FINAL
Modeling Tools Development Summary
Deliverable 2.4.4

Kissimmee Basin Modeling and Operations Study KBMOS
(Contract No. CN040920-WO02)

Prepared for:

SFWMD
3301 Gun Club Road
West Palm Beach, FL 33406
(561) 686-8800

Prepared by:

www.aecom.com

13450 West Sunrise Boulevard, Suite 200
Sunrise, Florida 33323

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Table of Contents

List of Figures

List of Tables

List of Appendices

1 INTRODUCTION

The Kissimmee Basin Modeling and Operations Study (KBMOS) is a South Florida Water Management District (SFWMD) initiative to identify alternative water control structure operating criteria for the Kissimmee Basin (KB) portion of the Central and Southern Florida (C&SF) Flood Control Project (Figure 1-1). The KBMOS was initiated in September 2004 in response to stakeholder concerns with how water was being managed in the Kissimmee Chain of Lakes (KCOL) relative to the Kissimmee River Restoration Project (KRRP) and Lake Okeechobee.

Phase I of the KBMOS, completed in June 2005, performed a comprehensive assessment of basin conditions (Earth Tech 2005) and identified KB operating objectives, the KBMOS planning approach and modeling tools. As part of the final deliverable for the Phase I KB Assessment Report, the AECOM Team (f.k.a Earth Tech) created the Task 1.9 Work Plan (Earth Tech 2005a). The work plan identified the recommended approach for the next phase of the KBMOS required to implement the Alternative Plan Selection Process. This document summarizes the modeling tool development activities completed during Phase II of the KBMOS effort.

1.1 Purpose

The purpose of this report is to provide a summary of work to develop the KBMOS modeling tools during Phase I and II of KBMOS from project initiation through the Fall of 2009. The original documentation and deliverables referenced in this summary provide details on the development of the modeling tools. This report was developed to serve as a single resource to describe the overall modeling approach including the initial collection of data used to construct and calibrate the modeling tools and the testing performed to validate these tools. The references section lists the major modeling deliverables produced during this study and described in this summary. A table found in Appendix A organizes the references cited along with an outline of this report.

The KBMOS Work Plan for Phase II is divided into five work areas, or tasks. The tasks follow a sequential approach from the initial data collection through the preparation of the final planning documents. The following summarizes these tasks:

> Task 2.1 – Project Management: Work under Task 2.1 included both the administrative requirements of the study as well as support tasks not specifically addressed in the remaining tasks. This task included the development of the Study Communications Plan, support to the SFWMD during the Peer Review Process and the development of data management processes.

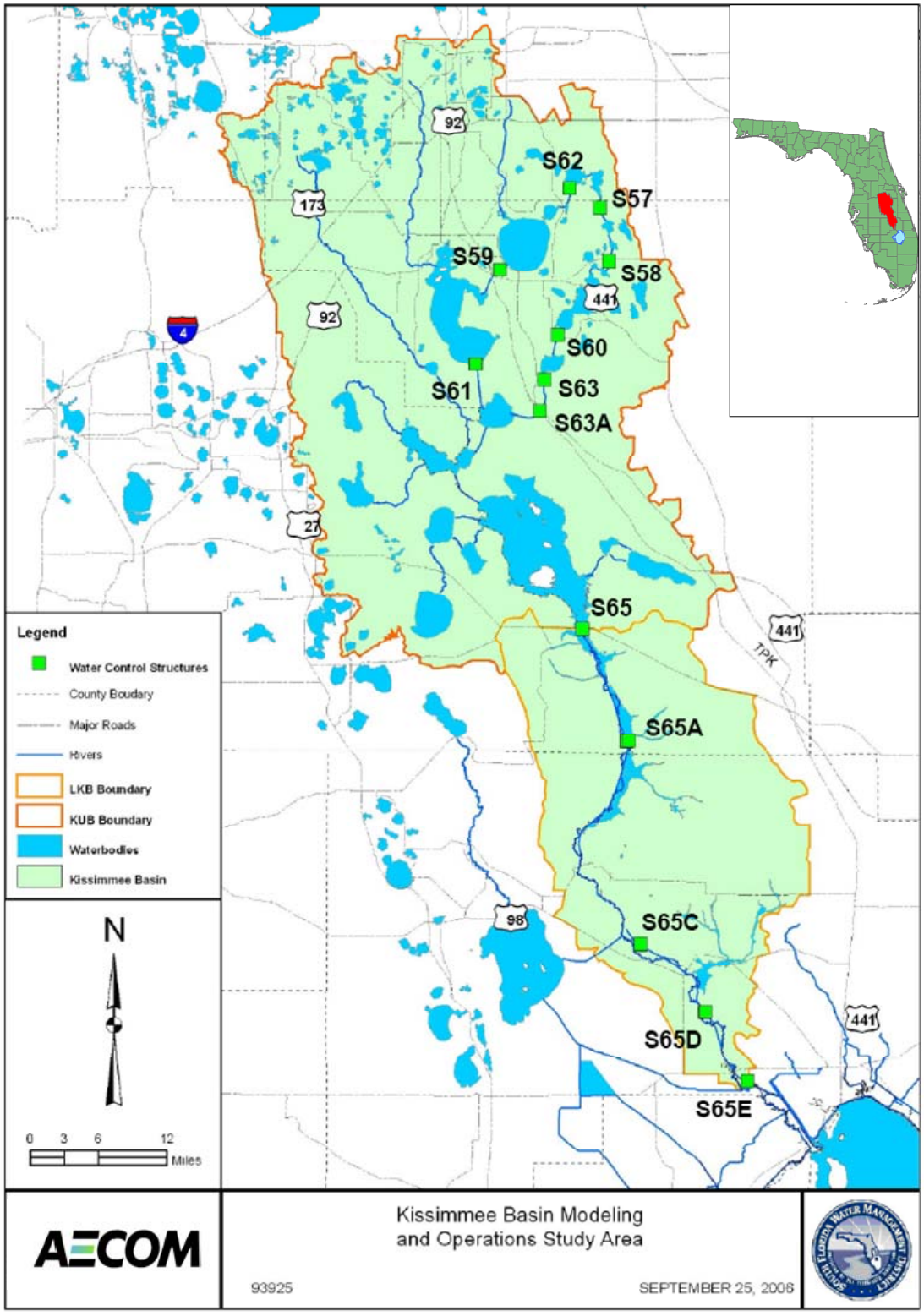

Figure 1-1: Kissimmee Basin

Task 2.2 – Hydrologic Performance Measure Development: Work under Task 2.2 included the development of the evaluation performance measures and evaluation performance indicators and the Alternative Evaluation System. These two pieces were consolidated during the implementation of the Performance Measure Evaluation Tool.

Task 2.3 – Preliminary Model Description: Work under Task 2.3 included the work necessary to compile and review the data needed to construct the modeling tools. The initial design of the modeling tools was included in these activities along with the testing required to demonstrate the applicability of the tools for the intended purpose.

Task 2.4 – KB Modeling Tool Development: Work under Task 2.4 included the development and calibration of the modeling tools to be used in the Alternative Plan Selection Process.

Task 2.5 – KB Water Control Operation Plan Development: Work under Task 2.5 includes the application of the modeling tools as part of the Alternative Plan Selection Process and the subsequent documentation to transmit the SFWMD's recommended interim and long term water control structure operating criteria for the KB portion of the C&SF Project.

1.2 Background

The technical approach applied in the KBMOS includes the sequential development and application of a suite of modeling tools to represent the movement of water through the KB portion of the C&SF Project. The suite of modeling tools includes three separate applications, starting at a very simple water budget model and progressing to a fully integrated groundwater surface water model that represents the complex hydrology and hydraulics of the C&SF Project.

The modeling strategies developed for this study focus on the "big picture" in terms of the overall goal of the project to achieve a more acceptable balance among the various water management objectives, including flood control, water supply and natural systems. These overarching objectives, represented as evaluation performance measures and evaluation performance indicators, have driven the model development process.

This document summarizes the development of the modeling tools that occurred concurrently with development of performance metrics specific to each lake management area in the Kissimmee Upper Basin (KUB) and the Kissimmee River. The approach followed in this project allowed the modeling team to frequently check and validate the three models' ability to simulate the hydrology necessary to represent the performance measures.

The planning approach was developed around the MIKE SHE/MIKE 11 tool (DHI 2007), which was selected as the model for the evaluation of alternatives. The MIKE SHE/MIKE 11 model (also known as the Alternative Formulation and Evaluation Tool, or, AFET-W) was used to

simulate the hydrology of the system and is the model that will be used in the final evaluation of the top performing alternative plans. To simplify the initial screening and development of potentially hundreds of alternative plans, the modeling strategy included the development and application of two screening-level modeling tools (OASIS and MIKE 11). The simulated hydrology of the KB, that was developed using AFET, was then used to simulate the distributed daily runoff time-series that were the drivers for the two simpler modeling tools, MIKE 11 and OASIS.

