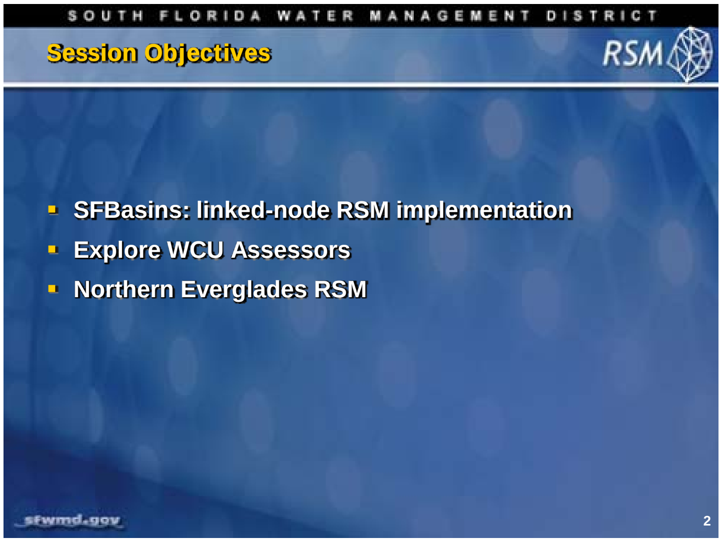
Lecture 16: Management Simulation Engine (MSE): Linked Node Implementation

This lesson provides a more detailed presentation of the mseNetwork and an application in the Northern Everglades RSM (NERSM)

NOTE:

Additional Resources

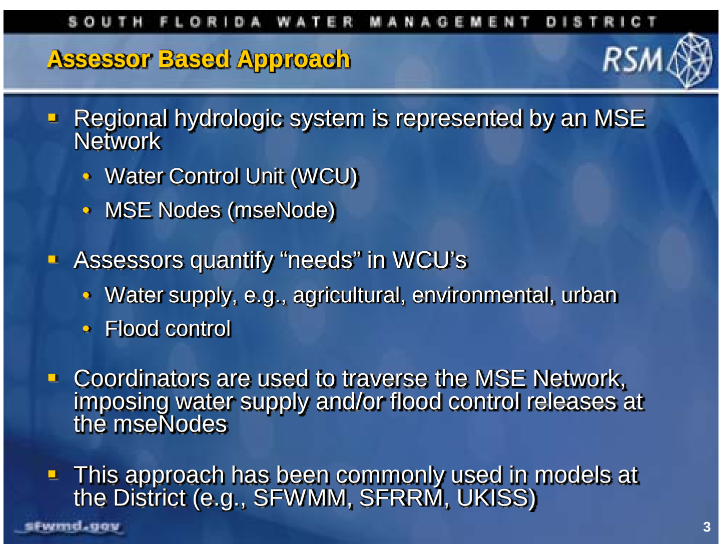
A number of additional MSE reference materials can be found in the labs/lab16_assessor directory



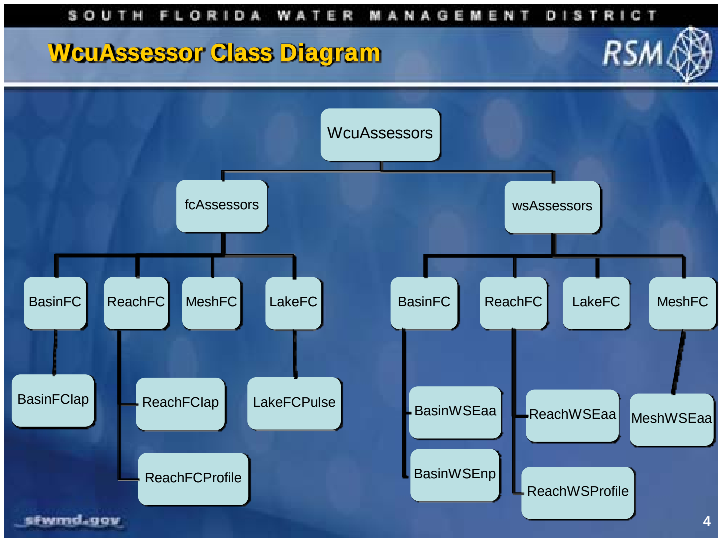
In this session, the linked-node implementation of the RSM will be discussed. The linked-node implementation of the RSM focuses on simulating the water management rules for the selected water control units (WCUs). The domain is represented by a series of lakes or basins. This implementation of the RSM uses simplified hydrology but implements the complete set of management rules to test alternative plan formulations. Complexity in the hydrology is only added where necessary.

The key component of the linked-node RSM is the WCU assessors. The assessors are used to determine how much water should be between WCUs based on flood control, water supply and environmental requirements.

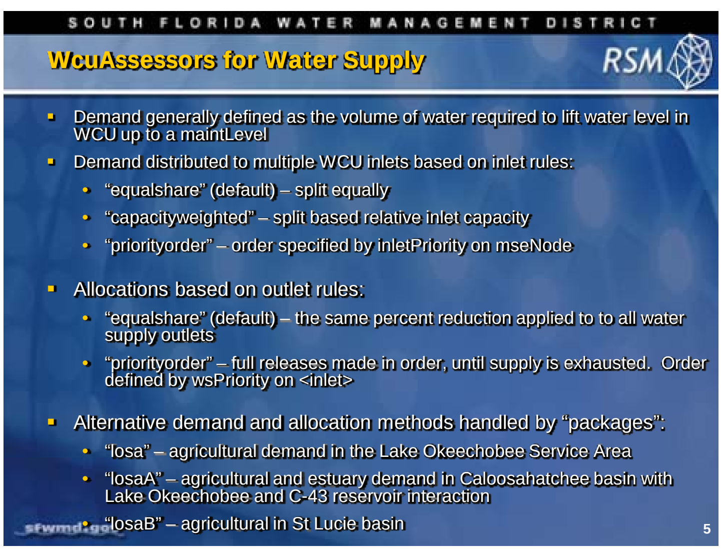
The Northern Everglades RSM is the most complete implementation of the linked-node RSM. This implementation of the RSM simulates the Kissimmee upper basin, the lower Kissimmee River, Taylor Creek/Nubbins Slough, Indian Prairie/Lake Istokpoga and Fishing Eating Creek.



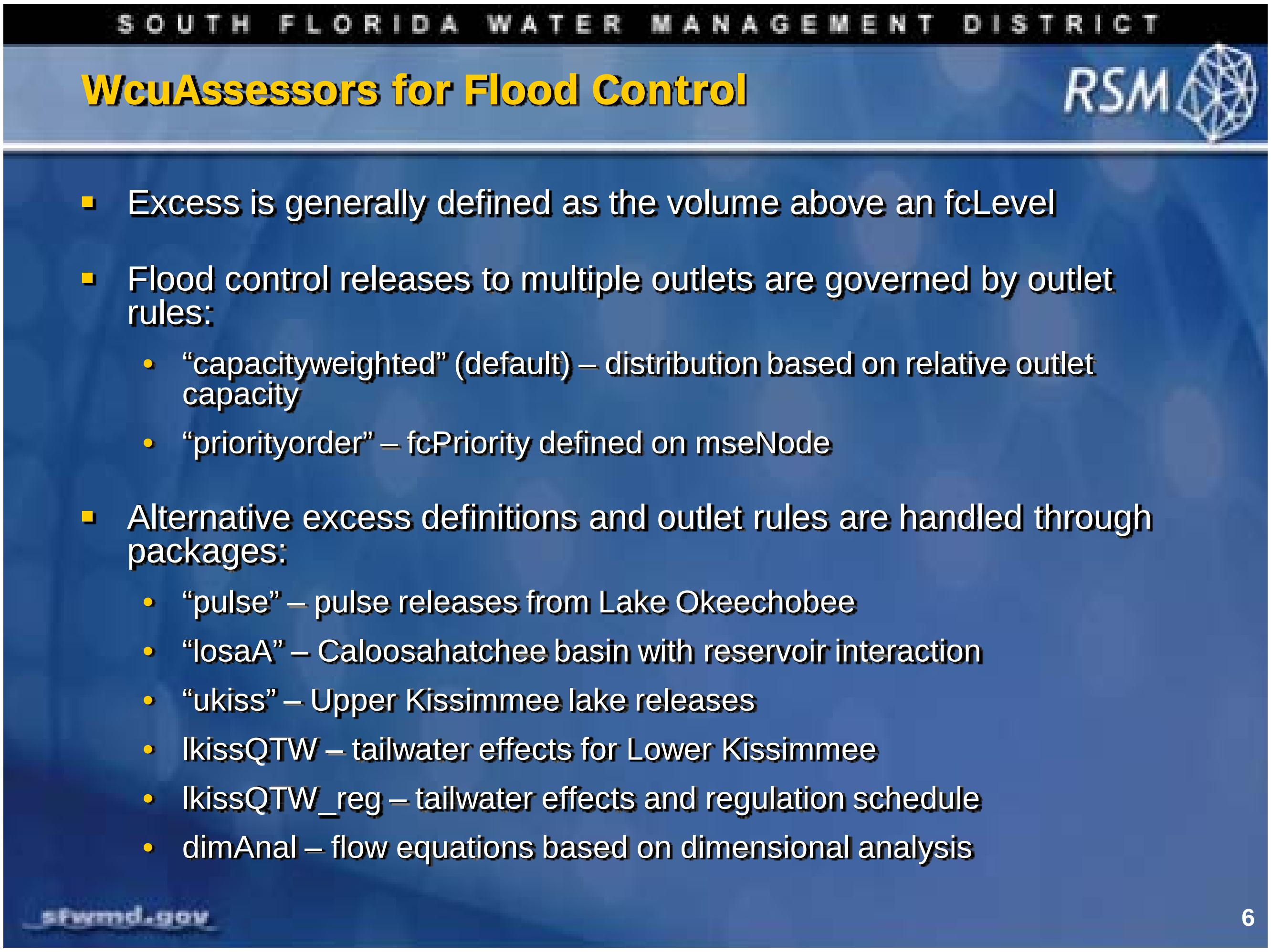
The linked-node RSM is implemented using the MSE network with assessors to determine the regional needs. The WCUs represent the lakes and basins in the system which is represented by the MSE nodes. The inflows/outflows from the associated watersheds are represented by HPMs and external boundary conditions. Assessors are used to quantify the need (flood control, water supply, etc) in each WCU. Coordinators are used to meet the needs of the WCUs regionally through coordinated releases at managed structures in the MSE Network. This approach has been implemented through other models used in south Florida.



These are the available assessors. This is the basic C++ object diagram for assessors. Under the flood control (FC) objects there is a need for specialized methods and procedures for the FC functions of the different waterbodies. Any kind of waterbody that can be assigned as a WCU needs a set of functions for FC. This is good for the generic waterbodies. For special WCUs specific assessors or "packages" are developed. When a new set of rules for water supply (WS), environmental enhancement (EE) or FC are required, we first need to understand what the rules are and how they are meant to be implemented. Then we need to know how the rules affect the flow at the inlets and outlets. Once we know that, we go to the base assessors to see if it fits any currently available tools. If an assessor is similar, we can develop a variant of that assessor. One advantage to this approach is that once a set of rules is created into an object, it is available for any of the different assessors to access. Another important method available through the wcuAssessor is the profiler. The profiler assesses all of the inflows/outflows for a reach and estimates what the profile of the canal will be. It uses that information to help determine what the WCU inflows and outflows ought to be. As different approaches are developed for managing water resources in the future, there will be greater use of these methods. There is a one-to-one correspondence between these assessors and the input xml.



The water supply assessor determines the amount of water necessary to maintain the specific water level in the WCU. There are several options for applying the WS assessors. These include alternative methods of applying the demand among multiple inlets and similarly for multiple outlets. Specific "packages" have been created for selected structures and WCUs for applying a specific set of flow equations and management rules. The parameters and the input time series for the packages are specified in the input XML.



The FC assessor determines the amount of water that needs to be released from the WCU. Where there are multiple outlets the amount of water released through each outlet is determined by the weighted design capacity of each structure or by management defined priority. For selected WCUs there are specific packages of management rules and structure flow equations. These include the following:

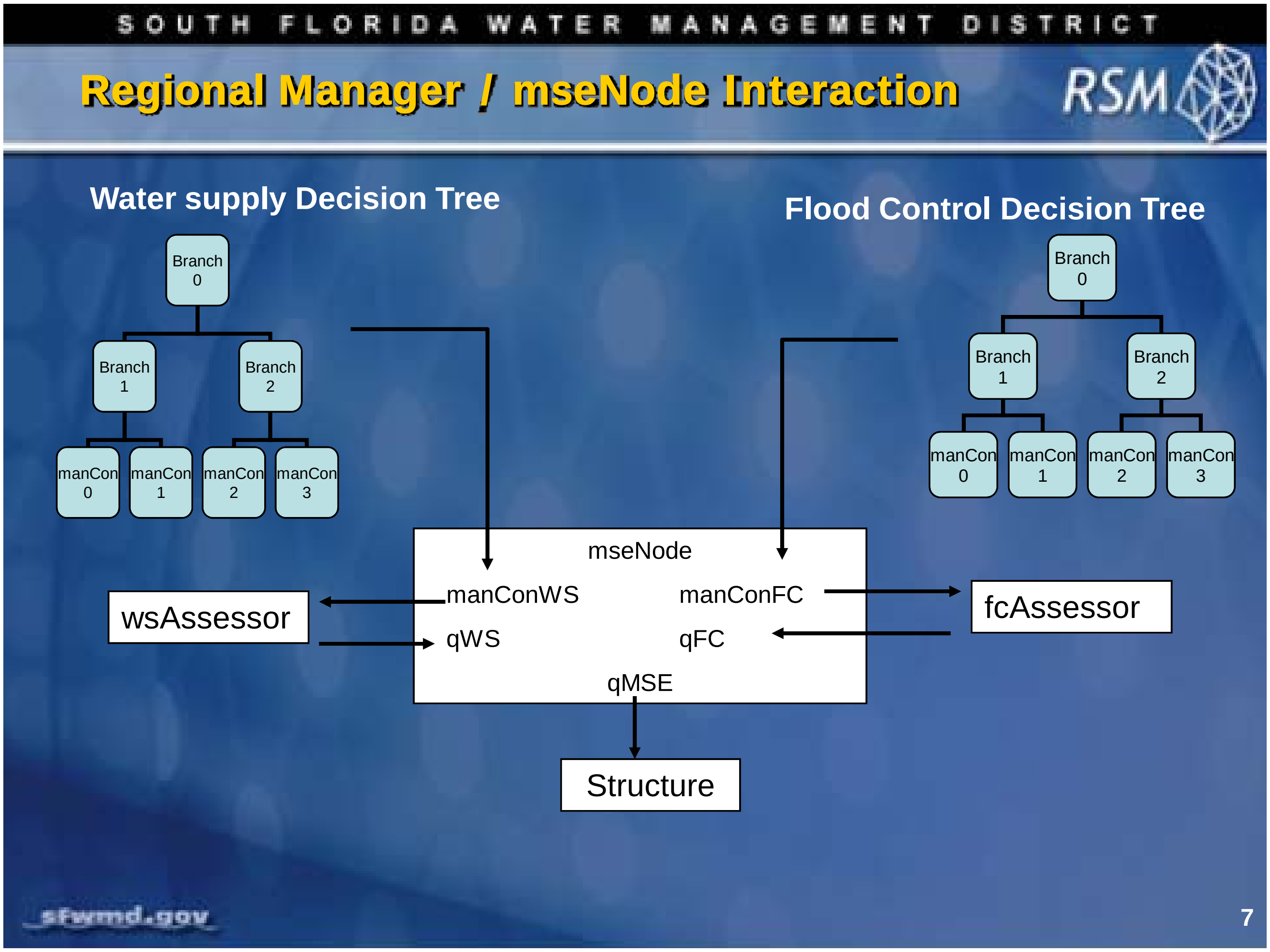
flowProg - District's FLOW program

ukiss – original KROUTE model (Fan, 1986) aka FLOW

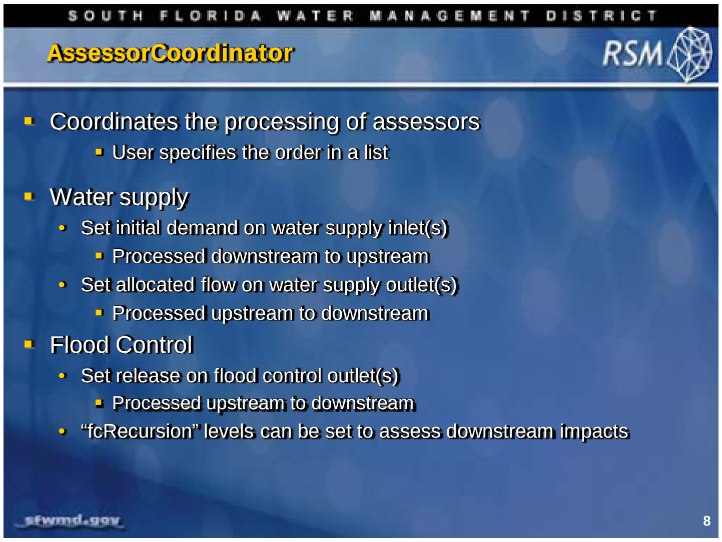
ukissA - ukiss package with a user specified tail water head feature

ukissB - ukiss package with modifications to address large fluctuations and unrealistic flow estimates when tailwater > crest elevation (EarthTech and Hydrologics, 2006). Currently used in kub model for all spillways

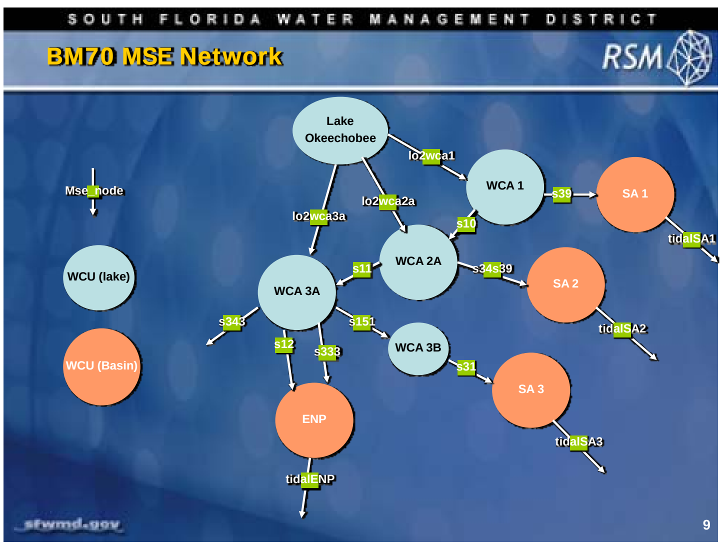
dimAnal - flow equations based on dimensional analysis (Ansar et al, 2005)



The regional managers are used to implement the regulation schedules and regional management rules for flood control, water supply and environmental protection. The regional management is implemented through decision trees. At each mseNode the wsAssessor and the fcAssessor determine the amount of flow at each structure and the regional manager determines whether the structure is open or closed based on the beginning of the time step state variable values.

