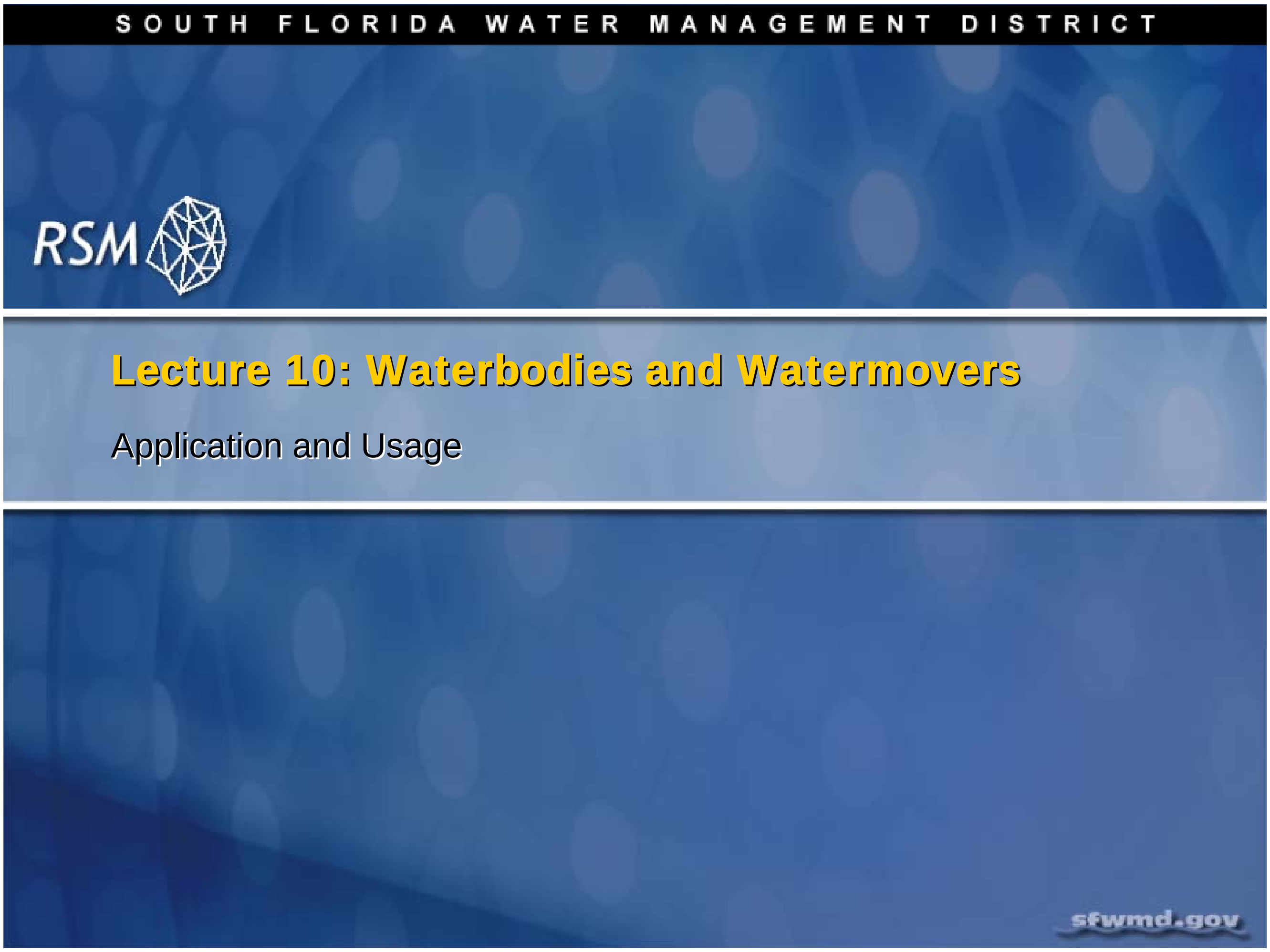


Lecture 10: Waterbodies and Watermovers—Application and Usage

The Regional Simulation Model (RSM) is conceptualized around waterbodies and watermovers. In earlier lectures, mesh cells and network segment waterbodies were discussed, along with the simple watermovers necessary to create simple RSM implementations.

There are several waterbodies currently available in the RSM and the architecture allows for the creation of additional waterbodies as the need arises. There are also a large number of watermovers available based on the types of physical structures used to move water. Additional watermovers can be created as necessary to meet specific needs.

Currently, there are six types of waterbodies in RSM. Additional waterbodies can be added to the RSM as the need arises.

The mesh cells and the network segments are the typical components of a distributed RSM implementation.

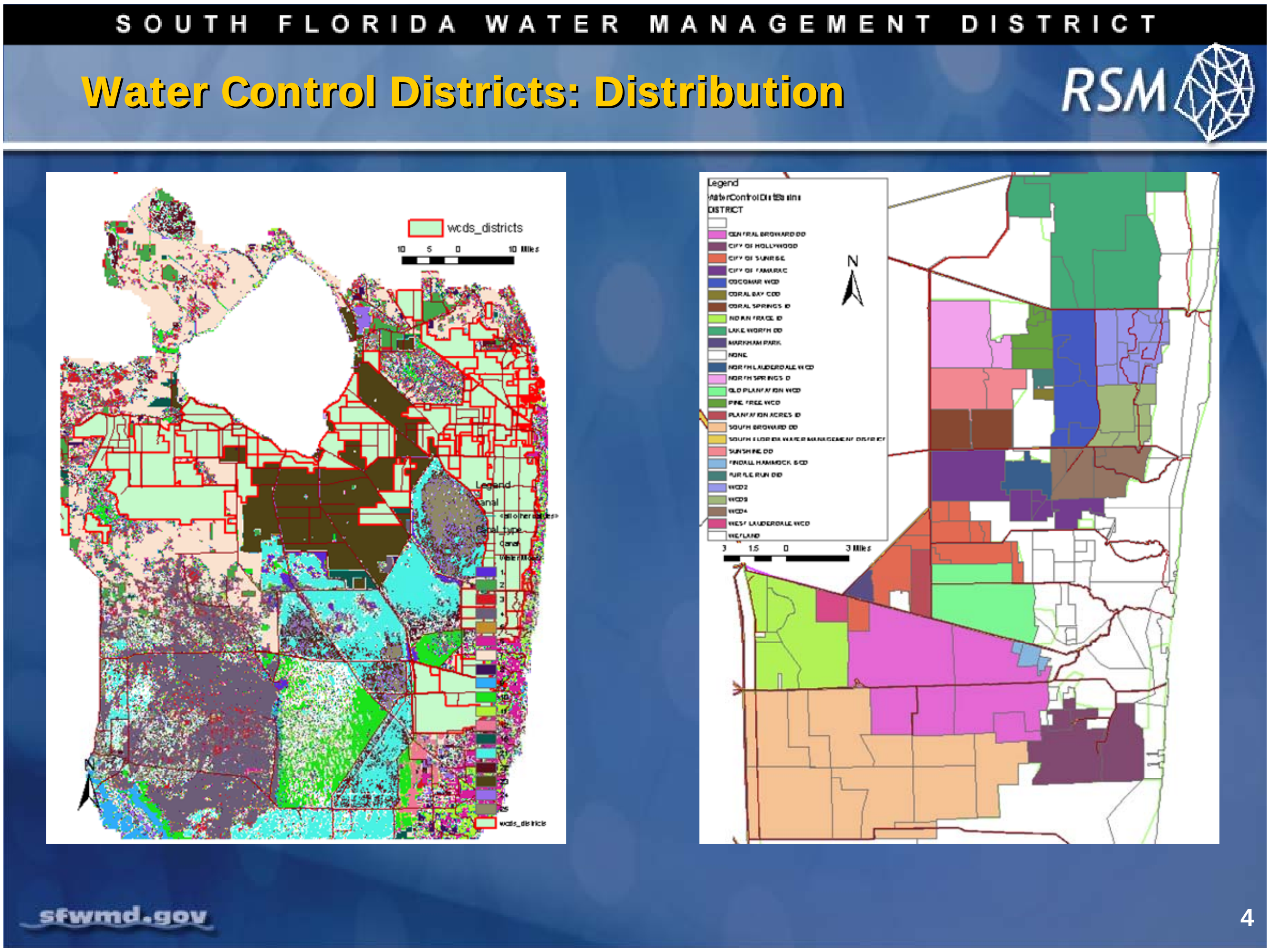
Water control districts are features that allow the user to implement secondary water management systems with the RSM without expanding the canal network.

Impoundments and lakes are used to model reservoirs, stormwater treatment areas (STAs) and typical lakes.

The basins and lakes are the components of a linked-node RSM implementation, which is used to model complex management alternatives with minimal hydrology.

The Water Control District (WCD) element was developed to represent the hydrology of the Water Control Districts authorized by the State of Florida (Chapter 298, Florida Statutes) as taxing districts to develop drainage or water supply facilities.

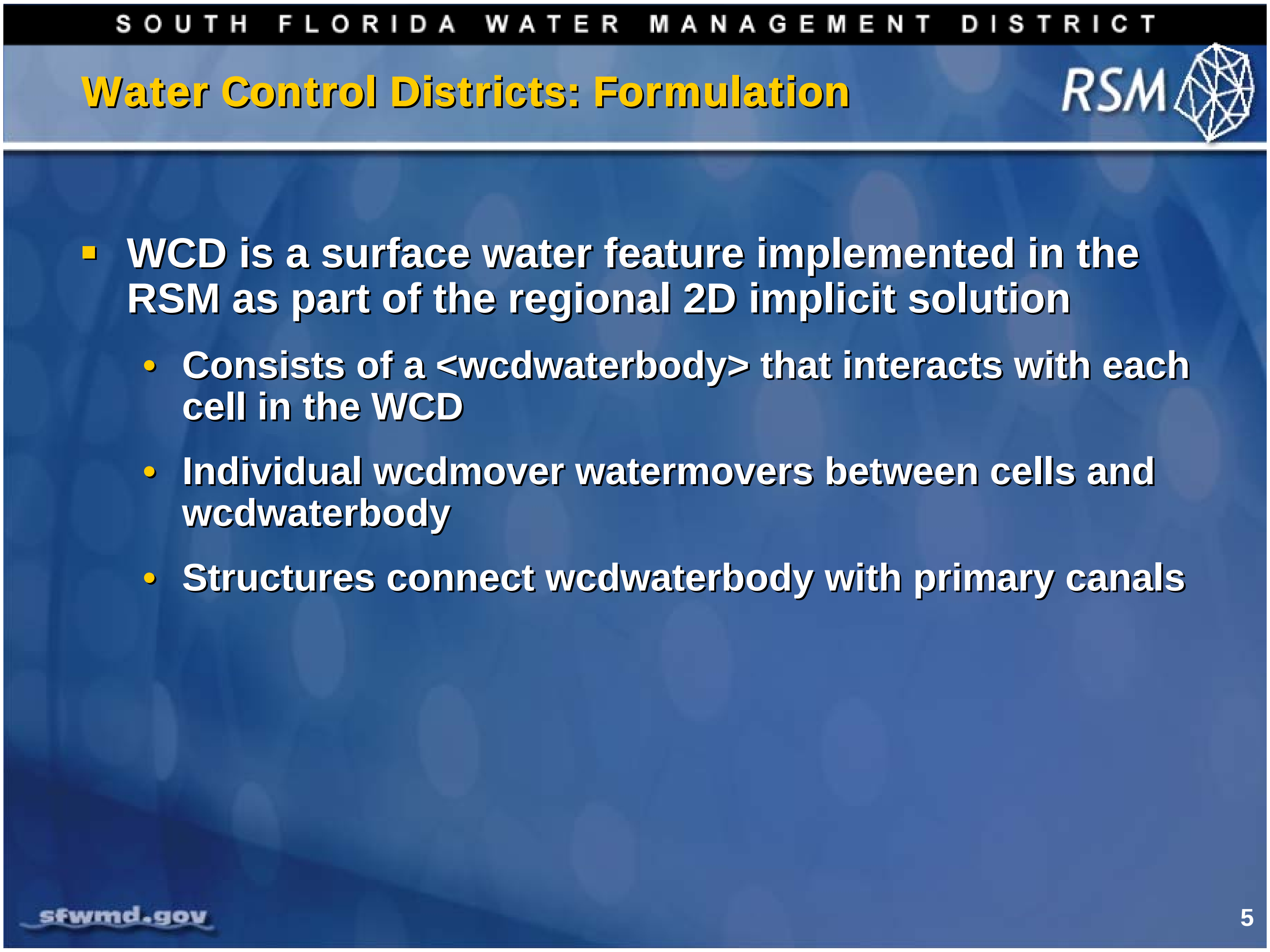
The WCDs provide for local flood control as well as local groundwater recharge and serve as a primary irrigation water supply. These facilities included drainage ditches, collector/distribution ditches, detention ponds and structures for controlling water levels. The structures may be gravity structures such as gate weirs, culverts or pumps. Where the WCDs are designed for both water supply and flood control there are both inflow and outflow pumps.



