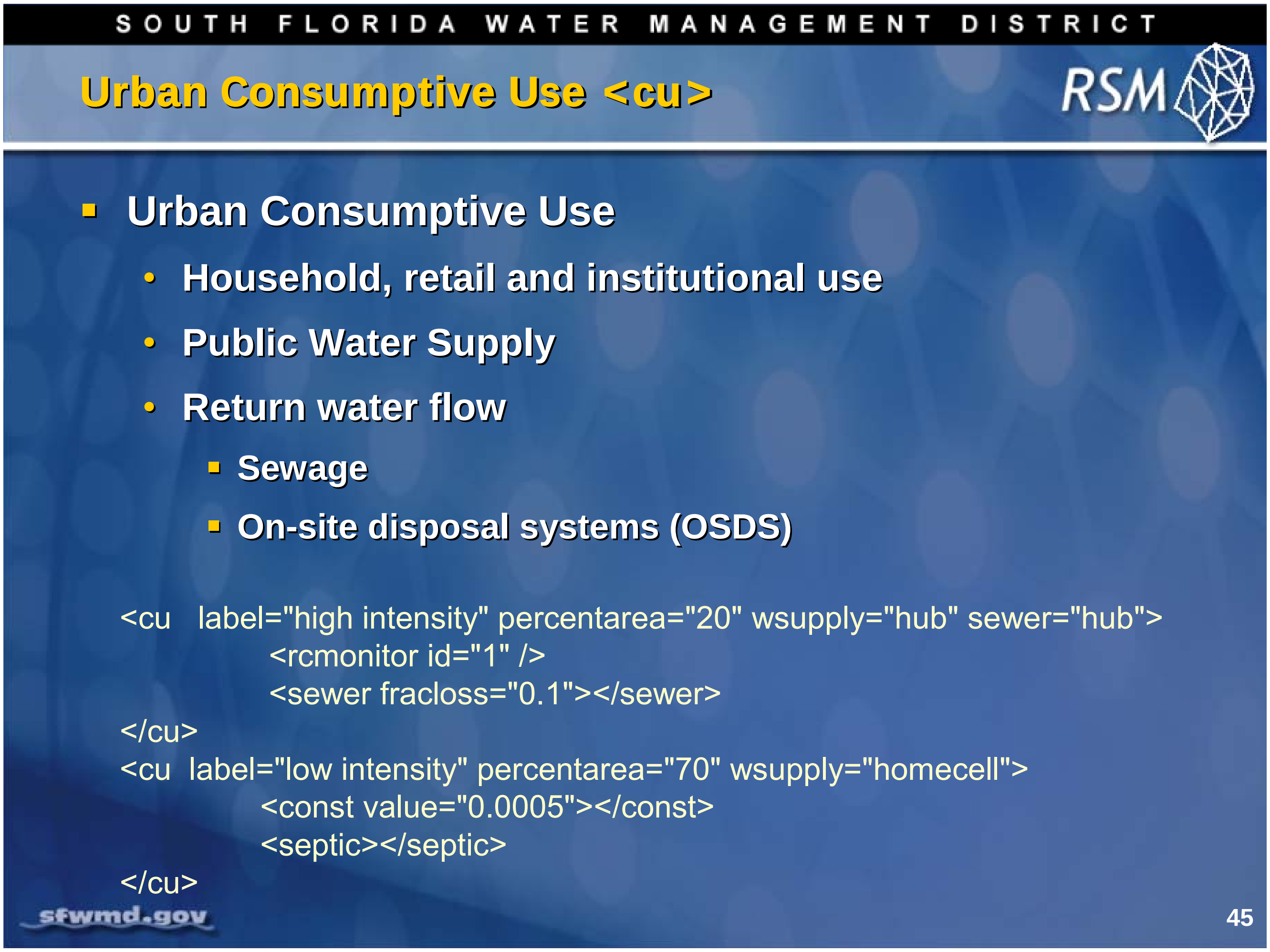
It contains an interception storage term, which is the small storage equivalent to dew or wetting of the surface from rainfall. This can be important in estimating ET where there is a large amount of dew formation.

It also contains a detention storage term, which represents storage in potholes. This can be a significant source of storm water storage on older surfaces.



The Urban Detention <urbanDet> pond HPM models storm water detention and discharge. The pond is sized and the weir dimensions are determined during GIS pre-processing of the landuse information for the cell. Pre-processing applies the SFWMD surface water management rules as part of the Environmental Resource Permit to create a "standard" detention pond. The criteria are applied during pre-processing to allow for adjustment of the detention area size and depth when additional drainage criteria are adapted for different basins in south Florida. The pre-processing software creates the XML input with the appropriate parameter values.

The <urbanDet> HPM routes the discharge through the weir using a 30-minute timestep. This HPM also allows for the use of the water for irrigation. The <urbanDet> HPM differs from the agricultural impoundment in that it has a deep pool that does not dry out.

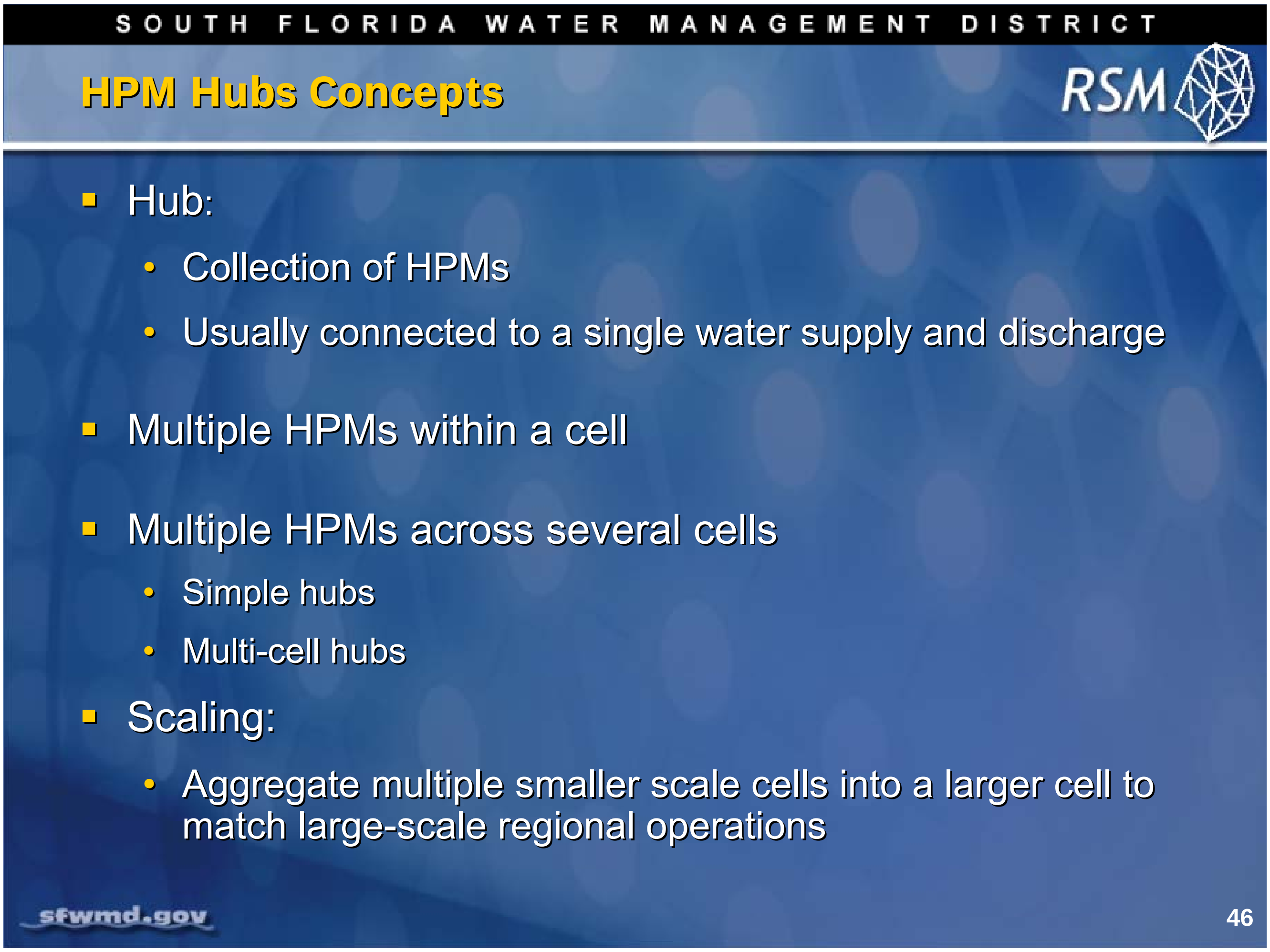


Consumptive use is an important component of the urban water budget. Water is distributed to households, institutions, retail and industrial sites. The water may be used for landscape and lawns.

Source water may be the homecell, local wells or central wells.

Return water may be discharged through wastewater treatment plants to canals, wetlands or gray-water reuse. Additionally, return water may be discharged to on-site disposal systems (septic tanks). This significant volume of water should be tracked.

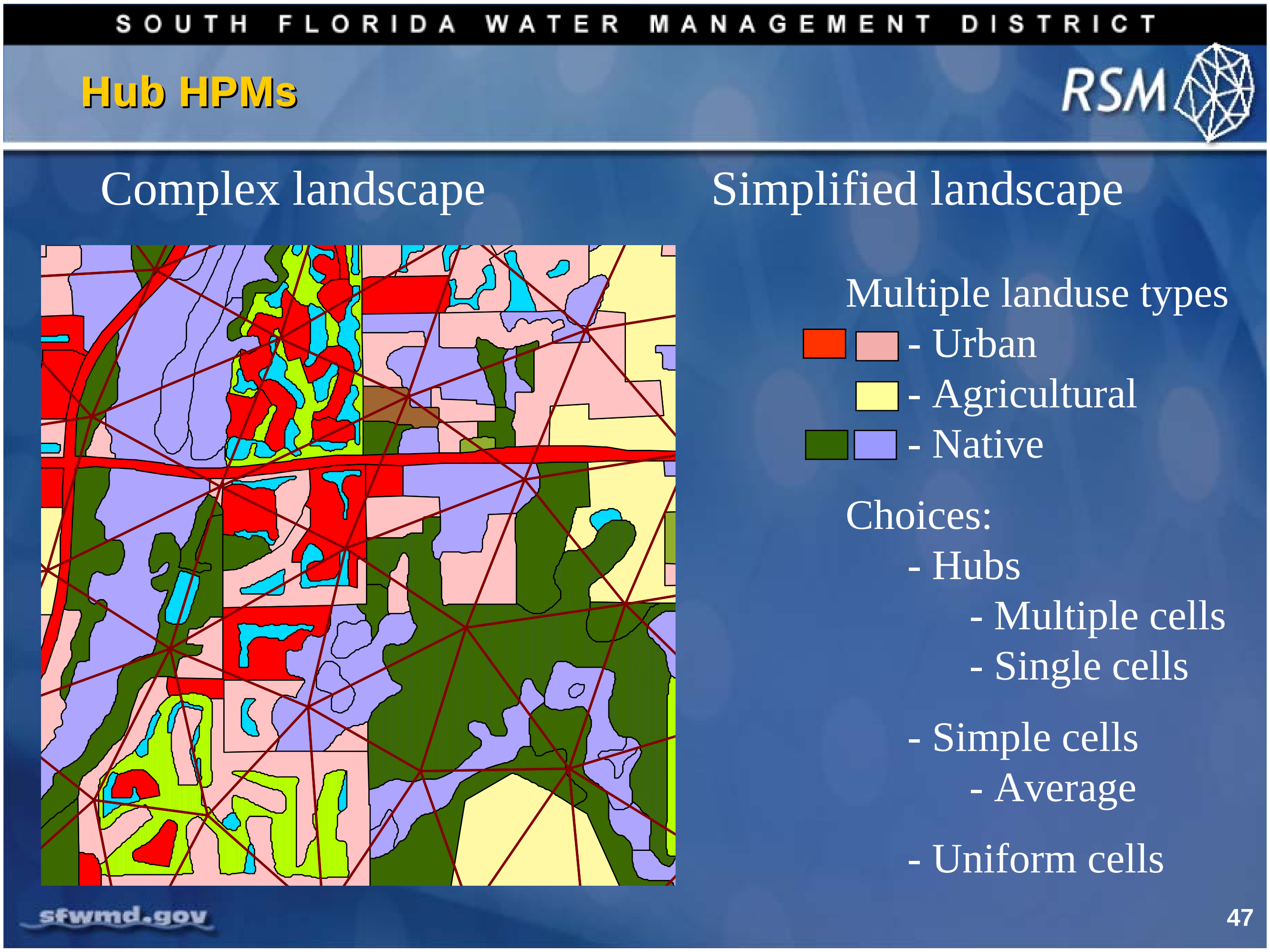
Furthermore, return water can be discharged to a waterbody from which irrigation water is withdrawn for gray water reuse.



The Hub concept provides the capability to develop local hydrology in a diverse landscape. Hubs are a collection of HPMs that represent different landuse types that are typically connected to a single water supply or discharge point. They can be applied across several cells similar to a water control district (WCD), or to a single cell where the landscape is very diverse and the cells are large.

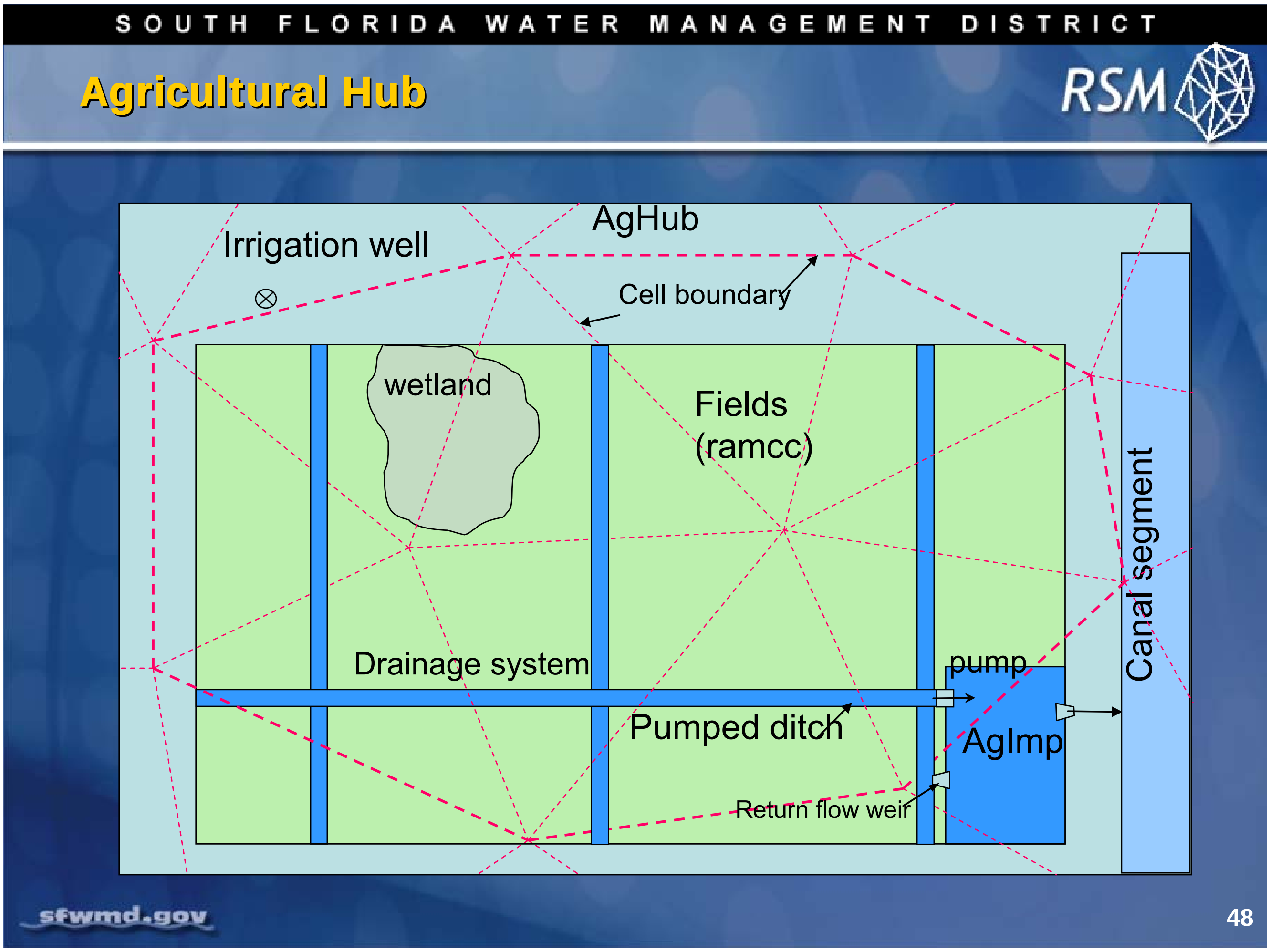
The most common approach is to create a Hub for each cell that contains several different HPMs to model urban or agricultural developments. Where the urban or agricultural developments are large, the Hub may be applied to multiple cells. These multicell Hubs may interact with the unique water table in each cell or average the water table characteristics under the entire Hub.