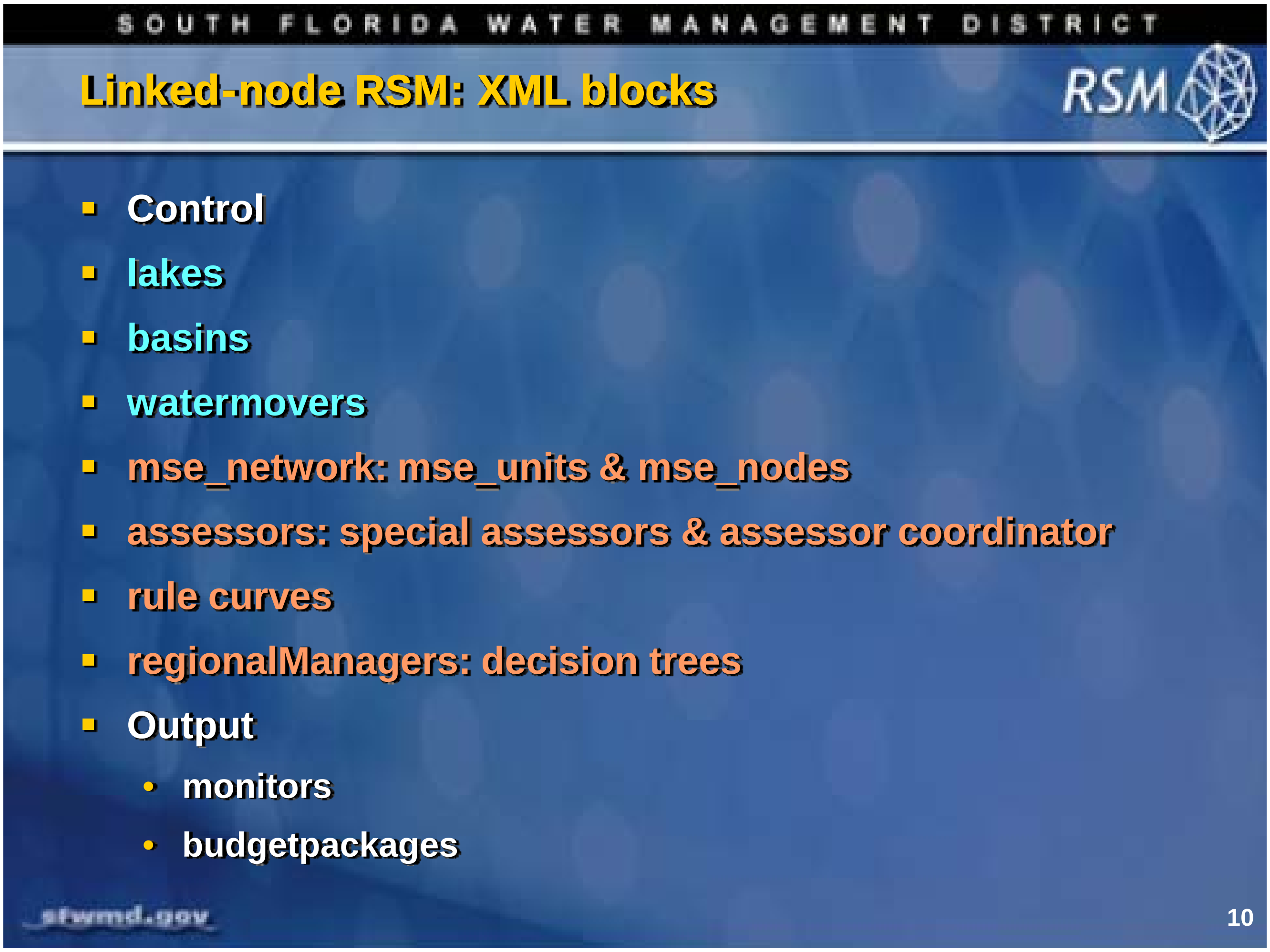


The assessor coordinator determines the order in which the water supply and flood control features are implemented. This may be obvious in a linear series of lakes and basins but more complicated where there are branches and multiple inflows to Lake Okeechobee (LOK). The inlet and outlet releases serve as boundary flows to upstream and downstream WCUs. The <**fcAssessor**> and <**wsAssessor**> specifications are distributed in the MSE Network with their respective WCU.

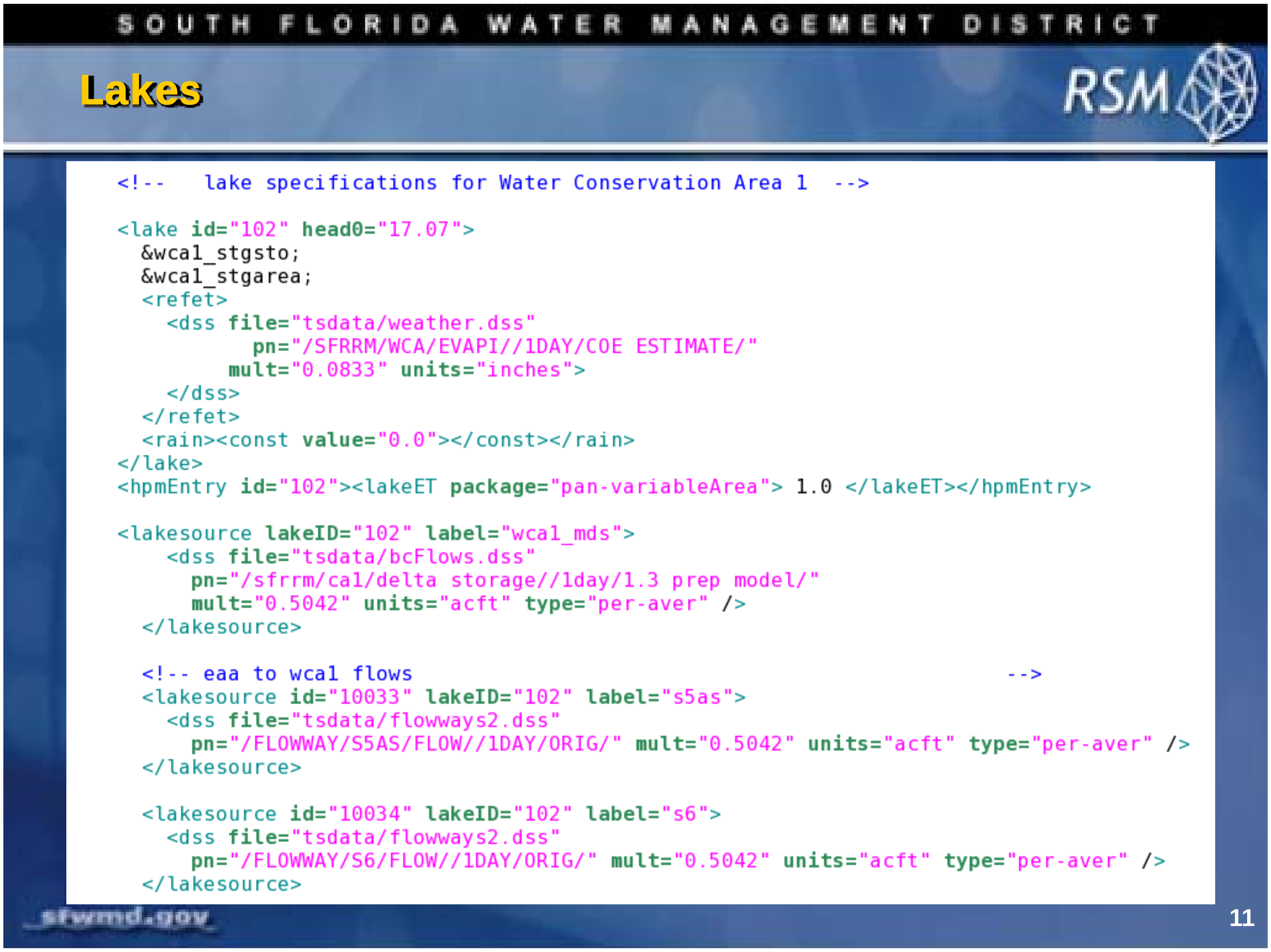


This is an illustration of the MSE Network approach used in the linked-node RSM for refining the configuration of the water management system. The system is defined as a set of lakes and basins connected by the MSE nodes. This is fully defined by the MSE network. The XML files are presented in benchmark BM70.

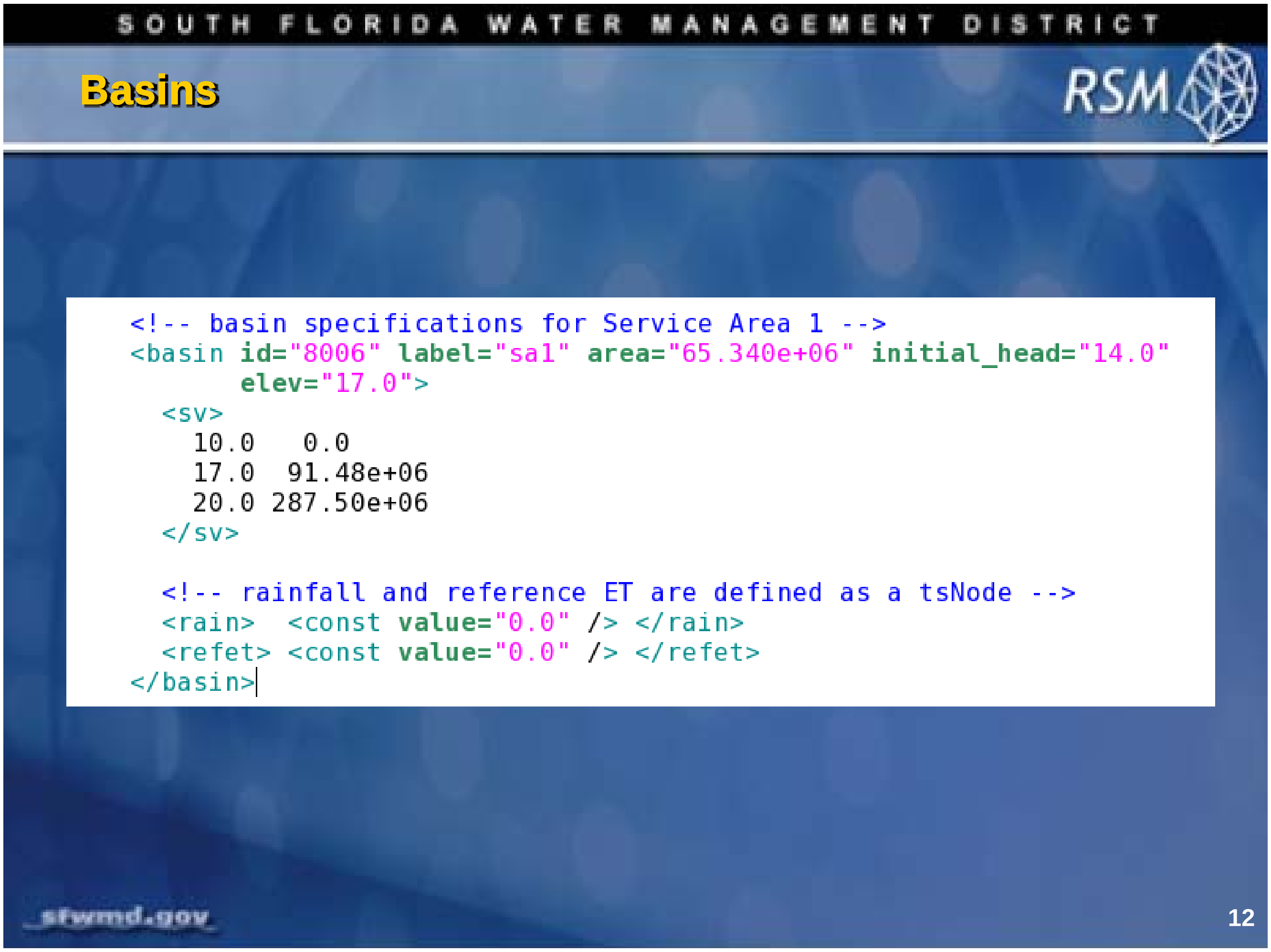
There are several types of assessors used in this benchmark. There are assessors for determining water supply using various methods, such as comparing current water levels with defined schedules, time series on constant values. There are FC assessors for lakes. The processes are different from those FC assessors used for basins and meshes. There are specific assessors made for selected WCUs; one specific FC assessor which was developed for WCA-3A. There are multiple outlets and there is a specific rule for determining how much water is released through the specific structures for WCA-3A. On the source code side, there is a subclass of the FC assessors that contains the specific rules. On the XML side, there are additional specifications for the BasinFC assessor. This code exists for the basin waterbody, but not for a mesh. The AssessorCoordinator will handle them the same way in the order presented in the XML input file. There are FC assessors for each of the waterbodies. There are WS assessors for selected waterbodies. The AssessorCoordinator implements the appropriate assessors in order. A comprehensive linked-node RSM is being developed to include all major operations within the Central and Southern Florida Flood Control Project (CSFFCP).



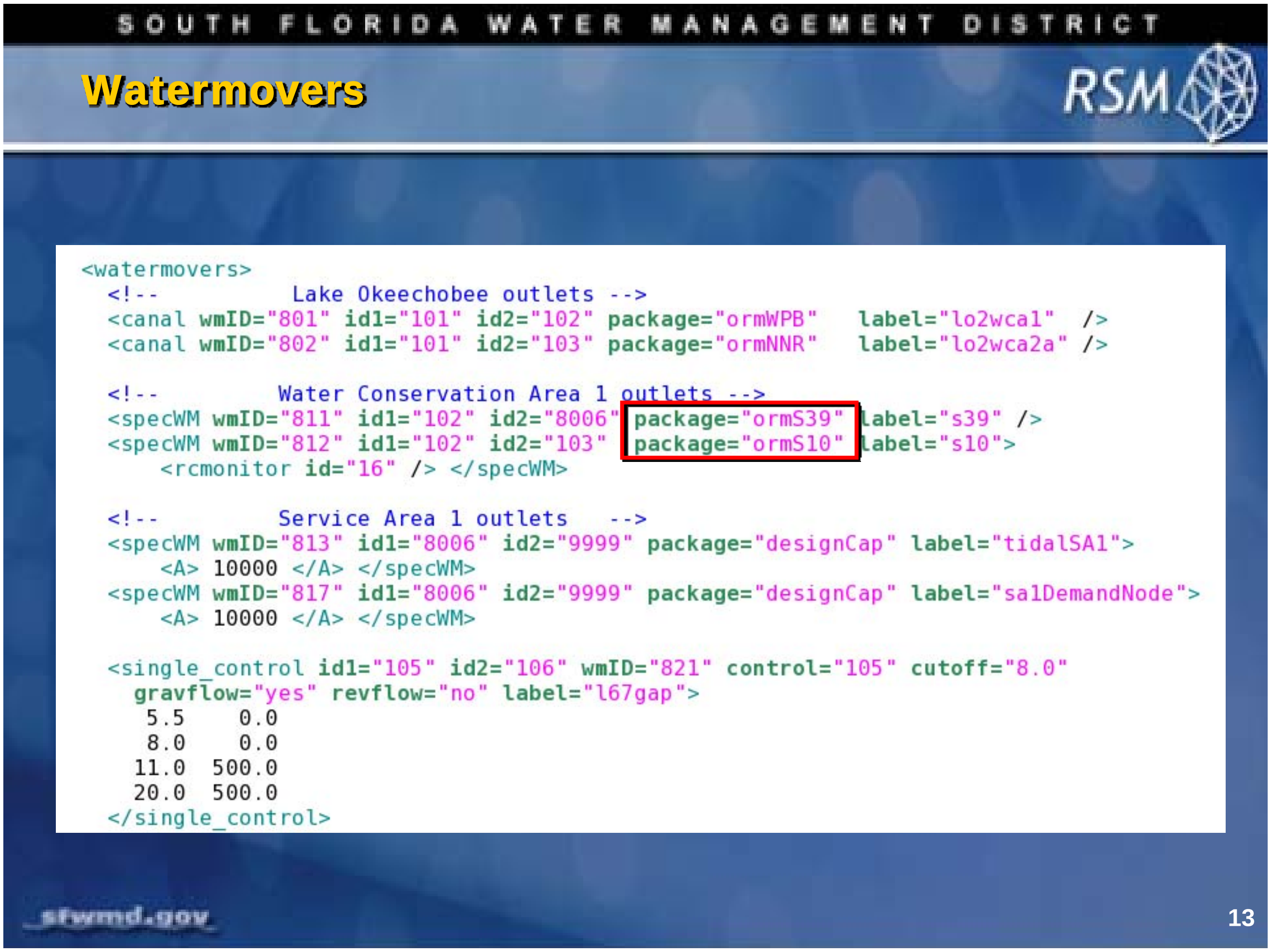
The typical linked-node RSM implementation contains these XML blocks. The HSE components contain the description of the waterbodies used in the mse_units are commonly lakes and basins, as well as the watermovers which are managed by the MSE. The MSE consists of the mse_network which describes the WCUs in the <**mse_unit**> elements and <**mse_node**> elements.