The OASIS modeling code (Hydrologics 2006) was used to develop an the initial screening tool (known as OKISS) to allow the project team to screen and refine a large number of potential alternative plans and better understand the inter-related nature of control structure operations and hydrology. Operating strategies developed during alternative plan screening were translated into the MIKE 11 model (DHI 2007). The MIKE 11 model (known as the Alternative Formulation Tool (AFT)) was used to further refine the alternative plans to address the hydraulics of the system.

1.3 Report Organization

The following summarizes the content of this report:

Section 1: Introduction – This section presents the study background and the purpose for this report.

Section 2: Alternative Plan Selection Process – Section 2 summarizes the Alternative Plan Selection Process and the components that make up the AES that was developed to evaluate alternative plan performance for this study.

Section 3: KBMOS Modeling and Evaluation Tools – Section 3 provides a background on the modeling tools that were considered for KBMOS and the background on the selection of the suite of modeling tools applied in KBMOS.

Section 4: Preliminary Modeling Activities – Section 4 describes the compilation of data, model planning activities and testing that preceded the development and calibration of the modeling tools.

Section 5: Model Development Activities – This section summarizes the work to calibrate the KBMOS modeling tools and their initial application for the Base Conditions.

Section 6: References – Section 6 contains a summary of the references cited in the report. Appendix A includes a table that contains the document outline and identifies the references cited in each section of the report, along with a brief description of the reference.

2 ALTERNATIVE PLAN SELECTION PROCESS

The KBMOS Alternative Plan Selection Process was developed to systematically evaluate alternative plan performance at three increasing levels of detail and sophistication (Figure 2-1). The process is initiated with the development of an alternative plan describing a set of modified water control structure operating criteria for the KB. The alternative plan is simulated using the Alternative Plan Screening Tool. Screening model results are post-processed and sent to the Alternative Evaluation System for scoring to identify operating criteria strategies that best meet the basin's operating objectives. The Alternative Evaluation System uses the evaluation performance measures to score alternative plans and evaluation performance indicators to report on constraints and opportunities. Alternative plan scores are used to rank alternative plans. The best performing alternative plans are simulated in the AFT and refined and finalized to meet constraint indicator requirements. The Alternative Evaluation System is used to score alternative plans and report alternative plan performance relative to constraints and opportunities. The final round of evaluation is simulation of the top performing alternative plans from Formulation in the fully integrated Alternative Formulation and Evaluation Tool (AFET-W). The final step in the process is preparation of a Decision Package that summarizes alternative plan performance across all evaluation performance measures and evaluation performance indicators.

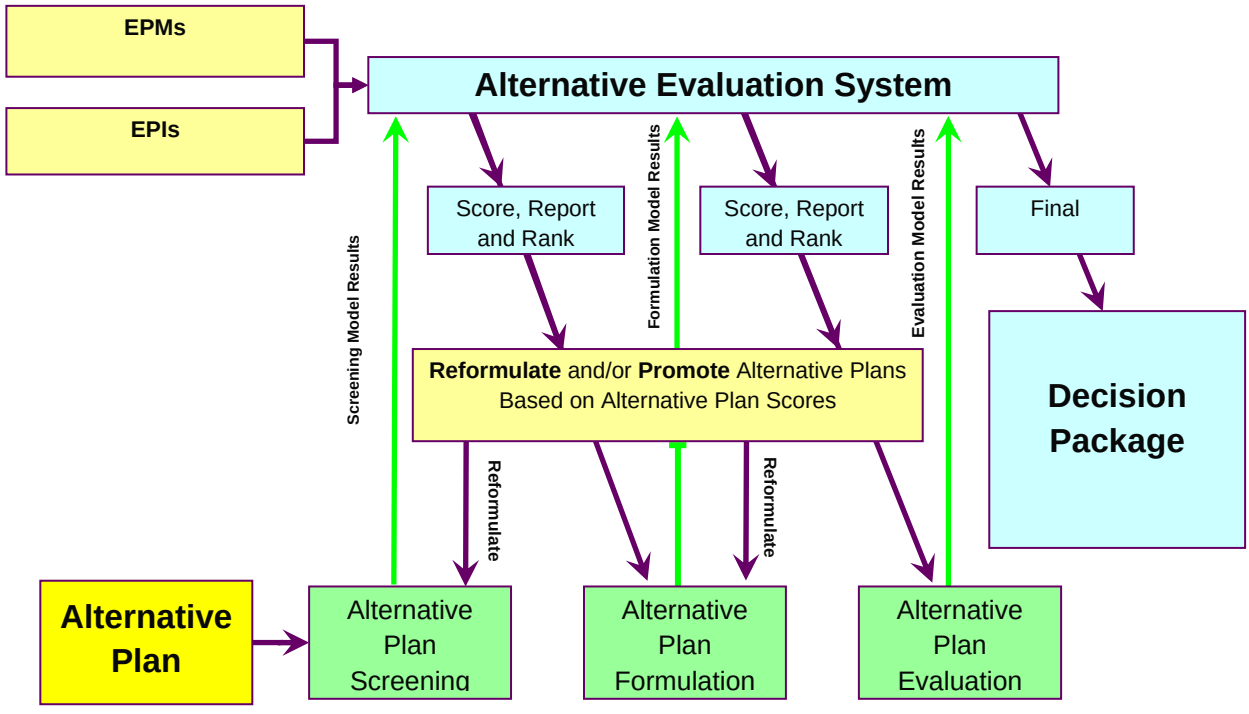

Figure 2-1: Alternative Plan Selection Process

2.1 Alternative Evaluation System

The Alternative Evaluation System (AES) for the KBMOS is a grading process that provides a systematic means for comparing alternative plans using a set of shared standards. The shared standards are the evaluation performance measures and the evaluation performance indicators. The components, rationales, justifications and evaluation protocols for the evaluation performance measures and evaluation performance indicators will be presented in the Alternative Plan Selection Document. Once finalized, the Alternative Plan Selection Document will serve as the Decision Package and will include detailed information on the scoring methodology and components used to calculate alternative plan scores. This approach was chosen to provide an objective, unbiased, transparent, repeatable, implementable and documented means for differentiating and ranking alternative plans.

All components of the AES were developed in consultation with basin stakeholders. Interagency Study Team and stakeholder participation was facilitated through team workshops, teleconferences and public meetings. These forums were used to provide information about the study, solicit input, review deliverables, refine tools and develop and evaluate alternative plans. The Interagency Study Team was comprised of representatives from the SFWMD, USACE, Florida Fish and Wildlife Conservation Commission (FWC), United States Fish and Wildlife Service (USFWS), Florida Department of Environmental Protection (FDEP), United States Environmental Protection Agency (USEPA), Florida Department of Agriculture and Consumer Services (FDACS) and Osceola County. Local stakeholder group participants included the Alligator Chain of Lakes Homeowners Association, Audubon of Florida, Deseret Ranch and Lake Mary Jane Alliance, as well as local utility and water supply interests.

Figure 2-2 illustrates the relationship between the refinement of the AES (represented by the Performance Measure Evaluation Tool) and the initial application of the modeling tools during the screening portion of the Alternative Plan Selection Process. The AES component and tool development activities are shown on the left side of the diagram. Alternative Plan Selection Process activities are shown on the right side of the diagram. The activity on the right side of the diagram is anchored to the Alternative Plan Selection Process that is divided into the three levels of analysis including screening, formulation and evaluation.