The <Hub> HPM also provides the opportunity to implement local hydrology at a different scale from the regional hydrology by creating Hubs with more detailed landscapes or more lumped landscapes than the mesh discretization allows.



This slide illustrates a typical simplification of the landscape near Fort Myers, Florida. There is a mix of urban, agricultural, native uplands and wetlands in close proximity. This landscape can be modeled using simple HPMs representing the majority of the land in each cell, individual Hubs for each cell, or Hubs that cover several cells.

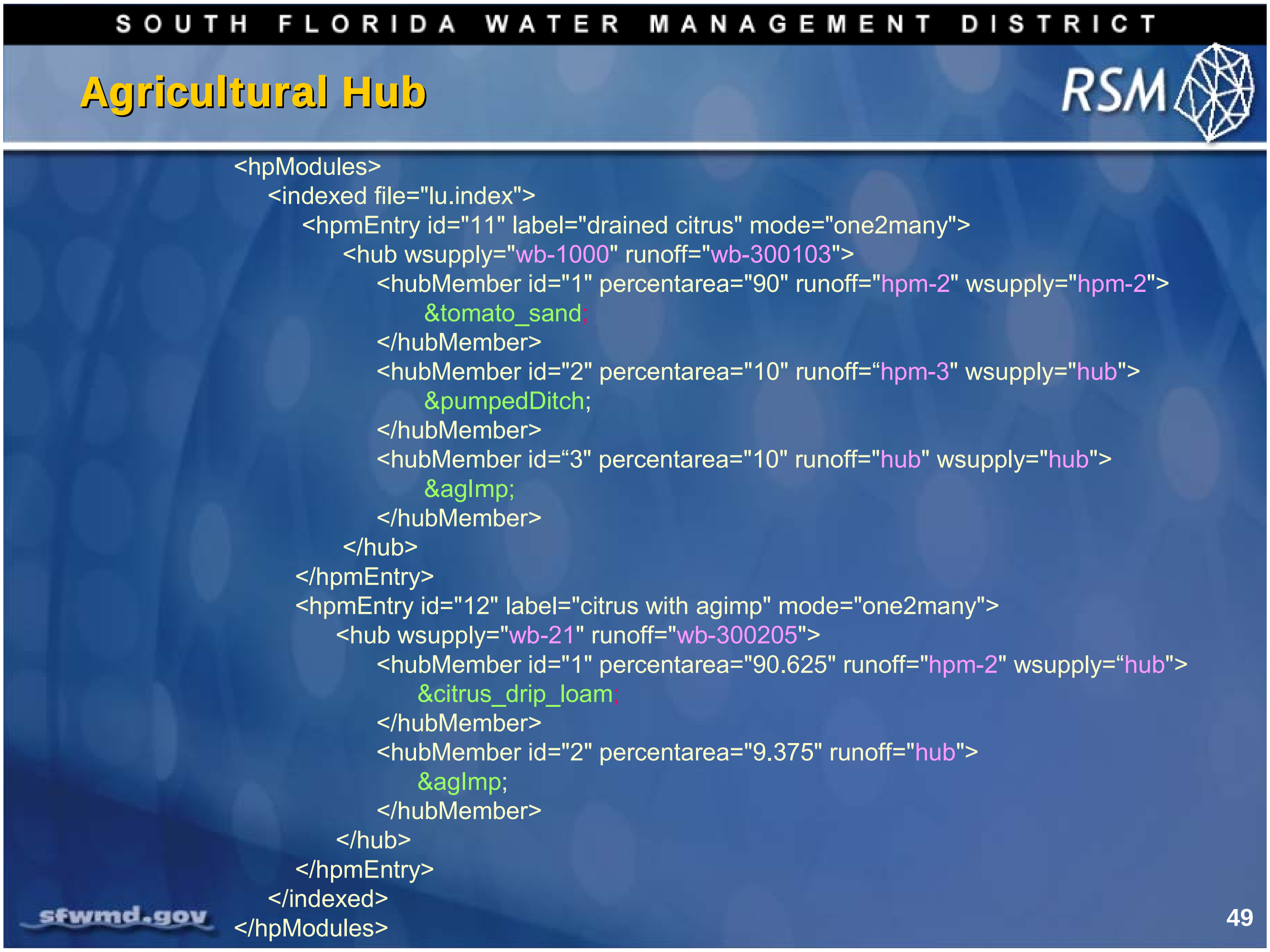
In this example there are opportunities for each of these alternative HPM implementations for the golf courses and agricultural land.



The Agricultural Hub <agHub> HPM is used when there is an agricultural operation such as a citrus grove or vegetable farm that covers several cells and is irrigated through a central irrigation system, and there is a central discharge point for drainage water.

With a central irrigation system, there is typically a single well, group of wells or a surface water supply source at a river or canal. These source waterbodies may not be within the farm or the mesh cells that cover the farm. Similarly, the agricultural operation is likely to have a single discharge point where drainage water drains off-site into a canal. If the farm or grove was developed after 1985, there probably is an agricultural impoundment that is required to reduce the peak runoff volume to downstream landowners.

For these operations, the Agricultural Hub can be used to describe the surface hydrology. The farm can be described by a combination of agricultural land modeled using <afsirs> or <ramcc>, a <pumpedDitch> that captures the runoff and an <agImp> that captures the runoff.



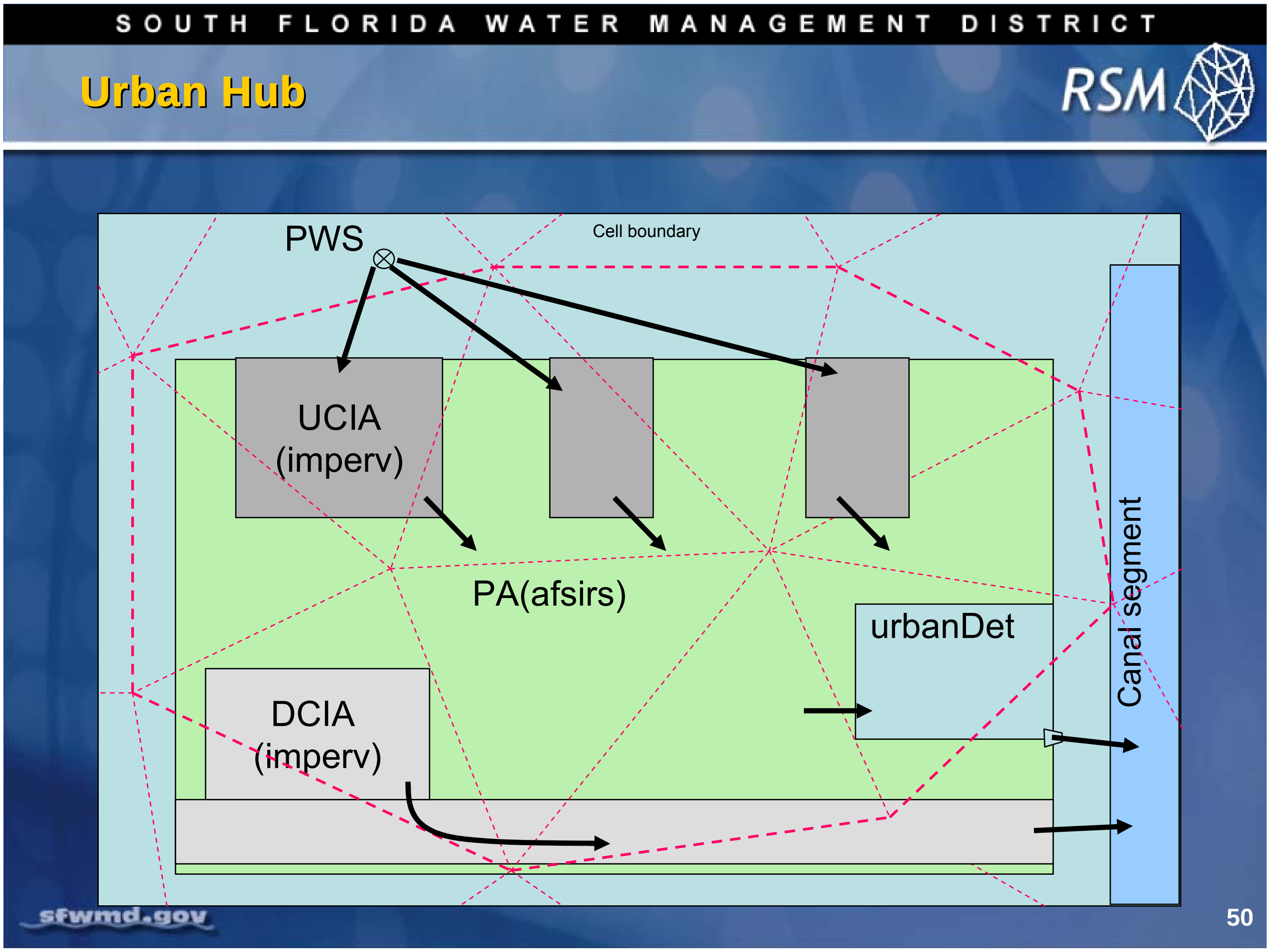
The Agricultural Hub <agHub> includes two or more HPMs each of which is described under the <hub> element that has assigned a waterbody ID to the water supply source and the runoff destination.

Waterbodies can be any waterbody in the model or the homecell. The hpmEntry's "id" cross-references with the "lu" value used in the <lu.index> file to assign one HPM to each cell in the mesh.

The Hub generally has two or more <hubmember> elements that contain, or reference, the XML for the HPM, as well as the area percentage and the waterbody designations for runoff and water supply.

The runoff and wsupply can be directed to the <hub>, and thus directed to the waterbody designated by the Hub (wb-1000), to a specific waterbody or to an HPM <hubmember> as identified by the <hubmember> "ID" (hpm-1) within the same <hub>.

The <hubmember> IDs are unique within the Hub but not unique between the Hubs. The waterbodies identified in runoff and wsupply may be any waterbody in the model. Typically these are adjacent cells, segments and impoundments, but they may be distant canals or lakes representing the final destination of runoff or source of irrigation water. Notice that the XML inputs for the HPMs are included here by reference from a standard library. The <hpModules> block can contain both Hubs and simple HPMs.



There are two typical Hub types in south Florida.

Urban Development

An urban neighborhood defined by a single drainage system. The HPM types include <imperv>, <ramcc> and <urbanDet>. A <pumpedDitch> instead of the <urbanDet>, if the detention pond is drained using a pump rather than a weir, may also be included. Water for consumptive use will probably come from a distant public water supply (PWS) or a local well.

Golf Courses

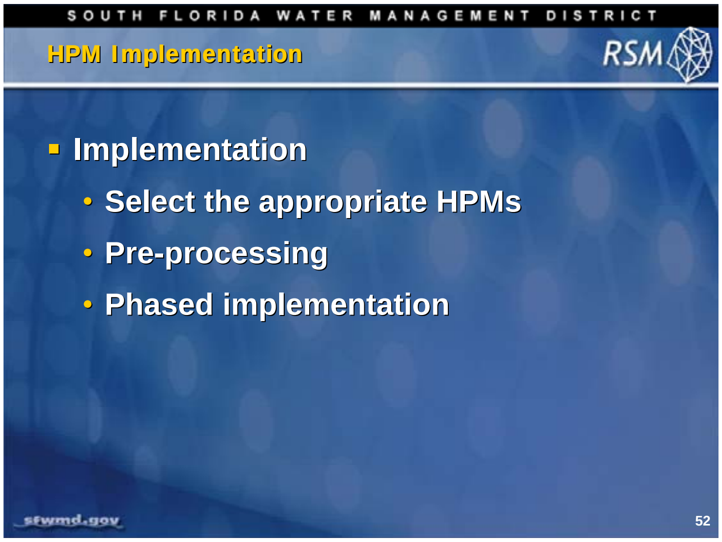
A golf course development typically consists of a golf course with associated high density residential (condos), low density residential landuse (single family homes), native area and a large detention pond (extensive water hazards). The golf course will have its own surface water management system that drains to a primary canal. Irrigation for the golf course comes from local groundwater and the surface water management system. Typically, primary canals are the source of golf course irrigation water. A separate water supply system for both the golf course and the residential areas may exist.

The Urban Hub presented in this slide consists of 70 percent impervious land, 20 percent lawns and landscaping, and 10 percent storm water detention pond.

The runoff routing for the Hub provides considerable flexibility in defining the surface hydrology.

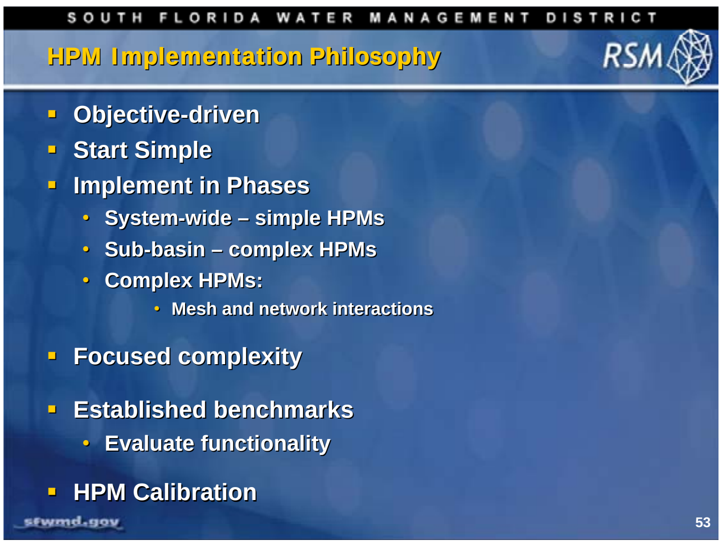
On the first line, the waterbodies are defined for the runoff destination (typically a segment), water supply source (either the cell where the large irrigation well is located or the canal segment, in the case of farm irrigation), and the destination of the return water flow for the sewage. The sewage return flow also has a seepage loss component. This is important when using an Urban Hub to model consumptive use.

Nested HPMs: <urbanDet> and landscape are examples of nested XMLs. If it were efficient, <imperv> could be converted to a nested XML.