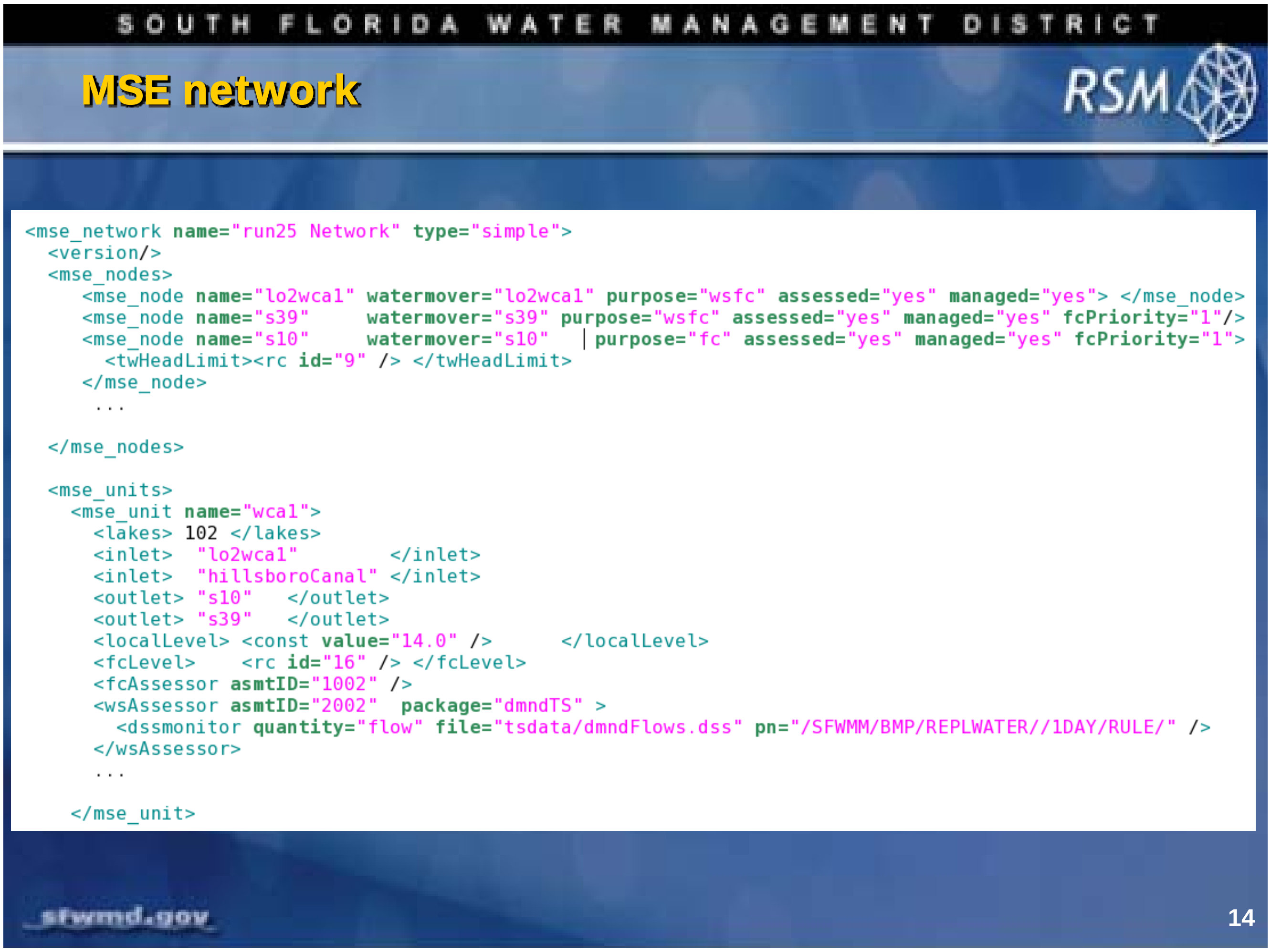
The typical lake specification includes the stage-volume and stage-area relationships, appropriate rainfall and refET sources data. The <**hpmEntry**> provides the evaporation function for the lake based on the lake area. There can be boundary condition inflows and outflows that are included as historical time series, outputs from other models are rule curves containing design flows.



The basins are defined in a similar way in the XML files. There is a stage-volume relationship that defines the water storage at different stages taking into account the change in topography in the basin and the storage capacity of the soil, microtopography and the surficial aquifer. The surface area may be fixed or it may be adjusted for the area of the reservoirs and STAs implemented in the basin. In this case the data was taken from the South Florida Regional Routing Model: with the base at 10.0 ft and the average land surface (elev) at 17.0 ft. The storage is 1500 ac-ft (65.34e06 ft) and "active groundwater storage" with 0.2 ft/ft soil the storage and the land surface is 65.34e06 ft^2. In this instance the rain and refET are set to zero and the net runoff for the basin is applied as a boundary condition (not shown).



The watermovers include specialized watermovers <**specWM**> which are controlled mse_nodes and typically are assigned a design capacity. Other <**specWM**> are managed using specific "packages" that contain specific structure equations and local management constraints that have been published in various SFWMD and USCAE documents. Other watermovers are defined by the canals on which they occur and the specific calculation packages for allowable structure discharge based on the available capacity. It is also possible to use simple watermovers such as <**single_control**>, modeling a simple pump. Each of these watermovers except the pumps are managed using the mse_network.



The MSE network is composed of a group of WCUs described by <**mse_units**> and the connecting watermovers representing structures at <**mse_nodes**>. The <**mse_nodes**> identify the associated watermover, the purpose of the MSE node and whether the node is assessed and managed.

The <**mse_unit**> identifies the type of WCU; lake or basin, inlets, outlets, control levels and the associated assessors. For the FC assessor the standard default assessor is applied. For the WS assessor, a specifc package, dmndTS, is applied as a time series of flows provided by the SFWMM model output to the water supply requirements for WCA1. For this package the maintenance level is not provided.

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Specialized Assessors

RSM

```
<!-- ================================================================
                  Assessor for S12 flood control release
     ================================================================  -->
<statassessor asmtID="901" package="TwoPointInterp" >
  <A> 1125 0 </A>
  <B> <rcmonitor id="13" /></B>
  <C> <rcmonitor id="12" /></C>
  <D><lakemonitor id="105" attr="head" /></D>
</statassessor>
<!-- ================================================================
                  Assessor for S333 flood control release
     ================================================================  -->
<LinWeightedConst asmtID="902" value="1375">
  <A><rcmonitor id="13" /></A>
  <B><rcmonitor id="12" /></B>
  <target><lakemonitor id="105" attr="head" /></target>
</LinWeightedConst>
<!-- ================================================================
                  Assessor for S31 flood control release
     ================================================================  -->
<TEMultipler asmtID="903">
  <tableEntries>
    0.10    0.0
    0.17    0.25
    0.23    0.50
  </tableEntries>
  <A><tsmonitor id="7"/></A>
  <B><wmmonitor wmID="808" attr="maxflow" /></B>
</TEMultipler>
```

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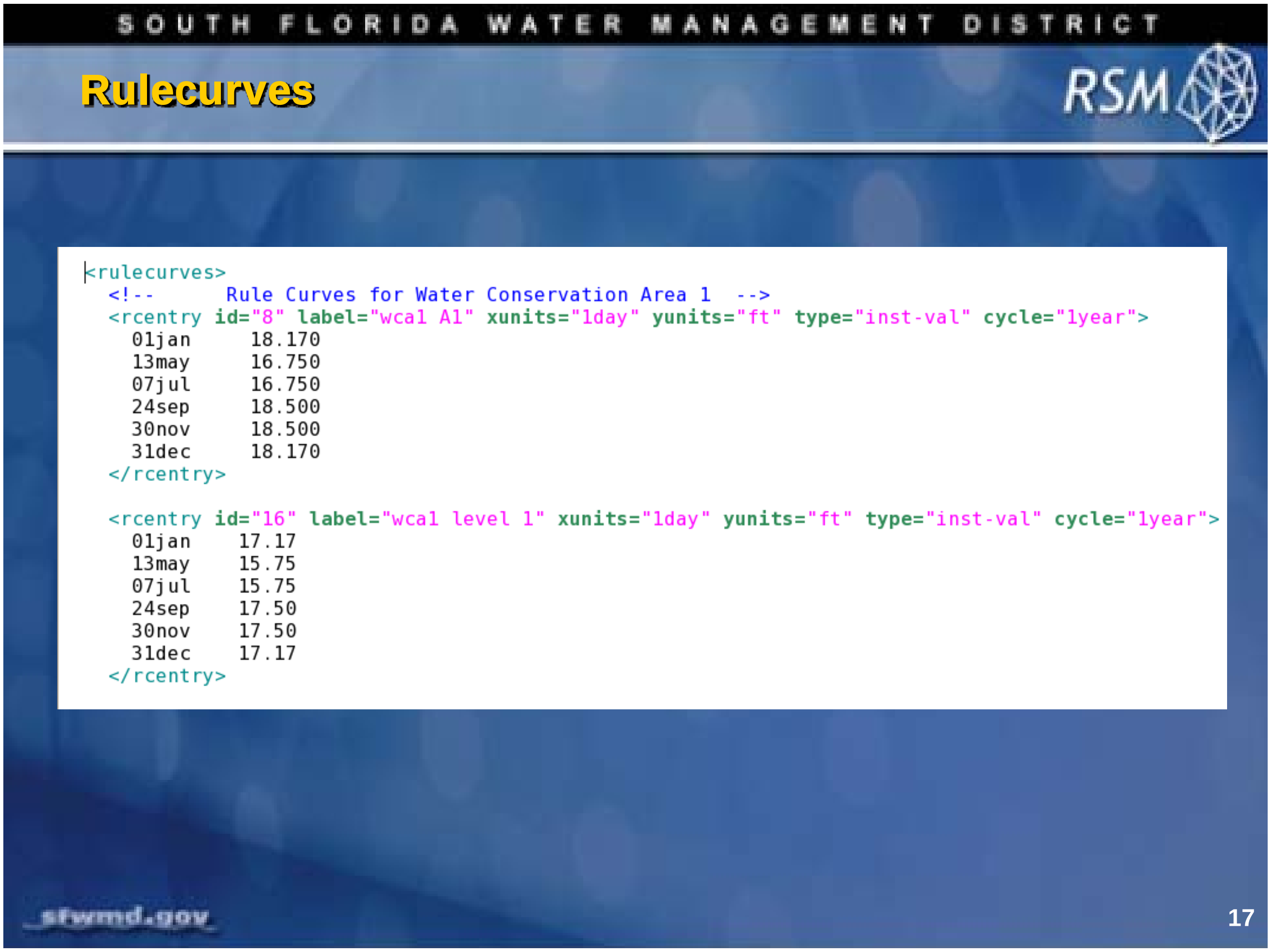
The first assessor, <**statassessor**>, is the state assessor with the two point interpolation package. This assessor will assign the flow to the mseNode based on the location of the lake head between the two rule curve values for that day and then apply that ratio to the flow range of 0 to 1125.

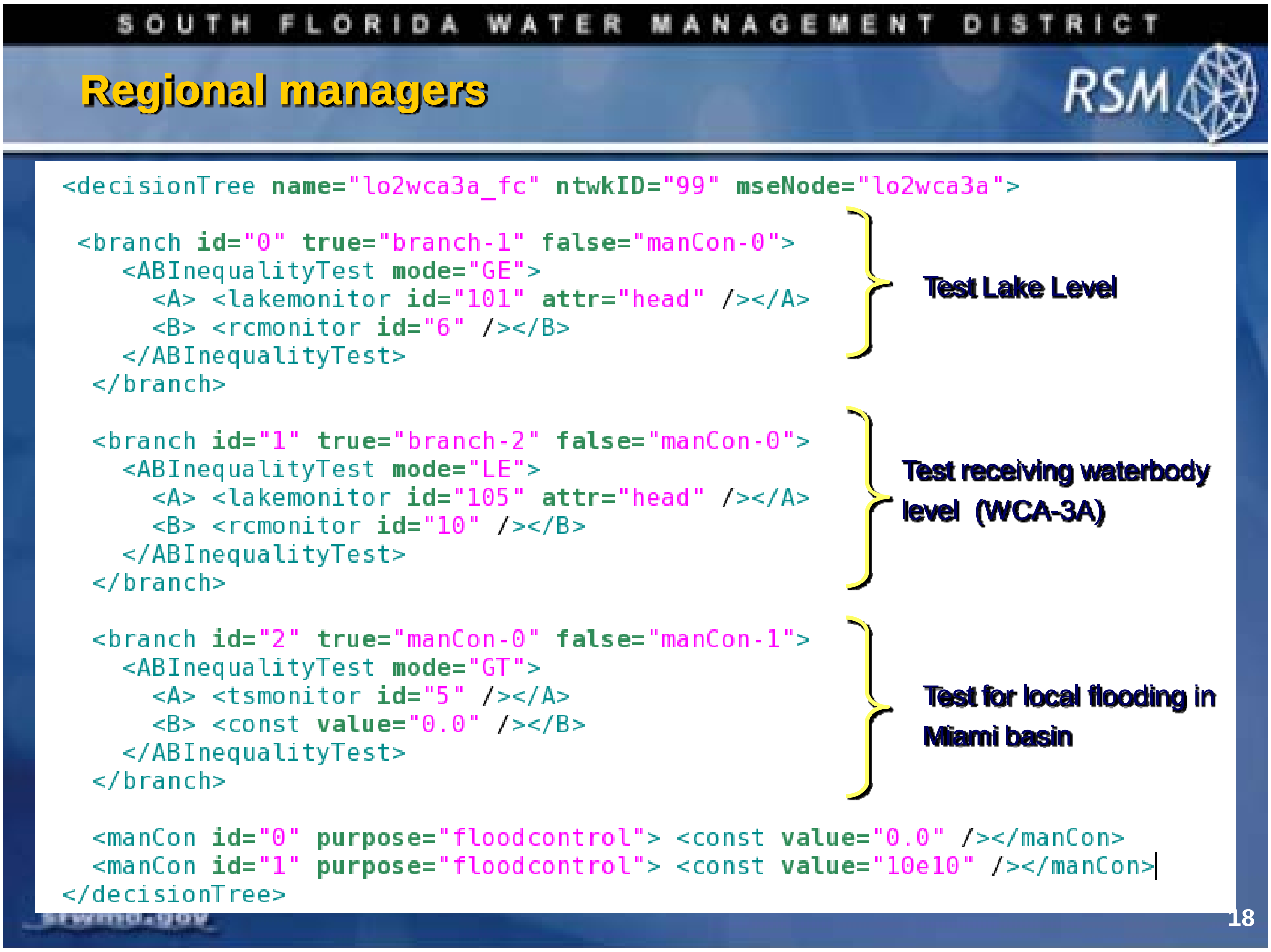
The second assessor, <**LinWeightedConst**>, is similar to the first assessor except the range of possible flows is not provided and the assessor outputs a value between 0 and 1.

The third assessor, <**TEMultipler**>, is the table entry assessor. In this case the maxflow is reduced by 0%, 25% or 50% based on whether the <**tsmonitor**>, which monitors rainfall, exceeds the values in the table.

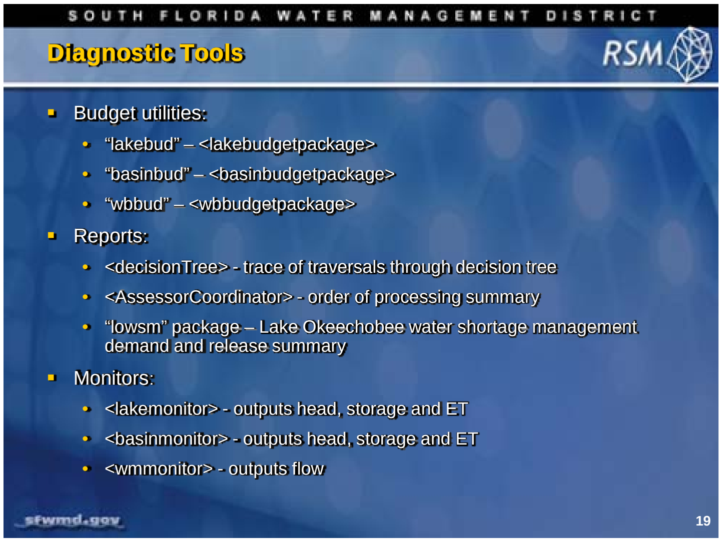
The <**pulseRelease**> assessors are used to set the flow release from a selected waterbody (LOK) based on the WSE decision tree (see slide 25-26). This is for managing the flows at structure "s308". Depending on the lake level and other conditions, pulse releases are initiated from the lake and the pulses consist of specific flows over a ten day period. This example demonstrates the flexibility of the assessor construct for setting flows for individual structures.



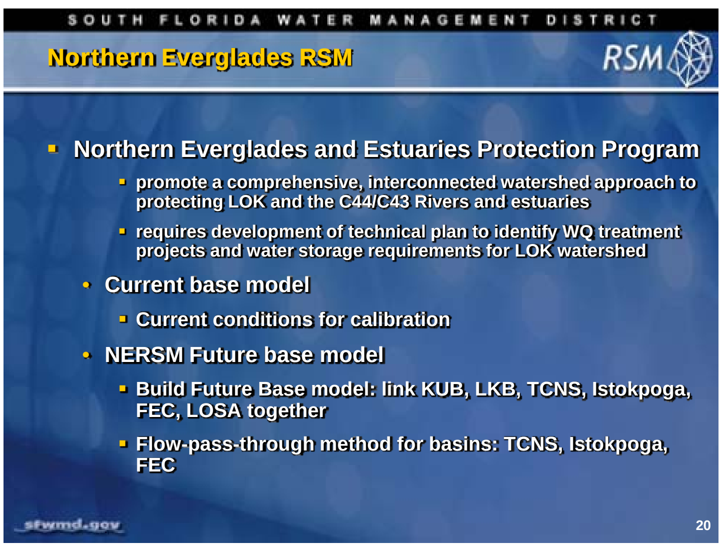
Rule curves are used to represent cyclic stage schedules for lakes, water conservation areas, reservoirs and STAs. These typically allow for a higher stage during the dry season.