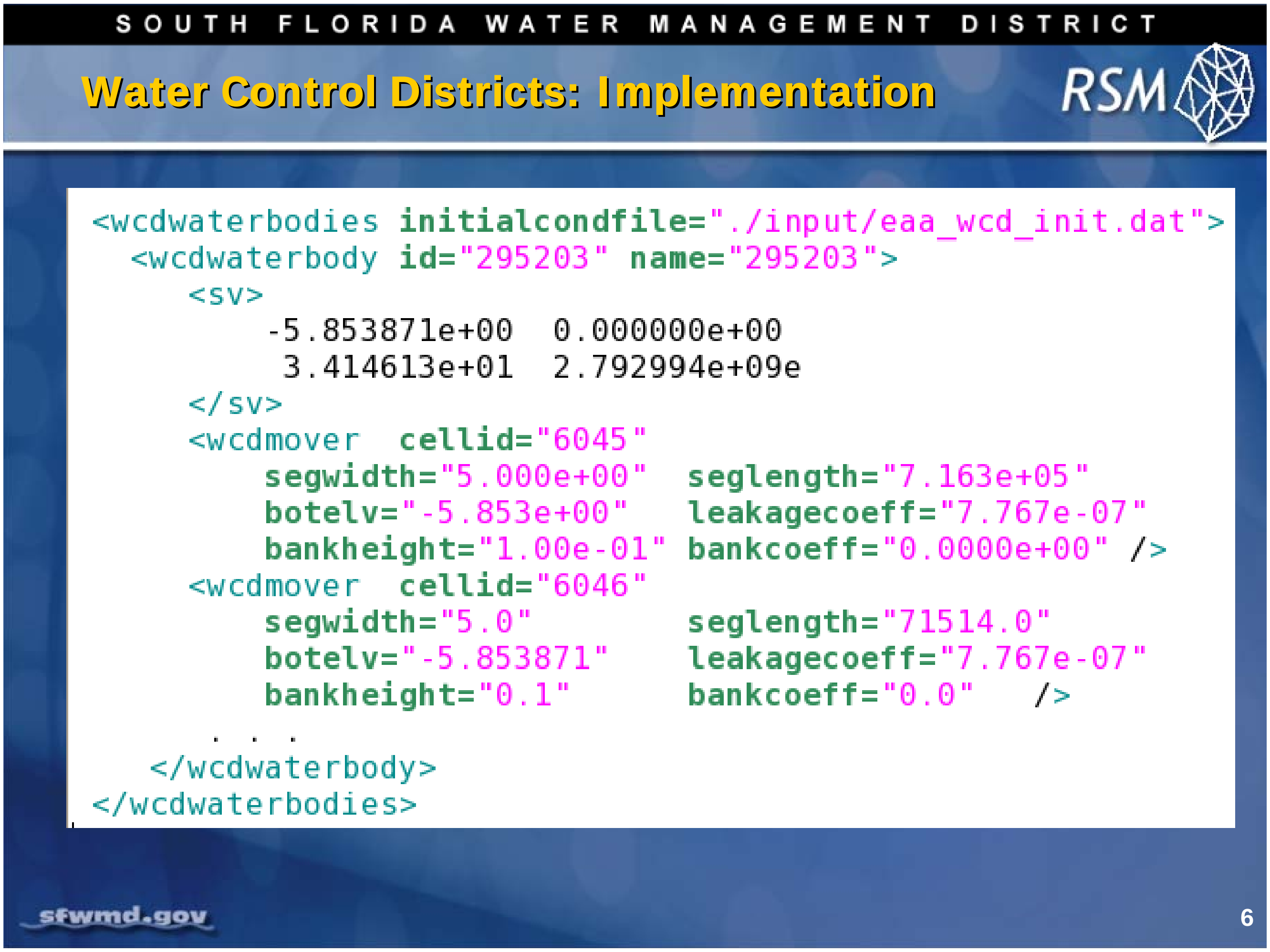
There are many WCDs in south Florida, including in the western part of the South Florida Water Management District (SFWMD) in Hendry County (refer to figure on left) developed to provide drainage and irrigation for agricultural land. These are the large WCDs.

The WCDs in Broward County (see figure on right) protect urban development from flooding and direct runoff to public water supply well fields.

The WCD concept can be applied to any urban or agricultural development that has a significant water storage capability.



Although the WCD is essentially a surface water feature and can be implemented as local hydrology within a Hydrologic Process Module (HPM) hub, it is implemented as part of the regional solution so that the flows between the <wcdwaterbody> and the associated cells, and the flows between the <wcdwaterbody> and the canal segments are solved as part of the implicit solution. The <wcdwaterbody> represents the storage lake or collector-ditch system in the WCD. The <wcdwaterbody> interacts with many of the cells in the WCD, but not necessarily all of them.



The <wcdwaterbodies> element consists of one or more <wcdwaterbody> element and specifies the initial head index file. Each WCD element is defined by the stage-volume <sv> relationship, and watermover <wcdmover> elements that connect each cell to the <wcdwaterbody>.

Each <wcdmover> is characterized by:

- Bottom elevation
- Width
- Length
- Leakage coefficient
- Bank height
- Bank coefficient

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Water Control Districts: Implementation

RSM

```
<watermovers>
   <single_control id1="109001" id2="310908" wmID="119001"
     control="109001" cutoff="12.293171"
     gravflow="no" revflow="yes" label="WCD 109001 FC Pump">
          -900000.00        0.00
               14.28        0.00
               14.29     1142.00
           900000.00     1142.00
 </single_control>

 <single_control id1=" 109001" id2=" 310908 " wmID="129001"
       control="109001" cutoff="-9.000000e+09"
       gravflow="no" revflow="yes" label="WCD 109001 WS Pump">
          -900000.00     -487.00
               11.79     -487.00
               11.80        0.00
           900000.00        0.00
 </single_control>
```

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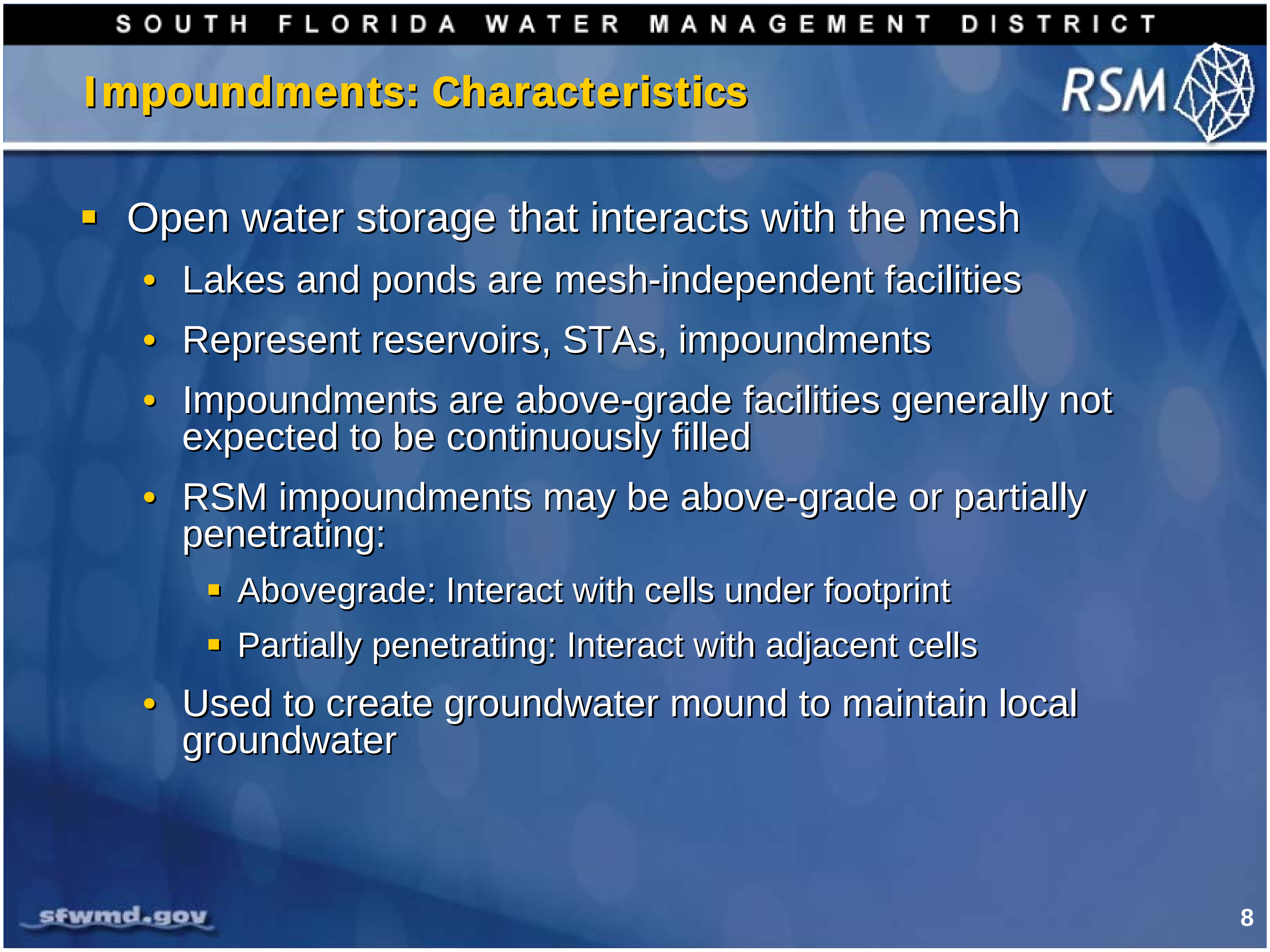
The typical watermovers for the <wcdwaterbody> are Flood Control (FC) and Irrigation Water Supply (WS) pumps. The FC pumps are large diesel-powered pumps that start up after the stage in the "control" waterbody exceeds a FC threshold. The control is typically the attached <wcdwaterbody>, but it can be any waterbody.

The "cutoff" is the stage below which the pumps stop. In the case of water supply, the pump will stay on until the turn-off stage is reached.

NOTE:

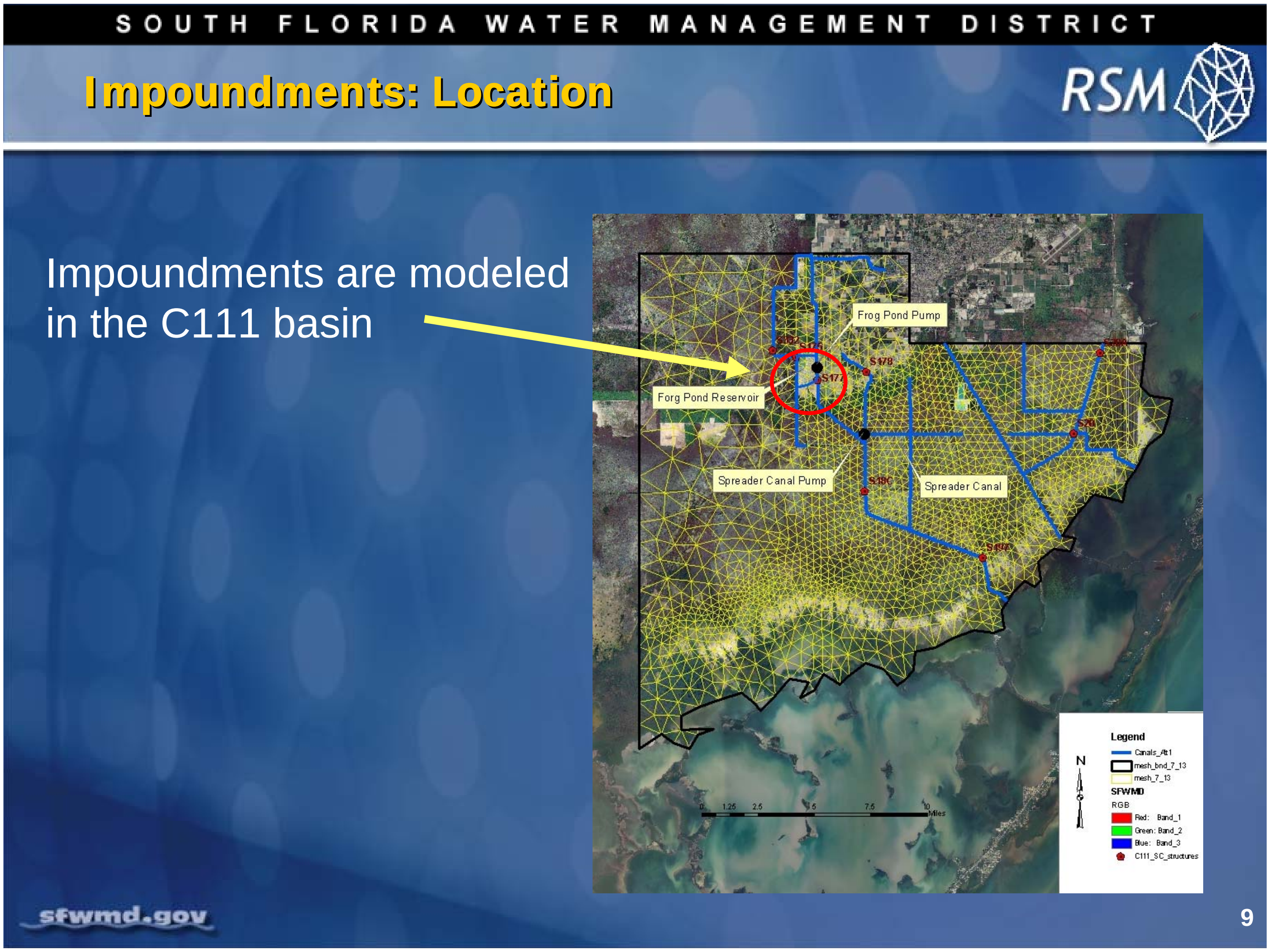
The WS pump has *negative* flow.