The previous section discussed the available HPMs and the details of the local hydrology. In the next section, the implementation of the HPMs is presented.

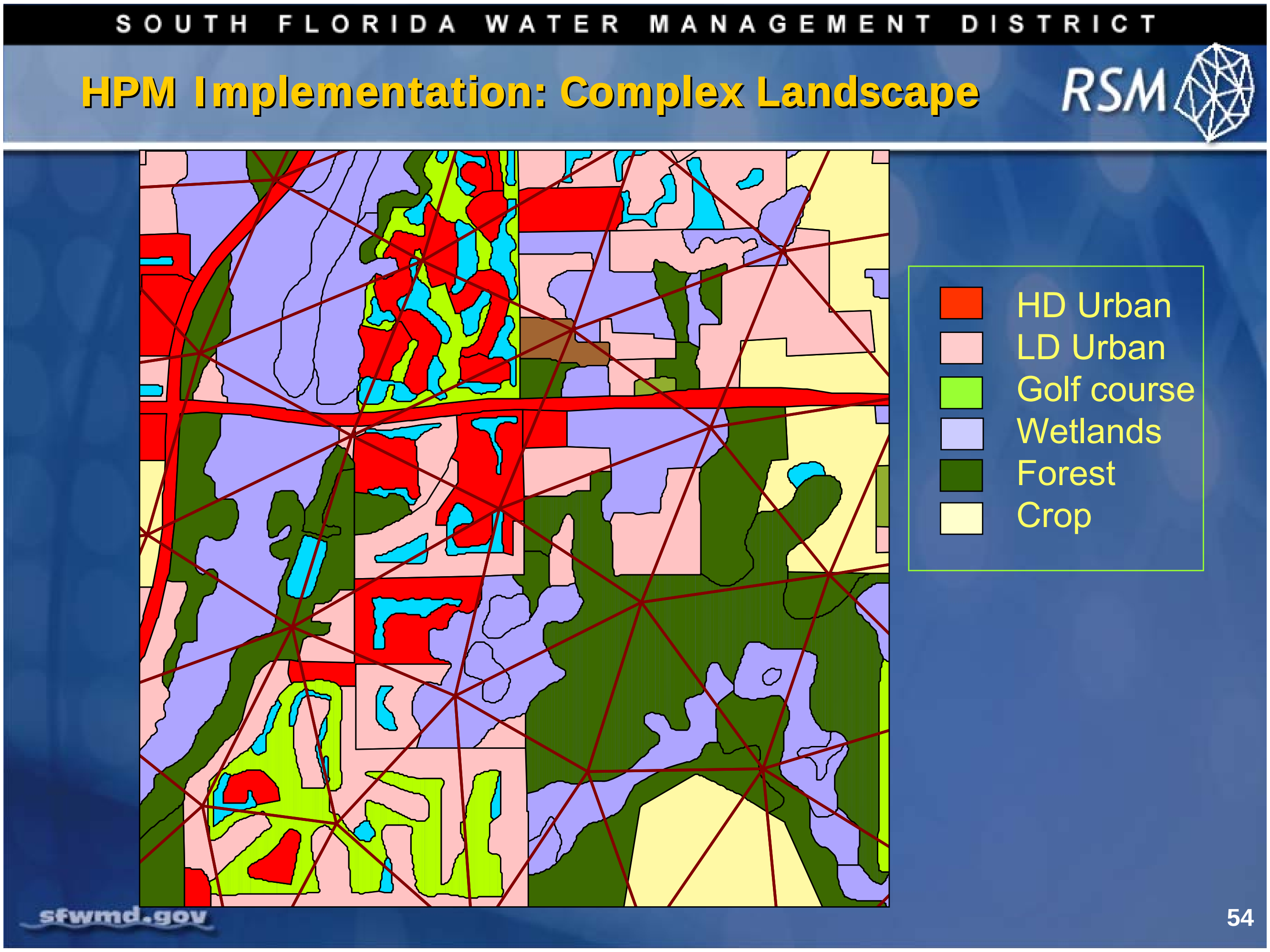
There is considerable flexibility available for the implementation of the HPMs, which enables implementation of more complexity than may be necessary and high model execution times. Insufficient complexity and miscalibration of the model due to the lack of important functionality may also occur.



Implementation of HPMs is based on focused complexity. With the high degree of flexibility to select among different ways to represent local hydrology, the user is advised to start simply, adding complexity only as warranted.

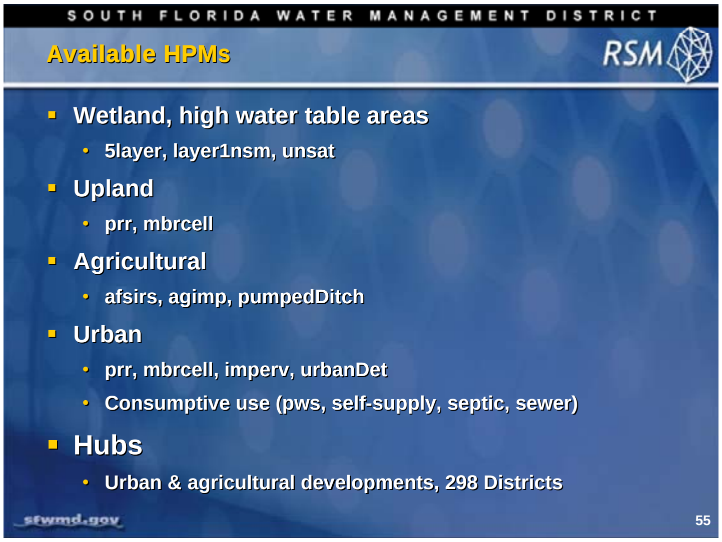
However, it is possible to overlook necessary complexity when working with a complex regional model. Proper selection of HPMs requires careful calibration of the HPMs based on water budgets.

The selection of the HPMs is dependent on the objectives of the simulations and evaluation of alternative water resource management formulations under consideration.

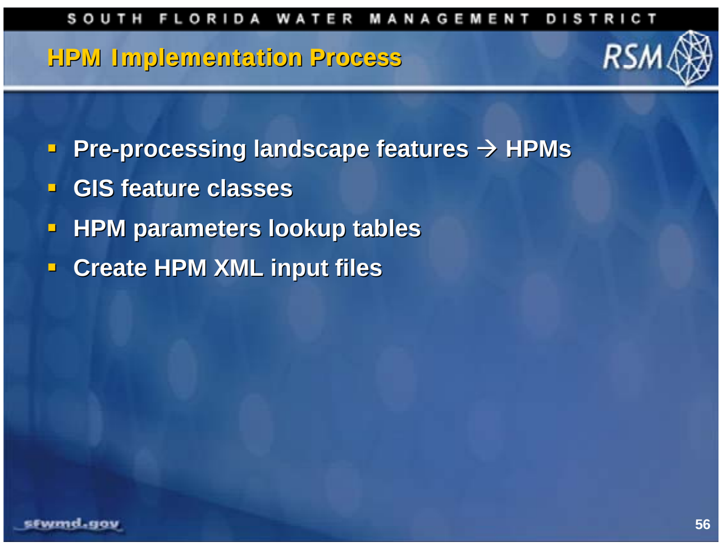


When studying a complex landscape, it is important to have a good understanding of the expected hydrologic response of the watershed. The concern is how to use HPMs to simulate the complex landscape.

It is possible to use single HPMs or complex HPMs to model this landscape. And, it is necessary to know whether the client needs to simulate irrigation requirements for different landuse types using different sources of water for irrigation. The objectives for the model will affect the selection of HPMs.

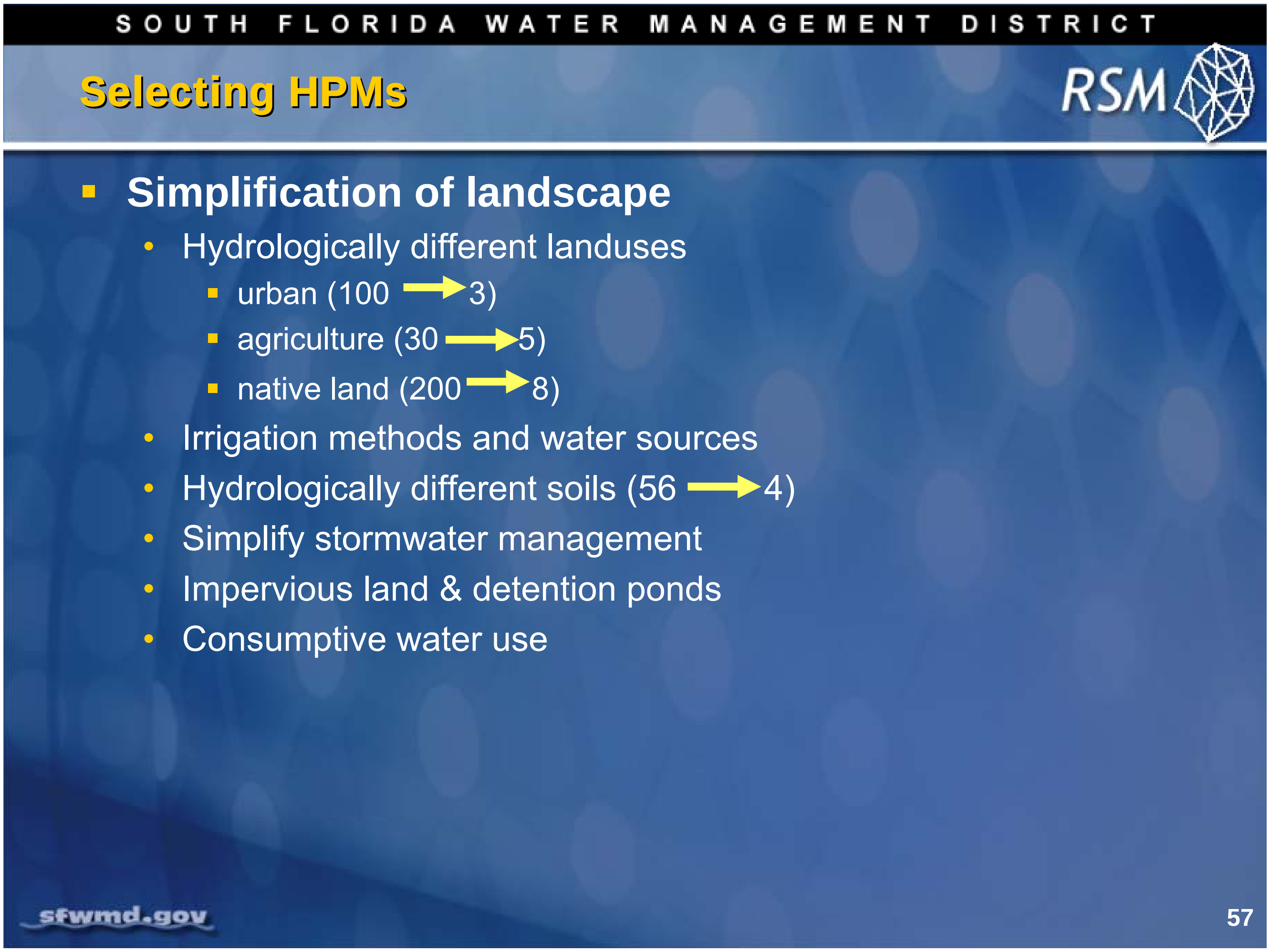


There are a variety of HPMs that can be used to simulate the local hydrology depending on the detail of the local hydrology that is required.



Implementation of HPMs is a four-step process.

1. A set of HPMs is selected based on the objectives of the model. The selection is typically based on landuse/land cover types. A table is created mapping the possible landuse types (there are more than 250 types) to the selected HPM instance.
2. Obtain the parameter values from the various feature classes in the geodatabase, such as:
   - Drainage
   - Soils
   - Depth to seasonal water table
   - WCD boundaries
3. Obtain the HPM parameter values from look-up tables for each HPM.
4. Create the HPM XML input files. We have a semi-automated approach for doing this that has not been implemented in the RSM Graphical User Interface (RSM GUI).

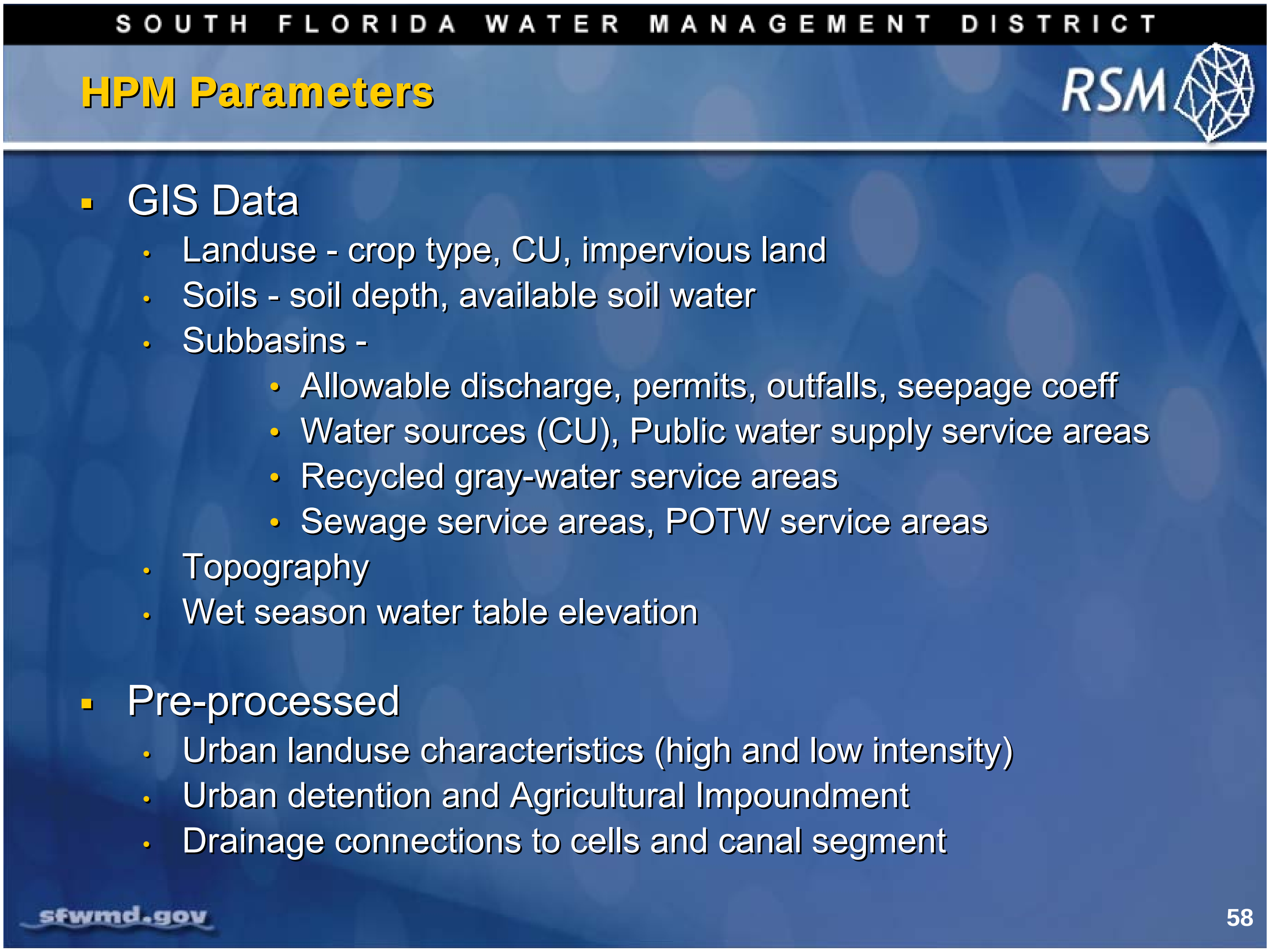


Implementing HPMs requires simplifying the representation of the landscape into a reasonable number of unique HPMs.