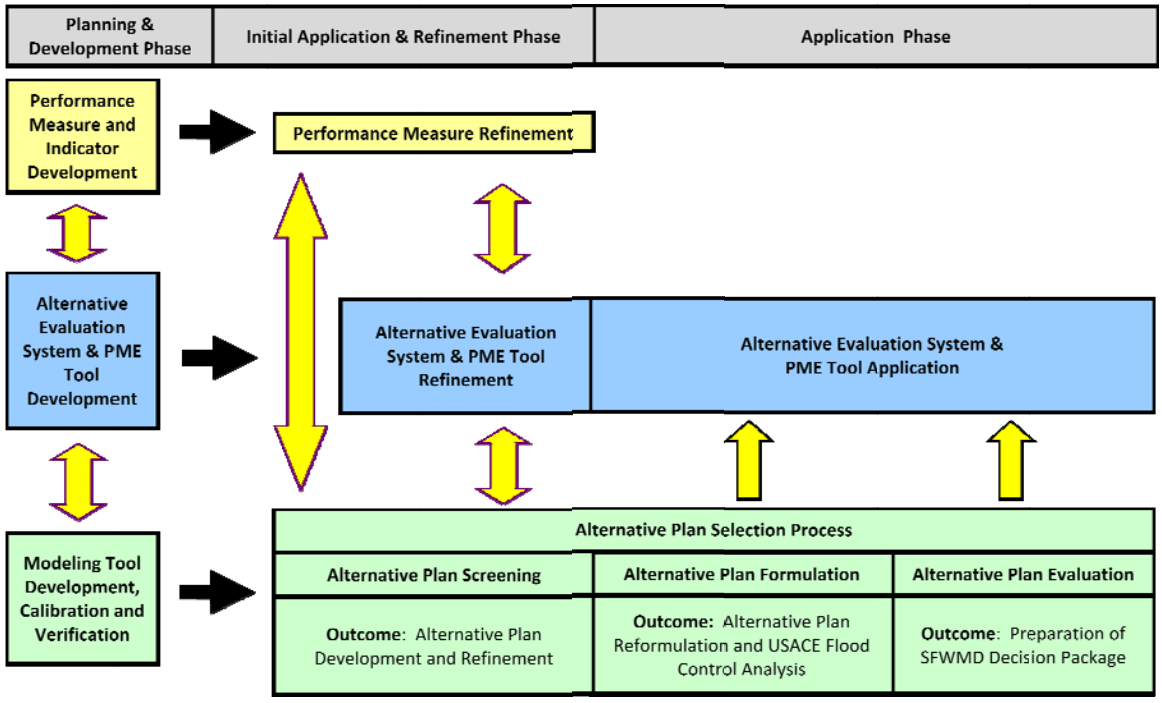

Figure 2-2: Development and Refinement of the Alternative Plan Selection Process Tools

Although some of the initial refinement activities took place during tool development (indicated by two-way arrows between development activities), the majority of the refinement activities took place during alternative plan screening. During tool development, key check-in points were identified to verify that the metrics defined in the evaluation performance measures and evaluation performance indicators could be simulated by the models and that the models could provide the necessary resolution to evaluate alternative plans.

The proposed development of the AES was described in Alternative Evaluation System Technical Design Document (AES TDD) (Earth Tech 2007d). The concepts and components that comprise the AES were presented, as well as how the components were to be integrated and applied in the KBMOS. The AES TDD was a guide that was used for the development of the Performance Measure Evaluation Tool.

2.1.1 Evaluation Performance Measures and Indicators

The evaluation performance measures (EPMs) and evaluation performance indicators (EPIs) developed for the KBMOS form the basic units of measurement for the AES and drive the Alternative Plan Selection Process. They are used in conjunction with the hydrologic and hydraulic modeling tools to determine how well a plan meets the study's operating objectives.

2.1.1.1 Evaluation Performance Measures

EPM targets define the hydrologic conditions desired to meet the natural resource requirements of water bodies controlled by KB C&SF Project structures. River EPM targets were derived from the restoration criteria defined for the Kissimmee River Restoration Project and analyses of pre-channelization data. Lake EPM targets were derived from a combination of pre-regulation data, lake management and fish and wildlife literature and professional judgment.

Each EPM has one or more evaluation components that represent specific hydrologic characteristics that will be assessed from simulation model output. Each evaluation component has a specified target or target range that is location specific. For the lake EPMs, there is only one location per measure and that location applies to all evaluation components. For the Kissimmee River, each performance measure has more than one evaluation location and each evaluation component is assessed at each of these locations. The EPMs developed for the KBMOS are listed in Table 2-1.

Table 2-1: KBMOS EPMs

No.	Name
River EPMs	
R-01	Kissimmee River Flow
R-02	Kissimmee River Stage Hydrograph/Floodplain Hydroperiod
R-03	Kissimmee River Stage Recession/Ascension
Lake EPMs	
L-01	Stages in Lakes Kissimmee, Hatchineha and Cypress
L-02	Stages in Lake Tohopekaliga
L-03	Stages in Lake Gentry
L-04	Stages in Lakes Joel, Myrtle and Preston
L-05	Stages in East Lake Tohopekaliga, Fells Cove and Lake Ajay
L-06	Stages in Lakes Alligator, Brick, Lizzie, Coon, Center and Trout
L-07	Stages in Lakes Hart and Mary Jane

2.1.1.2 Evaluation Performance Indicators

EPIs are similar to EPMs, except that they are not used to score and rank alternative plans. They provide additional information to help differentiate between alternative plans. There are constraint indicators and opportunity indicators. Constraint indicators must be met. Opportunity indicators report information on whether conditions created by an alternative plan meet, improve or degrade a desired condition. No specific goals or targets were specified for the opportunity indicators. Opportunity indicator information is reported so that the relative differences between alternative plan opportunity indicator information can be compared and considered during the

Alternative Plan Selection Process. Table 2-2 lists the EPIs, their type and applicable operating objectives.

Table 2-2: KBMOS EPIs, Indicator Types and Associated Operating Objectives

No.	Name	Indicator Type	Operating Objective
I-01	Probable High Lake Stages	Constraint	Flood Control
I-02	Kissimmee River Probable Flood Extents	Constraint	Flood Control
I-03	Lake Discharges and Stages for Hydrilla Management	Opportunity	Aquatic Plant Management
I-04	Water Supply for Consumptive Use	Opportunity	Water Supply
I-05	Kissimmee River Inflows to Lake Okeechobee	Constraint	Downstream Ecosystem
I-06	Stage Duration for Navigation and Recreation	Opportunity	Navigation/Recreation
I-07	Kissimmee River Channel Velocity	Constraint	Downstream Ecosystem

2.1.2 Development and Refinement of Evaluation Performance Measures and Indicators

The development of EPMs and EPIs began in July 2005 but were not completed until 2010. Refinement and consolidation was completed at the end of the screening level of evaluation. Figure 2-3 provides an overview of the development and refinement process. This process relied on the knowledge and participation of the Interagency and Consultant Team.

Figure 2-3: Performance Measure and Indicator Development, Refinement and Consolidation Process

As shown in Figure 2-3, performance metrics evolved through this step-wise process from preliminary through final EPMs and EPIs. All were developed using available science and tools and represent the current understanding of the major drivers and desired attributes for the KB.

2.1.3 Alternative Plan Selection Document

The Alternative Plan Selection Document describes the final version of the EPMs and EPIs, as well as the system for integrating the objective and subjective information into a final score. The implementation of the AES as a modeling tool is described in the Updated PME Tool Documentation, Version 1.3b (AECOM 2010).

3 KBMOS MODELING AND EVALUATION TOOLS

Three water resource modeling tools and the Performance Measure Evaluation tool have been developed as part of the KBMOS:

- **Screening Tool:** The screening tool is a water budget model that represents water bodies in a node-link network and applies operating rules to move water through the system. The screening tool selected for the KBMOS is a management simulation model, OASIS, developed by Hydrologics, Inc. (Earth Tech 2005).

- **Formulation Tool:** The formulation tool is a surface water hydraulic routing model similar to the screening tool, except that it uses the St Venant equations to route water through the system, providing a greater level of detail on the conveyance of water. The formulation tool will be used to evaluate whether alternative plans meet United States Army Corps of Engineers (USACE) flood control requirements and for ranking and promotion of alternative plans to the final evaluation round of the Alternative Plan Selection Process. The formulation tool selected is the MIKE 11 modeling package by DHI Water and Environment, Inc. (Earth Tech 2005).

- **Evaluation Tool:** The evaluation tool is a fully integrated hydrologic and hydraulic model that couples the formulation tool with a watershed model that includes overland and groundwater flow (MIKE SHE). The evaluation tool has the greatest complexity and is capable of examining the full set of EPMs. The fully integrated modeling tool will be used to develop the Governing Board Decision Package that is included with this report for the final three alternative plans. The evaluation tool selected for this project is MIKE SHE/MIKE 11 by DHI Water and Environment, Inc. (Earth Tech 2005).

- **PME Tool:** The PME Tool implements the scoring calculation defined within the AES. The tool uses a series of scripts and macros in a spreadsheet shell to automate calculations and graphics from the screening, formulation and evaluation tools. The PME Tool provides a standardized report for each alternative plan. This report outputs alternative plan and evaluation component scores and includes the graphical and tabular information described in the EPM and EPI evaluation protocols (AECOM 2010).

Each of the modeling tools were designed to be used in conjunction with the PME Tool.