This is decision tree for LOK to WCA-3a flow-way from Benchmark 70. This XML code describes a decision tree which specifies the management constraints applied to the release of water. This decision tree controls how much flood control water can be passed from a lake to a WCA. First, the level in LOK is compared to a rule curve for the stage schedule. If the stage is below the curve (A<B) control passes to manCon-0 which sets the flow to zero. If stage is greater than the curve, the stage in WCA-3A is compared to the regulation stage schedule. If the stage is greater than the rule curve, manCon is set to zero. If stage is less than the rule curve, control is passed to the last decision test. If the tsmonitor is greater than zero the manCon is set to zero, otherwise the manCon returns a very high value, essentially setting the flow control to the highest possible value.



There are several outputs that are useful for monitoring the performance of the model as well as determining where there are problems with the model. The budget utilities are used to check the water budgets for each of the WCUs to ensure that the results are appropriate. There are several reports that document the structure flow decisions and implementation of the various structure or WCU specific packages. These are useful because of the complexity of the decisions and wide variety of possible system states. The standard monitors are available for all state variables and dynamic variables.

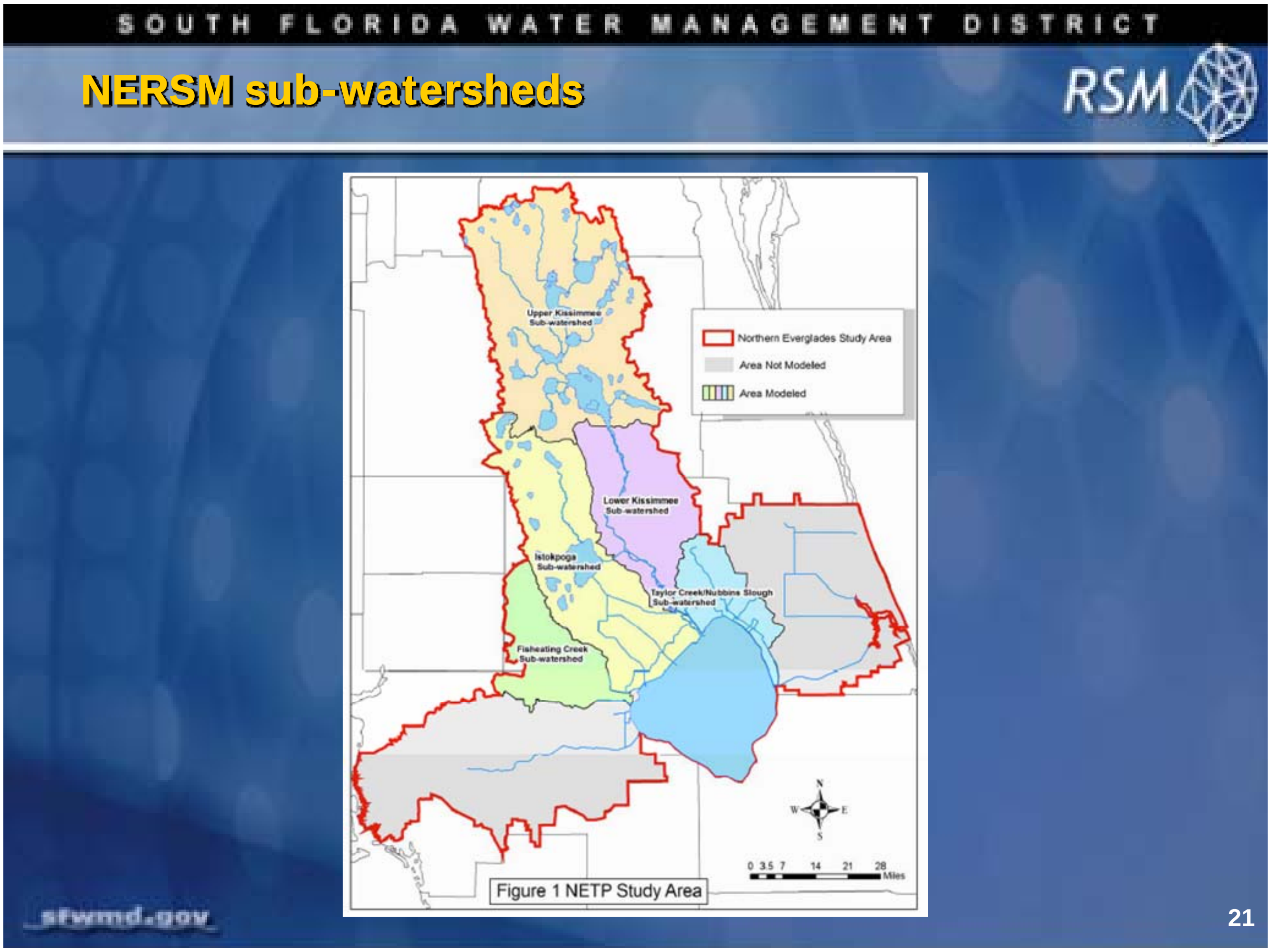


The model should reflect conditions around the year 2015 when all Acceler8 projects are in place. The future condition also assumes that the Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization projects are in place.

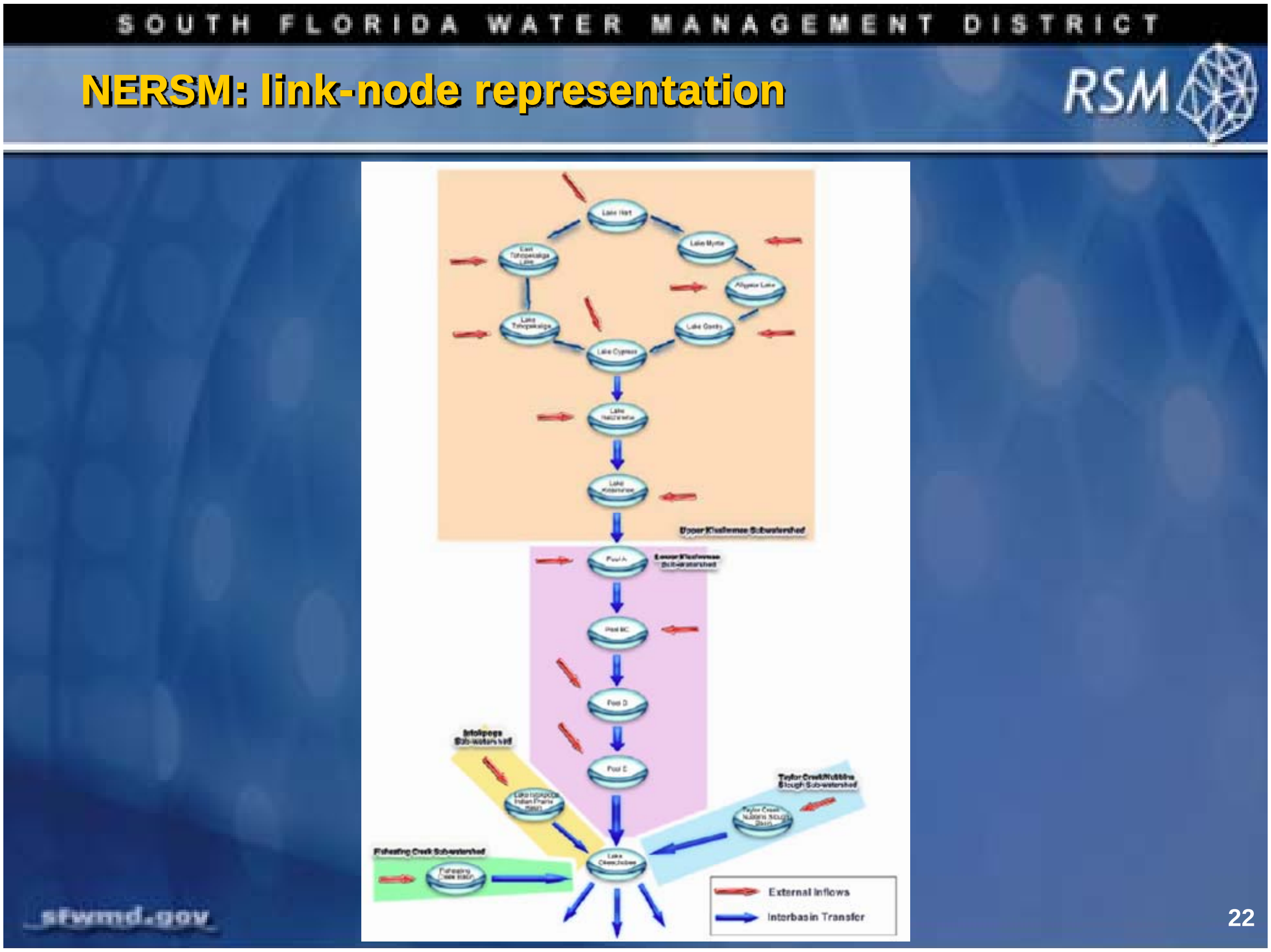
Basins: flow-pass-through method. Taylor Creek/Nubbin Slough; Lake Istokpoga Basin; Fisheating Creek Basin are all simulated as flow-pass-though: historical flow is imposed as boundary conditions. The basin is not simulated in the model due to the lack of detailed topography in this region. The flow will pass through the basin and discharge into LOK. Historical flow patterns from these basins into LOK are assumed to be preserved while simulating management measures.

In different alternatives, the flow in the basin will be diverted to reservoirs and STAs. Rainfall-runoff relationships and drainage/routing characteristics within a sub-watershed are assumed not to change from before to after management measures are operational. The volume of divertible runoff from a management measure, such as a reservoir, is equal to the total historical sub-watershed outflow reduced by the ratio of the total footprint of the management measure and total area of the sub-watershed.

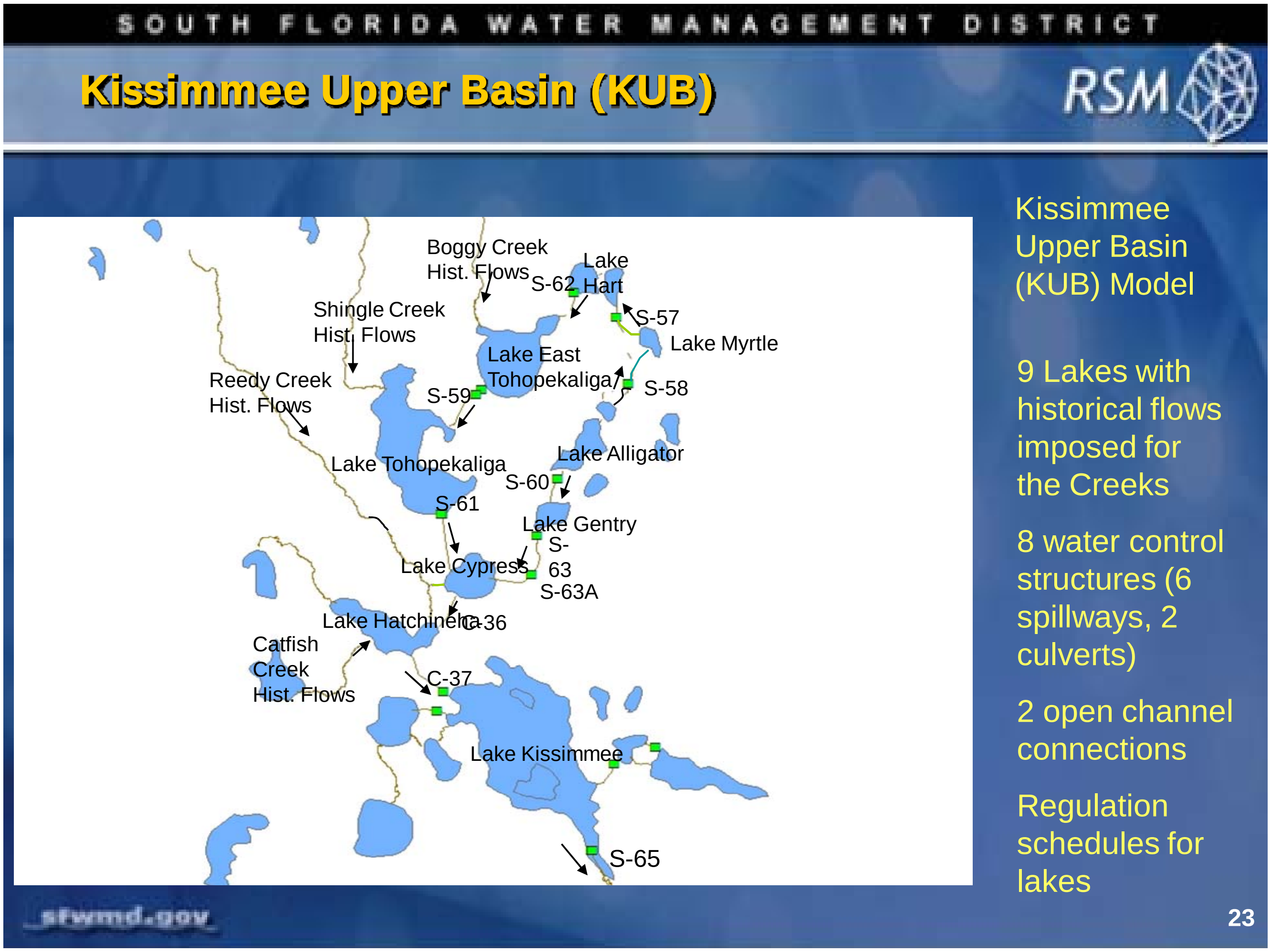
More details on the plan and the modeling can be found at https://my.sfwmd.gov/northerneverglades.



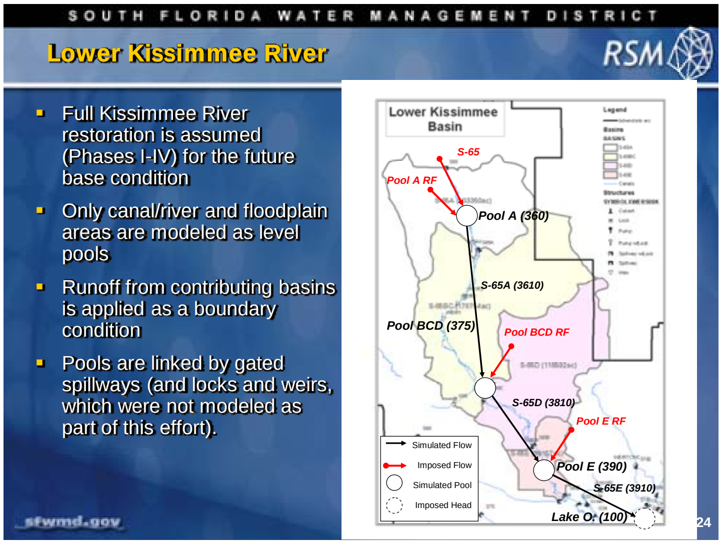
The Northern Everglades model simulates the five basins of the Northern Everglades region as well as LOK. The estuarine basins are not included in this version of the model. The model should reflect conditions around the year 2015 when all Acceler8 projects are in place. The future condition also assumes that the Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization projects are in place. Period of simulation is 1970 to 2005. Model timestep is daily.



NERSM – basin budget/link-node implementation of the RSM. It is the first regional model that links the simulation of the Kissimmee Upper Chain of Lakes to the simulation of LOK. The various components of the system will be represented by lakes and basins with watershed inflows as boundary conditions.



The Kissimmee Upper Basin (KUB) model is designed to simulate the lake system in the Upper Kissimmee basin. Lakes are assumed to be level pools and storage routing is based on mass balance. Watershed inflows to the lakes were based on the datasets developed as a part of the calibration of the UKISSWIN model. Historical flows obtained from USGS for Shingle, Boggy, Reedy and Catfish creeks were also imposed as boundary conditions for the lakes Toho, East Toho, Cypress and Hatchineha. For Reedy Creek the flow split was assumed to be 70% into Lake Hatchineha and 30% into Lake Cypress. The KUB model simulates the management of the KUB lakes and canal system with a set of management rules implemented in the model as regulation schedules, gate operation criteria, and rules of operation of the water control structures. Rainfall and ET data were derived from the time series developed for the SFWMM (extended "super grid") for the climatic period of record 1970-2005.



Level pool approximation is reasonable for Pools A & E, where the main conveyance element is the channelized Kissimmee River. However, river head drops on the restored portion of the river (Pool BCD) are expected to be significant.

Steady-state HEC-RAS model results show that lateral inflows (runoff) have a minor effect on the S-Q-H relationships for the pools (EarthTech, 2006). A single SV relationship was selected for each channelized pool by assuming no lateral inflows and the flows through the pool are equal to the design flow of the upstream structure.

For the restored portion of the Kissimmee River (Pool BC), these relationships were further manipulated and defined in terms of average heads at the upstream and downstream ends of the pool.