Although lakes are useful for simulating large open-water features, they are position-independent and do not interact with the mesh unless the user creates specific watermovers that connect the lake to each cell.

The impoundment provides a feature that interacts with the mesh and thus better represents stormwater treatment areas and shallow reservoirs that interact with the regional groundwater typical of south Florida. Impoundments, which are defined as aboveground structures surrounded by embankments, only interact with the cells immediately below the impoundment.

Impoundments may also extend below the ground, particularly where the material in the embankments are dug from the inside of the impoundment. In this case, the impoundment also interacts with the surrounding cells.



A major component of the C-111 Basin restoration project was testing the construction of impoundments near the Frog Pond. These impoundments have several purposes, which include:

- Providing storage for spreader canal flow to improve the hydroperiod in the downstream marsh
- Providing a groundwater mound to prevent drainage of water from Everglades National Park
- Preventing drainage water from the urban and agricultural land from moving into Everglades National Park

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Impoundments: Implementation

RSM

```
<impoundment id="9300" label="South"   head="5.6"  bottom="5.5"
            owCoeff="1" swCoeff="1" swDepth="1">

   <cellConnect cellId="3579" fullCoverFlag="1"
               kOverDelV="0.000008102" SCconf="0.001"> </cellConnect>
   <cellConnect cellId="3580" fullCoverFlag="1"
               kOverDelV="0.000008102" SCconf="0.001"> </cellConnect>

   <cellConnect cellId="1581" fullCoverFlag="0"
               kOverDelH="0.0001215">  </cellConnect>
   <cellConnect cellId="3583" fullCoverFlag="0"
               kOverDelH="0.0001215">  </cellConnect>
   <cellConnect cellId="1582" fullCoverFlag="0"
               kOverDelH="0.0001215">   </cellConnect>
   <cellConnect cellId="3584" fullCoverFlag="0"
               kOverDelH="0.0001215">   </cellConnect>
</impoundment>
```

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The <impoundment> element consists of attributes that specify the bottom elevation, initial head and the reference cover evapotranspiration (ET) correction factor for the open water <owcoeff> and for the shallow water <swcoeff>, which represents littoral zone vegetation.

The "swDepth" determines the depth of water in the impoundment at which point the ET function switches coefficients.

The <impoundment> includes several <cellConnect> elements, one for each cell the impoundment footprint sits on (fullCoverFlag = "1") and one for each adjacent cell (fullCoverFlag = "0"). Each <cellConnect> specifies a conductivity term that is used with the Darcy Equation to determine the leakage into the groundwater.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Impoundments: Implementation

RSM

Inflow from a dummy lake based on SFWMM 2x2

```
<setflow wmID="7002" id1="40000" id2="9300" label="Inflows from 2x2 run">
  <dss file="../input_12_01_06/daily_str_flw_2005BS.dss"
     pn="/SFWMM/S332D/FLOW/01JAN1965-31DEC2000/1DAY/SIMULATED/"
     mult="1.0" units="cfs"> </dss>
</setflow>
```

Outflow to a canal

```
<genxweir wmID="7004" id1="9300" id2="309517" fcoeff="1.0" bcoeff="1.0"
            crestelev="5.5" crestlen="8.52" dpower="1.0" spower="0.0">
</genxweir>
```

Outflow to another impoundment

```
<genxweir wmID="7003" id1="9300" id2="9100" fcoeff="1.0" bcoeff="3.0"
        crestelev="8.1" crestlen="1900.0" dpower="1.5" spower="0.0">
</genxweir>
```

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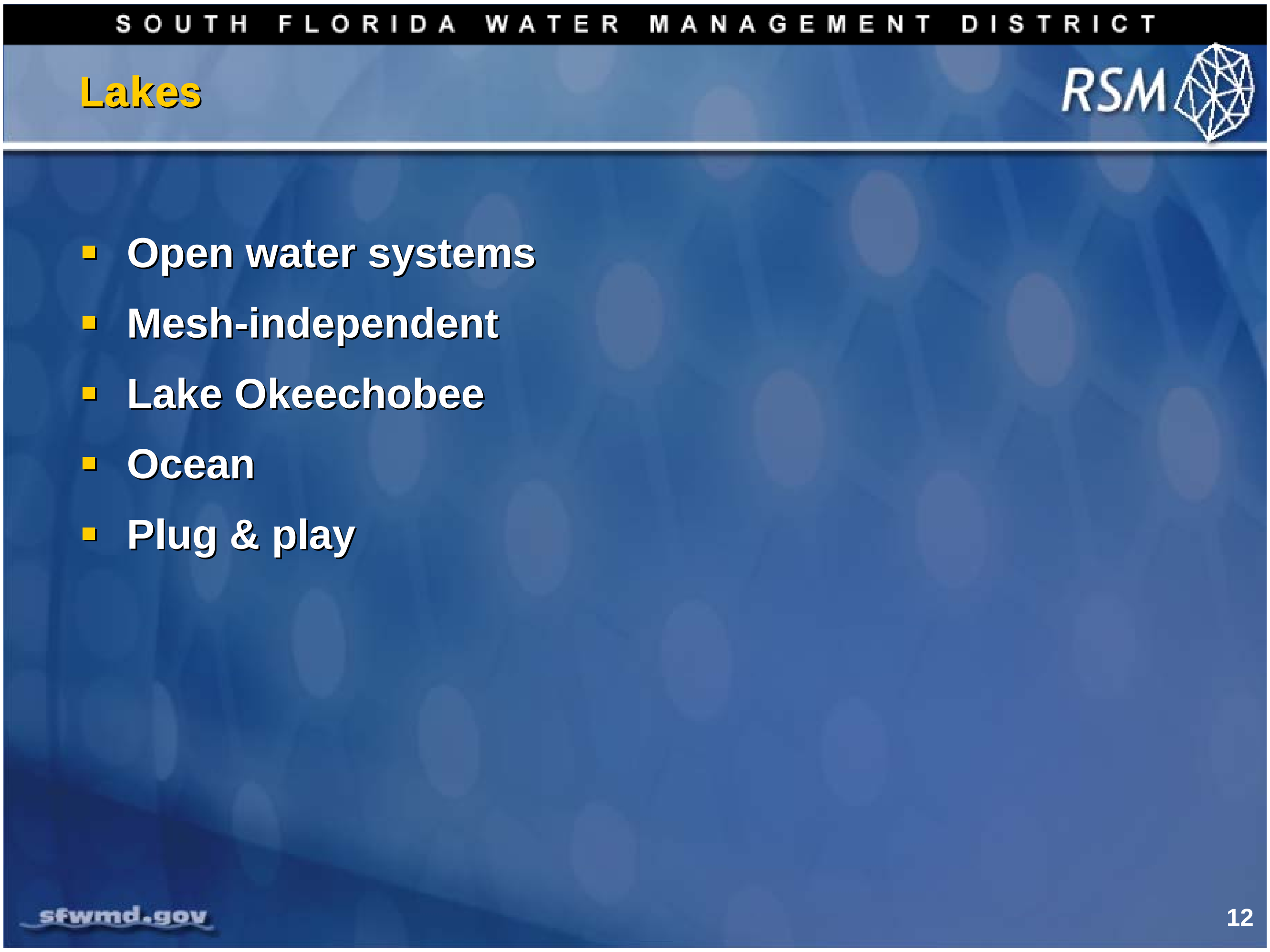
Any watermover can be used to connect the impoundments to other waterbodies. The preferred watermovers include <genxweir> and <setflow>.

The <setflow> element, which is described later in this lecture, behaves like a boundary condition with a time series for flow. In this example, the <genxweir> is set up to behave as a pump where the depth-term exponential is set to 1.0 and the slope-term exponential is set to 0.0. In this instance, the wmID 7004 discharges to a segment and wmID 7003 discharges to another impoundment.



The <lakes> element was developed to represent lakes, reservoirs and other waterbodies that do not require a mesh of cells to simulate hydrology. The <lakes> element is used to represent Lake Okeechobee and the Atlantic Ocean.

This element is useful for creating virtual waterbodies for boundary condition flow. The <lakes> element is used in the Plug & Play modeling approach for substitution for Water Conservation Areas as well as lakes for simulating a simplified regional system for evaluating regional water management strategies (see Lecture 16).

The Plug & Play approach is a linked-node version of the RSM which consists of <lake> and <basin> elements connected by watermovers. Because of the ease with which additional <lake> and <basin> elements can be added to the model, it is referred to as Plug & Play.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Lakes: Implementation

RSM

```
<lakes>
   <lake id="102" head0="17.07">
          &wca1_stgsto;
          &wca1_stgarea;
      <refet> <tsin id="2"> </tsin> </refet>
      <rain><const value="0.0"></const></rain>
   </lake>

   <EvapRainStressors>
      <litZoneET lakeID="102" owcoef="1.0" swcoef="1.0" swdepth="10.0"/>
   </EvapRainStressors>

   <lake_bc>
      <lakesource id="10033" lakeID="102">
         <dss file="data/flowways2.dss"
                   pn="/FLOWWAY/S5AS/FLOW//1DAY/ORIG/"
                   mult="0.5042" units="acft" type="per-aver" />
         </dss>
      </lakesource>
   </lake_bc>
</lakes
```

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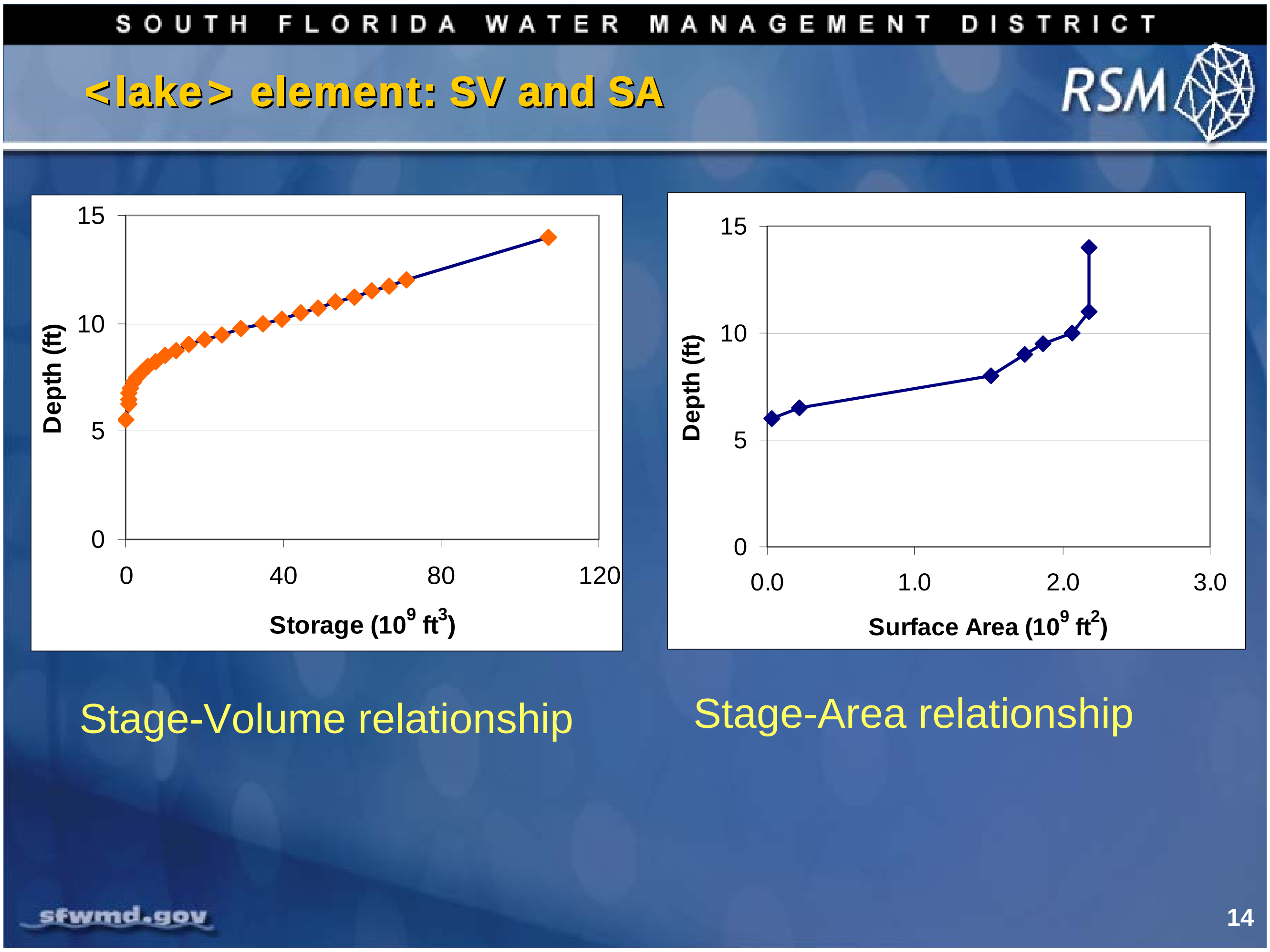
The <lakes> block includes three kinds of elements:

- A <lake> element for each lake
- An <EvapRainStressor> element for each lake
- Boundary conditions which may include one or more <lakesource> elements

The <lake> element has an initial head and a stage-volume (SV) relationship and a stage-area (SA) relationship.

The <EvapRainStressor> element has an ET correction factor (Kc) for open water and shallow water. The shallow water depth determines depth from ground surface for which the shallow water Kc applies.

The <lake> element may have one or more inflows set as a time series boundary condition.