3.1 Modeling Tool Selection

The development of the modeling tools for the KBMOS during Phase II was preceded by an investigation of the basin's operating objectives and known water resource issues and concerns within the KUB and the Lower Kissimmee Basin (LKB) in Phase I. Once the study team reviewed and understood these issues and objectives, available modeling tools capable of

simulating changes to operating criteria were identified and evaluated. The purpose of the evaluation was to select a modeling tool (or suite of modeling tools) capable of simulating the change in hydrology and hydraulics resulting from modified operating criteria. The investigation utilized three evaluation criteria to select the modeling tool(s): functionality, defensibility and cost-effectiveness.

3.2 MIKE SHE/MIKE 11 Model Selection

During the Phase I Basin Assessment, the Study Team performed an evaluation of potential modeling tools capable of simulating surface and ground water interactions for use in this study. The functionality, defensibility, and implementation costs for these model tools were considered as part of this evaluation. Selection criteria were developed and applied to short list six models for further, more detailed evaluation by the interagency team in a workshop forum. The following is a list of six models that were considered:

- WASH123D (USACE)
- FTLOADDS (USGS)
- MOD-HMS (Hydrogeologic)
- MIKE SHE / MIKE 11 (Danish Hydrologic Institute)
- MODFLOW (USGS)
- XP-SWMM (XP-Software)

Experts for each of the short-listed models were given an opportunity to address how their assigned model best met the project needs based on the pre-selected criteria. The interagency team, including the SFWMD, USACE, and USFWS staff participated in the evaluation and selection process. During the workshop, the members of the team considered how well each model could simulate water resources problems and rainfall/runoff relationships within the data constraints identified during the Phase I Basin Assessment. The MIKE SHE/MIKE 11 modeling tool was selected through this process to be used for the final evaluation of alternative plans and to compile information for submittal to the USACE.

3.3 OASIS Model Selection

OASIS was selected to serve as the Kissimmee Basin Screening Tool. The screening tool was used to evaluate the one hundred plus alternative water management plans that were considered during the initial stages of KBMOS. A secondary objective of the development of the Kissimmee Basin Screening Tool was to have a fast running model that can be applied in public forums to assist in the development of structure operating criteria. The OASIS modeling software

(Hydrologics 2006) was selected through a proof-of-concept approach that compared OASIS performance to the UKISS model in use by SFWMD at that time. The proof-of-concept approach included an evaluation by members of the Interagency Study Team of the two modeling packages. The team met in a one-day workshop to implement the Screening Tool Proof of Concept Test Plan (Earth Tech 2005c). Based on the results of this effort, the OASIS model was selected.

4 PRELIMINARY MODELING ACTIVITIES

The preliminary modeling activities can be broken into two main areas. The first is the collection and review of basin hydrologic and hydraulic data necessary for development of the modeling tools. The second is the preparation of planning documents that describe the source of data and initial parameters for development of the modeling tools.

4.1 Data Collection and Compilation

Data collection and compilation was started early in Phase II and continued, as needed, throughout the project. Initial data collection requirements were identified during Phase I as part of the development of the modeling strategy documented in the KB Assessment (Earth Tech 2005). Data sets collected included time series data, spatial data (geographic information system (GIS) shape files), previously completed modeling efforts and aerial photographs. The following briefly summarizes the data collection activities.

4.1.1 Data Acquisition and Review

The AECOM team worked closely with the SFWMD in acquiring data. During the early stages of the study, an AECOM team member downloaded and collected data required for the study. Subsequent data compilation activities were coordinated with SFWMD staff.

4.1.1.1 Daily Data

The initial collection activities focused on daily data over a recent period that was intended to include the calibration/verification periods. The data collected included rainfall depth, surface water flow and stage, groundwater heads and gate openings, as well as spatial data sets and recent modeling work. Available time series data were collected at a daily time scale over the period from January 1990 through December 2004. However, the period of record for each data source at each station was also documented. These data were compiled in the Interim Data Summary Table (Earth Tech 2005b) that was submitted to the SFWMD in September 2005. Following an initial review of the data collected by the modeling team, a subset of stations was identified for further review prior to their application in the modeling efforts (Earth Tech and Marco Water Engineering 2006).

4.1.1.2 Hourly Data Summary

Hourly data was required for the event calibration/verification activities during the development of the AFET in 2006/07. Data collected was limited to surface water stage and structure flow data. The data collected went through a visual review and verification to evaluate and identify potential anomalies (Earth Tech 2006).

4.1.2 Rainfall Data

Rainfall is the primary source of water that drives the hydrology of the KB. Various data sets were collected for the modeling effort. Available data from rainfall gauging stations, compiled in

the Interim Data Summary Table (Earth Tech 2005b), were used to create raster files for the calibration/verification periods. The period of data collected is from January 1, 1993 to December 31, 2004. The methodology for the review of the data and creation of the daily rainfall depth raster files are documented in the Phase II, Alternate Formulation and Evaluation Tool Development - Interpolated Rainfall Grids Technical Memorandum (Earth Tech 2006a).

Hourly rainfall depth raster sets were created for the event calibration/verification activities during the development of the AFET in 2006/07. These raster files were created using 15-minute Next Generation Radar (NEXRAD) data provided by the SFWMD over the period from August 1, 2004 to October 15, 2004. The review of these data was completed through a visual comparison of maps for specific high rainfall periods. The methodology for the creation of the NEXRAD raster files and the data review are documented in the NEXRAD Rainfall Grids Technical Memorandum (Earth Tech 2007).

Rainfall depth for calendar years 1965 through 2005 were provided from the SFWMD's daily rainfall depth data over a 2-mile by 2-mile grid. These raster files were converted into a scale and format that could be input directly into the modeling tools. Double mass analyses were performed to compare this accumulated 2-mile by 2-mile rainfall data to the previously collected interpolated rainfall data collected over the period from 1993 to 2004. The processing and review of these data sets are documented in the Processing of SFWMM 2mi. x 2mi. Rainfall Grids to Create AFET Input Files Technical Memorandum (Earth Tech 2007a).

4.1.3 Topographic Data

The structure of the KB represented in the modeling tools is based on multiple sources of topographic information from various agencies. In the KUB, there were two main sources including the United States Geological Survey's (USGS's) National Elevation Data Set that was expressed as a 1 one-arc second Digital Elevation Model (DEM) and bathymetry data collected by the USACE. For the LKB, the primary sources of information within the Kissimmee River floodplain are pre- and post-construction surveys collected as part of the Kissimmee River Restoration Project and the (USGS's) National Elevation Data Set. The processing and creation of the KB DEM was completed over two separate efforts, with considerable input by the USACE. The processing and creation of the DEM that describes the topography of the KB is documented in the Digital Elevation Model of the Kissimmee Basin (Earth Tech 2007b).

5 MODEL DEVELOPMENT ACTIVITIES

5.1 Preliminary Model Preparation Activities

Prior to initiation of model tool development, the approach to model construction and calibration was summarized in Technical Design Documents for review by the Interagency Study Team. The following describes the preliminary work that was completed for each modeling tool.

5.1.1 MIKE SHE/MIKE 11 Technical Design Document

As the first step in the MIKE SHE/MIKE 11 model development, the modeling team created the Kissimmee Basin Modeling and Operations Study, Alternative Formulation Evaluation Tool (AFET) Development Technical Design Document (Earth Tech 2006b) to describe the initial conceptualization of the fully integrated surface and groundwater model for the KB. The AFET Technical Design Document included the following:

- An evaluation of watershed stability;
- Review of the quality and quantity of input data;
- Preparation of graphical and tabular format of input files for model development;
- Preparation of preliminary MIKE 11 model input data sets; and
- Preparation of Alternative Formulation/Evaluation TDD describing the model development for calibration and verification.

Development of the MIKE SHE/MIKE 11 model was based on an expansion of the Lake Tohopekaliga Drawdown Model documented in the Integrated Surface and Groundwater Model for Lake Tohopekaliga Drawdown Project (DHI and GeoModel 2001). The domain of the original modeling effort included C&SF lakes north of the S-61 and S-63 Structures in the KUB. The intent documented in this approach was to add the remaining lakes, from Cypress Lakes south into the Kissimmee River in the LKB.

A complimentary document, the Kissimmee Basin Modeling and Operations Study, Alternative Formulation/Evaluation Tool Acceptance Test Plan (Earth Tech 2006c), was created to describe the calibration and verification time periods for continuous and event simulations and to define the statistical criteria that was to be used as the starting point to assess model calibration. The model was calibrated against best available observed surface water discharges, surface water elevations and groundwater levels at locations for which data were available. Statistically based surface water and groundwater targets were defined for long-term calibration/verification periods and for a storm period representing the 2004 hurricane season. Additionally, a qualitative inspection of the overall model performance was identified to compare the long-term water budget of the KB with water budgets derived from concurrent modeling efforts studies.