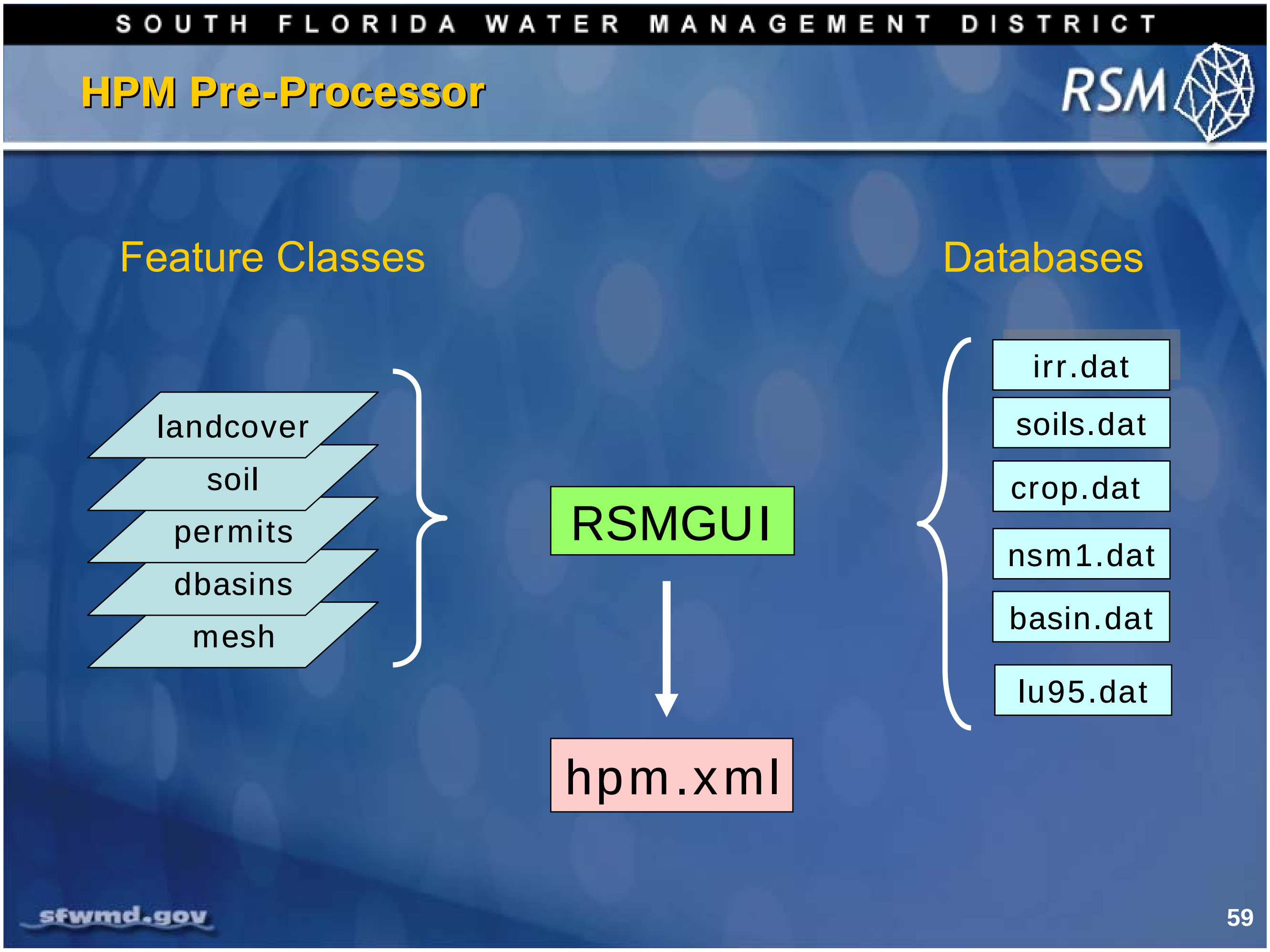
The hydrologically relevant landuse types can be reduced, from the hundreds of unique land cover classes found in our landuse/land cover feature class, to a small number of hydrologically meaningful types.

Similarly, the relevant soils have been reduced from 56 types to 4 types.

Because the storm water systems are built to meet the same permit requirements, the parameter values for runoff characteristics can be tabulated for these facilities.



The information required to characterize the HPMs can be obtained from a small number of available Geographic Information System (GIS) feature classes. These can be preprocessed to provide the XML for each parcel.



The HPM Pre-Processor will obtain the necessary attributes from selected feature classes and the associated HPM parameters from databases or data tables and generate the hpm.xml file.

The feature classes provide the boundaries for assigning specific attributes to each HPM.

If there are unique Hubs for each cell, the hpm.xml file can be more than 10,000 lines. It is accessed once at run time.

The details of the pre-processor are provided in the *RSM GUI User Guide*.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Standard <hpmEntry> Elements

RSM

HPM	SFWMM	Landuse	HPM	SFWMM	Landuse
1	CAT	Cattails	14	MLP	Open Land
2	CIT	Citrus	15	ROW	Row crops
3	FUP	Forested Upland	16	RS1	Ridge & Slough 1
4	FWT	Freshwater wetlands	17	RS2	Ridge & Slough 2
5	GLF	Golf courses	18	RS3	Ridge & Slough 3
6	HDU	High Density Urban	19	RS4	Ridge & Slough 4
7	IRR	Irrigated Pasture	20	RS5	Ridge & Slough 5
8	LDU	Low Density Urban	21	SAW	Sawgrass
9	MAN	Mangrove	22	SHR	Shrubland
10	MAR	Marsh	23	SUG	Sugar cane
11	MDU	Medium Density Urban	24	WAT	Open Water
12	MEL	Melaleuca	25	WET	Wet Prairie
13	MIX	Mixed cattail/sawgrass			

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There is a standard group of HPMs based on the landuse types that are simulated in the South Florida Water Management Model (SFWMM). The HPM value is the <hpmEntry> ID value found in the standard `evap_prop.xml` file. For any subregional model, a subset of these HPMs will be implemented.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Standard HPMs Simulated in the RSM

RSM

HPM	SFWMM	Land use	HPM	SFWMM	Land use
1	CAT	layer1nsm	14	MLP	Open Land
2	CIT	afsirs	15	ROW	afsirs
3	FUP	layer1nsm	16	RS1	layer1nsm
4	FWT	layer1nsm	17	RS2	layer1nsm
5	GLF	afsirs	18	RS3	layer1nsm
6	HDU	Urban hub	19	RS4	layer1nsm
7	IRR	afsirs	20	RS5	layer1nsm
8	LDU	Urban hub	21	SAW	layer1nsm
9	MAN	layer1nsm	22	SHR	layer1nsm
10	MAR	layer1nsm	23	SUG	afsirs
11	MDU	Urban hub	24	WAT	layer1nsm
12	MEL	layer1nsm	25	WET	layer1nsm
13	MIX	layer1nsm			

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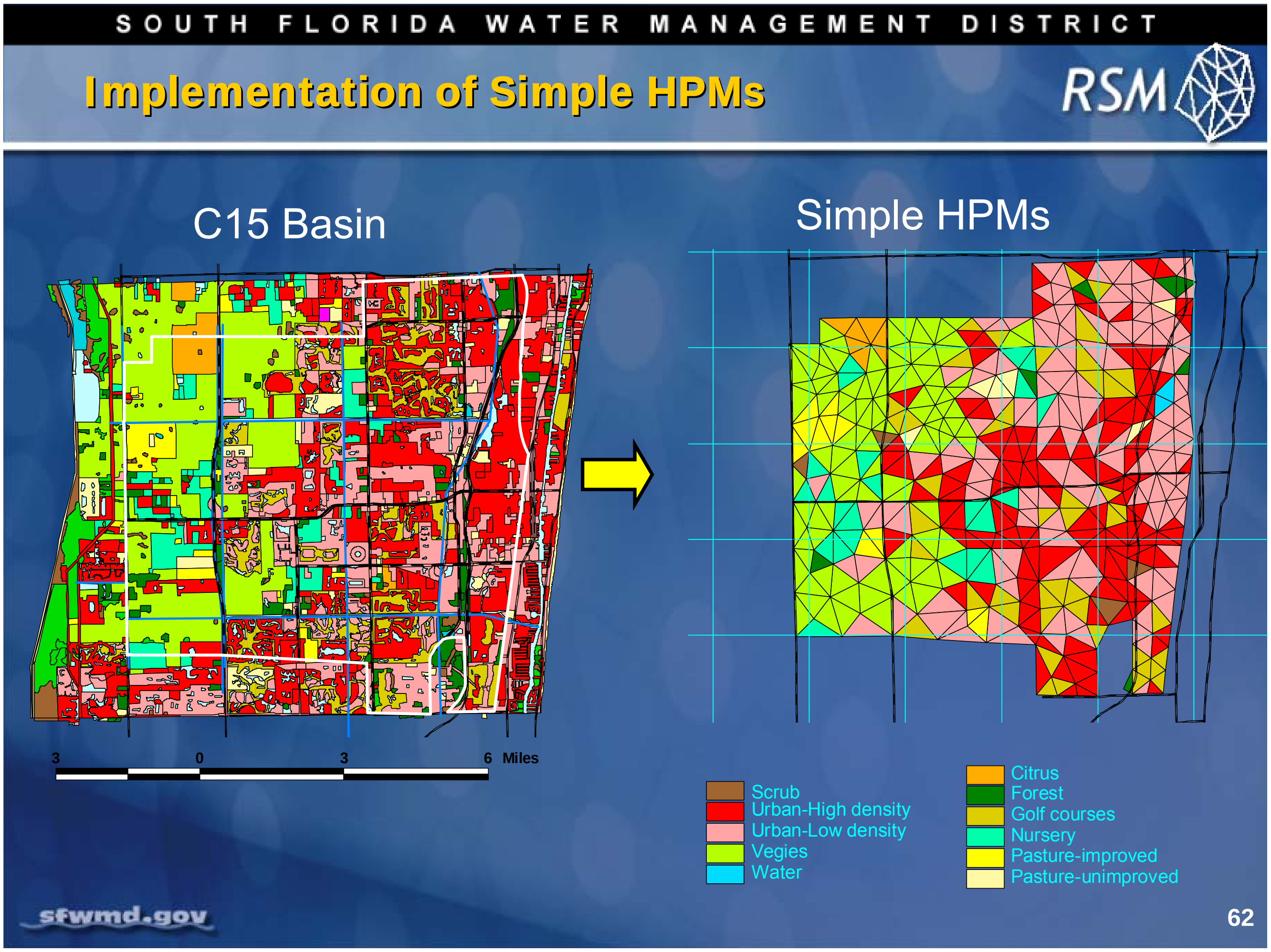
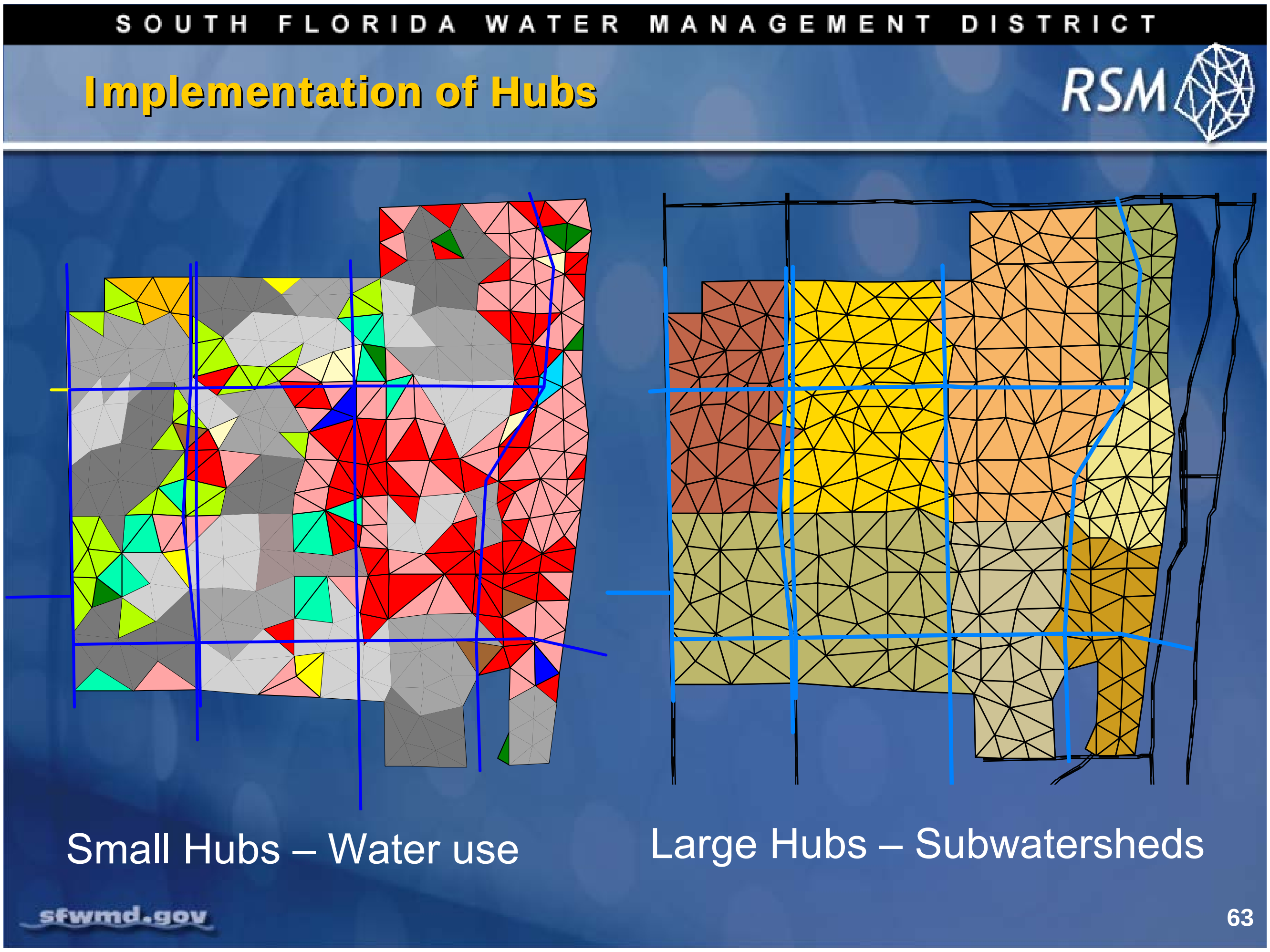
The content of the standard HPM file (`evap_prop.xml`) is a combination of single HPMs and Hubs. The primary single HPMs are the <layer1nsm> which is used extensively for wetlands and some upland sites, and the <afsirs> HPM for agricultural land and uplands. Urban land is modeled using Hubs. This is the default HPM utilization. The pre-processing tool is used when there are more detailed requirements.



Hydrologic Process Modules can be implemented as simple HPMs with a single HPM assigned to each cell based on the landuse type that occupies the majority of the cell or some other useful criteria.