Typical SV and SA relationships obtained from field data are shown in the slide above. This set of graphs represents Water Conservation Area 3A.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Basins

RSM

- Functionally simple
  - Single Rain and refET
- Plug and play

```
<basins>
  <basin id="8001" label="cypress" area="7.58e+09" initial_head="8.0" elev="10.7">
      <sv>
           6.7  0.0
           10.7 6.066e+09
           14.7 3.640e+10
      </sv>
    <rain> <dss file="weather.dss" pn="/LOSA/AREAL/RAINFALL//1DAY/ESTIMATED/"
                                   mult="0.0254" units="INCHES">   </dss>
    </rain>
    <refet> <const value="0.015" /> </refet>
  </basin>
</basins>
```

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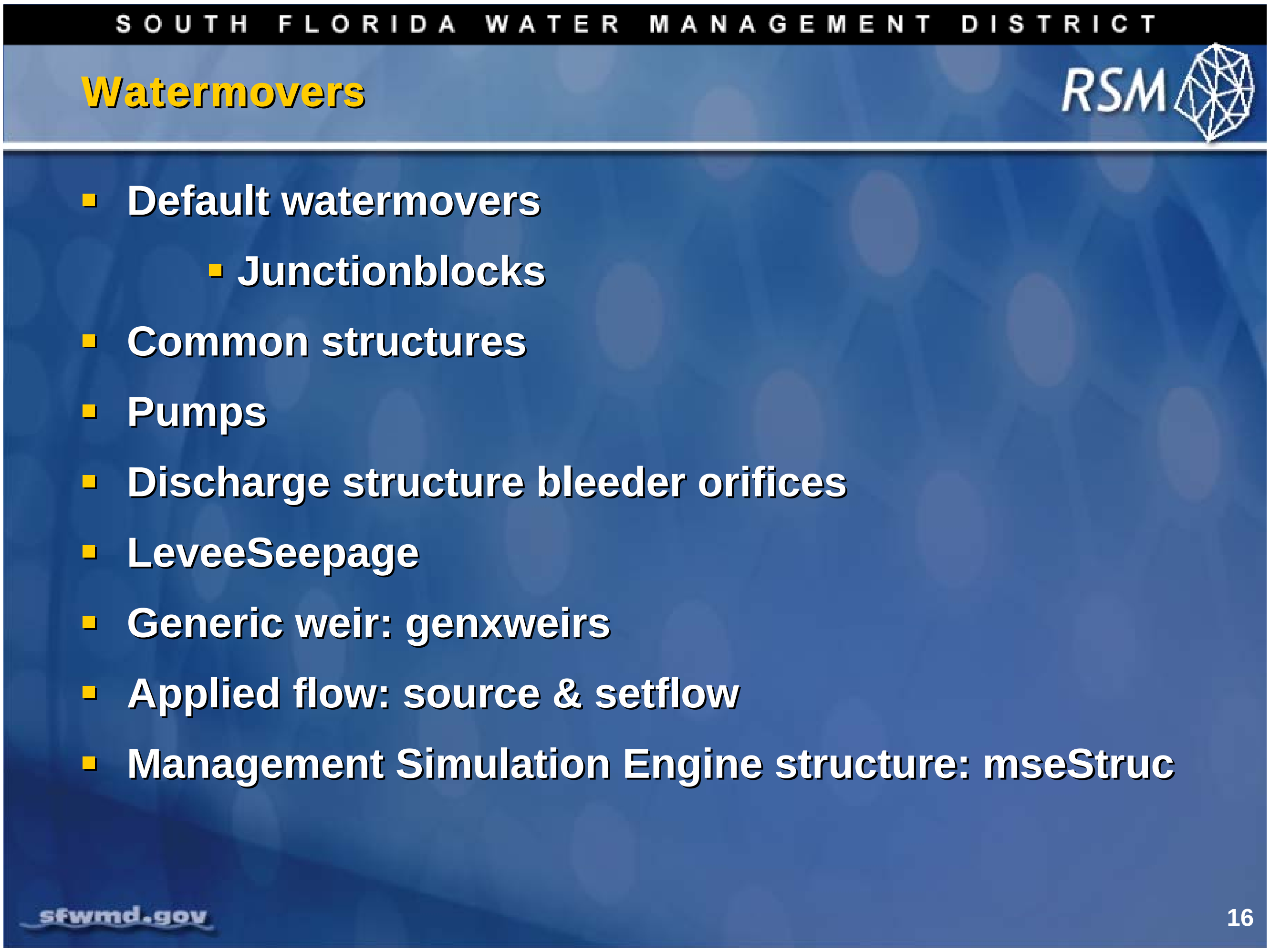
Basins were developed as simple surrogates for complete meshes in a regional model. For resolving regional water management policy issues, the Plug & Play approach was developed (see Lecture 16) because the model execute times for a complete mesh for the entire south Florida domain are considered prohibitive. Basins can be used for the subregions of the domains that are not of detailed interest.

The syntax for a <basin> element includes the area, initial head and average surface elevation. A stage-volume relationship is provided, and in this case the value for specific yield is set to the default value of 0.20 for estimating the storage volume between the bottom (6.7) and the surface (8.0).

A rainfall and reference vegetation evapotranspiration can be provided as standard input here as a constant or a time series.



There are 32 types of watermovers available in the Regional Simulation Model. The RSM creates default watermovers between all adjacent cells and segments. All other watermovers must be specified in the XML input. In the case of in-line structures in the primary canals, a <junctionblock> must be inserted between adjacent segments to override the default watermover so that the user-specified watermover controls flow.

The watermovers can be grouped by function. Common structures such as pipes, culverts and weirs, pumps, and bleeders, are an implementation of standard structure flow equations.

The <genxweir> is a special case equation that mimics a weir and is unconditionally stable. The <source> and <setflow> watermovers apply the flow from a time series to selected waterbodies. The <mseStruc> is a simple watermover that is controlled by the MSE (see Lecture 15 and Lecture 16).

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

User-specified watermovers

RSM

single_control	vnotchbleeder
dual_control	circularbleeder
deltaControlPump	rectbleeder
delta_control	genxweir
hq_relation	genStruc
mbrbroadweir	source
mbrsharpweir	setflow
mbrdropweir	shunt
standardweir	mseStruc
pipe	lpStruc
culvert	hydropower
gateweir	yarnell
spill	lakeseepage
genweir	leveeSeepage
genxweirsub	ormConstCap

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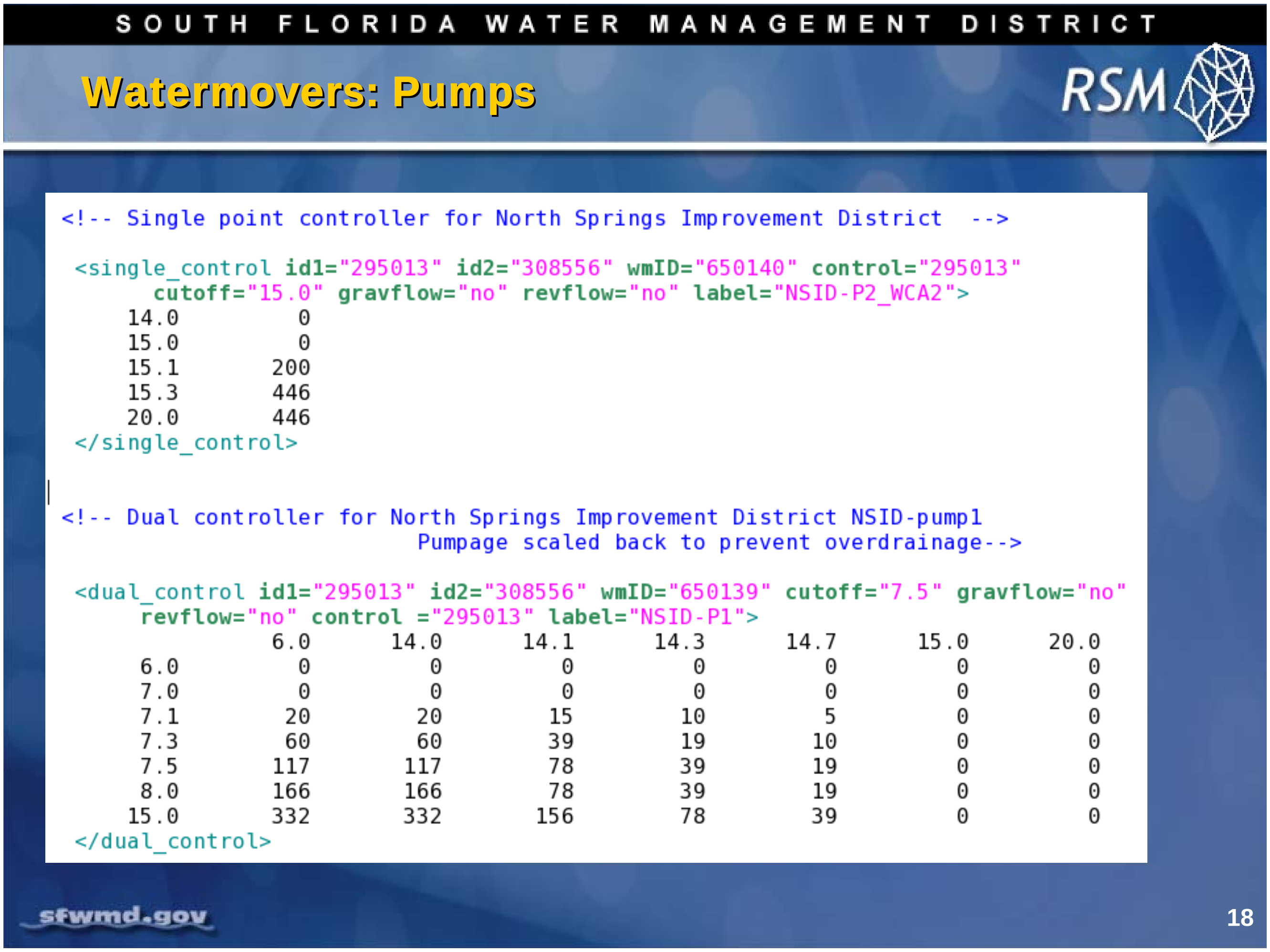
Currently available structures in the RSM include:

- Red watermovers are commonly used types, with black and green watermovers used for special conditions.
- Yellow structures are implementations of standard structure equations. These are not frequently used in the RSM because they do not function well at large timesteps (6-hour to daily), used in the RSM regional water management simulations.
- Green watermovers are particularly useful when calibrating the model. It is desirable to fix the known structure flows to historical time series in order to calibrate canal-aquifer interactions.
- White watermovers are used infrequently.

A detailed discussion of the equations governing the implementation of the watermovers is available in the *HSE User Manual*.



There are two commonly used pump types:

1. The <single_control> element, which was discussed in Lab 2, **Fig. 2.7.**
2. The <dual_control> element, which models a pump where there is significant backwater effect.

The <dual_control> element requires:

- "from" waterbody ID number
- "to" waterbody ID number
- "cutoff" – the elevation at which flow ceases
- "gravflow" – whether water can flow by gravity through the structure
- "revflow" – whether water can flow in the reverse direction if the "downstream" head is higher

This <dual_control> element is difficult to use because it requires considerable knowledge of the physical structure and its flow regimes.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Watermover: genxweir

RSM

Unconditionally stable

$$Q(H_j^{n+1}, H_i^{n+1}) = Q(H_j^{n}, H_i^{n}) + \frac{\partial Q}{\partial H_j}\Delta H_j + \frac{\partial Q}{\partial H_i}\Delta H_i \quad (1)$$

genxweir

$$Q = C_d L (H_u - z_c)^a (H_u - H_d)^b \quad (2)$$

H_u – upstream water level $0.9 < a < 1.9$
H_d – downstream water level $0.2 < b < 0.9$
Z_c – weir crest elevation

genxweirsub

$$Q = C_d L (H_u - z_c)^a \left(1 - \left(\frac{H_d - z}{H_u - z}\right)^p\right)^q (H_u - H_d)^b \quad (3)$$

where: *p* = 1.2 and *q* = 0.385
z = H – d, surface water level – submergence depth