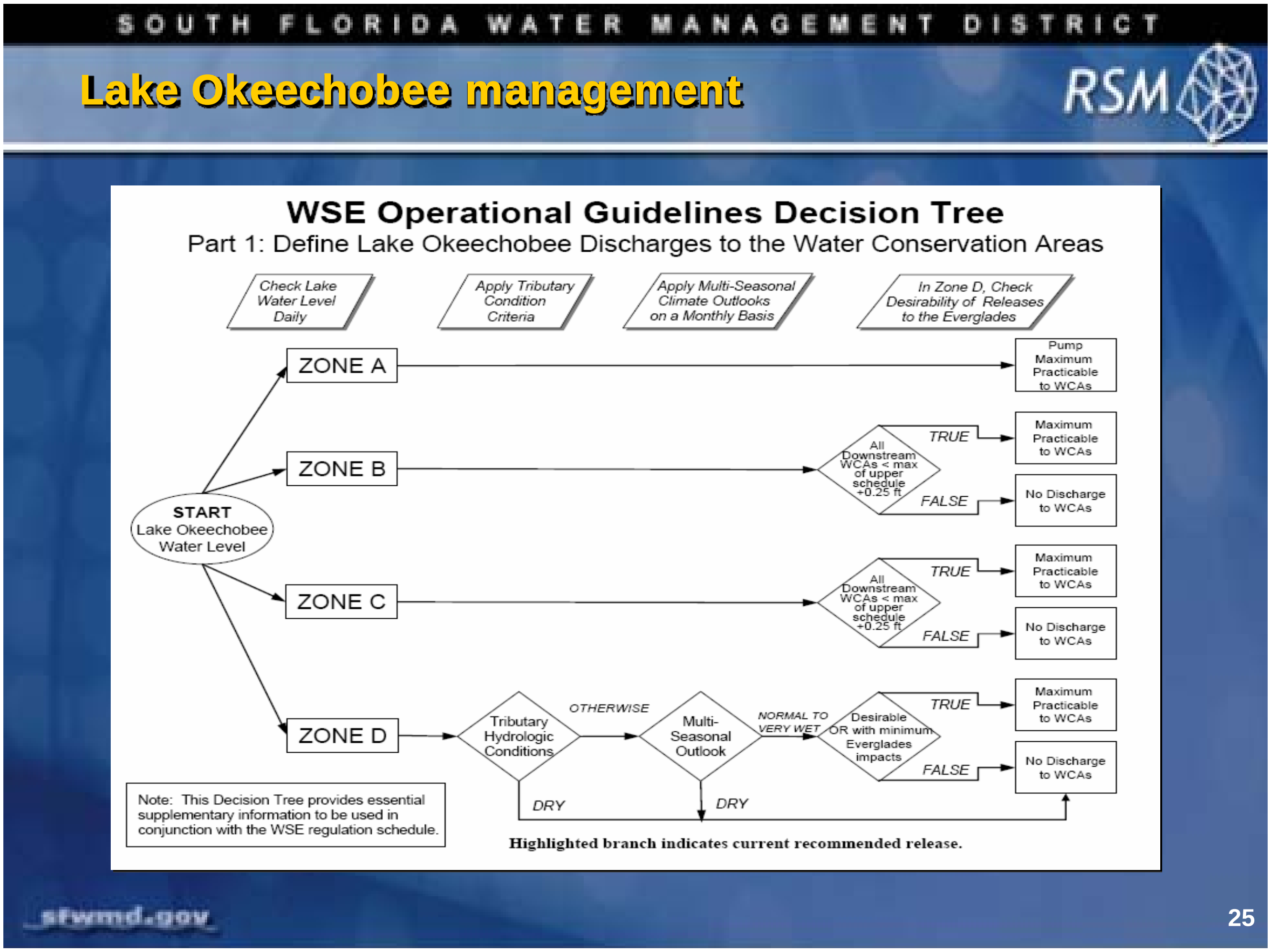
Based on the HEC-RAS simulations, flows through Pool BCD are only dependent on S-65A TW stages (a mild slope condition develops where water depth approaches normal depth at the upstream end of the reach, i.e. Manning's equation applies). Therefore, a Q-TW relationship was used at S-65A to account for local tailwater constraints.

Consistent with the SFWMM methodology for translating S-65 into S-65E flows, lateral inflows were estimated based on historical S-65E – S-65 flows (9.8 in/yr). Runoff was prorated based on each contributing basin area and the resulting time series were imposed as boundary conditions to each level-pool.

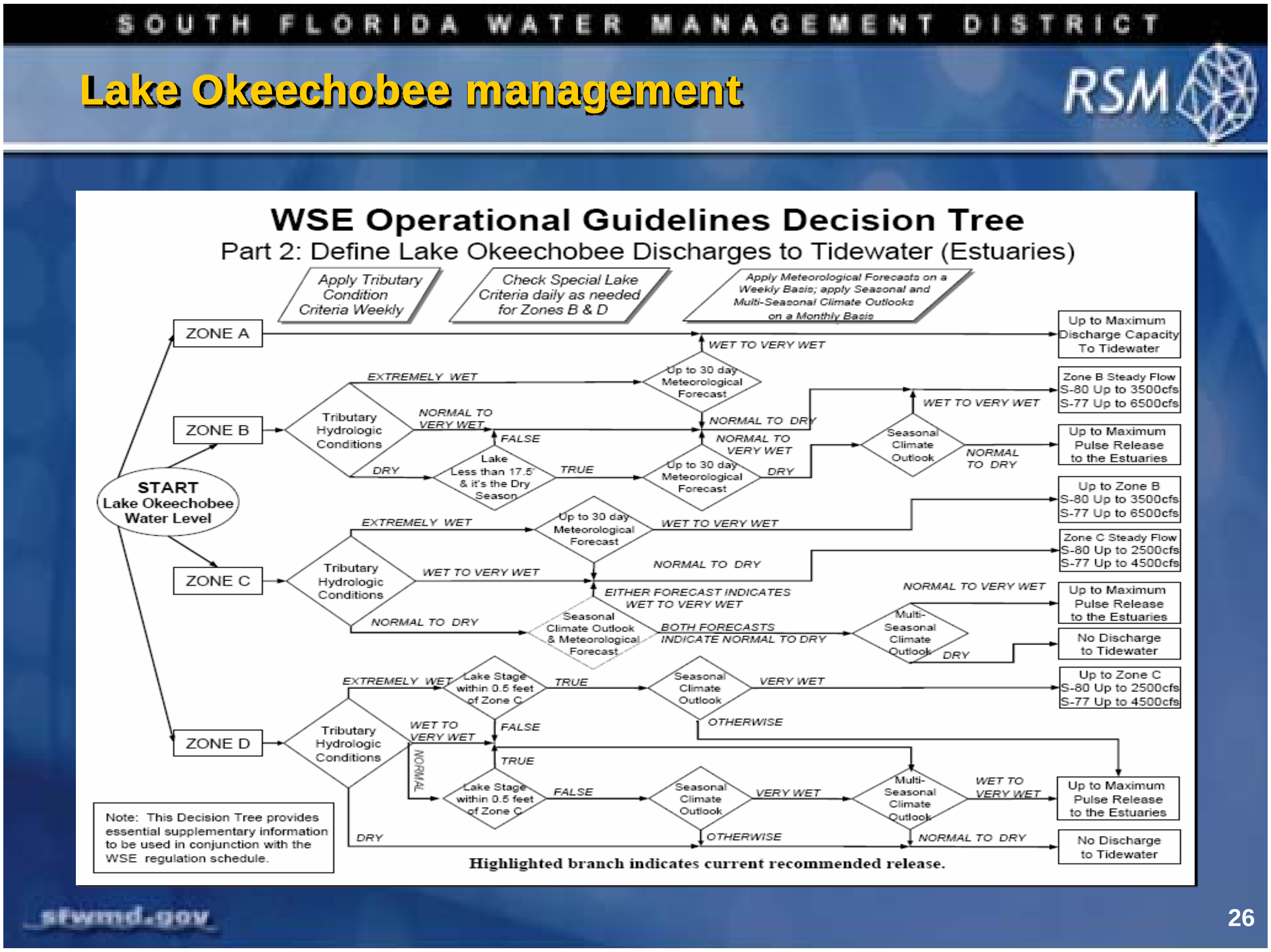
Rainfall obtained from the 1914-2005 2-mi x 2-mi rainfall binary developed for the SFWMM.

Reference ET obtained from the 1948-2005 2-mi x 2-mi binary file based on the FAO-56 Penman-Monteith reference equation.

Spillways are simulated based on new District rating curves developed from dimensional analysis (Ansar et al., 2005) and MAGO curves. Spillways are operated primarily for flood control, but in the future S-65D will also be operated to meet hydroperiod objectives in the restored Pool BCD.



The decision tree for LOK water release comes in two parts, discharges to the water conservation areas and discharges to the estuaries (next slide).



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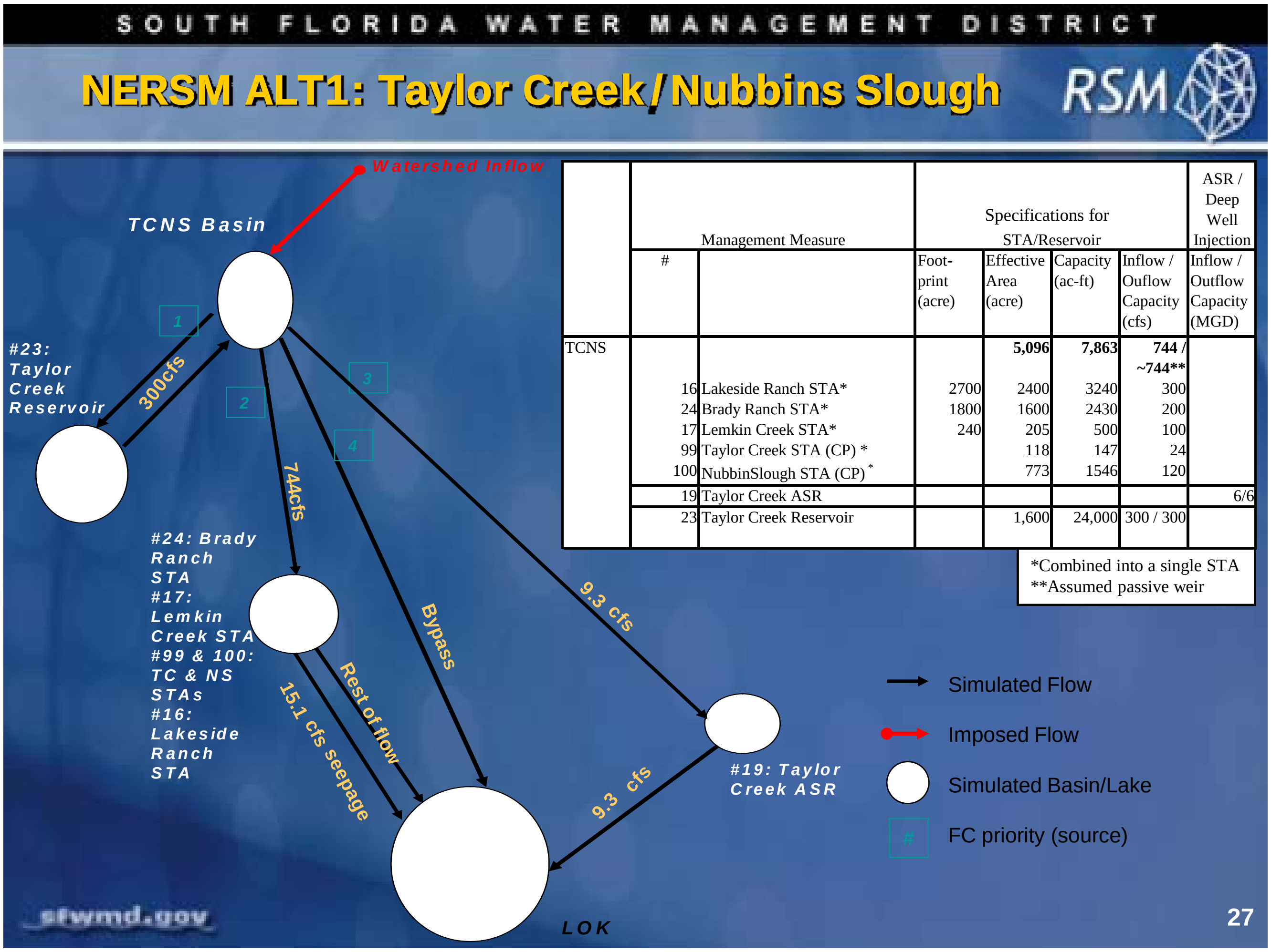


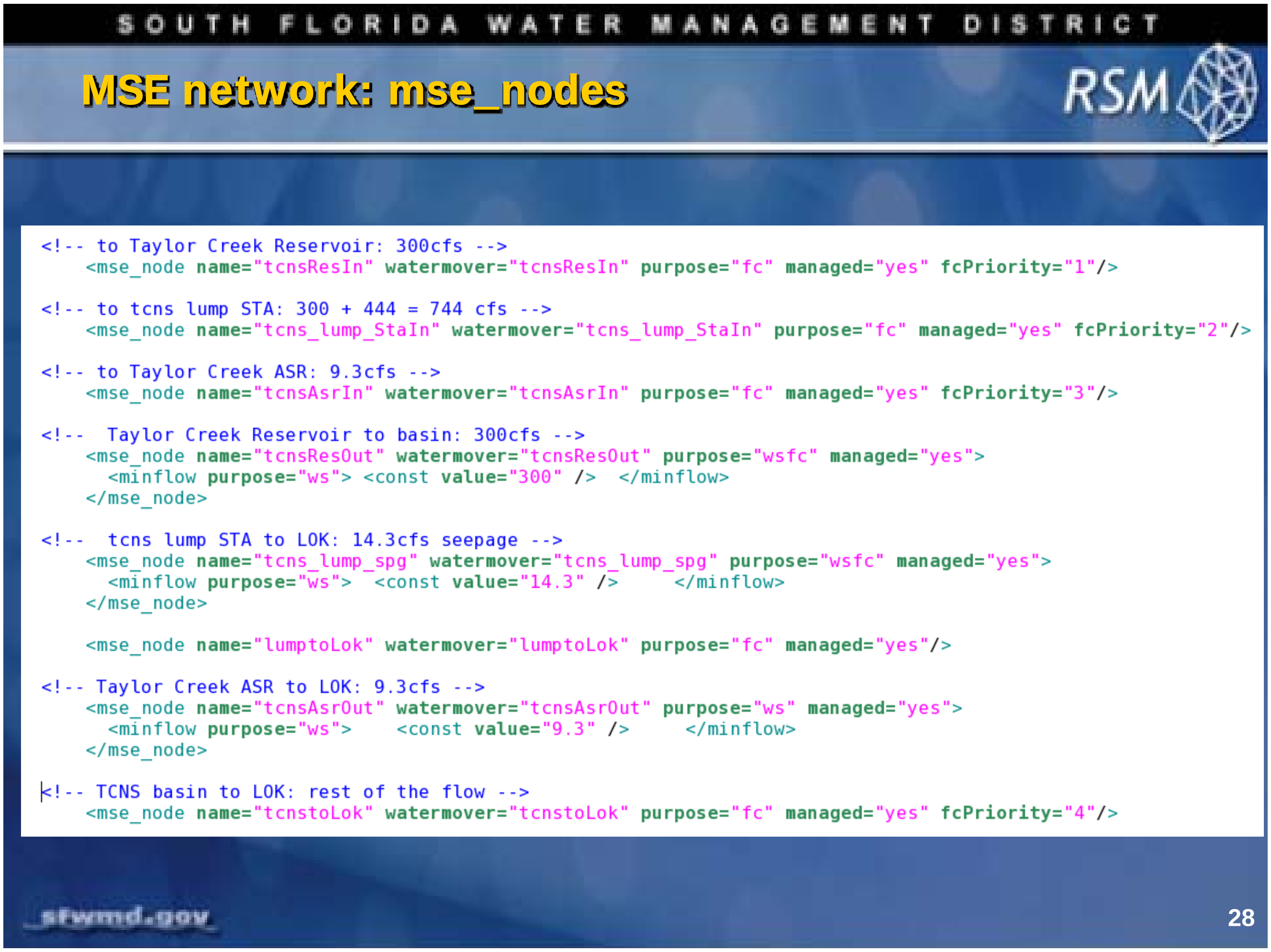
	Management Measure		Specifications for STA/Reservoir				ASR / Deep Well Injection
	#		Foot-print (acre)	Effective Area (acre)	Capacity (ac-ft)	Inflow / Ouflow Capacity (cfs)	Inflow / Outflow Capacity (MGD)
TCNS				**5,096**	**7,863**	**744 / ~744****	
	16	Lakeside Ranch STA*	2700	2400	3240	300	
	24	Brady Ranch STA*	1800	1600	2430	200	
	17	Lemkin Creek STA*	240	205	500	100	
	99	Taylor Creek STA (CP) *		118	147	24	
	100	NubbinSlough STA (CP) *		773	1546	120	
	19	Taylor Creek ASR					6/6
	23	Taylor Creek Reservoir		1,600	24,000	300 / 300	

*Combined into a single STA
**Assumed passive weir

Several alternative plan formulations for future projects to improve water supply and water quality in the Northern Everglades watershed. Each alternative simulated several "management measures" defined as structural or water management changes to the system. The alternative 1, ALT1, management measures for Taylor Creek/Nubbins Slough includes several STAs, an ARS and a reservoir. The STAs are combined together into a single STA for modeling purposes. The system is simulated as one basin (TCNS) and several lakes. The NETP required the simulation of four alternative groups of "management measures" to improve water supply and water quality in the Northern Everglades. This discussion includes the management measures for Alternative 1.

NOTE:

The seven management measures identified in the table are grouped into three features in the model. The table can be found on the Northern Everglades website at http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_koe/pg_sfwmd_koe_northerneverglades in Appendix B (Northern Everglades Regional Simulation Model) of the Lake Okeechobee Watershed Construction Project, Phase II Technical Plan.