5.1.2 OASIS Model Technical Design Document

As the first step in OASIS model development, the modeling team created the Kissimmee Basin Modeling and Operations Study, Screening Tool Technical Design Document (Earth Tech 2006d). The Screening Tool Technical Design Document established the required specifications for the development of the screening tool and its application to the study objectives. The Technical Design Document included the following:

- A conceptual approach for design of the KB screening tool;
- A proposed design methodology for construction and calibration of the model;
- A definition for creating a linkage between OASIS operating goals and the KB decision tree;
- A proposal to apply the screening tool in public computer-aided participation sessions;
- An update storage area elevation data in the lakes to be consistent with the bathymetry data used for the MIKE SHE/MIKE 11 model development; and
- A methodology to represent the Kissimmee River.

5.2 Development of the KBMOS Modeling Tools

Following the review and acceptance of the Technical Design Documents for the modeling tools, the AECOM team initiated the construction and calibration of the modeling tools. Three teams were formed: one to work on the watershed components in MIKE SHE, a second to work on the hydraulics of the surface water conveyance in MIKE 11, and a third to work on the OASIS implementation concurrent with the MIKE SHE and MIKE 11 teams. Coordination meetings and discussions occurred on a monthly basis.

At the same time as the models were being developed, the SFWMD had a full-time 'contract hydrologist' on-site coordinating the development and documentation of the hydrologic EPMs and EPIs. In this role, the contract hydrologist assisted the SFWMD and Interagency Study Team to develop the linkage between the science and biology and the hydrology (flows and stages) simulated in the modeling tools.

Construction of the modeling tools was advanced sequentially, with deliverables at key points in the process to allow the SFWMD and the Interagency Study Team the opportunity to review the status of the modeling tools.

5.2.1 Development of the Fully Integrated Hydrologic/Hydraulic Model

5.2.1.1 Initial Model Development – AFET

The MIKE SHE/MIKE 11 modeling effort kicked off in 2005. This work culminated in the AFET model. The following describes the initial development of this model.

5.2.1.1.1 MIKE SHE Model Development of the Kissimmee Basin – AFET

The watershed modeling team started with the Lake Tohopekaliga Drawdown Model and added the southern portion of the KUB and LKB. Data sources for the initial construction of the model were derived from the past groundwater modeling efforts by the SFWMD and included the East Central Florida Groundwater Model (in conjunction with the St. John's River Water Management District (SJRWMD)) and the Glades-Okeechobee-Highlands MODFLOW Model. Summaries of these models are provided in the Phase I Kissimmee Basin Assessment (Earth Tech 2005).

Once the MIKE SHE model was constructed and debugged (verified that the model ran without errors), the initial construction was documented in an interim report and the model files were submitted to the SFWMD and Interagency Study Team for review. This interim status was documented in the Alternative Formulation/Evaluation Tool Development of MIKE SHE Documentation (Earth Tech 2006h).

5.2.1.1.2 MIKE 11 Model Development of the Kissimmee Basin – AFET

The surface water conveyance features of the KB portion of the C&SF Project are simulated in MIKE 11. Similar to the MIKE SHE development, the initial source of model information was the Lake Tohopekaliga Drawdown Model developed by DHI. Additional canal cross sections and hydraulic data were obtained from past modeling by the SFWMD and the USACE in UNET and HEC-RAS in the KB.

Once the MIKE 11 model was constructed and debugged (verified that the model ran without errors), the initial construction and source of the hydraulic information used was documented in an interim report and the model files submitted to the SFWMD and Interagency Study Team for review. This interim status was documented in the Phase II, Alternate Formulation and Evaluation Tool Development – Development of MIKE 11 Documentation (Earth Tech 2006i).

5.2.1.1.3 Merged MIKE SHE / MIKE 11 Model of the Kissimmee Basin – AFET

The initial modeling culminated with the merging of the two separately developed models. The work required to merge the models included:

- **The Definition of the Runoff/Groundwater Links:** The model development team defined the runoff/groundwater links for the model that allow exchange of water to occur between MIKE SHE and MIKE 11. Streambed leakage coefficients that control the interaction of MIKE 11 with the saturated zone models were defined based on the best data available for these parameters.
- **Definition of Flood Inundation:** Flooding can occur in many areas of the KB. This effort included the definition of the areas where flooding from the river network is allowed to occur and to develop the data sets required to simulate flooding in the model.

- **Completion of Test Simulations:** After the model was fully linked and debugged, test simulations were completed. The model results were evaluated to verify that the model was stable and not generating unreasonably high or low values at specific locations within the model domain.

Upon completion of the test simulations, the merged and debugged code was submitted to the SFWMD. The submittal included an interim technical memorandum that described the definition of the links and flood inundation data described above. This initial effort was documented in an interim deliverable. Comments were addressed in the final draft of the model documentation report entitled Kissimmee Basin Modeling and Operations Study, Phase II, AFET Model Documentation/Calibration Report (Earth Tech 2007e).

5.2.1.1.4 Calibration and Verification of MIKE SHE/MIKE 11 – AFET

5.2.1.1.4.1 Initial Sensitivity Analysis of the Merged MIKE SHE/MIKE 11 Model – AFET

A sensitivity analysis of a select number of parameters was performed prior to the beginning of the KBMOS model calibration process. The parameters selected for evaluation in the sensitivity analysis were based on the modeling team's understanding of parameter sensitivities developed in previous integrated surface and groundwater projects conducted for the SFWMD. The purpose of the MIKE SHE/MIKE 11 sensitivity analysis was to evaluate the sensitivity of several key parameters. The sensitivity analyses were used to identify the parameters that have a significant effect on model results and guide the calibration process (Earth Tech 2007e).

5.2.1.1.4.2 Calibration and Verification of MIKE SHE/MIKE 11 Model – AFET

AFET was constructed and calibrated along the guidelines established for the study. Those guidelines identified the need for a simulation of flow and stage in the surface water features in the KB and their sensitivity to alternate structure operations. Statistical criteria used to define the acceptance of the model were defined and applied during the calibration and verification processes.

The approach used to calibrate the model was defined along with the criteria that were applied to evaluate model performance in the Acceptance Test Plan. These criteria were further refined during the calibration process based on data limitations identified and discussions with SFWMD staff.

The calibration and verification process included three time periods. The calibration period represented the hydrology and hydraulics of the post-Phase I restoration conditions, over the period from November 1, 2001 through December 31, 2004. The purpose of the selection of this time period was that it represented a recent condition with a portion of the C-38 Canal back-fill in place and a long term simulation typical of the expected planning period model runs. Two separate verification periods were selected. The first was another long term period, but

represented the pre-Phase I condition in the basin. These two models used a daily time-step (end of day) being driven by accumulated daily rainfall. However, calculations occurred on a much shorter duration. A second verification period was selected to evaluate performance of the model for the simulation of flood events. The time frame selected for the flood event verification was the 2004 hurricane season (from August 1 to October 15, 2004), when three back-to-back hurricanes past over the KB.

As part of the flood event verification, a site specific MIKE 11 model was developed for the Phase I portion of the restored Kissimmee River (Pool B-C between the S-65A and S-65C Water Control Structures). The purpose of this sub-model was to refine the surface water hydraulics conceptualization used in the KBMOS model to be consistent with the witnessed stage and flows. The objectives and results of the small-scale MIKE 11 model were key to defining some of the complex hydraulics of the restored river reaches, especially in the area of the unintended connection between the restored river and the upstream extent of the un-restored C-38 Canal. Development of this model was essential to simulate the restored portion of the Kissimmee River and was used as a guide to develop the remaining portions of the restored portions of the Kissimmee River in the future conditions model developed in a subsequent phase of the KBMOS.

Calibration of this first-ever regional model of the KB was challenging because of the complexity and size of the area. The calibrated model met the criteria defined for the project and adequately represented the hydrologic processes in the KB and was determined sufficient for use in the evaluation of operational criteria modifications in the KB. The results of this calibration process are documented in the Kissimmee Basin Modeling and Operations Study, Phase II, AFET Model Documentation/Calibration Report (Earth Tech 2007e).

5.2.1.2 Daily Planning Model Re-calibration – AFET-W

During the initial application of the fully integrated modeling tools to develop the base conditions for the planning study, it was observed that the model was over-predicting runoff from the KB. Although this issue was not evident in the observed and simulated runoff during the calibration and verification time periods, it was apparent when the model was applied to the longer term application in the base conditions simulation. Two theories were developed to explain the potential source of this over-simulation of runoff. The first possible source was the assumptions used to develop the future condition land use. The second possible source was the reference evapotranspiration used in the original modeling effort. Because of the uncertainties associated with the future land use, it was decided to eliminate the ‘future’ base condition from future simulations.