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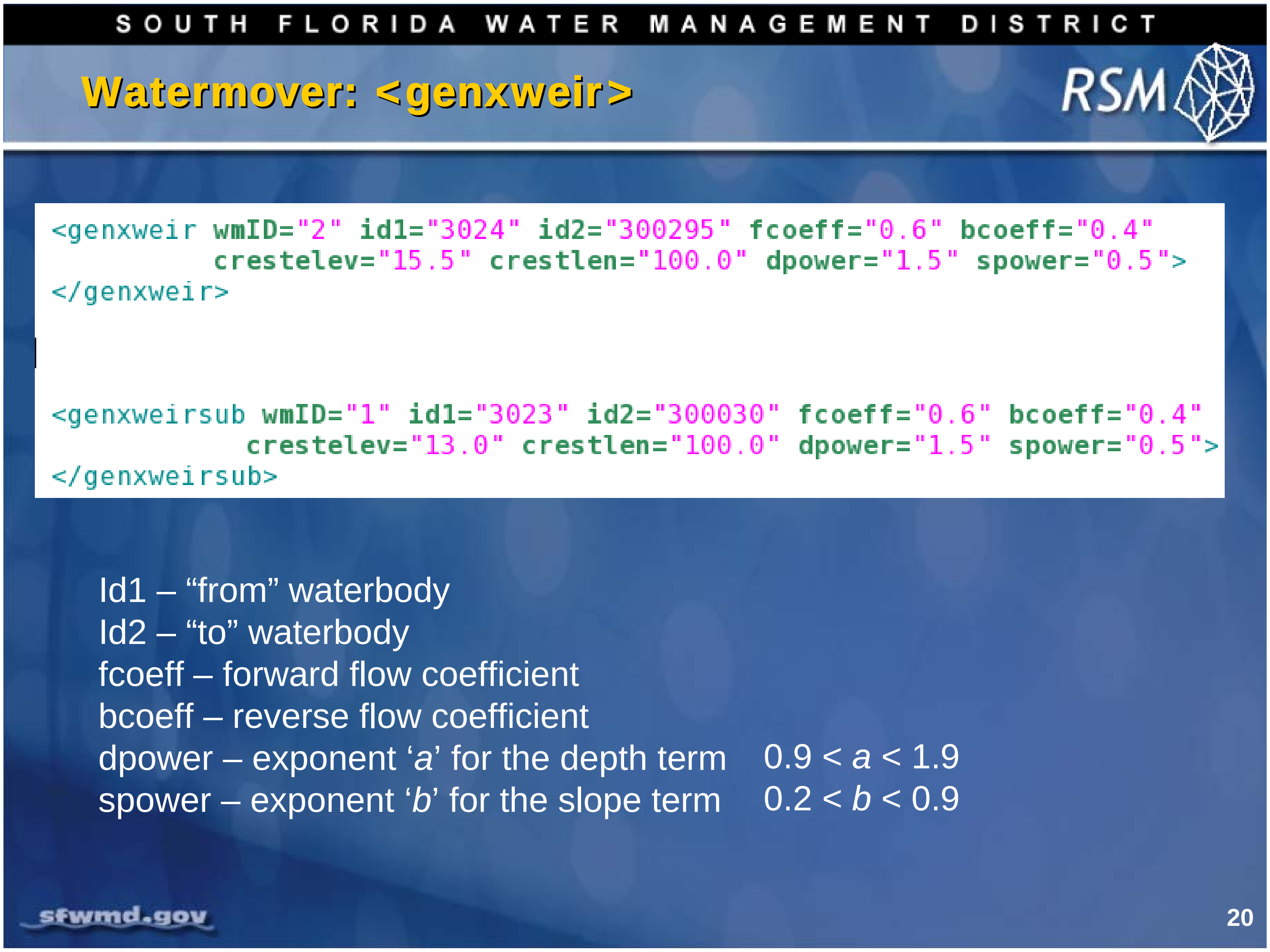
The generic structure <genxweir> is the preferred user-specified watermover. The watermover specified in Equation 2, solves the numerical solution of Equation 1, because it is a smooth, continuous function that is differentiable throughout its range of application.

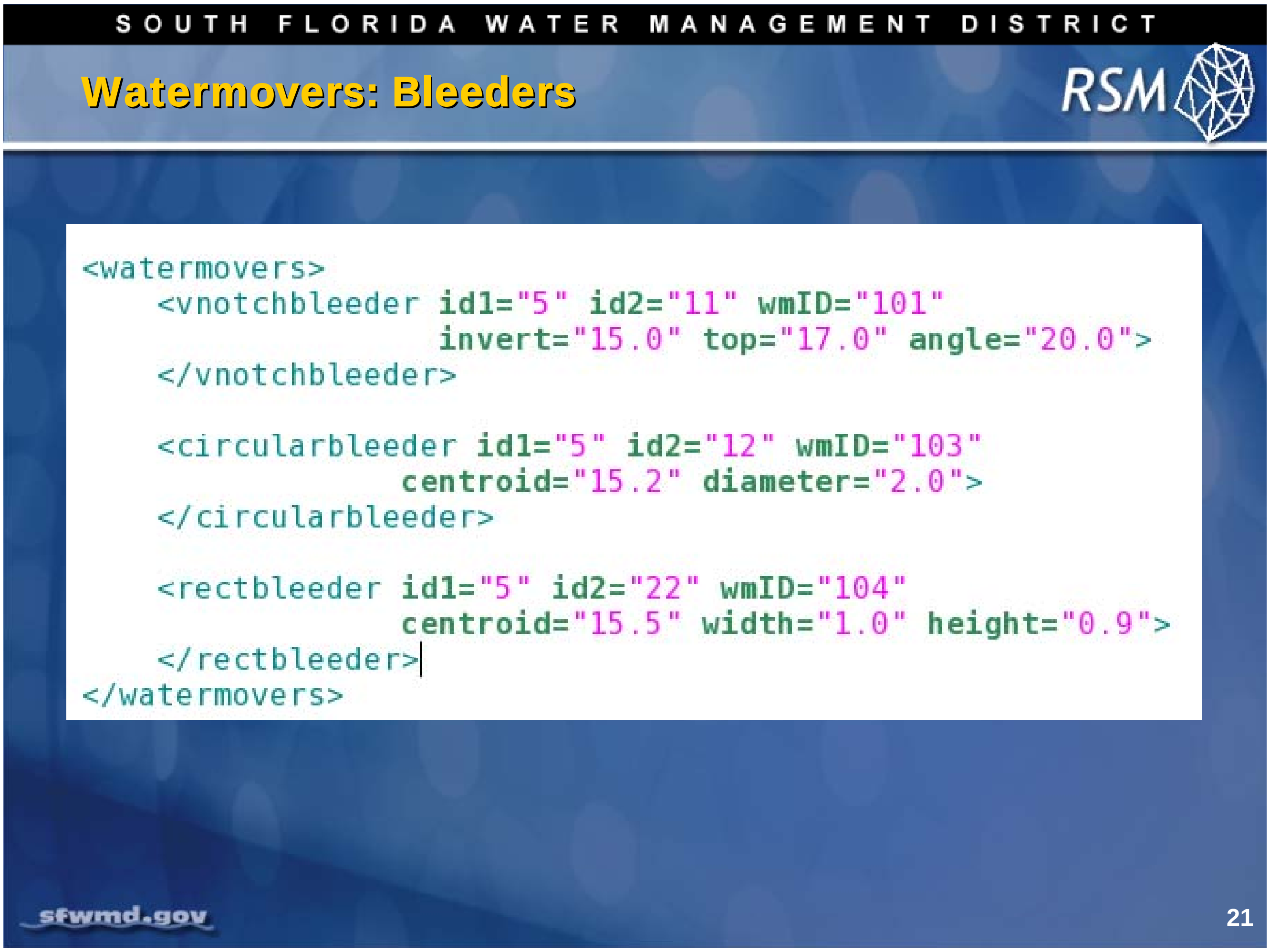
The <genxweir> equation accounts for both the effect of depth of water in the source waterbody and the slope of the energy gradeline. With the appropriate values of C_d, L, *a* and *b,* most structures from culverts to weirs can be represented by this function: `$RSM/labs/lab10_WB&WM/genxweir.pdf`.

For the case where the structure is submerged, <genxweirsub> (Equation 3), the values of *p* and *q* are fixed.

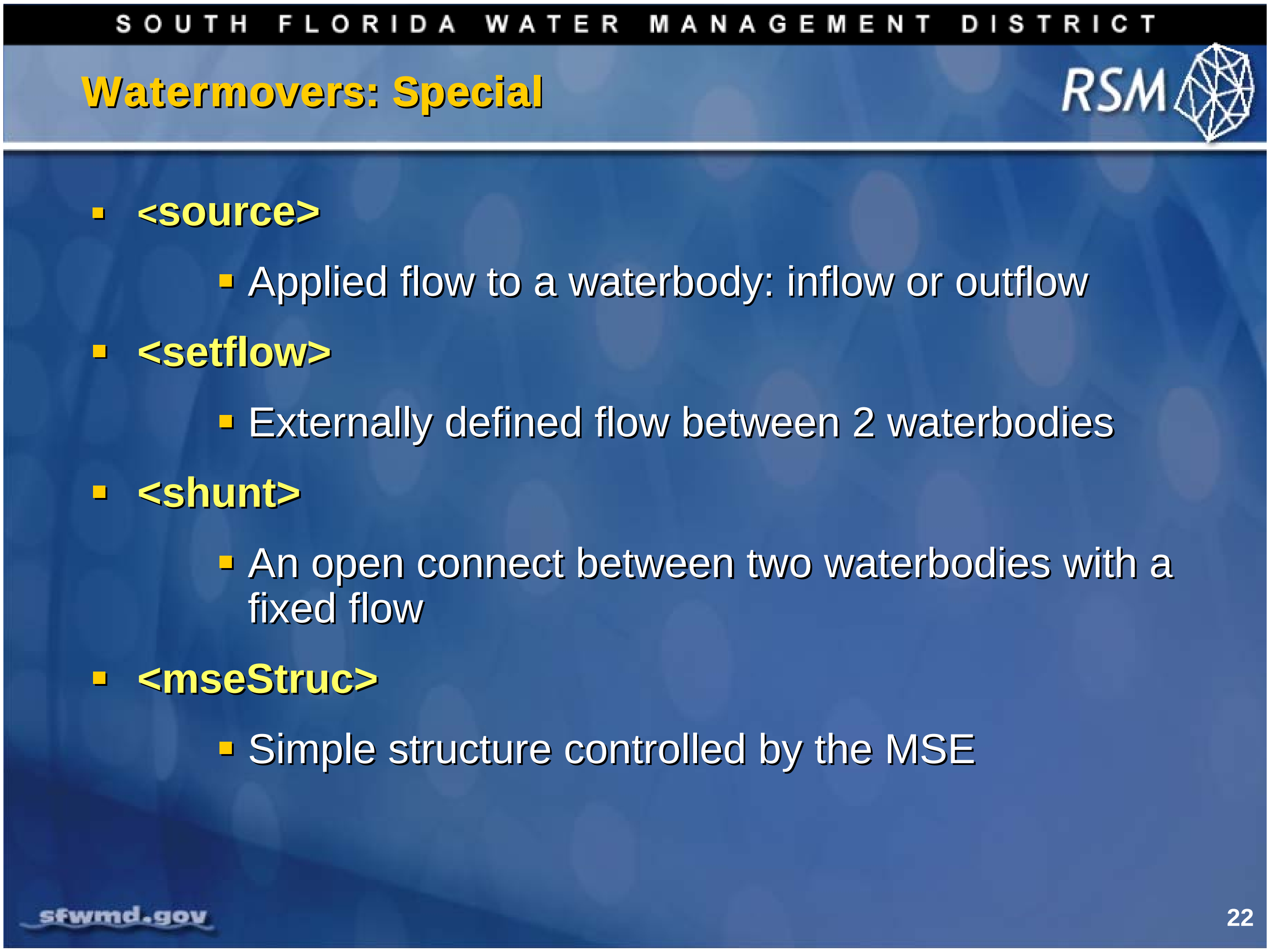
The <genxweir> can be used to replace all structures with the exception of pumps.



The standard form of the <genxweir> element includes the crest elevation, the stage below which no flow occurs, an effective crest length, and coefficients for forward and reverse flow. The effective crest length must be estimated through calibration or some other method for structures that do not have a typical crest. There are default values for the exponents and the flow direction coefficients; other values must be selected carefully.



Bleeders can be used with stormwater detention ponds and impoundments. The flow equations follow the standard hydraulic equations for these structures. Bleeders can work with short or long time steps.



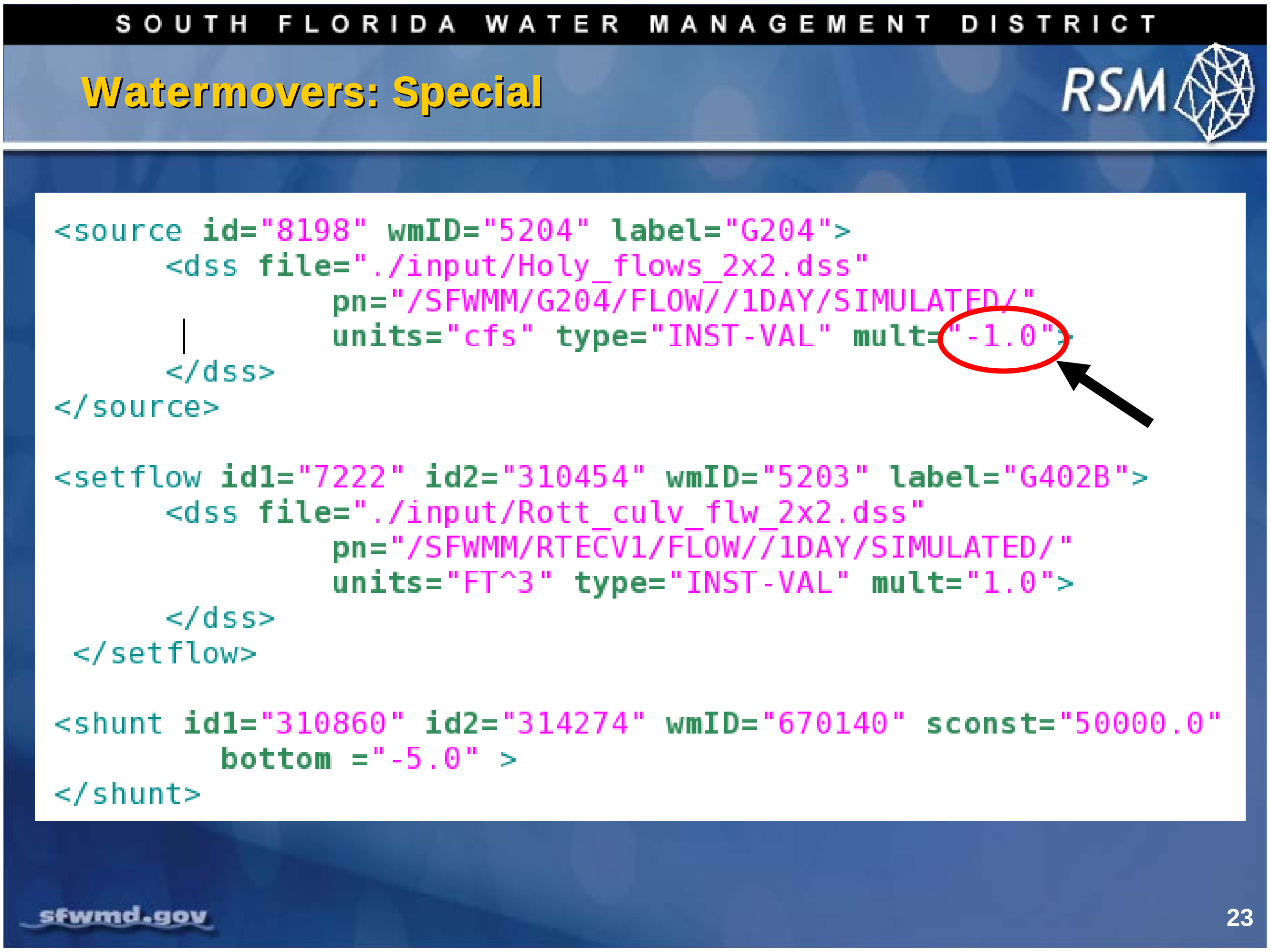
There are several special watermovers that are used to impose known flows on the RSM.