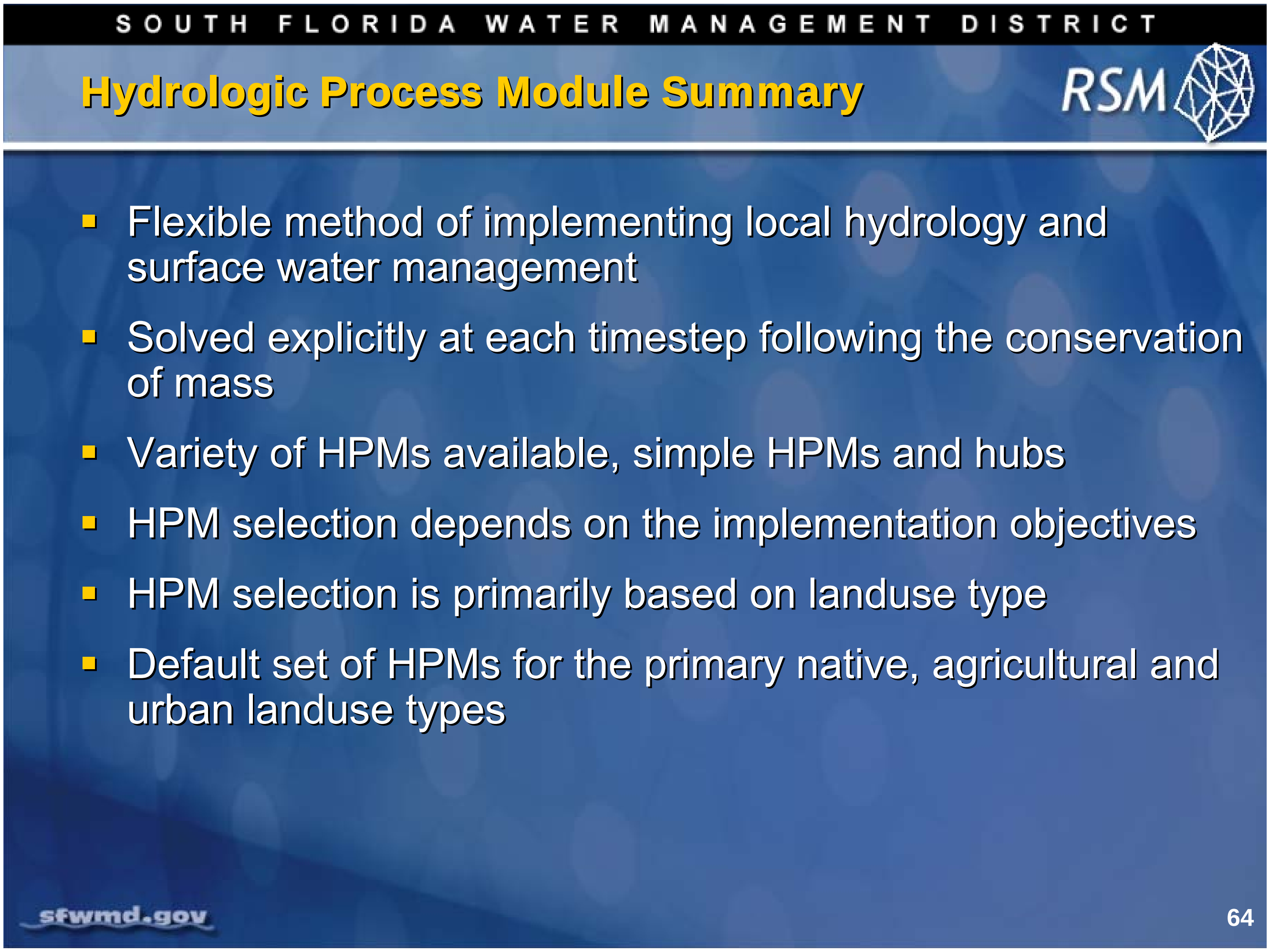
In this example, the HPMs are derived from the 1995 landuse coverage for the C-15 Basin in the Lower East Coast of south Florida. The white line (in the figure at left) is the basin boundary. The light blue grid (in the figure at right) is the grid from the SFWMM illustrating the improvement in the spatial discretization.



To obtain a more detailed model of local hydrology, Hubs can be implemented in the C-15 Basin based on surface water management systems.

In the figure at left, the individual secondary systems that have water control structures have been used to create Hubs for agricultural and urban developments. This better captures the water use and drainage characteristics of urban and agricultural land. The large Hubs (in the figure at right) are based on the drainage provided by the primary and secondary canals of the Lake Worth Drainage District.

The use of Hubs affects the recharge characteristics of the local well fields and the hydrographs of the local canals.


SOUTH FLORIDA WATER MANAGEMENT DISTRICT
Hydrologic Process Module Summary
RSM
Flexible method of implementing local hydrology and surface water management
Solved explicitly at each timestep following the conservation of mass
Variety of HPMs available, simple HPMs and hubs
HPM selection depends on the implementation objectives
HPM selection is primarily based on landuse type
Default set of HPMs for the primary native, agricultural and urban landuse types
sfwmd.gov
64

KNOWLEDGE ASSESSMENT

(pre- and post-lecture quiz to assess efficacy of training materials)

1. Do all RSM implementations use the same HPMs?
2. What key attributes does the HPM architecture provide to the RSM model?
3. How many HPMs can you have in an RSM implementation?
4. What processes can be implemented through HPMs?
5. What are the three broad classes of HPMs?
6. How do the HPMs interact with the cells?
7. How are the HPMs solved?
8. How many different types of HPM are available?
9. What are hubs?
10. How are HPMs selected for RSM?
11. What information can be used to select and parameterize HPMs.

Answers

1. Each RSM implementation can have a unique group of HPMs. However, there is a standard set of HPMs that have been developed to implement the landuse/land cover types used in the SFWMM model.

2. The HPM architecture provides flexibility, variable complexity which keeps the matrix solution simple and the ability to use legacy code for implementing surface hydrology.

3. You can have no HPMs, a single HPM or as many HPMs as there are cells.

4. Soil and unsaturated zone processes as well as surface hydrology processes including irrigation and surface detention storage can be simulated using HPMs.

5. The three classes of HPMs are native land, agricultural and urban/upland HPMs.

6. The HPMs can interact with the cells through Recharge, Water Supply (demand) and Runoff. The water supply demand and runoff can be directed to other cells.

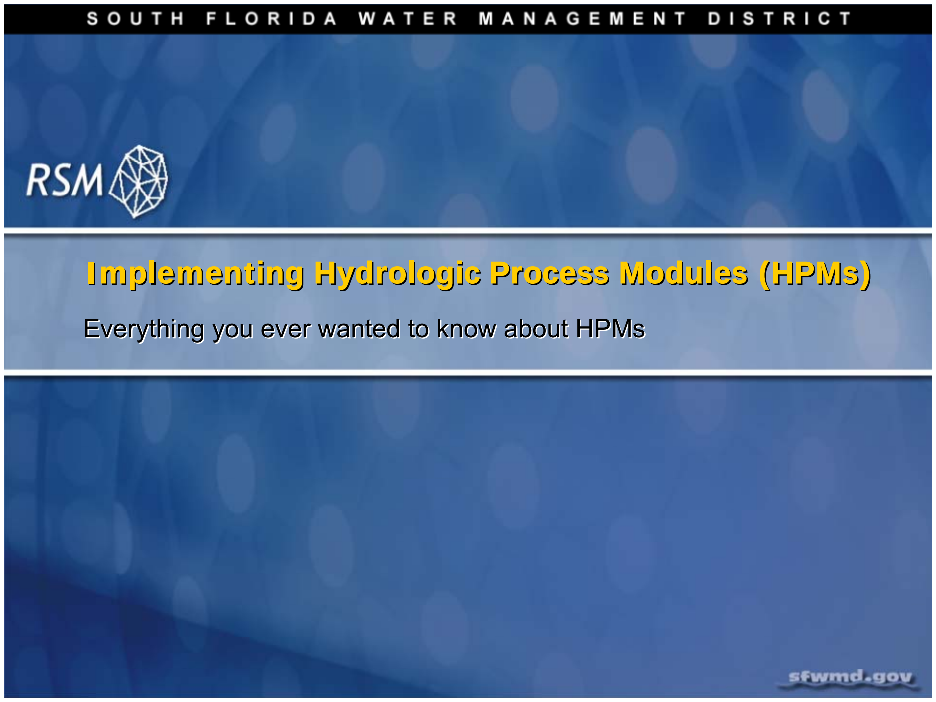
7. The HPMs are solved explicitly in a fixed order and the results are applied to the 2D RSM solution as boundary condition flows.

8. There ten simple HPM types whose parameters can be adjusted to represent different land cover types and two different hub formulations to represent developed urban and agricultural land.

9. Hubs are groups of HPMs that interact with each other and have a single runoff outlet and a single water supply source that can be redirected to other waterbodies.

10. The simplest way HPMs are selected is by assigning a landuse or land cover type to each mesh cell and assigning an HPM to model that land cover type. In a more complex selection, a hub can be created for each cell that includes a fraction of the land in each land cover type within that cell.

11. The GIS feature classes for soils, landuse/land cover, drainage basins, permits, topography, PWS service areas, sewage service areas and WCD boundaries can be used to define and parameterize the appropriate HPMs.



Lab 11: Implementing Hydrologic Process Modules (HPMs)

Time Estimate: 8 hours

Training Objective: Demonstrate the implementation of Hydrologic Process Modules (HPMs)

This lab provides the user with experience running several benchmarks, and practice adding and using HPMs. HPMs are used to model the soil processes and the local hydrology that occurs within the areal extent of each cell. Several HPMs commonly used in the Regional Simulation Model (RSM) for specific land use/land cover types are listed in **Table 11.1**.

In this lab, the exercises include running benchmarks for the HPMs and changing the HPMs in the Everglades Agricultural Area-Miami Canal (EAA-MC) Basin RSM (created in previous labs). The EAA-MC Basin HPMs are used to simulate the surface hydrology of native wetlands and uplands, and developed agricultural and urban land (**Table 11.1**).

NOTE:

For ease of navigation, you may wish to set an environment variable to the directory where you install the RSM code using the syntax

```
setenv RSM
/nw/oomdata_ws/nw/oom/sfrsm/workdirs/<username>/trunk
```

Once you have set the RSM environment variable to your trunk path, you can use $RSM in any path statement, such as: `cd $RSM/benchmarks`

Training files are currently located in the following directories:

```
INTERNAL_TRAINING
|
|____data
|        |__geographic
|        |__C111
|        |__rain+et
|        |__glades_lecsa
|        |__losa_eaa
|        |__BBCW
|
|____trunk
|        |___benchmarks
|        |___hpmbud
|
|____labs
```

Files for this lab are located in the **`labs/lab11_hpm`** directory. Additional materials in the directory include:

`mesh.ppt`

`HPM_documents subdirectory, containing:`

```
1988_landuse.doc
Afsirs.pdf
index_model_crosswalk_hpms.xls
index_model_crosswalk_hpms.csv
lu_95_2000_2050.xls
ramcc_Design.doc
RSM_HPM_whitepaper.doc
RSMLU.doc
supercodes_4-digit_1988_1999_SFWMM.xls
SWFFS2000FLUCCS2.xls
```

Activity 11.1 Explore HPM benchmarks

Overview

Activity 11.1 includes four exercises:

- Exercise 11.1.1. Run Benchmark 33 AFSIRS HPM
- Exercise 11.1.2. Run Benchmark 33r RAMCC HPM
- Exercise 11.1.3. Run Benchmark 54 Urban Hubs
- Exercise 11.1.4. Run Benchmark 57 Agricultural Hubs

There are several benchmarks that demonstrate the performance of the different HPMs that are described in the HSE User Manual (**`hse_userman.pdf`** in the **`$RSM/labs/lab2_BM2`** directory) and the HPM white paper (Flaig et al. 2005, also **`RSM_HPM_whitepaper.doc`** in the **`$RSM/labs/lab11_hpm`** directory).

Significant HPMs for south Florida are presented in:

- BM33 (afsirs, layer1nsm, unsat)
- BM33r (ramcc),
- BM54 (urban hubs)
- BM57 (agricultural hubs: pumpedditch and agimp)

The following exercises explore these HPMs.

Table 11.1 Hydrologic Process Modules (HPMs) used in the RSM

HPM Elements	Application
<layer1nsm>	Simple wetlands Marsh Forest Scrub Swamp Cypress Mangrove
<unsat>	Simple uplands
<afsirs>	Agricultural, landscaping and golf courses
Urban Hubs **<imperv>** **<afsirs>** **<urbandet>**	Urban water management systems Impervious land Landscaping Stormwater detention
AgHubs **<afsirs>** **<pumpedDitch>** **<agImp>**	Agricultural water managements systems Crop land Vegetables Citrus Sugar cane Improved pasture Nurseries Agricultural water collection ditches Agricultural impoundments

Benchmark 33 (BM33) Agricultural HPMs

Benchmark 33 provides an example of using the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) Model for simulating agricultural land. The model was developed by Smajstrla (1990) to provide a method for estimating irrigation requirements for selected crops, soil types and irrigation methods.

The parameter values used by the model are provided for:

- Perennial crops (**Table 11.2**)
- Annual crops (**Table 11.3** and **Figure 11.1**)
- Irrigation systems (**Table 11.4**)
- Soil types (**Table 11.5**)

These tables are copied from the AFSIRS Manual (**`Afsirs.pdf`** in the **`$RSM/labs/lab11_hpms/HPM_documents`** directory; Smajstrla, 1990). The implementation of the **`<afsirs>`** HPM is illustrated in **Fig. 11.2**, which provides an excerpt of the **`afsirs.xml`** file. Notice how the **`depth1`**, **`depth2`**, **`kc`** and **`awd`** parameters for citrus provided in **Table 11.2** are specified in the xml file.

Table 11.2 Perennial crop data used in the AFSIRS Model

PERENNIAL CROPS : ROOT ZONE AND WATER USE COEFFICIENT DATA
CROP DEPTH(IN) .... KC / AWD ....