The MSE network consists of the <**mse_nodes**> and the <**mse_units**>. Inlet structures into management measures are defined as flood control <**mse_node**>s. First priority is to send excess to Reservoirs, then to STAs, thirdly to ASR, and the remainder downstream to LOK. The outlet structures discharge from the **`tcns_lump_StaIn`** and **`tcnsAsrOut`** when the stage in LOK falls below the water supply envelope at a rate defined by the <**minflow**> capacity (here fixed as a constant but could be a scheduled flow defined by season). This flow is in addition to the passive weir flow defined in the table in slide 27. Outlet structures also discharging when emergency stage/depth is exceeded are defined as flood control <**mse_node**>s.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

MSE network: mse_units

RSM

```
<mse_units>
    <mse_unit name="tcns">
      <basins> 501 </basins>
      <inlet>    "tcnsResOut"  </inlet>
      <outlet>   "tcnsResIn"  </outlet>
      <outlet>   "tcns_lump_StaIn"  </outlet>
      <outlet>   "tcnsAsrIn"  </outlet>
      <outlet>   "tcnstoLok"  </outlet>
      <fcLevel><const value="14.0" /> </fcLevel>
      <fcAssessor asmtID="500001"/>
      <wsAssessor asmtID="500201" inletRule="PriorityOrder" />
  </mse_unit>

  <mse_unit name="tcns_res">
         <lakes> 591 </lakes>
         <inlet>  "tcnsResIn"  </inlet>
         <outlet>  "tcnsResOut"  </outlet>
         <resLevel>  <const value="35.6"/>   </resLevel>
         <fullLevel> <const value="50.5"/> </fullLevel>
         <fcLevel>   <const value="51.0"/> </fcLevel>
         <fcAssessor asmtID="500004" />
         <wsAssessor asmtID="500014" inletRule="PriorityOrder" />
  </mse_unit>
```

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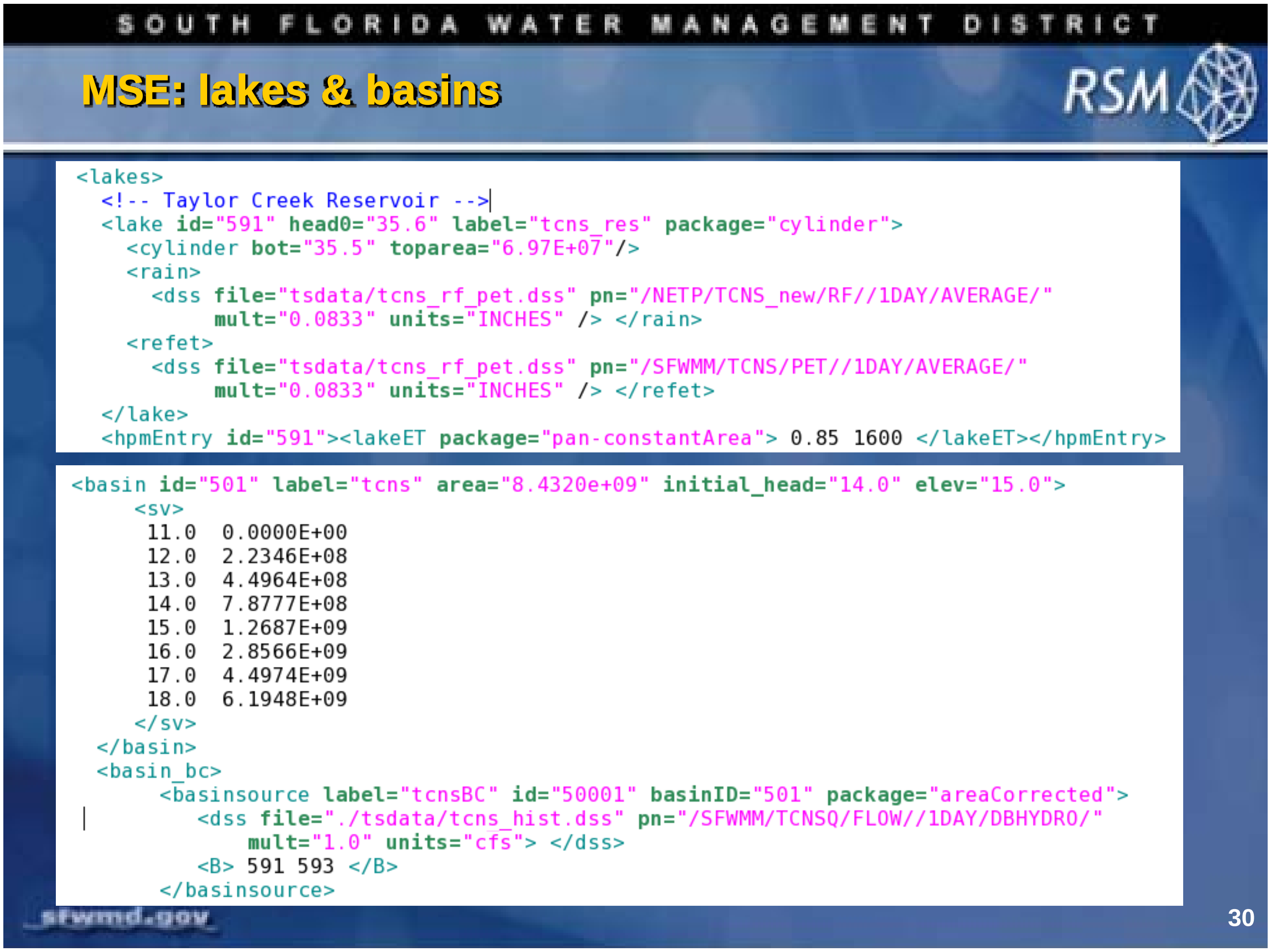
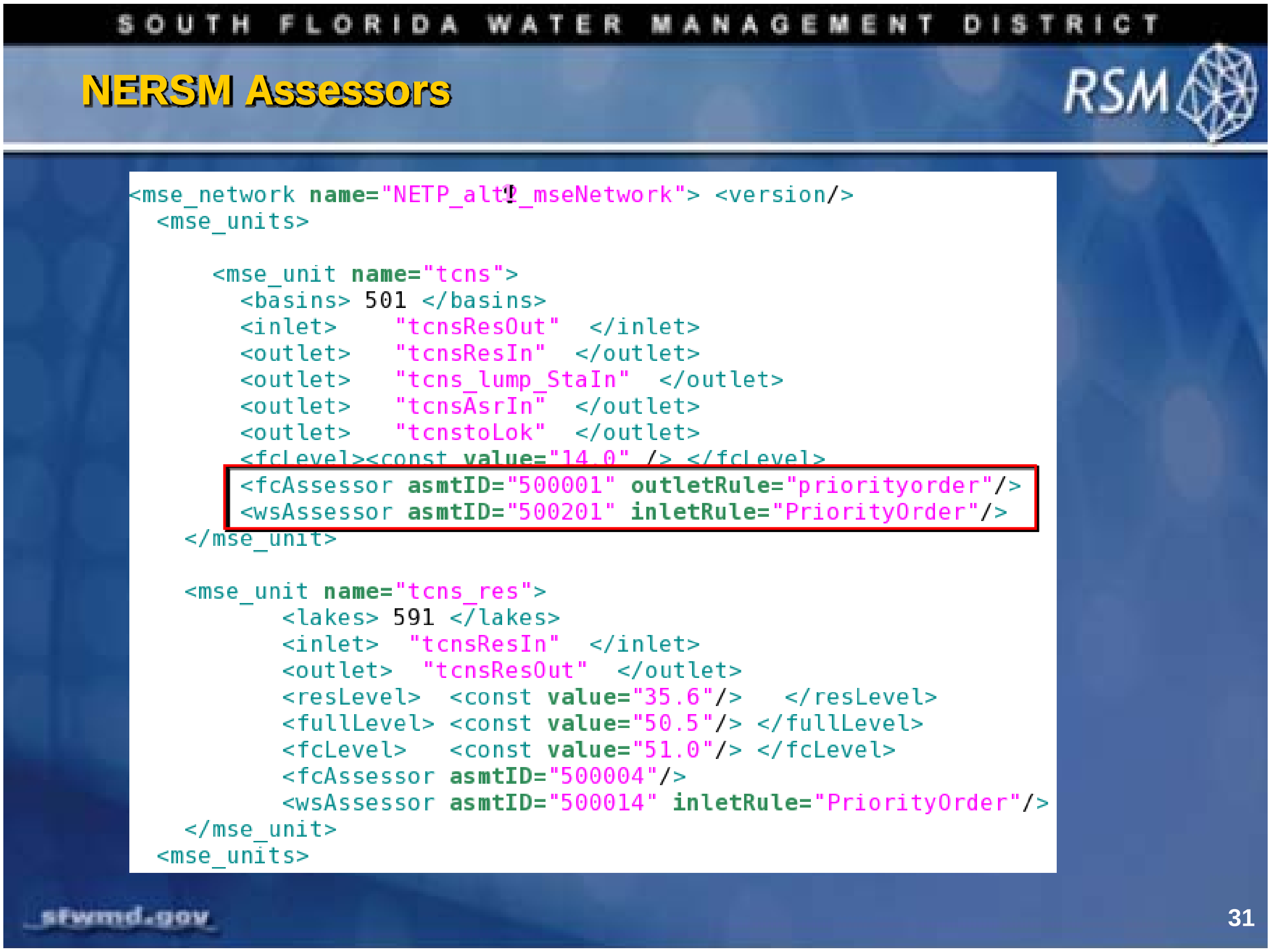
There are four WCUs in the TCNS basin and here are two of those represented as <**mse_unit**>s. The management water levels are set for each of the <**mse_unit**>s. For flood control, outflows are triggered from management measures when its stage exceeds this level. For reservoirs, it is set to its emergency stage/depth and for the STA, it is set to 1.5 ft depth (outlet spillway crest elevation). The <**resLevel**> stops outflows from management measures when its stage goes below this level. This is set to a very low value to prevent management measures from drying up completely (e.g. 0.01 ft depth). The full level stops inflows into management measures when its stage exceeds this level. For the reservoir, it is set to the maximum allowable stage/depth (emergency stage/depth – 0.5 ft).



The TCNS basin includes a basin and three lakes. The lakes, reservoirs, STA and ASR are simulated using cylindrical <**lake**> waterbodies (stage and area are meaningless for ASR). Note: the initial head for the lake is in ft² while the initial area for the <**hpmEntry**> for calculating ET is in acres. The TCNS basin is defined by a fixed area and a stage-volume relationship. The runoff is provided by a boundary condition that provides historical runoff from the basin to the management measures that are located near the outlet to the lake. Runoff generated by the basin must be corrected based on the area occupied by the reservoirs/STAs in the basin (use package="**areaCorrected**" for basinsource). The element <**B**> for <**basinsource**> provides the IDs for reservoirs/STAs located in the TCNS Basin:591, Taylor Creek Reservoir; and 593, combined STAs.



The FC and WS assessors used in the TCNS basin are the typical default assessors. As a typical <**mse_unit**>, the TCNS basin is defined as basin “501” with open inlet and several outlets. Notice that the TCNS basin is only managed for flood control level although the wsAssessor is included so that the basin can be used as a source for downstream water supply requirements. The reservoir is managed for water supply based on priority order. A review of the associated <**mse_node**>s would show the priority of each outlet.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

NERSM Assessors

RSM

```
<mse_unit name="PoolBCD">
     <lakes> 375 </lakes>
     <inlet>  "S65A"  </inlet>
     <outlet>  "S65D"  </outlet>
     <fcAssessor asmtID="375001" package="lkissQTW_reg" inletRule="CapacityTest">
     <!--HW versus Q relationship for S65D (kind of a regulation schedule)-->
     <A>
       28.7       0
       28.8       1000
       30.0       3000
       32.4       23500
      </A>
      <!-- Q versus TW relationship for S65A (a physical constraint)-->
      <B>
       100   40.94
       650   43.08
      1250   43.87
      2650   45.14
      4050   46.05
      5450   46.80
      6850   47.50
      8250   48.14
     15100   50.72
     22000   52.63
     </B>
     </fcAssessor>
</mse_unit>
```

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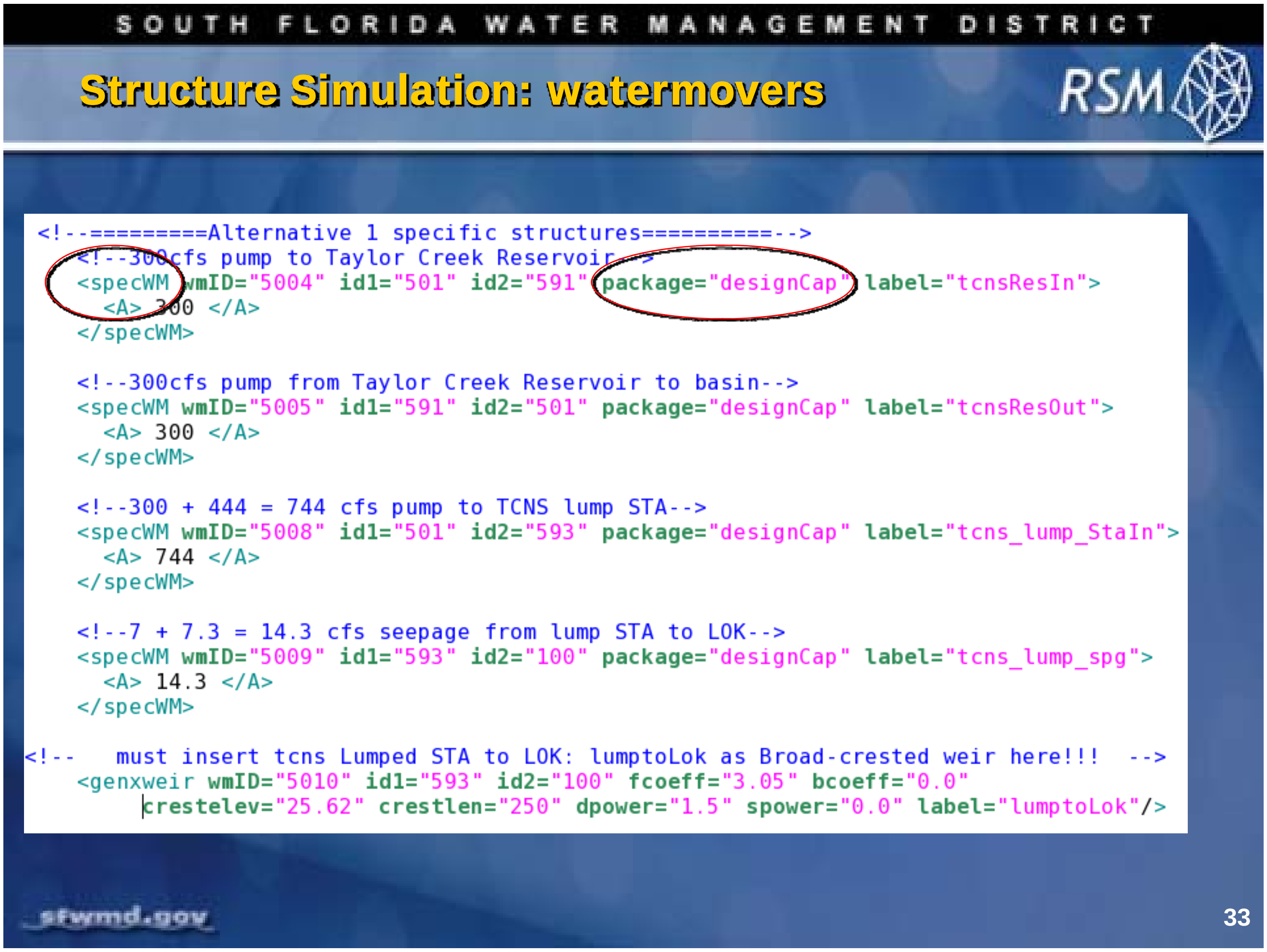
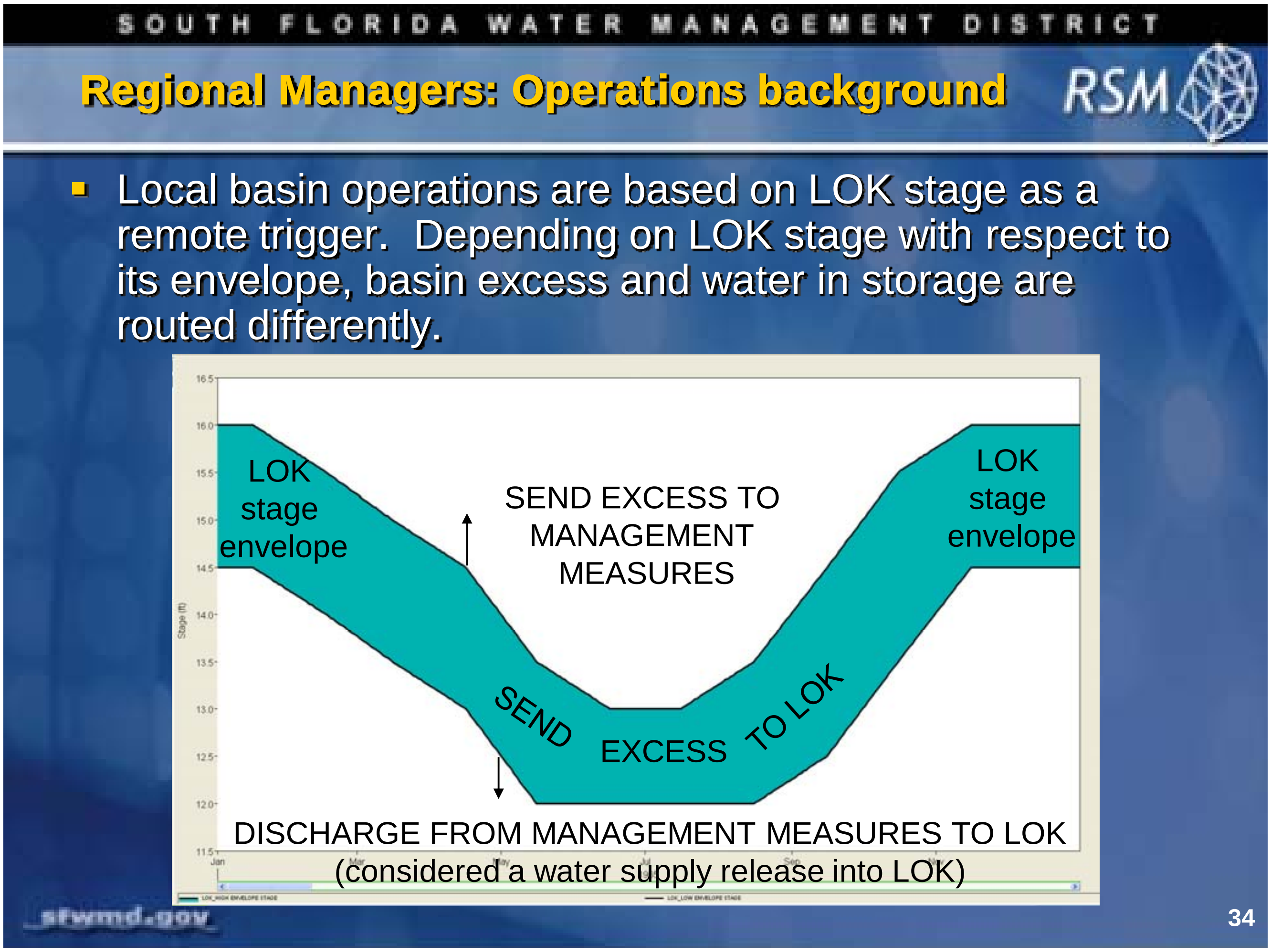
The TCNS basin only has simple assessors. Here is an example of specialized assessor used for Pool BCD of the Lower Kissimmee River sub-basin. The flood control assessor is solved using a special package that sets the flow based on the tailwater and the headwater levels.