The <source> element allows us to apply a time series of flows to a waterbody. This can be an inflow or an outflow by changing the sign of the multiplier. It is useful when there is a known inflow but it is not a standard boundary condition.

The <setflow> element sets the flow between two waterbodies, typically between two segments where there is a structure. This is useful in the calibration stage where known flows are used to calibrate canal-aquifer interactions. It is also useful when you want to reduce run time in sections of the domain while evaluating other features.

The <shunt> element is used to model open connects between canals.

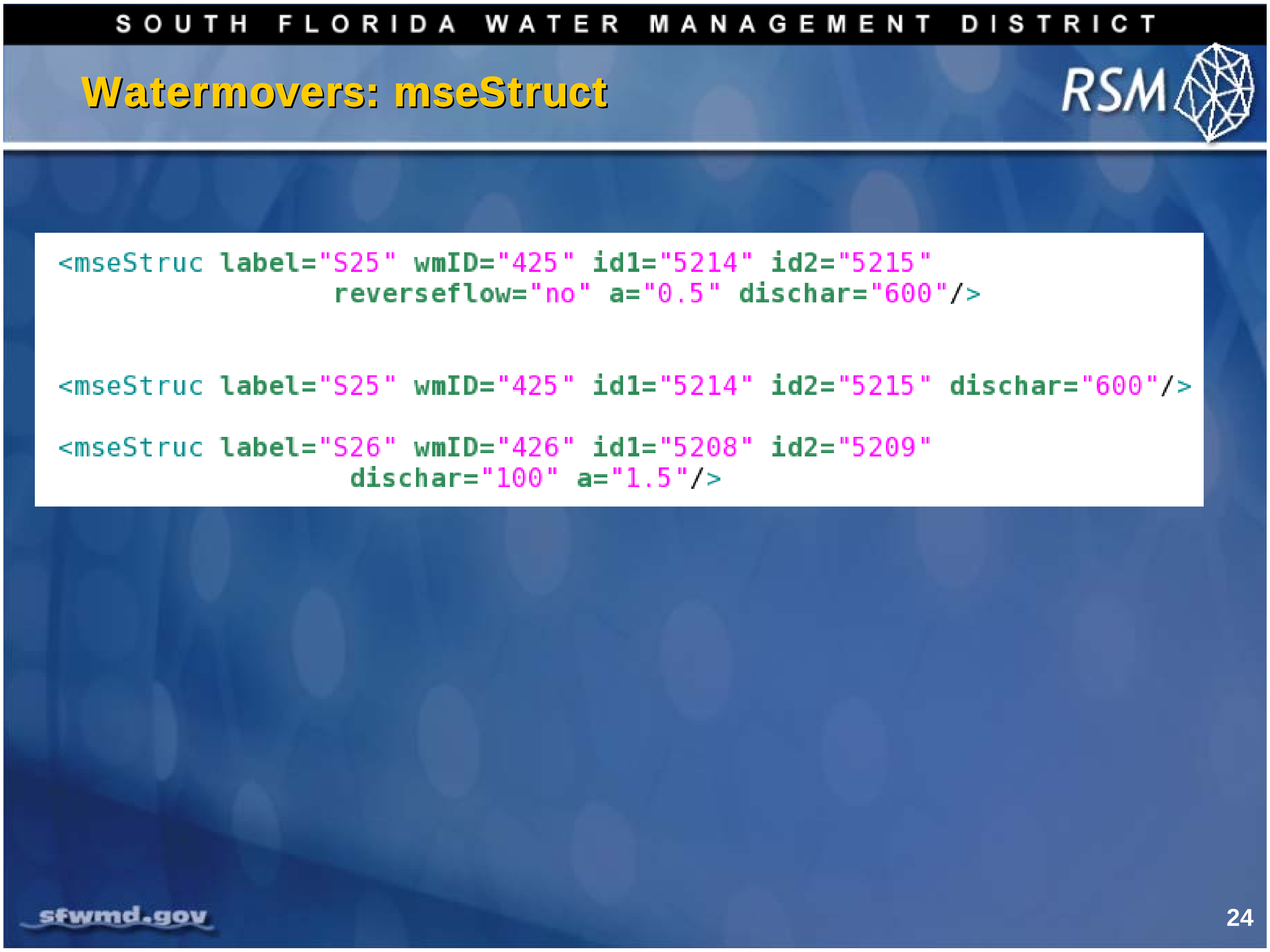
The <mseStruc> element is a simple structure that has a maximum discharge, which can be modified based on the Management Simulation Engine results.



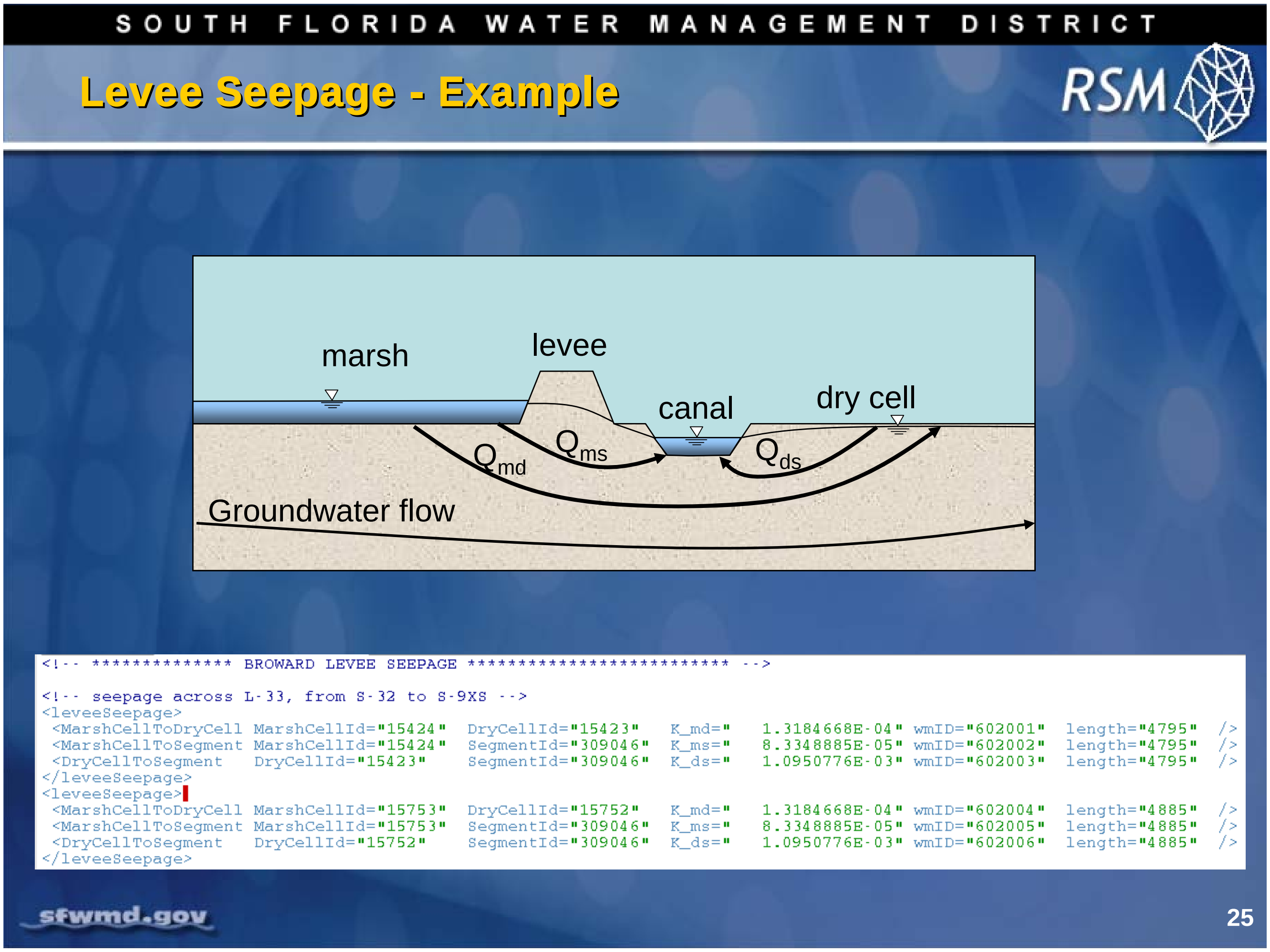
Typical syntax for the special watermovers is presented in the slide above. The input time series for <source> and <setflow> typically come from DSS files, either the standard RSM datasets or specifically developed datasets. The input for the <shunt> specifies the constant flow and the cutoff elevation.

NOTE:

Outflows are defined using a negative multiplier.



The <mseStruct> element is a typical discharge structure with a = 0.5 for the slope exponential. It can be varied according to structure type. Maximum discharge rate that is modulated using the Management Simulation Engine.



The <leveeseepage> watermover was created to handle water movement from wetlands to canals through levees. This function creates three distinct watermovers: Qms, Qds and Qmd, which replace the cell-canal watermovers.

The cell-canal watermovers that are made by default, based on the network/mesh geometry, are disabled. There is no water flow into the canal except through the <leveeseeage> watermover. Water moves to the canal and to the dry cell based on the heads in the:

- Dry cell
- Marsh cell and segment corresponding conductivities
- Length of the cell-canal line of interaction

For each levee, a no-flow surface water mesh boundary condition is created. There is no surface water flow between cells, but there is groundwater flow.

KNOWLEDGE ASSESSMENT

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

1. How many types of waterbodies are available in RSM?
2. What are the primary uses of the Water Control Districts?
3. What are the elements necessary for a WCD?
4. How do impoundments differ from lakes?
5. How do impoundments interact with the mesh?
6. What are Lakes typically used to model?
7. How are Basins used in RSM?
8. How many types of watermovers are used in RSM?
9. Which watermovers are frequently used in RSM?
10. What three watermovers are implemented when the <LeveeSeepage> element is implemented?

Answers

1. There are several methods for creating an RSM mesh: create by hand (small meshes), USACE GMS mesh generator, import a mesh.

2. The WCDs are used to simulate secondary canal systems that are separated from the primary system by managed water control structures.

3. The elements of the WCD include the following:
    - <wcdwaterbody>, the central storage waterbody;
    - <sv>, which defines the stage-storage relationship for the waterbody, <wcdmover> which defines the connection between each cell in the WCD and the WCDwaterbody,
    - <watermovers> which contains the structures that connect the WCD to the primary canals.
    - <noflow> boundary conditions that define the extent of the WCD..

4. Impoundments are waterbodies that sit on top of the mesh and interact with the mesh cells below the footprint and the adjacent cells. Lakes have no geographic location and their connectivity is specifically defined by the watermovers used to connect them to other waterbodies.

5. Impoundments may model above-ground storage and only interact with the cells below the footprint or they may be in-ground storage that also interact with adjacent cells.