CITRUS	0.90	0.90	0.90	0.90	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30* 60+	0.67	0.67	0.33	0.33	0.33	0.33	0.67	0.67	0.67	0.67	0.67	0.67
GENERIC CROP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24 48	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
NURSERY,CNTR.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8 8	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
NURSERY,FLD.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8 16	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
PASTURE	0.65	0.70	0.75	0.90	0.90	0.95	0.95	0.95	0.90	0.80	0.70	0.65
36 72	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
SOD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8 24	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SUGARCANE	0.80	0.60	0.55	0.80	0.95	1.00	1.05	1.05	1.05	1.00	0.95	0.90
18 36	0.65	0.65	0.35	0.35	0.35	0.50	0.65	0.65	0.65	0.65	0.65	0.65
TURF,GOLF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9 24	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
TURF,LNDSCP.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12 24	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

* irrigation depth
+ root depth

Table 11.3 Annual crop data used in the AFSIRS Model

ANNUAL CROPS : ROOT ZONE AND WATER USE COEFFICIENT DATA

CROP	DEPTH(IN)		...KC...		.....FRACTION ...				ALLOWABLE DEPLETION			
BEANS,GRN.	8	12	0.95	0.85	0.20	0.33	0.33	0.14	0.45	0.45	0.45	0.45
CABBAGE	8	12	1.00	0.85	0.25	0.38	0.25	0.12	0.45	0.45	0.45	0.45
CORN,FIELD	12	18	1.05	0.55	0.16	0.28	0.32	0.24	0.60	0.60	0.60	0.80
CORN,SWEET	12	18	1.05	0.95	0.25	0.25	0.38	0.12	0.35	0.35	0.35	0.35
FIELD CROPS	12	18	1.05	0.60	0.20	0.30	0.30	0.20	0.50	0.50	0.50	0.67
GENERIC CROP	8	12	1.00	0.90	0.25	0.33	0.25	0.17	0.50	0.50	0.50	0.50
MELONS	8	18	0.95	0.65	0.21	0.29	0.33	0.17	0.35	0.35	0.35	0.35
PEPPERS,GRN.	8	12	0.95	0.80	0.24	0.28	0.32	0.16	0.35	0.35	0.35	0.35
POTATOES	12	18	1.05	0.70	0.23	0.29	0.29	0.19	0.25	0.25	0.25	0.40
SMALL VEGETS	8	12	1.00	0.85	0.24	0.33	0.29	0.14	0.37	0.37	0.37	0.40
TOMATO	9	12	1.05	0.75	0.22	0.30	0.30	0.18	0.40	0.40	0.40	0.65

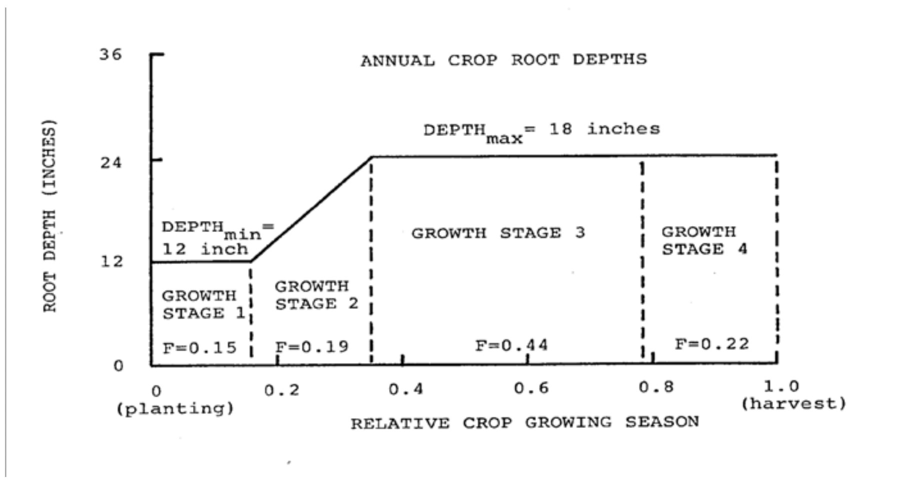


Figure 11.1 Annual crop root development function for barley

Table 11.4 Irrigation systems data used in the AFSIRS Model

9 IRRIGATION SYSTEM DATA

CODE	EFF	ARZI	EXIR	SYSTEM TYPE
1	1.00	1.00	1.00	USER-SPECIFIED SYSTEM
2	0.85	0.50	0.40	MICRO, DRIP
3	0.80	0.50	0.40	MICRO, SPRAY
4	0.75	1.00	0.70	MULTIPLE SPRINKLER
5	0.20	0.30	0.70	SPRINKLER, CONTAINER NURSERY
6	0.70	1.00	0.70	SPRINKLER, LARGE GUNS
7	0.50	1.00	1.00	SEEPAGE, SUBIRRIGATION
8	0.50	1.00	0.70	CROWN FLOOD (CITRUS)
9	0.50	1.00	1.00	FLOOD (RICE)

EFF – irrigation efficiency, ARZI – area of land irrigated
EXIR – fraction of irrigation requirement extracted from irrigated land

Table 11.5 Soil types used in the AFSIRS Model

CODE	SERIES	TEXTURE	DEPTH	WCL	WCU
1	SANDY SOILS	FS S	96	04	10
2	SANDY LOAM SOILS	SL	96	09	15
3	LOAM SOILS	L LS LFS	96	14	20
4	CLAY LOAM SOILS	CL SCL	96	16	22
5	SILTY CLAY SOILS	SiC	96	18	24
6	CLAY SOILS	C	96	20	26
7	MUCK SOILS	MK MKS	96	20	50
8	PEAT SOILS	PT SPT	96	20	50

WCL – lower range for available soil water
WCU – upper range for available soil water

```
    <hpModules>
      <indexed file="lu.index">
        <hpmEntry id="1">
           <unsat ew="0.2" kw="1.0" rd="0.5" xthresh="0.02"
             pthresh="0.10" pd="3.0" kveg="0.75">
           </unsat>
        </hpmEntry>

        <hpmEntry id="2">
          <layer5 ew="0.2" kw="1.0" rd="2.0" xd="5.0" pd="3.0" kveg="0.5">
</layer5>
        </hpmEntry>

        <hpmEntry id="3">
          <layer5 ew="0.2" kw="1.0" rd="0.0" xd="0.5" pd="3.0"
kveg="0.65">  </layer5>
        </hpmEntry>

        <hpmEntry id="4" label="citrus - micro drip">
          <afsirs>
           <afcrop label="citrus" id="4" j1="01-01" jn="12-31" depth1="30"
depth2="60">
             <kctbl>
                  0.90 0.90 0.90 0.90 0.95 1.00
                  1.00 1.00 1.00 1.00 1.00 1.00
             </kctbl>
             <awdtbl>
               0.67 0.67 0.33 0.33 0.33 0.33
               0.67 0.67 0.67 0.67 0.67 0.67
             </awdtbl>
             </afcrop>
             <afirr  wtd="8.0">
                  <irrmeth label="MICRO, DRIP" id="2" eff=".85" arzi=".5"
exir=".4"></irrmeth>
                  <irrmgmt label="DEFICIT" trigcode="2"
value="100"></irrmgmt>
             </afirr>
             <afsoil label="0.8  SOILS" depth="96" minwc=".07" maxwc=".07"
cond="1"></afsoil>
          </afsirs>
        </hpmEntry>
       …
     </indexed>
  <hpModules>
```

Figure 11.2 afsirs.xml file excerpt from Benchmark 33

Exercise 11.1.1 Run Benchmark 33: AFSIRS Hydrologic Process Module

Benchmark 33 illustrates the use of the **<afsirs>** HPM for the principal agricultural landuse types (see **Fig. 11.2**).

5. Run the RSM Python Toolbar: RSM Graphical Use Interface (RSM GUI)
6. Edit the **run3x3.xml** file: **$RSM/labs/lab11_hpm/BM33/run3x3.xml**

   Make sure that the correct **<wbbudgetpackage>** and <**hpmbudgetpackage>** elements are in the **<output>** block. If not, edit the **run3x3.xml** file and add this element:

```
<wbbudgetpackage file="wbbudget.nc" />
```

7. Run the benchmark using the RSM GUI (see Lab 1 if you need to review this material)
8. Observe the results by creating a water budget for different HPM types.
9. List the **afsirs.xml** file.
   - Observe that there are seven agricultural HPMs and three native landuse HPMs.
10. List the **lu.index** file. This file lists the HPM for each cell.
11. Create a file for each cell (e.g., cell2) with only the number of that cell as the content of the file. This will be used by the hpmbud utility to create the budget for that cell.
12. Create the HPM water budgets using hpmbud as shown in Exercise 1.3.3 in Lab 1 using the following command:

```
$RSM/trunk/hpmbud/hpmbud –n hpmbudget_yr.nc –s cell2 –d –m 12
```

The switches are defined in the psbud directory.

n	List the name of the netCDF file
s	Followed by the name of a file that contains the list of cells for the HPMs
d	Provide the results in depth (feet or meters) rather than volume
m	Provide a multiplier to the output. (x12 provides results in inches)

13. Run the **hpmbud** script to view the results for several HPMs as a group.
    - How do the waterbudgets for the HPMs change between the different crops?
14. Observe the time series of irrigation requirements and runoff using HecDssVue
    - Open **output.dss**
    - Sort on **Part A** > Select **C7** > Select **wsupply** and **runoff** of **Part C**
    - Plot
15. Repeat for Cell 1 and Cell 2.
    - What are the differences?

16. Add cell head monitors for cells 1-7, 14-16.

```
<cellmonitor id="1" attr="head">
      <dss file="head1.dss" pn="/c1/citrus/head//1day/micro/"></dss>
  </cellmonitor>
```

17. Rerun the model.
18. Observe the changes in the local head.
    - **`dssvue head1.dss`** > Plot heads.
    - What are the differences?

Exercise 11.1.2 Run Benchmark 33r: RAMCC Hydrologic Process Module

This benchmark contains the **<ramcc>** HPM which is an improved agricultural land HPM.

1. Go to Benchmark 33r

   cd $RSM/labs/lab11_hpm/BM33r

2. List the **run3x3.xml** file; make sure that the correct **<wbbudgetpackage>** and **<hpmbudgetpackage>** elements is in the **<output>** block. If not, edit the **run3x3.xml** file and add this element:

```
<wbbudgetpackage file="wbbudget.nc" />
<hpmbudgetpackage file="hpmbudget_yr.nc" dbintl="43200"/>
```

3. Run the benchmark using the RSM GUI
4. Observe the results by creating a water budget using the **hpmbud** script (**./hpmbud**) at the command line in the BM33r directory.
   - How do the waterbudgets for the HPMs change between the different crops?
5. Observe the time series of irrigation requirements and runoff using HecDssVue utility for **output.dss** in the RSM GUI.
   - Sort on **Part A** > Select **Cell7** > Select **wsupply** and **runoff** of **Part C** > Plot
6. Repeat for Cell 1 and Cell 2.
   - What are the differences?
7. Observe the changes in the local head using the HecDssVue utility with **head1.dss** > Plot heads.
   - What are the differences?

Exercise 11.1.3 Run Benchmark 54: Urban Hubs

Benchmark 54 implements hubs. The hub provides the capability to use multiple land use types within the same cell or the application of a group of HPMs with a single water source and drainage outlet to a group of several cells.

In BM54 there are three different HPMs within each hub. These HPMs are connected through the routing of runoff: runoff from the houses and sidewalks **`<imperv>`** drains to the lawns **`<afsirs>`**; the lawn drains to the stormwater detention pond **`<urbandet>`**; and the runoff from the pond drains offsite (see **Fig.11.3** and slide 50 from lecture**)**. Use the mesh in **`$RSM/labs/lab11_hpm/mesh.ppt`** as a starting point.

8. Go to **`$RSM/labs/lab11_hpm/BM54`** directory.
9. Draw the typical benchmark mesh from the 2dm file.
   - Identify the hpm assigned to Cell 2.
   - Identify and connect the flows between the hpm and the cells. You can use the mesh in **`$RSM/labs/lab11_hpm/mesh.ppt`** as a starting point.
   - Identify and connect the flows between the hpms and the cells.
10. Edit the **`run3x3.xml`** file. Add **`<wbbudgetpackage>`** and **`<hpmbudgetpackage>`** for annual output.

```
<hpmbudgetpackage file="hpm_yr.nc" dbintl="525600"></hpmbudgetpackage>
<wbbudgetpackage file="wbbudget.nc" />
```

> **NOTE:**
>
> **<budgetpackage> element has been removed from `run3x3.xml` file.**

11. Add cell monitors to record head in Cell 2, Cell 13, and Cell 14 (see Lab Exercise 1.2.3 for an example).
    - Add cell monitors to the **`run3x3.xml`** file
    - Create files “cell2”, “cell13”, “cell14” containing the single values 2, 13, and 14, respectively.
12. Run the benchmark 54 **`run3x3.xml`** using the RSM GUI.
13. Observe the heads in Cell 2, Cell 13, and Cell 14
14. Run HPM water budget and cell water budgets for Cell 2 and Cell 14

```
$RSM/trunk/hpmbud/hpmbud –n hpm_yr.nc –s cell2 –d –m 1
```

15. Run the WBBud tool from the RSM GUI Process Model Output menu (see Lab Exercise 2.1.1 for details on WBBud).
    - What are the differences?

16. Edit **`hpms.xml`**.
    - Change the percent of high intensity land consuming water to 5 percent.
17. Rerun the model and observe the results: heads and water budgets.

```
<hpModules>
  <indexed file="lu.index">

    <!-- unsat -->
    <hpmEntry id="1">
      <hub runoff="homecell" wsupply="homecell">
        <hubMember id="1" percentarea="100" runoff="hub">
          <unsat ew="0.2" kw="1.0" rd="0.5" xthresh="0.02"
            pthresh="0.10" pd="3.0" kveg="0.75">
          </unsat>
        </hubMember>
      </hub>
    </hpmEntry>

    <!-- impervious routed to landscape routed to detention area -->
    <!-- runoff (detention area outlet) discharged to cell #14 -->
    <!-- water supply (landscaping) withdrawn from cell #14 -->
    <hpmEntry id="2">
      <hub runoff="wb-14" wsupply="wb-14">
        <hubMember id="1" percentarea="10" runoff="hub">
          &urbandet;
        </hubMember>
        <hubMember id="2" percentarea="20" runoff="hpm-1" wsupply="hub">
          &landscape;
        </hubMember>
        <hubMember id="3" percentarea="70" runoff="hpm-2">
          <imperv sdet="0.1" isto="0.01"></imperv>
        </hubMember>
      </hub>
    </hpmEntry>

    <!-- impervious (dirconn) routed to landscape and to urban detention -
->
    <!-- runoff (detention area outlet) discharged to cell #5 -->
    <!-- water supply (landscaping) withdrawn from cell #5 -->
    <hpmEntry id="3">
      <hub runoff="wb-5" wsupply="wb-5">
        <hubMember id="1" percentarea="10" runoff="hub">
          &urbandet;
        </hubMember>
        <hubMember id="2" percentarea="20" runoff="hpm-1" wsupply="hub">
          &landscape;
        </hubMember>
        <hubMember id="3" percentarea="70" runoff="hpm-1">
          <imperv sdet="0.1" isto="0.01" dirconn="1"></imperv>
        </hubMember>
      </hub>
    </hpmEntry>

  </indexed>
</hpModules>
```

Figure 11.3 HPM code from Benchmark 54

Exercise 11.1.4 Run Benchmark 57: Agricultural Hubs

Benchmark 57 has been enhanced to provide additional outputs to evaluate the effect of using the farm collector ditch storage, **<pumpedDitch>** HPM, and agricultural impoundments **<agImp>** HPM for onsite water management. This new benchmark, BM57test, implements an AFSIRS citrus landuse with low-volume irrigation. The runoff is directed to an offsite lake or offsite canal.

18. Go to the **`$RSM/labs/lab11_hpm/BM57test`** directory
19. Edit the **`run3x3.xml`** and add two lakes.

```
<lake id="81" head0="60.0"><cylinder toparea="2.788e+8" bot="25.0" />
  </lake>
<lake id="82" head0="60.0"><cylinder toparea="2.788e+8" bot="25.0" />
  </lake>
```

20. Edit **`afsirs.xml`** file and redirect the water supply and runoff from the mixed-irr citrus to Lake 82, and the wsupply and runoff from the citrus with agimp to Lake 81.
21. Add **<lakemonitor>** monitors for Lake 81 and Lake 82 similar to the **<lakemonitor>** for Lake 80 to the **`run3x3.xml`** file.
22. Add hpmmonitors for water supply and runoff for HPM 4 to the **`run3x3.xml`** file:

```
<hpmmonitor id="1" attr="hpm_wsupply" label="hpm4_ws"><dss file="hpm" />
</hpmmonitor>

<hpmmonitor id="1" attr="hpm_runoff" label="hpm4_ro"><dss file="hpm" />
</hpmmonitor>
```

23. Repeat for HPM 11 and HPM 12.
24. Add **<hpmbudgetpackage>** and **<wbbudgetpackage>** for annual output:

```
<hpmbudgetpackage file="hpm_yr.nc" dbintl="525600"></hpmbudgetpackage>
<wbbudgetpackage file="wbbudget.nc" dbintl="525600"></wbbudgetpackage>
```

25. The **`afsirs.xml`** file should look like **Fig. 11.4**. Run the benchmark.
26. Observe the time series of irrigation requirements for different HPMs using the HecDssVue utility for **`hpm.dss`** in the RSM GUI.

27. Observe the annual water budgets for the HPMs. Run annual hpmbud for each HPM.

```
$RSM/hpmbud/hpmbud –n hpm_yr.nc –s cell2 –d –m 12
```

- What is the effect of using a **<pumpedDitch>** compared to an **<agImp>** HPM?