Based on the results from the FC and the WS assessors, the MSE nodes set the appropriate flows at the managed structures between the WCUs. Inlet/outlet structures for reservoirs, inlet structures/seepage for STAs, are simulated with a special watermover of constant capacity. This example shows four special watermovers with capacities of 300, 300, 744, and 14.3. The <**genxweir**> is an unmanaged structure in the basin.



The Regional Manager for the Northern Everglades is largely determined by the operation of LOK.

When LOK stage is greater than the high envelope line, local basin runoff/excess is sent to management measures. The first priority is to send excess to Reservoirs, then to STAs, thirdly to ASR, and the remainder downstream to LOK. If reservoir/STA stage/depth exceeds a specified maximum stage/depth (emergency stage/depth – 0.5 ft), inflows are not allowed. When LOK stage is less than low envelope line, local basin runoff/excess is discharged from management measures to LOK. When LOK stage is within the envelope, local runoff/excess water will be sent to LOK (through STAs as first priority or directly to LOK as second priority). In addition, if emergency stage/depth in reservoir/STA is exceeded, there is discharge from these facilities to LOK.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Decision trees

RSM

```
<decisionTree mseNode="tcnsResOut" name="tcnsResOut" ntwkID="99"
             report="./output_alt1/tcnsResOut_decisiontree_report">

  <!-- Check LOK low envelope stage -->
  <branch false="manCon-3" id="0" label="LOK low envelope stage" true="manCon-2">
    <ABInequalityTest mode="LT">
      <A> <lakemonitor attr="head" id="100"/> </A>
      <B>
         <dssmonitor quantity="stage" file="./tsdata/lok_stage_envelope.dss"
              pn="/NETP/LOK_LOW/STAGE//1DAY/ENVELOPE/"
              units="FT" type="PER-AVER">
         </dssmonitor>
      </B>
    </ABInequalityTest>
  </branch>

  <manCon id="2" label="lok_stg_low" purpose="watersupply"> <const value="300"/></manCon>
  <manCon id="3" label="no_flow" purpose="watersupply"> <const value="0"/></manCon>

</decisionTree>
```

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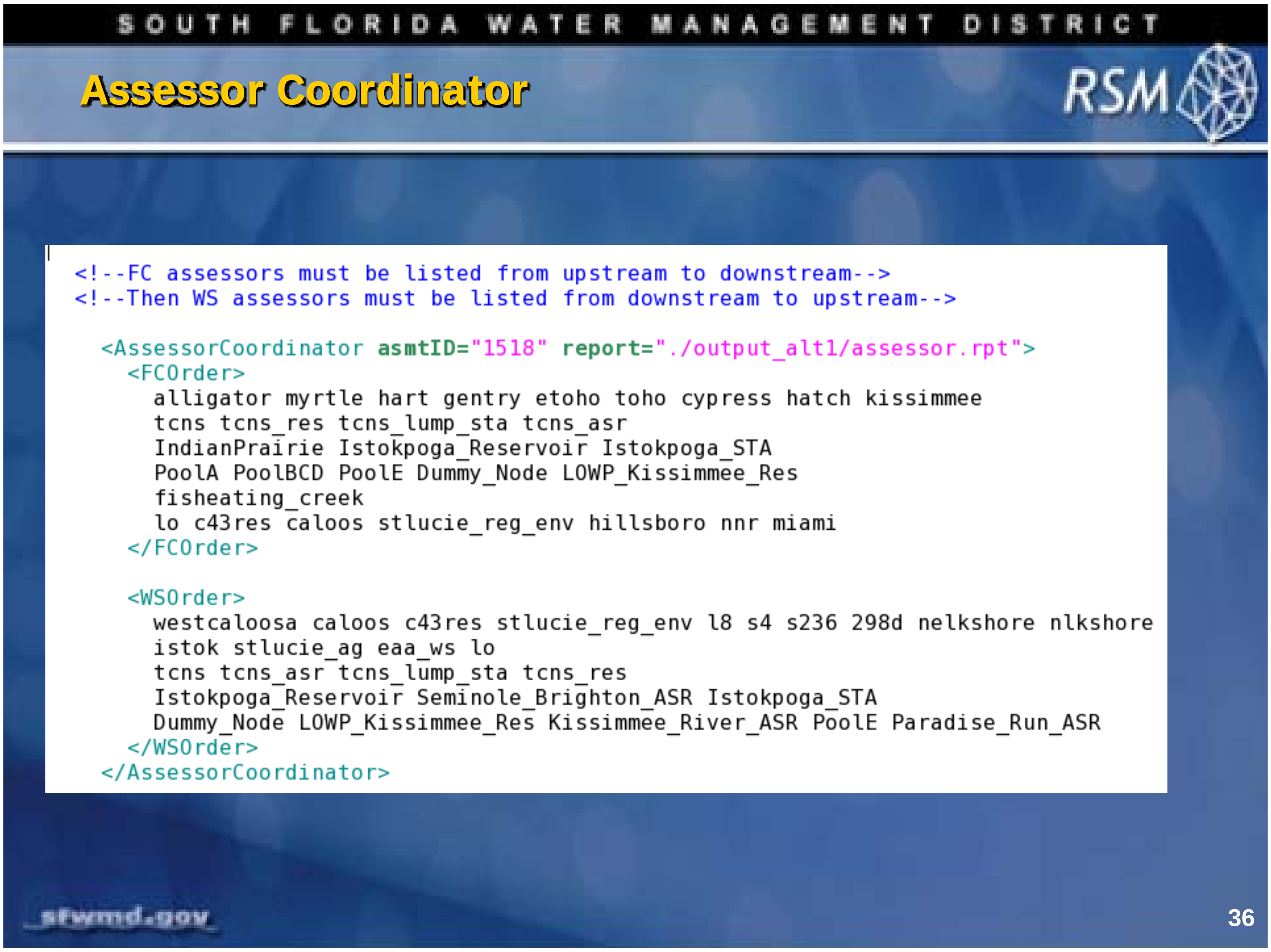
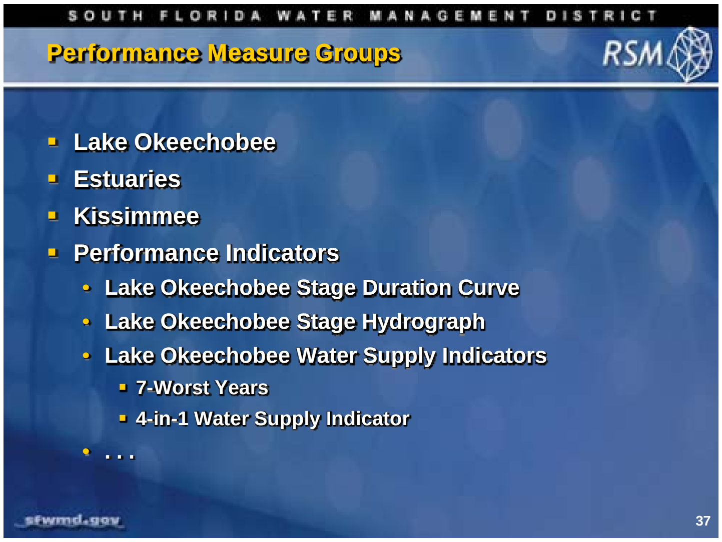
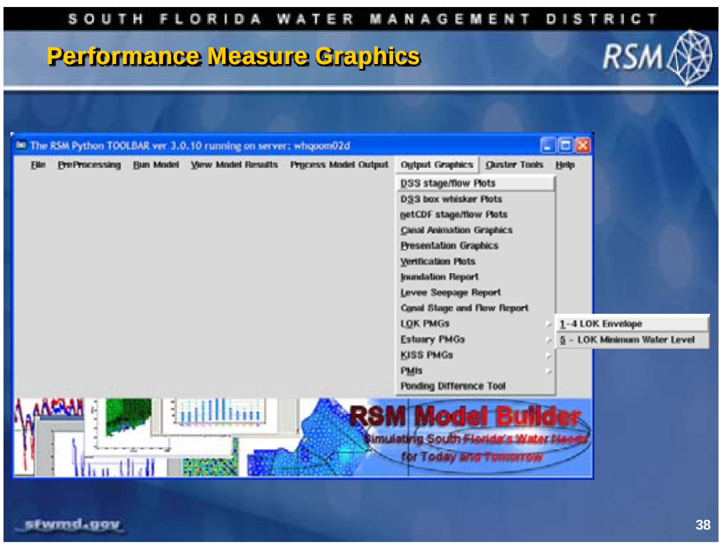
Decision trees are designed and implemented with the regional managers, and they are setup for each management measure inlet/outlet to determine action based on LOK stage. Water management policies at the highest level and spanning multiple WCUs are done through Regional Managers. The decision tree places management constraints (manCon) to limit flood control or water supply releases at a mseNode to a value specified by the regional manager. This decision tree compares the lake levels determined by the <**lakemonitor**> identified in element <**A**> to the LOK stage time series provided by the <**dssmonitor**> in element <**B**>. Based on the results the flow is set to 300 cfs or 0 cfs.



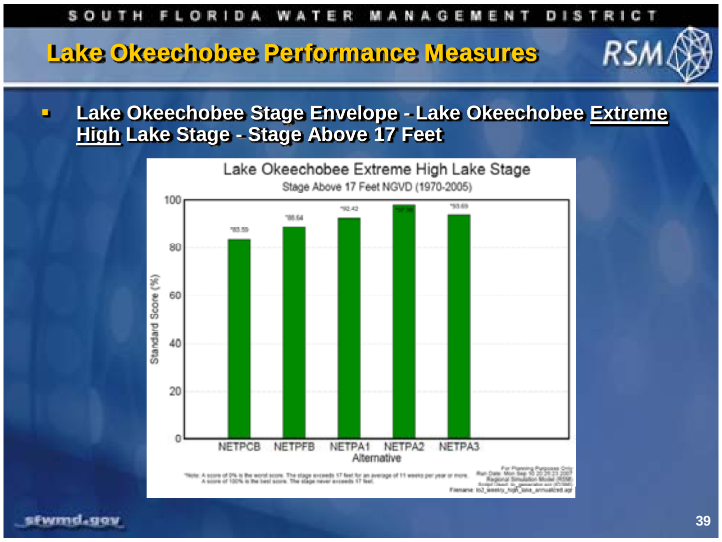
The Assessor Coordinator sets the order in which the mse_units will be resolved. The flood control order starts at the top of the system and the water supply coordinator starts at the bottom of the system. All branches are resolved before the solving the next mse_unit in order. The results of the assessors are output in the assessor report that is used for evaluating the assessors.



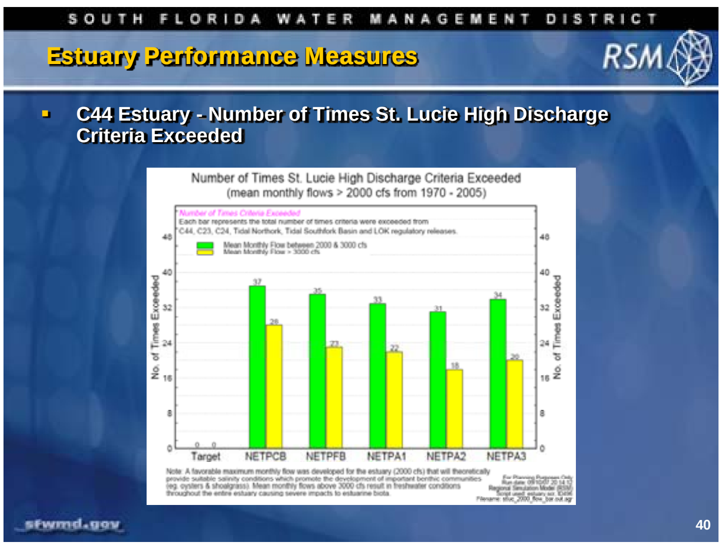
The important output from the NERSM is the presentation of the performance measures which are the model simulation results, system observations and targets that have been agreed upon by the stakeholders for evaluating alternative water resources management strategies. There are separate performance measures for the different parts of the system.



The output from the NERSM is post-processed using the RSM GUI Output Graphics utility to produce performance measure graphics using the standard output from the RSM.



This is an example of one Performance Measure for LOK for five different alternative plan formulations.



This is an example of one Performance Measure graphic for the St. Lucie estuary for five alternative plan formulations. The RSM GUI post-processor uses the data identified by the modeler to create the complete graphic for the stakeholder. The details on the creation of the Performance Measure graphics are described in the RSM GUI User Guide.

KNOWLEDGE ASSESSMENT

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

1. What is the purpose of the WcuAssessor?
2. What do special assessors do?
3. What are the ways the water supply requirements can be apportioned when there are multiple inlets?
4. What is the purpose of “packages”?
5. What is the source of the code used for the packages?
6. How are regional managers implemented?
7. What is the purpose of the Assessor Coordinator?
8. Which HSE features are used in the linked-node implementation of RSM?
9. What kinds of watermovers are typically used in linked-node RSM?
10. How are HPMs implemented in the Northern Everglades RSM?
11. What is the output from a decision tree?
12. What are the final outputs from an RSM implementation run?

Answers

1. The WcuAssessor determines the water supply, flood control or environmental water needs for a Water Control Unit.

2. Special assessors determine the amount of allowable flow through a structure based on special rules or schedules.

3. The water supply requirements can be apportioned as equal share, capacity weighted, or priority order.

4. Packages contain specialized code for assessors that apply to one or more WCUs and structure flow equation's associated mse_nodes.

5. The algorithms and structure flow equations implemented in the packages are typically obtained from other models and hydrologic investigations of selected areas.

6. The regional manager is implemented using decision trees to apply regulation schedules and flood control or water supply rules to determine structure flows.

7. The ordered list of WCUs in the Assessor Coordinator determines the order in which the water supply and flood control features are assessed.

8. The linked-node implementation of RSM uses the lakes, basins and watermovers from the HSE.

9. The common watermovers are specWM and genxweir.

10. The net runoff from local hydrology is implemented as a boundary condition and the NERSM simulates the impact of different management measures on the outflow from each basin.

11. The decision trees produce constraints that are applied to selected structure flows.

12. The final outputs of an RSM implementation run are the Performance Measures that show how well the RSM performed.

Lab 16: MSE Network and NERSM

Time Estimate: 4.0 hours

Training Objective: To gain knowledge of the Management Simulation Engine (MSE) Network and Northern Everglades Regional Simulation Model (NERSM)

The **Management Simulation Engine (MSE)** was developed to impose regional water management policies and rules on the hydrology of the regional system of canals and water management structures. The MSE constructs an abstraction of the system: **Water Control Units (WCUs)** to represent the basins and **MSE-node** to represent water control rules at the structures.

The MSE uses **assessors** to determine, from the **Hydrologic Simulation Engine (HSE),** the amount of water that needs to be moved through each managed structure to meet the water supply needs and the flood control requirements of the system. The exercises in this lab are designed to review the basic mechanics of using the **MSE assessors**, the **MSE network** and the **SFBasins model**. The exercises also illustrate the effect of changing various system parameters on the behavior of the system.