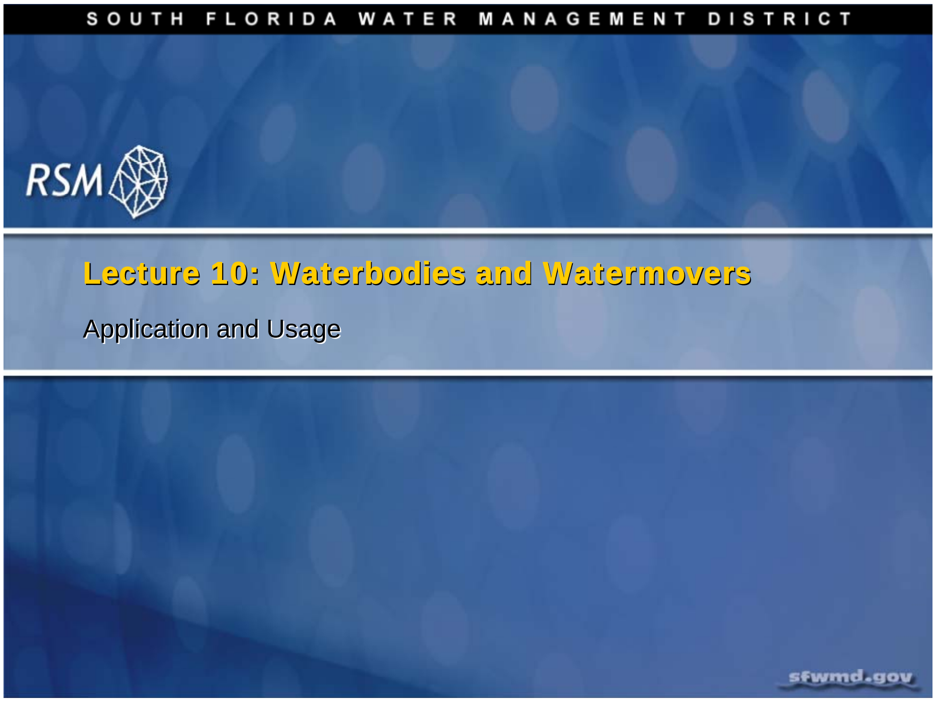
6. Lakes are used to model the ocean, upstream water sources, lakes and Water Conservation Areas.

7. Basins are used to model water control units where a detailed mesh is not desired.

8. There are currently over 32 watermovers available for RSM.

9. The frequently used watermovers include the genxweir, single-control (pump), mse_struct and leveeSeepage.

10. The <leveeSeepage> watermover implements the following watermovers: MarshCellToDryCell, MarshCellToSegment and DryCellToSegment



Lab 10: Waterbodies and Watermovers – Application and Usage

Time Estimate: 3.5 hours

Training Objective: Familiarize the user with the different types of waterbodies and user-specified watermovers

The typical Regional Simulation Model (RSM) implementation consists of a mesh and canal network. The watermovers between the cells and segments are created automatically. The user can add lakes, basins and impoundments as additional features to the model.

In this lab, you will add lakes, a basin and an impoundment to the Everglades Agricultural Area–Miami Canal (EAA-MC) RSM application that was developed in Lab 4. In the second part of this lab, you will implement watermovers in the RSM.

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/lab10_wbwm`** directory. Additional materials in the directory include:

`genxweir.pdf`

Activity 10.1: Implementation of Waterbodies in the RSM

Overview

Activity 10.1 This activity includes three exercises:

- **Exercise 10.1.1.** Add two lakes to the EAA-MC RSM to representWCA3A.
- **Exercise 10.1.2.** Add an impoundment to the EAA-MC RSM north of the Holeyland
- **Exercise 10.1.3.** Add the S236 Basin to the EAA-MC RSM Impoundment

In this activity you will add a lake, basin and impoundment to the Everglades Agricultural Area–Miami Canal (EAA-MC) RSM application (developed in Lab 4, see **Fig. 10.1**).

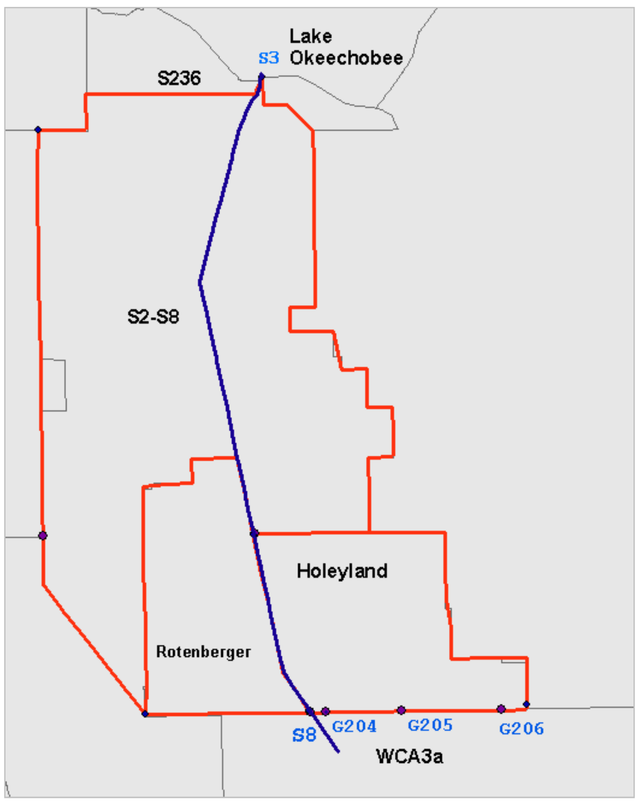


Figure 10.1 Subbasins and structures in the Everglades Agricultural Area-Miami Canal Basin

In addition to the mesh and segment waterbodies available in the simple RSM implementation, there are additional special purpose waterbodies available in the RSM. These include lakes, basins, water control districts and impoundments. Additional waterbodies may be developed in the future as necessary.

Lakes

The basic conceptualization for the <**`lakes`**> element is presented in Benchmark 13 (see **`$RSM/benchmarks/BM13/run3x3.xml`** and **Fig. 10.2**). The first example has a variable stage-volume and stage-surface relationships. The second lake is presented as a simple cylinder.

The first example provided below is for Water Conservation Area 3A (WCA3A). The second example can be used for Lake Okeechobee, which is modeled as a very large cylinder with no evapotranspiration (ET) or rain.

The stage-volume and stage-surface area relationships are provided in files in the **`lab10_wbwm`** directory **`(<wca3a_stgsto.xml>`** and **`<wca3a_stgarea.xml>`**) and illustrated in **Fig. 10.3**.

The rainfall and reference vegetation evapotranspiration are provided as time series.

The ET losses are calculated using the **`<EvapRainStressors>`** element with a separate vegetative cover ET adjustment coefficient for open water (**`owcoef`**) and for shallow water (**`swcoef`**).

Lake boundary conditions can be assigned to the lake reflecting seepage from the lake into the surrounding basins.

```
<lakes>
  <lake id="23" head0="490.0" label="Lake koko" package="standard"
   supplant="-1" top="1000">
    <sv>
        10.0     0.0
       400.0     4.0e8
       600.0     6.0e8
    </sv>
    <sa>
        10.0     3.0E6
       600.0     3.0E6
    </sa>
  </lake>
  <lake id="24" head0="515.0" supplant="3" label="Pond wawa"
   package="standard" top="1000">
        <cylinder toparea="6.0E6" bot="10"></cylinder>
  </lake>
.
.
.
</lakes>
```

Figure 10.2 Lake component of Benchmark 13

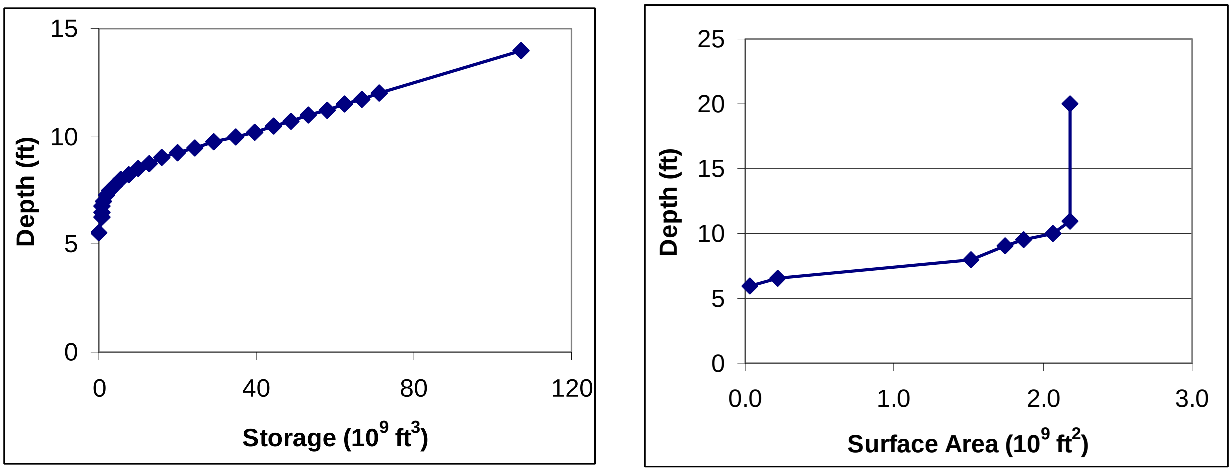


Figure 10.3 The Stage-Volume and Stage-Surface Area relationships for WCA3A

Exercise 10.1.1 Add two lakes to the EAA-MC RSM to represent WCA3A

Add the <lake> element for WCA3A, described above, to the eaamc_net2.xml RSM implementation (developed in Lab 6; check the lab6/answers directory).

3. Add the lines of code listed in **Fig. 10.4** into the **`run3x3.xml`** file. Modify the code to represent WCA3A based on the information in the **`losa.xml`** in Benchmark 70 (BM70).

```
    <!-- ================================================================
               lake specifications for Water Conservation Area 3a
         ================================================================
-->
    <lake id="105" head0="9.51">
      &wca3a_stgsto;
      &wca3a_stgarea;
      <refet>
        <dss file="tsdata/weather.dss"
               pn="/SFRRM/WCA/EVAPI//1DAY/COE ESTIMATE/"
             mult="0.0833" units="inches">
        </dss>
      </refet>
      <rain><const value="0.0"></const></rain>
    </lake>
```

Figure 10.4 Example XML file for a water conservation area modeled using Stage-Volume and Stage-Surface Area relationships.

4. Add the <ENTITY> elements at the top of the file for including the stage-storage and stage-area relationships (see **`$RSM/benchmarks/BM70/losa.xml`**).
5. Replace the boundary condition for the network segment 300013 and add a watermover between the network and the lake.
6. A simple watermover, <single_control> can be used to move water from the network to WCA3A (Fig. 10.5). Change the id1, id2 and control values to reflect the lake id= 4005 for WCA3A.

```
    <single_control id1="105" id2="106" wmID="821" control="105"
cutoff="8.0"
         gravflow="yes" revflow="no" label="l67gap">
            5.5    0.0
            8.0    0.0
           11.0  500.0
           20.0  500.0
    </single_control>
```

Figure 10.5 Example XML entry for a “single”control” <watermover> used to model a pump.

7. Remove the <bcmonitor> and replace it with a <wmmonitor>. Modify the wmmonitor appropriately for the appropriate watermover ID.

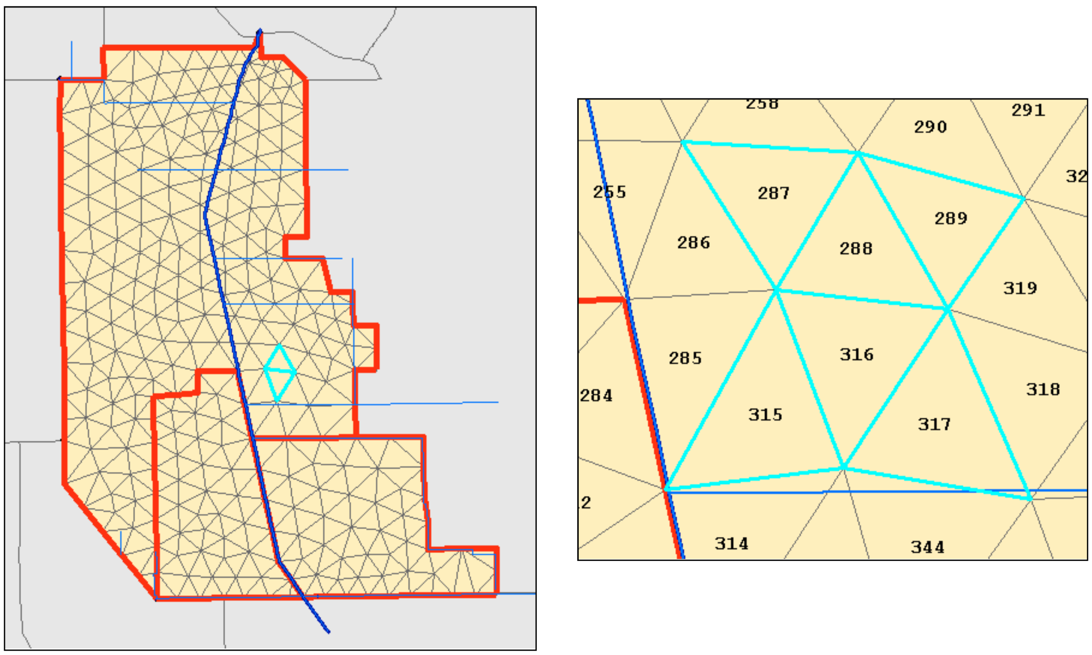
```
<wmmonitor wmID="801" attr="flow" label="-lo2wca1">
      <dssfile="flows" /> </wmmonitor>
```

8. Add a <lakemonitor> for WCA3A based on the output found in BM70:
   - (see **`$RSM/benchmarks/BM70/output/losa_output.xml`**).
9. Run **`eaamc_wca3a.xml`** using the RSM Graphical User Interface (RSM GUI) and observe the results.
10. Add a cylinder lake to represent Lake Okeechobee. The lake characteristics should be as follows:
    - **`Bottom = -15.0, ID = 4001, area = 10e10, head0=15.0`**
11. Replace the boundary condition for the network segment 300001 and add a watermover between the network and the lake.
12. A simple watermover, <single_control> can be used to move water from the network to Lake Okeechobee. Correct the id1 and id2. The control value should be based on the head in the canal, which is set so that the stage in the canal will not drop below 7.0.
13. Add a <wmmonitor> and a <lakemonitor> for Lake Okeechobee.
14. Save the model as **`eaamc_lakes.xml`**
15. Run the model and observe the resulting heads in the segments and mesh cells using HecDssVue from the RSM GUI.