Following the initial development of the AFET model, the development of a more robust evapotranspiration data set was completed by the SFWMD (SFWMD 2008

). Comparing these data with those applied in the calibration and application of the AFET revealed that the original data set (which represented the best available data at the time) may have been under-predicting a major component of the hydrologic cycle.

Based on the modeling team's review of the data sets and recommendation from the Modeling Peer Review Panel (Loucks, et al. 2008), the SFWMD directed the modeling team to re-calibrate the AFET with the new reference evapotranspiration data set. In addition to the new reference evapotranspiration data, the recalibration effort incorporated information from the project team working on the calibration of the East Central Florida Transient (ECFT) MODFLOW Model (Project Communication).

The revised model was given the designation "AFET-W". The "W" in AFET-W refers to water supply. This designation was given to the model to differentiate it from the original AFET model and to identify it as the version of the model that would be used to evaluate surface water availability in the KCOL (AECOM. 2008). This version of the model was later selected as the tool to use for rule development for the Kissimmee Basin Water Reservations.

5.2.1.2.1 AFET-W Calibration Approach

The intent of the calibration of AFET-W was to incorporate the revised reference evapotranspiration data and improve the AFET ground water calibration. SFWMD modelers working on the ECFT MODFLOW Model assisted with the ground water portion of the recalibration effort.

A report summarizing the proposed calibration approach was submitted and reviewed by the SFWMD concurrently with the initiation of the modeling (AECOM 2008). The calibration approach identified target calibration statistics to be used in the calibration process. The specified calibration period was similar to the original AFET verification period and was selected to overlap with the concurrent ECFT calibration effort. Since one of the goals of this modeling effort was to improve the simulation of runoff within the KB, a 10-year verification period was also used (from 1995 through 2004) to compare simulated cumulative discharges at the S-65 and S-65E Water Control Structures.

5.2.1.2.2 AFET-W Acceptance

Following the development of the AFET-W model and review by the SFWMD, the simulation was determined to be superior to the AFET. As a result, the modeling team was directed to replace the AFET with the AFET-W as the daily simulation modeling tool to be applied as part of the KBMOS (AECOM 2008).

5.2.2 Kissimmee River Floodplain Hydraulic Model

The development and calibration of the AFET-W model addressed the watershed condition that existed within the recent history of the KB. However, the calibration period did not consider the

completed portions of the Kissimmee River Restoration Project (Phase I was complete in 2001) nor the future fully restored condition. Therefore, the modeling team proceeded with a separate modeling effort to address the future condition hydraulics in the restored Kissimmee River floodplain. This was not a calibration effort.

The MIKE 11 network and cross sections of the Kissimmee River floodplain currently in the KBMOS future condition model were used in this modeling effort to represent the hydraulic condition of the fully implemented restoration project. The MIKE 11 network was reviewed to ensure accurate representation of restoration project features. Special attention was paid to areas where structural modifications have been made or will be made as part of project implementation. These areas included the structures adjacent to the S-65A Structure (tieback levees and weirs), the floodplain in the vicinity of the former Pool B weirs and the U-Shaped Weir and other Pool D structures. The model setup was reviewed to make sure that the cross sections in the selected branches would not intersect each other. Cross sections were also extended based on available topographic data to ensure that the entire floodplain was incorporated in the hydraulic representation. Some cross sections in Pool A were extended and one cross section on Meander 17 was extended to reach the floodplain (Earth Tech | AECOM 2008).

This effort was important to demonstrate how the hydraulics of the proposed restoration project would perform under the pre-channelization hydrologic conditions that existed from the 1930's through the 1960's. This modeling tool was used to refine and validate the river evaluation performance measure targets at key locations in Pool B-C-D (Earth Tech | AECOM. 2008).

Once completed, the revised MIKE 11 network was incorporated into the AFET-W model to represent the fully restored condition in the Kissimmee River floodplain for application in the 'With-Project' Base Condition Model (Earth Tech | AECOM. 2008).

5.2.3 Flood Event Model Development: AFET-FLOOD

The AFET-FLOOD model is being developed for application by the USACE in their flood analyses and evaluations of alternative plans for KBMOS. It is being derived from the AFET-W model and calibrated to the 2004 hurricanes and verified using Tropical Storm Fay in 2008. The effort is a joint effort between the USACE and the SFWMD as part of the Kissimmee River Restoration Project. The ultimate goal is to deliver a flood routing model that can be applied in support of operations for the Kissimmee River Restoration Project.

5.2.4 Development of the Screening Tool

5.2.4.1 Initial Model Development

The OASIS modeling effort kicked off in 2005 with the implementation of the proof-of-concept approach discussed in Section 3.1.3. This work culminated in the OKISS model. The following describes the development of this model.

5.2.4.1.1 OASIS Model Development of the Kissimmee Basin

The first step in the development of the OKISS model was development of a model with the same domain as the UKISS model. The OASIS model created for this domain was named O-KCOL to indicate it was specific to the KCOL. The development of O-KCOL was documented in the OASIS KCOL Model Report (Earth Tech 2006e). O-KCOL was then updated to include the Kissimmee River (Earth Tech 2006k), creating OKISS, which is the name used for the OASIS model applied during the Alternative Plan Screening Process for the KBMOS. OKISS was developed following the guidelines established in the Screening Tool TDD (Earth Tech 2006d).

A history matching exercise was performed to verify the results produced by OKISS. This exercise is documented in the OKISS Model Development and History Matching Report (Earth Tech 2007f). The version of OKISS used in the 2006 history matching was updated using information obtained from the calibration of the KBMOS AFET (MIKE SHE/MIKE 11) (Earth Tech 2007e). An additional history matching exercise was performed to validate the refined version of OKISS to be used in the KBMOS alternative screening.

5.3 Model Testing of Operating Criteria

Of critical importance to KBMOS is the ability of the modeling tools to simulate the complex operating rules employed in the KB to manage the water control structures. During the initial development of the modeling tools, the team completed activities to document current operational policies and to demonstrate the ability of the models to simulate these rules.

5.3.1 Operating Criteria Framework

As part of the initial data collection and compilation in Phase II, the modeling team needed to develop a basic level of understanding of the operational issues within the basin. To document this, the SFWMD created the Operating Criteria Framework Document (Konyha 2005) to describe the decision-making process used by the SFWMD and the USACE to manage water control structures in the KB. The intent of this document was to communicate sufficient information to the computer modelers to translate this process into a code and build this code into the modeling tools.

Following the completion of this SFWMD document, it was distributed to the modeling team and a code was developed (Hydrologics and DHI) for review and comment. The AECOM team

then hosted a teleconference with key members of the modeling team and the SFWMD to provide an opportunity for discussion of issues and methodologies that would be implemented to develop the logic required to convert these operating criteria into model code.

5.3.2 Initial Comparison of Modeling Tools

The models selected for the planning effort use two similar but different methodologies to simulate the operating rules. The OASIS code from Hydrologics, Inc. uses the Operating Control Logic (OCL) module that applies a linear programming approach to solve the complex, multi-dimensional relationship of hydrology to define operations. Application of the OCL approach was demonstrated successfully through the proof-of-concept testing during the selection of OASIS, which was documented in the OASIS KCOL Model Report (Earth Tech 2006e). This demonstration was successfully completed with the implementation of OASIS in the KCOL and its favorable comparison to the existing SFWMD UKISS model. In the DHI MIKE 11 model, structure operations are simulated in the Structure Operations Module, using a series of nested if-then type statements.

Although the code developers (DHI and Hydrologics) felt confident that the two approaches would generate similar results, testing of the operational rules simulation was implemented to demonstrate that the results were similar enough to support the approach defined by the Alternative Plan Selection Process. The process to compare the two approaches was documented in the Operating Criteria Simulation Engine Proof of Concept Approach (Earth Tech 2006f).

As part of the demonstration of the OASIS KCOL Model, the team developed modified operating criteria for the S-61 Structure that discharges from Lake Tohopekaliga into Cypress Lake. The intent of the operating criteria simulation engine proof-of-concept approach was to implement the same operating criteria in MIKE 11 and demonstrate that the two methods for simulation of water control structure operations was sufficiently similar to support the overall modeling strategy. The Alternate Formulation and Evaluation Tool Development – AFET Operating Criteria Simulation Engine OCSE Demonstration Report (Earth Tech 2006g) demonstrated that the MIKE 11 structure operations were able to implement the same modified operating criteria that were simulated in OASIS in the KCOL and provide similar results. Although there were some minor differences in the peak stages and flows, this was explained by the more detailed representation of hydraulics and better temporal resolution in MIKE 11.