This requires comparison of the heads in the different lakes as well as the heads in the cells with different HPMs.

  - How do the heads change?

```
<hpModules>
 <indexed file="lu.index">
  <hpmEntry id="4" label="mixed-irr citrus" mode="one2many">
   <hub wsupply="wb-80" runoff="wb-80" sewer="wb-80">
     <hubMember id="1" percentarea="50" wsupply="hub" runoff="hub">
               &citrus_drip;
     </hubMember>
     <hubMember id="2" percentarea="50" wsupply="homecell"
runoff="homecell">
              &citrus_crown;
     </hubMember>
   </hub>
  </hpmEntry>

  <hpmEntry id="11" label="drained citrus" mode="one2many">
   <hub wsupply="wb-81" runoff="wb-81">
    <hubMember id="1" percentarea="90" runoff="hpm-2" wsupply="hpm-2">
            &citrus_drip;
    </hubMember>
    <hubMember id="2" percentarea="10" runoff="hub" wsupply="hub">
             &pumpedDitch;
    </hubMember>
   </hub>
  </hpmEntry>

  <hpmEntry id="12" label="citrus with agimp" mode="one2many">
   <hub wsupply="wb-82" runoff="wb-82">
    <hubMember id="1" percentarea="90" runoff="hpm-2" wsupply="hub">
            &citrus_drip;
    </hubMember>
    <hubMember id="2" percentarea="10" runoff="hub">
        <agimp rks="0.0005" height="60.0" rd="2.0">
          <stdtriorif r25y3d="0.79167" allow="0.0625"
s="0.85"></stdtriorif>
        </agimp>
    </hubMember>
   </hub>
  </hpmEntry>
 </indexed>
</hpModules>
```

Figure 11.4 Content of **afsirs.xml** for Benchmark 57

Activity 11.2: Add HPMs to Everglades Agricultural Area-Miami Canal (EAA-MC) Basin RSM

Overview

Activity 11.2 includes four exercises:

- Exercise 11.2.1 Review Marsh **<layer1nsm>** HPMs
- Exercise 11.2.2 Differentiate Sugarcane **<afsirs>** and Marsh **<layer1nsm>** HPMs
- Exercise 11.2.3 Simulate Actual Landuse HPMs
- Exercise 11.2.4 Simulate Agricultural Hubs and Natural System Hubs

The Everglades Agricultural Area-Miami Canal (EAA-MC) Basin RSM models a basin that includes agricultural and native land (**Fig. 11.5**). The basin can be modeled using the **<afsirs>** and **<layer1nsm>** HPMs.

The simplest approach to model the local hydrology is to apply a simple **<layer1nsm>** HPM. The complexity can be increased by applying **<afsirs>:sugarcane** everywhere as a first approximation to the agricultural water use. As a higher level of complexity, simple hubs can be applied to the EAA-Miami Canal Basin containing a combination of HPM types in each area.

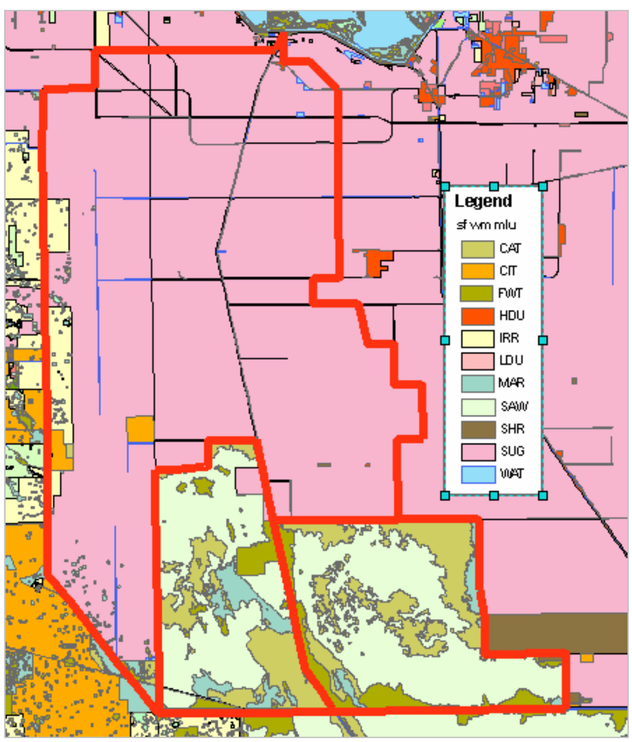


Figure 11.5 Landuse/land cover for 1995 for the EAA Miami Canal Basin.

Exercise 11.2.1 Review Marsh `<layer1nsm>` HPMs

Define all of the cells as **`<layer1nsm>`** HPM and evaluate water budget and cell heads.

28. Go to the **`eaamchpm`** directory: **`$RSM/labs/lab11_hpm/eaamchpm`**
29. Copy the XML file **`eaamc_gstruc.xml`** created in **`$RSM/labs/lab10_wbwm`** with the associated files. If Lab 10 exercises were not completed, find the appropriate files in **`$RSM/labs/lab11_hpm/eaamchpm_bak`**. Rename the file **`eaamc_hpm.xml`**. The path references to the **`hse.dtd`**, rainfall and ET files must be adjusted by prepending "**`../`**" to the paths because you are one directory deeper.
30. Create a new file for HPMs.
    - Remove the entire **`<hpModules>`** block from **`eaamc_hpm.xml`** and place it in a new file "**`hpm.xml`**".
    - Add the reference "**`&hpm;`**" in place of the **`<hpModules>`** block.
    - Add an **`ENTITY`** to the header part of the **`eaamc_hpm.xml`** that relates HPMs to **`hpm.xml`**.
31. The **`hpm.xml`** file should have three components (see **`BM33/Afsirs.xml`** as an example): one **`<index>`** element and two **`<hpmEntry>`** elements.
    - The **`<index>`** points to the **`lu.index`** file which assigns the HPM to each cell. It should contain 495 values of "10". If not, modify this file.
    - The first **`<hpmEntry>`** should have **`id=10`** and contain the **`<layer1nsm>`** HPM.
    - The second **`<hpmEntry>`** should have **`id=23`** and contain the **`<afsirs>`** HPM for sugarcane.
    - The resulting file should look like **`hpm_ex1.xml.`**
32. In **`eaamc_hpm.xml,`** make sure that the **`<runDescriptor>`** attribute in the **`<control>`** block is set to "**`nsm`**"

```
runDescriptor = “nsm”
```

33. Add an **`<hpmbudgetpackage>`** element to the **`<output>`** block that produces annual water budgets:

```
<hpmbudgetpackage file="hpmbudget_yr.nc" dbintl="525600"/>
```

34. Create **`<cellmonitor>`** elements for each indicator cell: 15, 135, 157, 259, 363, and 414 (see **Fig. 11.6**).
35. Save **`eaamc_hpm_nsm.xml`** and run the model using the RSM GUI.
36. Run the water budget for the entire EAA-MC basin. Save these values for comparison with other model runs.
37. Create individual files containing the values for the indicator cells.
38. Run the water budget for the indicator cells:

```
$RSM/hpmbud/hpmbud –n hpmbudget_yr.nc –s cell2 –d –m 12
$RSM/budtool/wbbud –n wbbudget.nc –t depth –s 2 –v –f month –m 12 –u inch
```

39. Observe the head changes in the indicator cells.
40. Run HecDssVue for **`heads.dss`**.

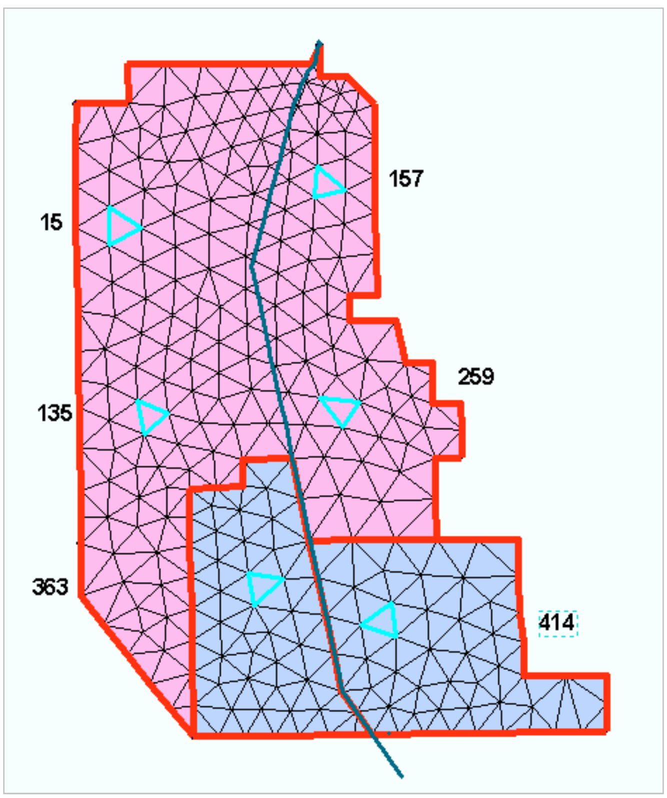


Figure 11.6 Indicator cells for **`<eaamc>`** HPM assessment

Exercise 11.2.2 Differentiate SugarCane `<Afsirs>` and Marsh `<layer1nsm>` HPMs

An improvement in the representation of the surface hydrology would be to simulate the agricultural land differently from the native wetlands. In this example, the pink area in **Figure 11.7** will be modeled using the **`<afsirs>`** HPM for sugarcane and the wetlands will be modeled using the **`<layer1nsm>`** HPM.

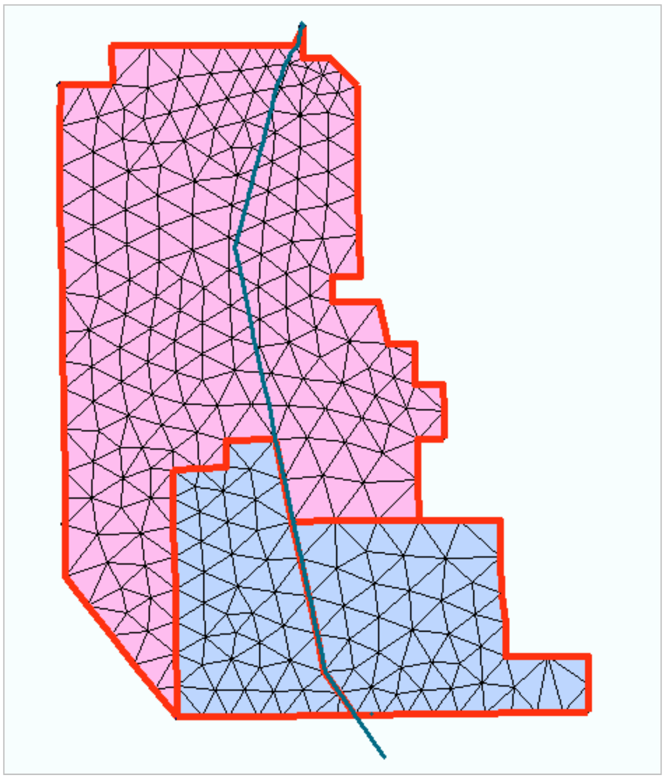


Figure 11.7 The two primary landuse types in the EAA-MC Basin are sugarcane (pink) and native wetlands (blue)

Work in the same eaamchpm directory: **`$RSM/labs/lab11_hpm/eaamchpm`**

41. Change the indexed landuse file in **`hpm.xml`** from **`lu.index`** to **`lu.index2`**. Notice this file contains both **`HPM = 10`** and **`HPM = 23`**. Save the HPM file as **`hpm_scnsm.xml`**.
42. Open **`eaamc_hpm_nsm.xml`** and make sure that the **`<runDescriptor>`** attribute in the **`<control>`** block is set to "**`scnsm`**"

```
runDescriptor = "scnsm"
```

43. Save the file as **`eaamc_scnsm.xml`** and run the model.

44. Run the water budget for the entire EAA-MC basin:

```
$RSM/hpmbud/hpmbud –n hpmbudget_yr.nc –d –m 12
$RSM/budtool/wbbud –n wbbudget.nc –t depth –v –f month –m 12 –u inch
```

45. Run the water budget for the indicator cells:

```
$RSM/hpmbud/hpmbud –n hpmbudget_yr.nc –s cell135 –d –m 12
$RSM/budtool/wbbud –n wbbudget.nc –t depth –s 135 –v –f month –m 12 –u
inch
```

46. Repeat for the other cells.

- Observe the head differences between the indicator cells and compare the heads from the different areas. The heads should be different from the previous example as a result of irrigation.

Exercise 11.2.3 Simulate Actual Landuse HPMs

Simulating the land based on the actual landuse is another modeling approach. Using ArcGIS, the primary landuse for each mesh cell can be assigned to each cell. As such the landuse can be represented by eight different landuse types of the standard eleven landuse types typically used in the SFWMM (**Fig. 11.8**). A standard HPM file (**`evap_prop.xml`**) has been created that contains the representation of each of these landuse types.

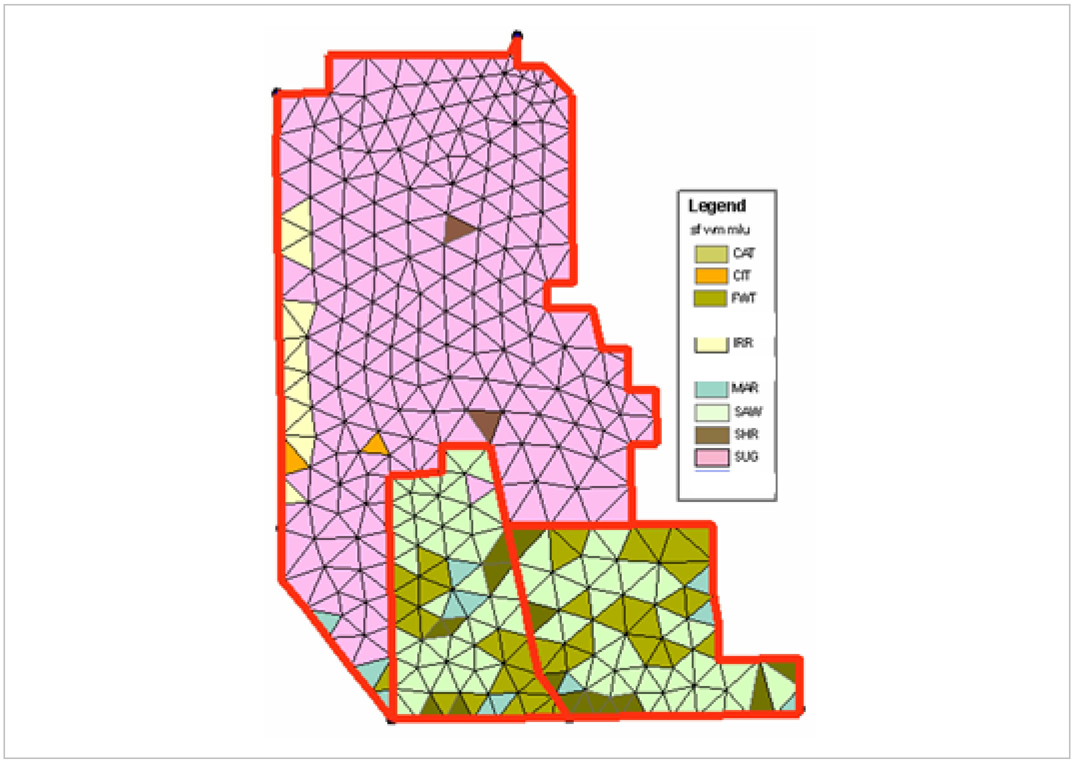


Figure 11.8 The primary landuse found in each cell of the EAA-MC mesh

Work in the same eaamchpm directory: **`$RSM/labs/lab11_hpm/eaamchpm`**

47. Change the HPM reference file.
    - Change the **`ENTITY`** entry from **`hpmsc.xml`** to **`evap_prop.xml`**.
    - Change the indexed landuse file in **`evap_prop.xml`** to **`lu95.index`**.
    - Notice this file contains 25 different HPM descriptions.
48. Set the **`<runDescriptor>`** attribute in the **`<control>`** block to "**`lu95`**"

    ```
    runDescriptor="lu95"
    ```

49. Save the model as **`eaamc_lu95.xml`** and run the model.
50. Run the water budget for the entire EAA-MC basin.
51. Run the water budget for the indicator cells.
    - Observe the head differences between the indicator cells and compare the heads from the different areas. The heads should be different from the previous example as a result of irrigation.