Impoundments

The impoundments are used to store water aboveground. They are leaky and will flow into the cells directly below the impoundment.

For the EAA-MC Basin, an impoundment will be added to capture the water from the Miami Canal (**Fig. 10.6a**). The water will be discharged into the Holeyland (see **Fig. 10.1**). The impoundment will occur in Cell 288 and Cell 316 (**Fig. 10.6b**).



a) Location of the impoundment

b) Cells in and around impoundment

Figure 10.6 Impoundment for EAA-MC Basin

The syntax for the impoundment is presented in Benchmark 71. The typical impoundment has a footprint that sits above two or more cells, and these cells are identified as fullCoverFlag="1" (see **Fig. 10.7**).

The impoundment interacts with the cells adjacent to the impoundment that have a wall along the side of the impoundment. These cells are identified as fullCoverFlag="0". The impoundment will have an outlet, typically a weir, but it may have other watermovers (refer to Lab 2).

```
  <impoundments>
    <impoundment id="28"
                 label="Frog Pond Reservoir"
                 head="501"
                 bottom="500"
                 owCoeff="1"
                 swCoeff="1"
                 swDepth="1">
      <cellConnect cellId="14"
                   fullCoverFlag="1"
                   kOverDelV="0.00000278"
                   SCconf="0.001">
      </cellConnect>
      <cellConnect cellId="5"  fullCoverFlag="1" kOverDelV="0.00000278"
SCconf="0.001">
      </cellConnect>
      <cellConnect cellId="4"  fullCoverFlag="0" kOverDelH="0.0001041">
</cellConnect>
      <cellConnect cellId="11" fullCoverFlag="0" kOverDelH="0.0001041">
</cellConnect>
      <cellConnect cellId="15" fullCoverFlag="0" kOverDelH="0.0001041">
</cellConnect>
      <cellConnect cellId="8"  fullCoverFlag="0" kOverDelH="0.0001041">
</cellConnect>
    </impoundment>
  </impoundments>
```

Figure 10.7 Impoundment covering cells 14 and 5, and adjacent to cells 4, 11, 15, and 8.

Exercise 10.1.2 Add an impoundment to EAA-MC RSM north of Holeyland

The impoundment should cover six cells and not touch the boundary of the Miami Canal.

1. Add an **`<impoundment>`** element to the **`eaamc_lakes.xml`**.
   - Set **`bottom = 13.0 feet, head = 12.0 feet, id=9000`**
2. Modify the **`<cellconnect>`** element to include the correct cells.
3. Add a **`<singlecontrol>`** pump to move water from the Miami Canal (segment=300009) into the impoundment (see **Fig. 10.8**). The stage in the impoiundment will control the flow.
   - Set the control to be the impoundment ID and set the cutoff at 15 feet.

```
<single_control id1="9000" id2="210" wmID="101" control="9000"
    cutoff="15.0" gravflow = "no" revflow="no" label="res_in">
    13.0  0
    13.5  100
    14.0  100
    15.0  100
    15.1  0.0
</single_control>
```

Figure 10.8 Syntax for single-control pump

4. Add a **`<genxweir>`** as an outlet structure for the impoundment (see **Fig 10.9**).
   - Set the outlet waterbody to a cell in the Holeyland.
   - Set the **`crestelev = 13.75`** and the **`crestlen = 20`**.

```
 <genxweir wmID="102" id1="9000" id2="4" fcoeff="0.6" bcoeff="0.4"
    crestelev="16.0" crestlen="1.0e2" dpower="1.5" spower="0.5">
</genxweir>
```

Figure 10.9. Syntax for genxweir outlet structure

5. Add an **`<impoundmentmonitor>`** to the **`<output>`** block to record the stage in the impoundment. (A suitable monitor can be found in Benchmark 71).
6. Add a **`<cellmonitor>`** to the **`<output>`** block for the cell into which the impoundment runoff is discharged.
7. Save the model as **`eaamc_impound.xml`**.
8. Run the model using the RSM GUI and observe the results using HecDssVue from the RSM GUI Toolbar.

Basins

For basin specifications for the S236 basin **($RSM/benchmarks/BM70/hse/basins/wse_basins.xml)**, refer to Benchmark 70 as an example. The S236 basin is north of the EAA-MC basin (Fig. 10.11).

The storage volume depends on the elevation. The storage coefficient for the aquifer is 0.2.

```
<basin id="8013" label="s236basin" area="0.287e9" initial_head="9.2"
        elev="10.7" sscoef="0.2">
  <sv>
     6.7      0.0
    10.7  0.230e9
    11.7  0.517e9
    12.7  0.804e9
  </sv>

  <rain>
    <dss file="weather.dss"
         pn="/S236/AREAL/RAINFALL//1DAY/THSN ESTIMATE/"
         mult="0.0833" units="INCHES" /> </rain>
  <refet>
    <dss file="weather.dss"
         pn="/S236/AREAL/PET//1DAY/INVERSE-DIST ESTIMATE/"
         mult="0.0833" units="INCHES" /> </refet>
</basin>
```

Figure 10.11 Syntax for a basin.

Exercise 10.1.3 Add the S236 basin to EAA-MC RSM Impoundment

9. Add the **`<basin>`** element for S236 described above to **`eaamc_impound.xml`**.
10. Add the **`<layer1nsm>`** HPM for Basin S236 to the **`eaamc_impound.xml`**.
11. Add a **`<single control>`** watermover to **`eaamc_impound.xml`** that connects the impoundment (described above) to the basin.
    - Set **`flow = 50.0 cfs, control = S236, cutoff = 10.0.`**
    - Create a stage-discharge relationship that delivers 50.0 cfs between 10.0 and 14.0 ft. Decrease the flow from the canal to the impoundment from 100.0 to 50.0 cfs.
12. Add a **`<basinmonitor>`** to the **`<output>`** block of **`eaamc_impound.xml`** (an appropriate **`<basinmonitor>`** can be found in Benchmark 70).
13. Save the model as **`eaamc_basin.xml`**.
14. Run the model using the RSM GUI and observe the results using HecDssVue.

Activity 10.2: Implementation of Watermovers in the RSM: genxweir and bleeders

Overview

Activity 10.2 This activity includes two exercises:

- **Exercise 10.2.1.** Add genxweir to the EAA-MC RSM.
- **Exercise 10.2.2.** Test the behavior of bleeders.

There are several user-specified watermovers that can be used in the RSM to model the behavior of various structures **(Table 10.1)**.

Table 10.1

pipes	genStruc	culvert	delta_control	deltaControlPump
single_control	dual_control	vnotchbleeder	circularbleeder	rectbleeder
gateweir	mbrbroadweir	mbrsharpweir	mbrdropweir	standardweir
genweir	genxweir	genxweirsub	mseStruc	genStruc
setflow	source	LPStruc	doublet	hq_relation
yarnell	shunt	spill		

Each of these watermovers has been tested for short timesteps in limited applications.

The **<genxweir>** and **<genxweirsub>** watermovers have been demonstrated to be unconditionally stable under all simulated conditions, particularly for large timesteps. Other watermovers that are commonly used include:

- Pumps (single_control, dual_control and delta_control)
- Bleeders (vnotchbleeder, circularbleeder, rectbleeder)
- MSE structures (mseStruc and ormConstCap)

The **<source>** and **<setflow>** watermovers are used to apply known flows to waterbodies.

In the following exercises, genxweirs and pumps will be added to the EAA-MC RSM model as part of adding waterbodies.

Exercise 10.2.1 Add genxweir to the EAA-MC RSM

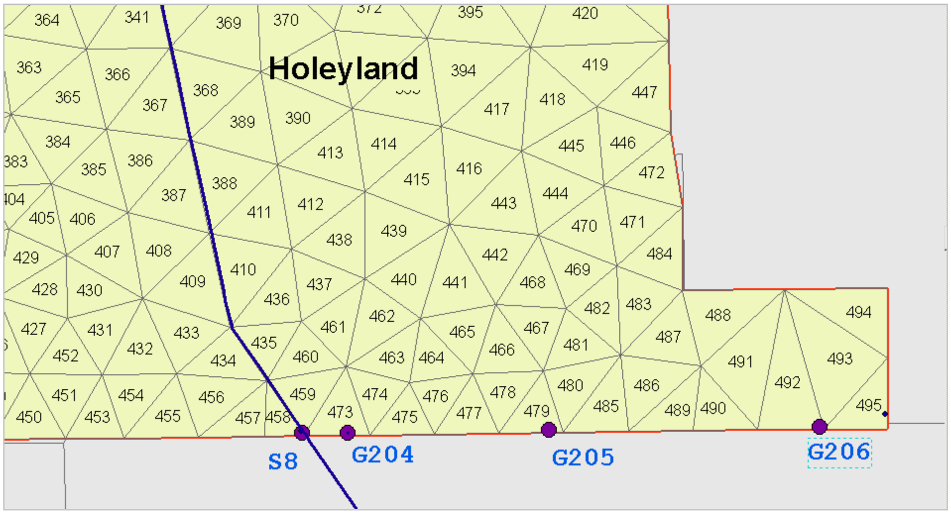


Figure 10.12 Subbasins and structures in the Everglades Agricultural Area-Miami Canal Basin

Add **`<genxweir>`** elements for the discharge structures G204, G205 and G206 to drain to this new waterbody.

15. Locate the cells where the structures originate.
16. Add the **`<genxweir>`** elements and the **`<watermover>`** block shown in **Fig. 10.13**.

```
<!-- ***** HL outflow structures G204 G205 and G206 ***** -->
<watermovers>
   <genxweir wmID="204" id1="8198" id2="105" fcoeff="3.13"
      bcoeff="3.13" crestelev="12.0" crestlen="327.5"
      dpower="0" spower="0" />
   <genxweir wmID="205" id1="8192" id2="105" fcoeff="3.13"
      bcoeff="3.13" crestelev="12.0" crestlen="423.0"
      dpower="0" spower="0" />
   <genxweir wmID="206" id1="8183" id2="105" fcoeff="3.13"
      bcoeff="3.13" crestelev="12.5" crestlen="333.0"
      dpower="0" spower="0" />
</watermovers>
```

Figure 10.13 Syntax for **`genxweir`** watermover

17. Change the values of **`id1`** and **`id2`** to match the appropriate cells and the **`<lake>`** used to represent WCA3A.
18. Set **`crest length = 10.0 ft.`**

19. In the **`<output>`** block, create **`<wmmonitor>`** monitors to record the flow through the watermovers and <**`cellmonitor>`** monitors to record head.
20. Save the model as **`eaamc_gstrucs.xml`**
21. Run the model and observe the results using HecDssVue.

There are three "bleeder" watermovers available within the RSM. These can be used with any waterbody. They are demonstrated in Benchmark 26. The syntax of these watermovers is listed in **Fig. 10.14**.

```
<watermovers>
    <vnotchbleeder id1="5" id2="11" wmID="101"
                   invert="500.5" top="501.5" angle="20.0">
    </vnotchbleeder>
    <vnotchbleeder id1="5" id2="15" wmID="102"
                   invert="500.5" top="501.5" angle="20.0">
    </vnotchbleeder>
    <circularbleeder id1="5" id2="12" wmID="103"
                   centroid="500.6" diameter="2.0">
    </circularbleeder>
    <rectbleeder id1="5" id2="22" wmID="104"
                   centroid="500.5" width="1.0" height="0.9">
    </rectbleeder>
</watermovers>
```

Figure 10.14 Syntax for bleeder watermovers.

Exercise 10.2.2 Test the behavior of bleeders

22. Select Benchmark 26 **($RSM/benchmarks/BM26)** and edit **run3x3.xml**.
23. Change timestep from 15min to 24hour and change the enddate to 01jan1995.
24. Change reporting field in DSS files from 15min to 1day.
25. Add a **<segmenthead>** boundary condition to Segment 22 in the network:

```
<network_bc>
      <segmenthead id=”22” label=”constant head”>
            <const value=”499.0”></const>
      </segmenthead>
</network_bc>
```

Figure 10.14 Example XML entry to define a constant head boundary condition

26. Add a monitor for rectbleeder:

```
<wmmonitor wmID=”104”  attr=”flow”>
    <dss file=”t3x3out1.dss”
     pn=”/hse/wm 104/flow//1day/calc/”></dss>
</wmmonitor>.
```

Figure 10.15 Example XML entry to define a watermover monitor

27. Change other output DSS files **to t3x3out1.dss** so these results do not conflict with the standard benchmark output.
28. Save as **run3x3a.xml**.
29. Run the model using the RSM GUI and observe results using HecDssVue.
30. Change the bleeder characteristics and rerun the benchmark:
    - vnotchbleeder: angle from 20.0 to 40.0
    - rectbleeder: width from 1.0 to 2.0
    - circularbleeder: diameter from 2.0 to 2.5
31. Change the last part of the DSS file specification from “**calc**” to “**test1**”.
32. Rerun the model and observe change in the results.

Answers for Lab 10

Exercise 10.1.1

Compare results with those in the lab10_wbwm directory

Exercise 10.1.2

Compare results with those in the lab10_wbwm directory

Exercise 10.1.3

Compare results with those in the lab10_wbwm directory

Exercise 10.2.1

1. Cells where the structures originate:

Structure G204 – cell 473
Structure G205 – cell 479
Structure G206 – cell 492

Exercise 10.2.2

Compare results with those in the lab10_wbwm directory

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