5.3.3 Demonstration of Transition Rules

The operating criteria simulation engine proof-of-concept was able to demonstrate that the OASIS and MIKE 11 approaches to the simulation of operating criteria were able to produce similar results. Additional testing was performed to compare the simulation of a more complex set of operation criteria and to demonstrate the level of effort required to program and debug structure operations in OASIS and MIKE 11, respectively. To perform this testing, the SFWMD developed proposed operating criteria for the S-65 Water Control Structure that defined releases

when headwater stages transition from Zone A to Zone B. The intent was to develop a 'soft landing' rule that would conserve water in Lake Kissimmee for environmental needs later in the season. The SFWMD created a white paper entitled Kissimmee Basin Modeling and Operations Study Proposed Operational Rules KR_Transition_Rules (Konyha 2006).

The transition rule is an example of the type and complexity of the operating criteria that was expected in the KBMOS Alternative Plan Selection Process. The Demonstration of Transition Rule Operating Criteria Technical Memorandum (Earth Tech 2007c) explained and documented the programming of the proposed transition rule in AFET and OKISS. This document includes the following:

- How operating rules are entered into the AFET structure operations and OKISS OCL;
- How operating rules developed in OKISS will be adapted for incorporation into the MIKE 11 logic structure; and
- The level of effort associated with putting together an alternative plan so that appropriate time and resources can be estimated for alternative plan evaluations.

5.3.4 Development of the PME Tool

The PME Tool is a common model tool interface that displays modeling results relative to the EPMs and EPIs developed to differentiate between alternative plans. The PME Tool was developed from specifications outlined in the Alternative Evaluation System Technical Design Document (Earth Tech 2007d). The concepts and components that comprise the AES were presented, as well as how the components were to be integrated and applied in the KBMOS. Components of the AES as well as the PME Tool were updated throughout the Alternative Plan Screening Process, based on knowledge gained through the application of the modeling tools and interactions with the Interagency Study Team and basin stakeholders. The Alternative Plan Selection Document describes the final version of the EPMs and EPIs, as well as the system for integrating these data into a final score. The implementation of the AES as a modeling tool is described in the Updated PME Tool Documentation, Version 1.3b (AECOM 2010).

The PME Tool includes a set of utilities that sequentially convert model output into a "report card" for each alternative plan. These utilities are grouped in a "shell" using a Microsoft Excel platform. The main components of the PME Tool, as depicted in Figure 5-1, are the "Data Extraction Utilities" and the "Excel Shell (Scoring Utility Tool)". These can be described as follows:

- **Data Extraction Utilities:** Obtains relevant (user specified) information from the model results files. OKISS results for each evaluation location are obtained from Data Storage System (DSS) files generated by OASIS. AFET output is extracted from MIKE 11 (.res11) and MIKE SHE (.dfs0 and .dfs2) result files.

- **Excel Shell (Scoring Utility Tool):** Consists of an Excel spreadsheet with automated macros that call the calculation scripts and import their results into the spreadsheet environment. The macro produces the Alternative Plan Report, which documents all information relevant to the evaluation of the metrics that comprise the alternative plan score.

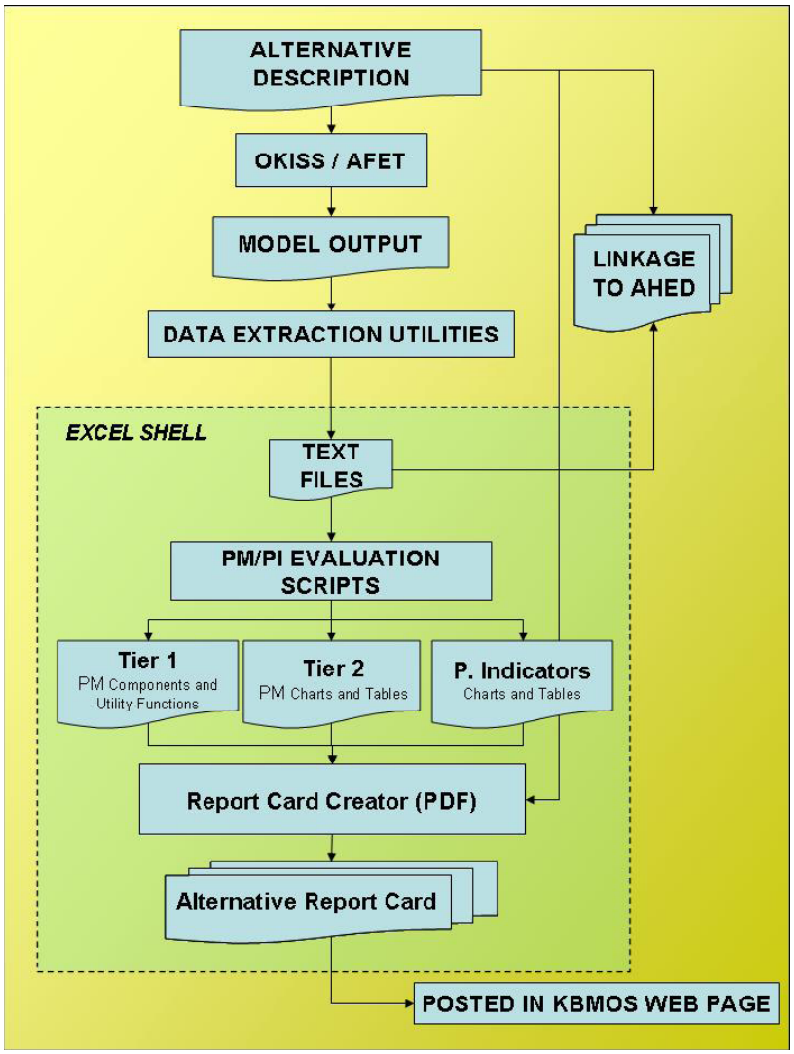

Figure 5-1: Flow Diagram of the PME Tool

The PME Tool has undergone extensive testing and validation throughout the Alternative Plan Screening Process. The documentation has been annotated and revised to document these updates with a versioning control section that describes these updates.

5.4 Application of the Modeling Tools

As mentioned previously, the Alternative Plan Selection Process calls for the sequential application of three increasingly complex modeling tools. Because the approach utilizes three different models, the first effort was to demonstrate that the three tools were able to provide similar results. The comparison was done using a simulation of the 'With-Project' Base Conditions.

The 'With-Project' Base Condition is the basis or platform to which the effectiveness of alternative plans can be compared, based on their ability to meet the desired conditions defined by the EPMs. Establishing base conditions involves the identification of key basin characteristics (and associated periods) that will serve as the basis for the alternative plan evaluation.

Once the hydrology and hydraulics of the basin are obtained through model calibration, the parameters of the basin are applied under a fixed set of conditions, or model drivers, to predict the basin response. This set of fixed conditions is called the base condition. The base condition combines the existing hydrologic conditions of the watershed (year 2000 land use and year 2008 water use) with the future infrastructure and geometry of the Kissimmee River Restoration Project (infrastructure, operations, etc.). These two components were augmented by climate drivers and other boundary conditions that were witnessed over the period from 1965 to 2005. The land use and water use data sets represent the best available data that existed at the beginning of each effort in the study. The year 2000 land use was the data set used during calibration of both the original AFET and the subsequent AFET-W model and represents the best available information at the time the 'with project' Base Condition was developed. The application of the 2008 water use was selected to represent the existing permitted uses of water that existed during the initial development of the water reservation. The development, implementation and results obtained from the base condition are documented in the Evaluation of "With Project" Base Conditions Report (AECOM 2009).

5.4.1 Development of Base Condition Models

The 'with project' base condition represents basin characteristics that are understood based on data collected to date or the experience of the basin stakeholders. It includes all features of the fully implemented Kissimmee River Restoration Project including the Headwater Revitalization Project. Base conditions are summarized in the KBMOS Base Conditions Summary Report (Earth Tech 2007g). This document describes the base conditions to be used during the evaluation of alternative operating criteria being considered for the future operation of the C&SF Project water control structures in the KB.

With the implementation of the AFET-W model and as a result of the modeling peer review (discussed below), the modeling team updated several assumptions related to the simulated base conditions. As a result, the 2008 Base Conditions Summary Report was updated to reflect the ongoing KB water reservations activities. The revised base conditions were described in the

Kissimmee Chain of Lakes Surface Water Supply Availability Study, Summary of "With Project" Base Conditions - Technical Memorandum (AECOM 2009a). The summary of the Base Conditions Report included references to the development of the material described below.