Exercise 11.2.4 Simulate Agricultural Hubs and Natural System Hubs

Another alternative for modeling the HPMs in the EAA-MC Basin is to create HPM hubs (**Fig. 11.9**). These hubs allow for a common inflow and discharge location and the application of multiple landuses within the hub.

For the agricultural land, this is consistent with the fact that the land is partitioned into farms that have single pump stations on the Miami Canal and a mix of landuses within the farms that include sugarcane, rice and pasture. The natural lands, Holeyland and Rotenberger, occur as enclosed subbasins with mixed landuses.

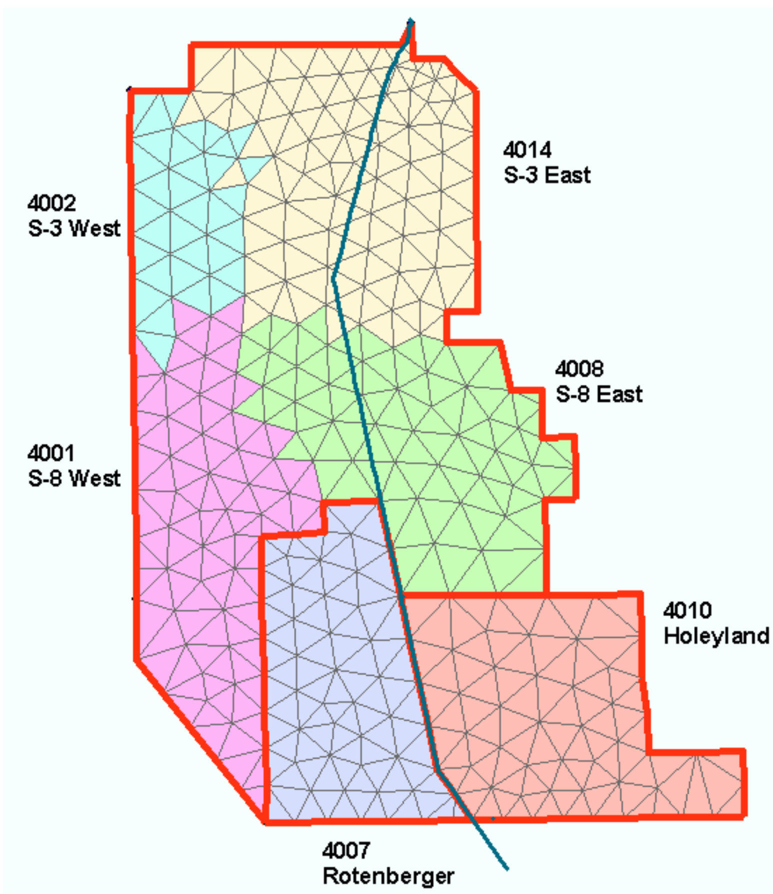


Figure 11.9 HPM hubs for the EAA-Miami Canal Basin

Implement a set of HPM hubs for representing the surface hydrology in the EAA-MC Basin. The cells assigned to each hub are provided in the **`eaahub.index`** file. These assignments were developed from a GIS feature class that contains the boundaries of the hubs. The HPMs in each hub are provided in the **`eaa_hub.xml`** file.

Work in the same eaamchpm directory: **$RSM/labs/lab11_hpm/eaamchpm**

52. Modify the **eaa_hub.xml** file to represent the composition of the HPM hubs. This file contains the prototype hub definitions for the hubs.
    - Modify the hubs from the agricultural areas to contain 20 percent rice to reflect the rotation of sugarcane with rice. Create a **rice.xml** file from the **BM33/afsir.xml** file.
    - Modify the routing so that the watersupply and runoff for hub 4014 is connected to segment 300005 and the wsupply and runoff for hub 4008 is connected to segment 300008.
    - Save this file as **eaa_hub2.xml**. The file content should look like **Fig. 11.10**.

```
<!--================================================================-->
<!--   S-8 (east) Hub                                                -->
<!--================================================================-->
     <hpmEntry id="4008" label="mix - irr EAA" mode="one2many">
       <hub>
        <hubMember id="4081" percentarea="75" wsupply="wb-300008" runoff="wb-300008">
          &sugar_cane;
        </hubMember>
        <hubMember id="4082" percentarea="5" wsupply="wb-300008" runoff="wb-300008">
          &improved_pasture;
        </hubMember>
        <hubMember id="4083" percentarea="20" wsupply="wb-300008" runoff="wb-300008">
          &rice;
        </hubMember>
      </hub>
    </hpmEntry>
<!--================================================================-->
<!--      S-3E Hub                                                   -->
<!--================================================================-->
     <hpmEntry id="4014" label="EAA-S3-E Hub" mode="one2many">
       <hub>
        <hubMember id="4141" percentarea="75" wsupply="wb-300005" runoff="wb-300005">
           &sugar_cane;
        </hubMember>
        <hubMember id="4142" percentarea="5" wsupply="wb-300005" runoff="wb-300005">
           &improved_pasture;
        </hubMember>
       <hubMember id="4143" percentarea="20" wsupply="wb-300005" runoff="wb-300005">
           &rice;
        </hubMember>
      </hub>
    </hpmEntry>
```

Figure 11.10 Excerpt of **eaa_hub2.xml** file containing modified code

53. Edit the **eaamc_lu95.xml** file. Save the file as **eaamc_hub.xml**.
    - Add the following entities to the **eaamc_hub.xml** file from the **$RSM/../data/losa_eaa/input folder**:

```
<!ENTITY hpm                 SYSTEM "eaa_hub.xml">
<!ENTITY improved_pasture    SYSTEM "improved_pasture.xml">
<!ENTITY sugar_cane          SYSTEM "sugar_cane.xml">
<!ENTITY rice                SYSTEM "rice.xml">
<!ENTITY scrub_land          SYSTEM "scrub_land.xml">
<!ENTITY cattail             SYSTEM "cattail.xml">
```

54. Run the **`eaamc_hub.xml`**
55. Run the water budget for the entire EAA-MC basin
56. Run the water budget for the indicator cells
57. Repeat for other cells
58. Observe the head changes in the indicator cells
59. Run HecDssVue for **`heads.dss`** and compare the heads from the different areas

Comparison between the different model runs illustrates the impact of alternative HPM configurations on the overall water budget and stages in the indicator cells.

Answers for Lab 11

Exercise 11.1.1

9. How do the waterbudgets for the HPMs change between the different crops?

Cell 2 – Landuse 5 – Citrus Crown Flood

This crop has the most consistent water supply requirements of the three and relatively high ET values.

Cell3 – Landuse 6 – Sugar, sub-irrigation

Sugar has sporadic water supply needs. Runoff comes once a year in the summer, with no runoff in between and has relatively high ET values.

Cell6 – Landuse 9 – Rice, seepage

Rice has the largest runoff volumes and the lowest ET values. Water supply is required only in January through April.

11. What are the differences in time series of irrigation requirements and runoff for Cell 7, Cell 1, and Cell 2?

Cell1 requires water January thru June and generates runoff June thru October. Cell2 requires water more consistently throughout the year on a weekly to bi-weekly basis with runoff typically occuring in summer and occasionally in the fall. Cell 7 has a large water supply need at the beginning of September, then consistent requirements through December with non the rest of the year. Runoff occurs in the summer months.

14. Describe the differences between the heads for Cells 1-7 and 14-16

All heads follow a similar pattern, reaching lows in June 1965, high in Oct 1966, with a marked increase occurring in July 1966. There are three groups of similar magnitude heads. The group with the lowest heads is for cells 1, 2, and 3. The middle heads are for cells 7 and 16. The highest heads are for cells 6, 15, 4, 14, and 5. Physically, the top (north) row of cells has the lowest cell heads and the middle row the highest heads.

Exercise 11.1.2

4. How do the waterbudgets for the HPMs change between the different crops?

Cell 1 – Landuse 4 – Citrus, micro-drip

This has a consistent water supply, no runoff and higher values of ET.

Cell2 – Landuse 5 – Citrus, crown flood

This crop requires the least water supply which is not needed every month but has very consistent runoff.

Cell3 – Landuse 6 – Sugar, subirrigation

Sugar requires the largest , and consistent, water supply of the three, has higher values of ET, and virtually no runoff.

6. What are the differences in time series of irrigation requirements and runoff for Cell 7, Cell 1, and Cell 2?

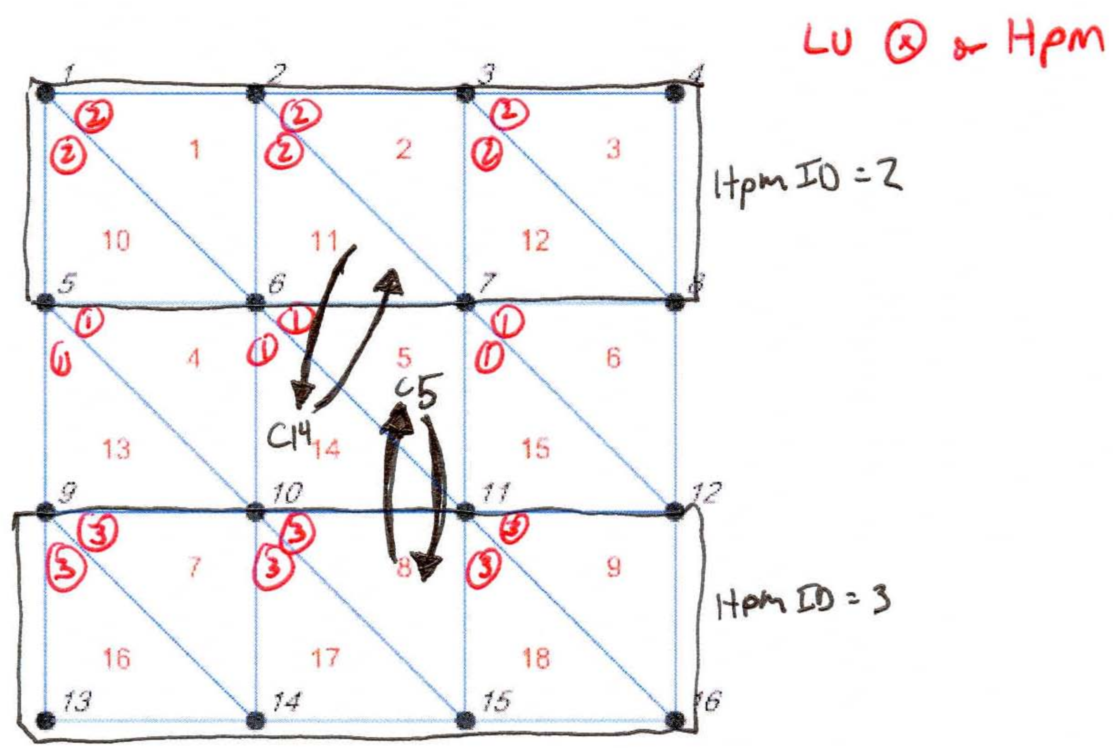
Cell 1 requires very consistent, small water supplies throughout the year with virtually no runoff. Cell2 requires periodic water supply (except in summer when none is needed), but always has runoff. Cell 7 requires water in Nov and Dec and then has runoff periods in the summer.

7. Describe the differences between the heads for individual cells.

The flooding crops, tomato (cell 5) and citrus (cell 11), produce the largest heads and the largest changes in heads on the order of 2 – 2.5 feet between seasons. The other crops show smaller variations in heads, on the order of half a foot, in response to smaller periodic irrigation events.

Exercise 11.1.3

1. Draw the typical benchmark mesh and contents of Cell 2 that contains hub Type 2 with the HPM components within the cell according to the correct dimensions and connect the flows.



7. What are the differences in the HPM water budget and cell water budgets for Cell 2 and Cell 14?

For the hpmbud, the ET in cell 2 is more than twice the ET for cell 14. The water supply and runoff for cell 14 is zero (which makes sense since it is detention), while cell 2 does receive water supply over the year and consequently has runoff. Cell 14 experiences a significant storage change (-14.58) in 1965.

The wbbud produces monthly results. Again, cell 2 has significantly higher ET values. The groundwater flow (gwFlow) for cell 14 is much larger, likely from seepage from the detention storage into the water table.

9. Compare results after changing high intensity land consuming water to 5 percent

It is assumed that where it says "high intensity land consuming water", that meant hubmember id="2" (&landscape) was changed to 5% and the impervious area was changed to 85% to balance this change. This addition of impervious lands creates a flashier system. Consequently, the head in cell 14 maintains a higher base value. The head in cells 2 and 13 does not change appreciably. Looking at the hpmbud, the water supply necessary for cell 2 is significantly less due less need for water. Runoff and storage change values do not change appreciably. The wbbud reveals larger groundwater flows for cell14 due to increased storage.

Exercise 11.1.4

9. What is the effect of using a <pumpedDitch> compared to an <agImp> HPM?

The agimp HPM requires nearly twice the water supply as the pumpedditch, produces slightly more runoff, and results in increased seepage.

How do the heads change between cells with different HPMs?

The agimp HPM leads to higher heads among nearby cells with a pumpedditch HPM, likely caused by the larger water supply and leading to higher seepage as noted above.

Exercise 11.2.1

Compare results with those in the lab11_hpm directory

Exercise 11.2.2

6. observe the head differences between the indicator cells and compare the heads from the different areas. The heads should be different from the previous example as a result of irrigation.

The heads between all the cells are virtually the same. The patterns are the same and the variations between cell heads are on the order of 0.04ft.

Exercise 11.2.3

5. observe the head differences between the indicator cells and compare the heads from the different areas. The heads should be different from the previous example as a result of irrigation.

Observe the head differences between the indicator cells and compare the heads from the different areas. The heads should be different from the previous example as a result of irrigation.

The indicator cells all follow the same pattern of heads, with little variation (head differences on the order of 0.03ft). The exception is cell 15 which follows the pattern but starting in mid-May, exhibits lower values of head by 0.1 ft, with a maximum difference 0.5ft by October. The pattern is different than that in ex 11.2.2, showing a more steady decrease, followed by a plateau (no rising of heads in the summer) and then a decrease again in the fall.

The cells of various land use types exhibit the same pattern of heads, steadily decreasing from 13.0 feet to about 11.2 feet, with a slight plateau in the summer. Cell 342 (LU – 4, Cypress Swamp/Forested Wetland), had the same pattern but with slightly lower heads beginning in May, but with differences less than 0.5 ft.

Exercise 11.2.4

7. Observe the head changes in the indicator cells, and compare the different model runs.

Compared with exercise 11.2.3, the heads show a more marked decrease in the spring, but then actually rise during the summer with a secondary peak around September first, then decreasing into the winter. The final head is higher than that in ex 11.2.3 (about 11.9 vs. about 11.2ft). The pattern and absolute values of the heads are actually more similar to those in exercise 11.2.2.

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