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 <path>
```

For SFWMD modelers, the path you should use for the NAS is:

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

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/lab16_assessor`** directory. Additional materials in the directory include:

DRE-223.pdf
MSE_CONTROLLER.pdf
MSE_SUPERVISOR.pdf
bm70.ppt
NERSM_UserGuide.pdf

Activity 16.1 MSE_network and SFBasins Model in Benchmark 70

Overview

Activity 16.1 includes one exercise:

- **Exercise 16.1.1.** Review SFBasins RSM

The **MSE_network** was developed to simulate the **Kissimmee Valley** as a linked lake-basin implementation of the **Regional Simulation Model (RSM).** There is no mesh or **HSE network**. The following exercise investigates the implementation of the **SFBasins RSM**.

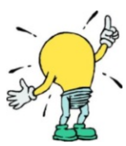
Exercise 16.1.1 Review SFBasins RSM

1. Copy Benchmark 70 to the lab16_assessor directory. All work for this activity will be done in the lab16_assessor/BM70 directory:

```
cp -r  $RSM/trunk/benchmarks/BM70 $RSM/labs/lab16_assessor
```

2. Create a diagram (hand sketch) of the **MSENetwork** used in the **run25Network.xml RSM** in **BM70/mse/mseNetwork**. The diagram should include the **waterbodies** (lakes or basins), **nodes** and **boundary conditions**. Use bm70.ppt as a starting point.

HINT



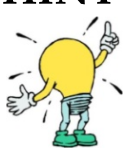
See Lecture slide #9 if you need help getting started.

3. Place the appropriate **IDs** on the components.
4. Based on the evaluation of the information in the `<decisiontree>` element in file `BM70/mse/regionalmangers/run25_regionlamanagers.xml`, under what conditions does flow occur at node lo2wca3a?
5. Run the model (run_25) using the **RSM Graphical User Interface (RSM GUI)**.
6. Create a new storage reservoir as a `<lake>` named "`res1`" that gets water from Lake Okeechobee and delivers the water to Service Area 1.
   - The reservoir should store 160,000 acre-feet at 16-foot depth
   - The flood control level should be set to 16 feet
   - The level below which water can be supplied is set at 1 foot
7. Evaluate the effect of the new reservoir on the **stage** in **Service Area 1**.
   - (Compare the stage without the reservoir to the stage following implementation of the reservoir.)

To create a new lake you will need the following components:

- A **rule curve** for **stage schedule** in the lake
    - Add the rule curve to the **run25_rulecurveshw.xml** file
- A **<lake>**
- Create a **stage-storage relationship**
- Create a **stage-area relationship**
- Create a **reference potential evapotranspiration** file **<refet>**
- Create a rainfall input equal to a constant value = "**0**"
- Add the lake to the **run25_lakeshw.xml** file
- One **<decisionTree>** (for the inlet) based on the **<decisionTree>** elements developed for the Water Conservation Areas (WCAs)
    - Add the **<decisionTree>** to the **run25_regionalmanagershw.xml** file
- Add an **inlet watermover** and an **outlet watermover**.
    - Use a **<specWM>** watermover that sets the maximum inlet water flow = **600** and outlet water flow = **1000**
    - Add the watermovers to the **run25_watermoverhw.xml** file
- Add the reservoir to the **<AssessorCoordinator>** so the flood control and water supply needs of the reservoir are evaluated in the appropriate order. (Refer to discussion on the following page).
- Create a monitor **<lakemonitor>** to see how your reservoir is performing and add the monitor to the **run25_outputhw.xml** file.
- Add the two new nodes for the **<mse_nodes>** and WCU **<mse_unit>** to the **<mse_network>** element in the **run25Networkhw.xml** file.

HINT



It is useful to study the model components that affect other lakes to better understand which components are necessary for this model and how to specify those components.

NOTE:

Most of the watermovers in Run25 are specifically defined watermovers. The corresponding equations are available in the South Florida Water Management District Technical Publication 86-3 (DRE-223.pdf in the lab16_assessor directory).

8. Change the model run file and add the references to the modified files:

- **run25_lakeshw.xml**
- **run25_watermovershw.xml**
- **run25_rulecurveshw.xml**

- **`run25_regionalmanagershw.xml`**
- **`run25_assessorshw.xml`**
- **`run25_outputhw.xml`**

9. Change the **`<runDescriptor=”rn25_hw”>`**
10. Run the model
11. Review the resulting stage in “**`res1`**” and Service Area 1 (SA1) using HecDssVue.

The model determines the amount of flow for each of the nodes based on the decision tree, the controllers, the watermovers and the assessors. The **watermovers** determine the capacity of the structures based on upstream and downstream heads or they have a constant capacity. The **decision trees** are used to set the “**gain**” for each structure. In this example, decision trees determine if the structures should be open (very high flow rate) or closed. The **flood control assessors** and **water supply assessors** determine how much water must flow through each structure to meet the needs of the **WCU**. The controllers in this example set the range in flow at the structure with the flow determined by the assessors.

Flood Control Assessors

The **flood control assessor**, such as the one for **WCU** “**`wca1`**”

```
<LakeFC  asmtID="1002" ntwkID="99" wcu="wca1"   subnetID="1024" />
```

goes to the **`mse_unit name=”wca1”`** in the **`mse_network`** and finds the flood control level:

```
<fcLevel  name="lake110 fc">  <rc id="16" /> </fcLevel>
```

In this case the **flood control level** is a **rule curve** and determines if there is a need for flood control releases. The **assessor** calculates the amount of flow and proportions the discharge among the outlets for the **WCU** identified in the **`<mse_unit>`** element.

Water Supply Assessors

The **water supply assessors** determine the water supply need for the named **WCU** by determining the needs of the **`<mse_unit>`** defined in the **`<mse_network>`**. The water supply needs are determined by looking at the **maintenance level** **`<maintlevel>`** for **`<mse_units>`** that are **`<basins>`** or the outlet requirements for downstream needs for **`<mse_units>`** that are **`<lakes>.`** The maintenance levels for the service areas are set to constant values, but they could be set to follow **rule curves**. These needs are applied to the **`<inlets>`** as an “**`equalshare`**”.

AssessCoordinator

The **`<assessCoordinator>`** is applied to the **flood control assessors** and the **water supply assessors** by first determining the flood control needs starting at the top of the network and working toward the ocean. The water supply needs are then assessed by starting at the bottom end of the network and working towards the top of the network. A second pass through the network is made from top to bottom checking the specified water supply releases with the **`<decisiontree>`** **constraints**, the **structure capacities** and the **lake storage capacities**. This process is iterated until the assigned flows for each of the structures converge.

Order of Assessors

When the assessors are placed in the **`<assessors>`** in the XML run file, they are placed in the order of assessment. For flood control, the reservoir is assessed with the lakes before the basins. For water supply, the reservoir is assessed after the basins. In both cases, the reservoir is assessed at a similar point in the sequence as Water Conservation Area #1 (WCA1).

Mse_network

In the **`<mse_units>`** it is necessary to specify the flood control water level **`<fcLevel>`**, above which water in the lake is drained off as rapidly as possible within the system constraints; and the local water level **`<localLevel>`**, below which there is a water supply requirement and no water can be discharged downstream.

Activity 16.2 Northern Everglades RSM

Overview

Activity 16.2 includes one exercise:

- **Exercise 16.2.1.** Add a reservoir for Taylor Creek – Nubbins Slough Basin.

Exercise 16.2.1 Add a reservoir for Taylor Creek–Nubbins Slough Basin

Build a "**Management Measure**" in **Taylor Creek and Nubbin Slough (TCNS) Basin**. Specifically create the reservoir in **Fig. 16.1** and add it to the mseNetwork.

1. Follow the example for the reservoir in **`netp_mseNetwork.xml`**:

`$RSM/data/NERSM/Alt1_partial/mse/mseNetwork/netp_mseNetwork_alt1.xml`

To make sure you get the names of inlet and outlet structures correct, check:

`$RSM/data/NERSM/Alt1_partial/hse/watermovers/tcns_watermovers_alt1.xml`

- What corresponding changes should be made to **LOK inlet**?

2. Complete the watermovers for the TCNS Reservoir:

`$RSM/data/NERSM/Alt1_partial/hse/watermovers/tcns_watermovers_alt1.xml`

- The watermover from the Lumped Stormwater Treatment Area to LOK (lumptoLok) is represented as a **`<genxweir>`**
- The watermover is named: lumptoLok and the watermover id (wmid): **`5010`**
- The equation used to solve **`<genxweir>`** is:

$$Q = C_d L (H_u - z_c)^a (H_u - H_d)^b$$

Q = Discharge (cfs)
C_d = weir discharge coefficient
L = weir crest length (ft)
z_c = weir crest elevation (ft)
H_u = upstream water level (ft)
H_d = downstream water level (ft)
a,b = constant exponents

Assume:

- **Q** = 744 cfs
- $\mathbf{C_d}$ = 3.05
- $\mathbf{H_u\text{-}H_d}$~=1 ft
- $\mathbf{H_u\text{-}z_c}$~=1 ft
  - $\mathbf{z_c}$ = 24 + 1.62 = 25.62 ft; **a** = 1.5; **b**= 0.0

Calculate **L**.

(Please check Page 44 in **`NERSM_UserGuide.pdf`** for specifying the genxweir)

- Create a **watermover** for the bypass flow from the **TCNS Basin** to **Lake Okeechobee** as a **`<specwm>` watermover** with the name "**`tcnstoLok`**" and **watermover ID: wmid="`5013`"**

    - How would you define the structure capacity?

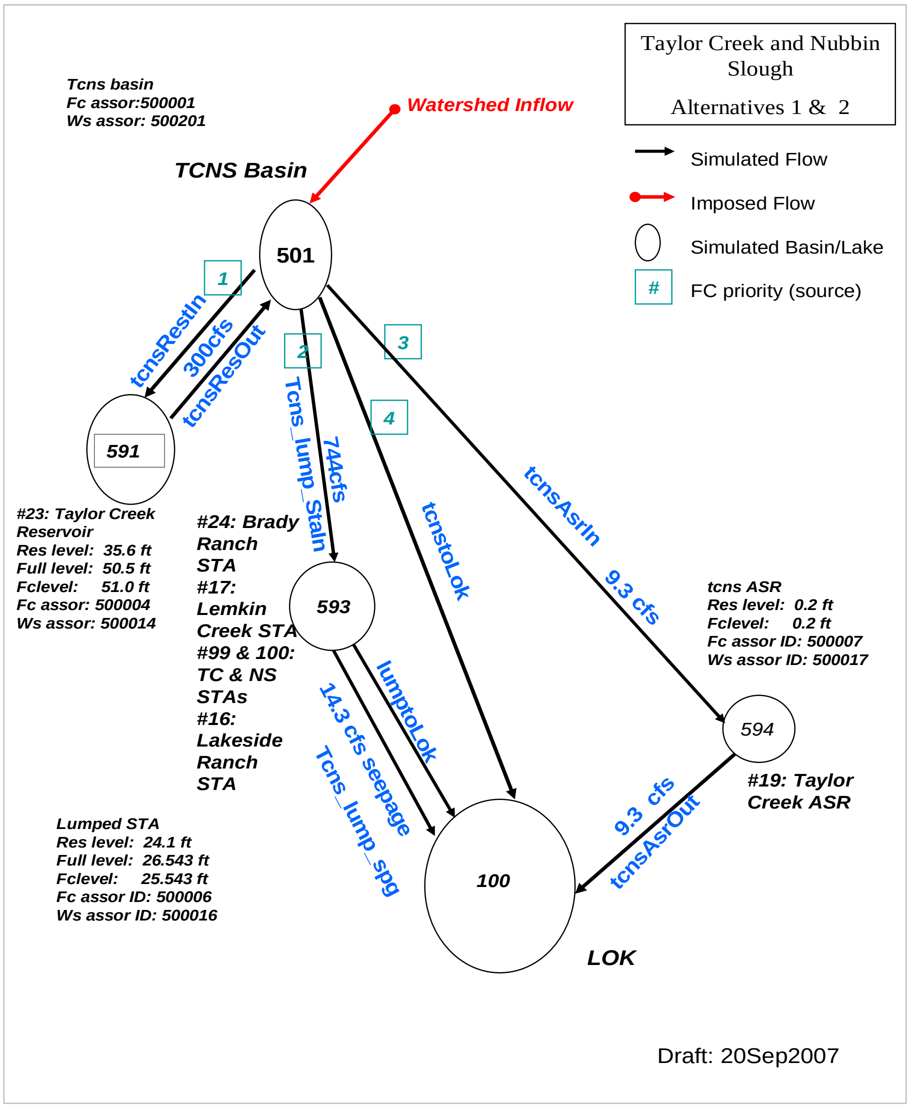


Figure 16.1 Schematic of Taylor Creek/ Nubbin Slough management measures

3. Set up a **regional manager** for **TCNS Reservoir inflow (tcnsResIn)** and **reservoir outflow (tcnsResOut)**:

`$RSM/data/NERSM/Alt1_partial/mse/regionalmangers/tcns_res_in_alt1.xml`
`$RSM/data/NERSM/Alt1_partial/mse/regionalmangers/tcns_res_out_alt1.xml`

- Implement the following operation rule of **Taylor Creek Reservoir (591)**:

When **LOK stage** is above the high envelope, **TCNS Basin** sends water through **tcnsResIn** to **Reservoir (flood control)**.

When **LOK stage** is below low envelope, **Reservoir** sends water through **tcnsResOut** to **TCNS basin** so that more water could be passed to **LOK (water supply)**.

See the **Istok reservoir example**:

`$RSM/data/NERSM/Alt1_partial/mse/regionalmangers/istok_res_I17_in_alt1.xml`
`$RSM/data/NERSM/Alt1_partial/mse/regionalmangers/istok_res_I17_out_alt1.xml`

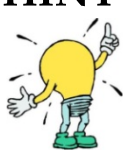
> **NOTE:**
>
> **The first** branch ID **is always "`0`". (If you have more than 1 branch, give different IDs to different branches.)**
>
> **Make sure the structure name is consistent with the name in:**
> `../tcns_watermovers_alt1.xml`
>
> **Pay attention to structure capacity**

4. Understand the **`areaCorrected`** **Package** set up in the basin. Open

`$RSM/data/NERSM/Alt1/hse/basins/tcns_basins_alt1.xml`

- What is the subelement **`<basinsource>`** Part B **`<B>`?**

HINT



(Check NERSM User Manual Page 26 and Lecture 16 slide 30)

5. Run the model using the **RSM GUI** and display the **TCNS Reservoir stage**, **inflow** and **outflow** using **HecDssVue** utility.

- How frequently is the reservoir used in the scenario?

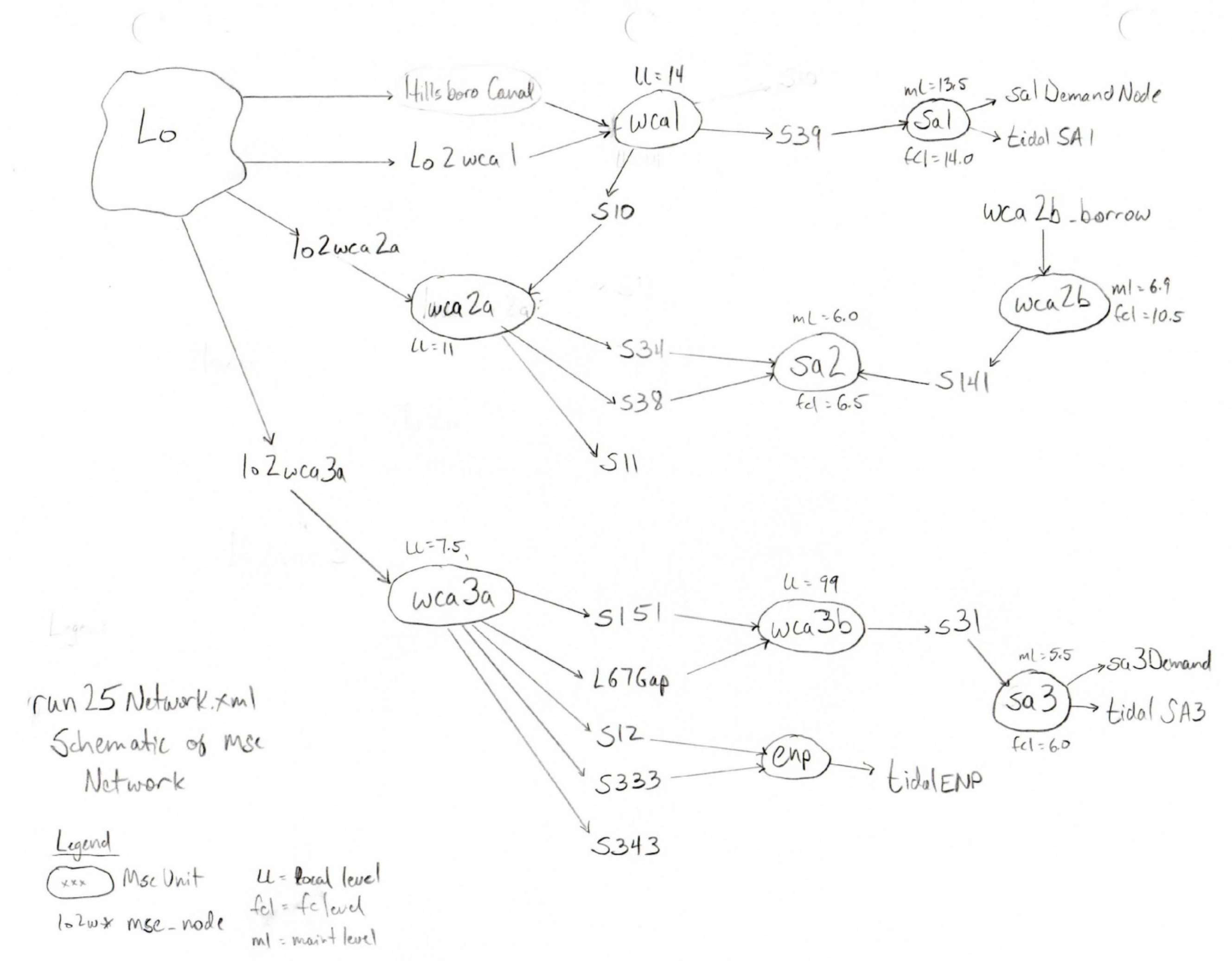
6. Display the **TCNS Reservoir outflow** and the **TCNS to Lake Okeechobee flow**.

- How much of the flow goes through the reservoir?

Answers for Lab 16

Exercise 16.1.1

2. Create a diagram (hand sketch) of the MSENetwork used in the run25Network.xml RSM in BM70/mse/mseNetwork. The diagram should include the waterbodies (lakes or basins).



4. Based on the evaluation of the information in the **<decisiontree>** element in file **BM70/mse/regionalmangers/run25_regionlamanagers.xml**, under what conditions does flow occur at node lo2wca3a?
With the very jagged controls removed the head and discharge curves became much smoother, but retained the same pattern as before.

7. Compare the stage without the reservoir to the stage following implementation of the reservoir.
The stage in Service Area 1 increases from 14.0 to 14.7 ft in 1969.

Exercise 16.2.1

> **NOTE:**
>
> **The answers for this lab can be found in the lab16_assessor/answers9mse directory.**

1. What corresponding changes should be made to **LOK inlet?**
   The additional inputs from tcnsAsrOut, LumptoLok, tcnstoLok, and tcnslump_spg need to be added to the LOK inlet.

2. How would you define the structure capacity?
   The capacity needs to be very large so it may handle all of the excess flow being sent to Lake Okeechobee.

4. What is the subelement <basinsource> Part B <B>?
   The basin area is corrected by subtracting the areas of the reservoirs (Lake=591 and 593) that have been created in this basin.

5. How frequently is the reservoir used in the scenario?
   Inflow to the reservoir is small (<10 cfs) but occurs nearly every year for periods throughout the summer months. Outflow is event-driven and occurs from zero to about 10 times per year, averaging 1 to 3 times per year. Outflow did not exceed approximately 300cfs.

6. How much of the flow goes through the reservoir?
   Very little flow goes through the reservoir (<10%) on its way from TCNS to Lake Okeechobee.

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