5.4.1.1 Downstream Boundary Condition – Lake Okeechobee

All of the discharges from the 2,279 square mile KB are directed through the S-65E Structure into Lake Okeechobee. The downstream boundary condition represents the influence that stages in Lake Okeechobee would have on these discharges. The KBMOS Draft Evaluation of Downstream Boundary Conditions Technical Memorandum (Earth Tech 2007h) describes the evaluation that was performed to define this boundary condition.

5.4.1.2 Interim Operation of the S-65D Structure

Prior to the development of the KBMOS modeling tools, interim operating criteria for the S-65D Structure had not been considered. A revision to the operating criteria for the S-65D Structure was required to develop the future conditions in the KBMOS models. The proposed interim operating criteria was documented in the KBMOS Draft Operating Criteria for Modeling S-65D Future Conditions (Earth Tech 2007i) Technical Memorandum. This was necessary because of the head loss that could result from the flow constraints represented by the U-shaped weir and the CSX Railroad crossing over the remnant channel between the US Highway 98 crossing and the S-65D Structure.

The description of the operating criteria included in this effort is to be used only as part of the modeling activities within the KBMOS. Additional analysis will be required to adapt the terms in which the proposed operating criteria are expressed to the language commonly used by the structure operators, once the downstream features of the KRRP have been finalized. Also, the effect of the proposed operating criteria on the flood control level of service within the Kissimmee River floodplain and in the overall stability of the structure will also need to be further evaluated.

5.4.1.2.1 Future Condition Water Use

The approach to simulating water use in the KB was described in both base condition summary documents. However, as part of the AFET-W implementation, these water use data were updated. One of the AFET-W's intended applications was to be used for water supply planning and the development of water reservations in the KB. Therefore, the modeling tool needed to include the influence of existing legal uses of water on the surface and groundwater resources of the KB. The modeling team published the Technical Approach to create the Existing Legal Users database included in the "With Project" base condition model (Earth Tech 2008), describing the inclusion of the existing legal users in the 'with project' base condition modeling effort.

5.4.2 Validation and Testing of the Modeling Tools

The KBMOS Work Plan included a process to validate the study modeling tools by comparing the results obtained for each performance measure. The validation process is needed to evaluate the effect of the differences in model conceptualization on the Alternative Plan Selection Process. The three modeling tools used in the study have very different technical approaches to simulate the hydrology and hydraulics of the KB, OKISS being the most unique approach of the three. OKISS is a water management model that runs in daily time-steps. OKISS has been adapted to model the hydraulics of the KB through the addition of a series of surrogate computations, while the AFT (MIKE 11 decoupled) and hydrology (MIKE SHE) both include sophisticated hydraulic computations and smaller time-steps (in the order of minutes). The approach that each model uses to simulate structure operations is also very different between OKISS and the AFET-W. These differences would explain discrepancies in model results for the same type of simulation. However, the selection of an alternative requires a smooth transition through the three levels of the Alternative Plan Selection Process.

Even though each modeling tool has been subject to model calibration and/or history matching, the validation process provides the required confidence in model results by comparing them under the wide range of climatic conditions found in the base condition period of simulation (1965-2005).

Three types of comparisons were performed to validate the results of the KBMOS modeling tools. The first comparison is to look at the calibration locations used in the development of the AFET-W over the period of simulation. This analysis compared each model to the other two models using the calibration statistics to define 'goodness of fit' metrics.

The second two comparisons were done with the data that defined the KBMOS performance measures. One comparison uses the same model output data that are used to calculate the values of the performance measure components, namely, the time-series of stages and flows of those locations identified as evaluation locations. Duration curves and stage hydrographs were used in this analysis. The second comparison is based on the numeric values of the performance measure components. Each KBMOS EPM is sub-divided into a series of evaluation components. Targets for the EPMs relate to the natural resource requirements of the KRRP and the KCOL and were derived based on analyses of hydrologic data obtained during the pre-regulation period and the recent history of management practices that have yielded positive ecological observations. The comparison, performed within the validation process, used the selected targets as a reference. Comparison results were presented as a series of charts and tables for each performance measure component.

The results of these comparisons demonstrated that the KBMOS modeling tools produce comparable component values for the EPMs. Furthermore, the results of this validation demonstrated that there should be a smooth transition from the screening tool (OKISS) to the

more sophisticated MIKE SHE/MIKE 11 models. The results of these comparisons are contained in the Evaluation of Base Conditions Report – AFET-W (AECOM 2009).

5.4.3 AFET Sensitivity Analysis

The AFET Sensitivity Analysis was performed as part of the development of the original AFET model. Although the original intent of this effort was to be an uncertainty analysis, the peer review panel felt the approach taken didn't meet the general intent of an uncertainty analysis. The approach was more consistent with a parameter uncertainty analysis similar to a sensitivity analysis. As a result, the modeling team agreed to re-conceptualize the report as a sensitivity analysis.

This sensitivity analysis provided a quantitative analysis of the impact of parameter uncertainty in the AFET modeling tool predictions on the evaluation of performance measures. This analysis has been conducted to demonstrate the AFET model sensitivity to the predicted effectiveness of existing operating rules developed using the model and how this parameter uncertainty is translated into the evaluation of the components of each performance measure during the alternative evaluation.

Special interest was added to the model's sensitivity to the runoff quantities produced by the AFET. Runoff is a result of several model parameters and does not constitute a specific model input. Therefore, runoff depths were calculated and the propagation of the parameter uncertainty in runoff was propagated to the values of each individual performance measure component. An evaluation of this propagation was performed by comparing the obtained component values with each one of their targets. Furthermore, a linear relationship was established between different values of potential runoff and the values of performance measure components.

5.5 KBMOS Peer Review Panels

The SFWMD convened two peer review panels to review the modeling tools and performance metrics for the KBMOS.

5.5.1 Environmental Peer Review Panel

The Environmental Peer Review Panel was convened to review the EPMs and EPIs in March and April 2007. The panel included experts with backgrounds in ecology, biology and water resource management. These panelists judged the quality and credibility of the science and assumptions used to develop the EPMs, particularly their applicability to provide the linkage between system ecology and hydrology (Karr, et al. 2007).

Several revisions were made to the EPMs to address the Environmental Peer Review Panel recommendations. These modifications included reorganizing KCOL performance measures into seven lake EPMs, improving documentation for linkages between EPM components and expected ecological responses and incorporating EPM and EPI documentation into a more

comprehensive document that summarizes the Alternative Plan Selection Process and components. To confirm revisions were consistent with peer review panel recommendations, the SFWMD conducted a third party review of the Draft Alternative Plan Selection Document that included the revised measures (Wetzel 2008).

5.5.2 Modeling Peer Review Panel

The overall goal of modeling peer review was to provide an unbiased expert assessment of the KBMOS planning effort to improve operational rules for water control structures within the KB. The intent of the modeling peer review was to assess the quality and credibility of the science used to develop the OKISS and the AFET models and their applicability to decision-making for operational management of structures in the KB (Loucks, et al. 2008). The modeling peer review panel included experts with backgrounds in modeling and application of modeling tools to water resource planning projects. These panelists judged the quality and credibility of the science behind the selection of the modeling tools and their suitability for evaluating existing and proposed KB structure operating criteria (Loucks, et al. 2008).

Comments received from the Modeling Peer Review Panel were addressed in the modeling tools. These revisions included a recalibration of the fully integrated model (MIKE SHE/MIKE 11) to an updated reference evapotranspiration data set, as well as several updates to the documentation for modeling tool development and their application to the Base Conditions.

5.5.3 Modeling Peer Review Activities

The modeling peer review consisted of two sessions to review the proposed planning process and modeling tools for the KBMOS. The first session was a formative review of the approach to the modeling tools and planning process. The following summarizes the objectives of the first session:

- Objective 2A: Assessment of the Process Used to Select Modeling Tools
- Objective 2B: Assessment of Modeling Tools and Performance Measures
- Objective 2C: Assessment of the AES

In their report at the conclusion of the first session, the panel concluded that “overall, the panel finds that the KBMOS plan for identifying suitable alternative operating criteria for hydraulic structures in the Kissimmee Basin is sound” (Loucks, et al. 2007). The conclusion was accompanied by a number of recommendations that the modeling team was able to incorporate into the planning effort.

During the second session, the panel was re-convened to evaluate the development and application of the base conditions in the original AFET model. As with the first session, the second session was also a formative review. The review was completed on the draft reports and the panel’s comments were used to clarify parts of these reports that were judged unclear and

make suggestions relative to possible additional work that would clarify the project goals. The objectives of the second session were the following:

- Objective 3A: Assess whether the selected models have been appropriately formulated and calibrated to evaluate existing and proposed KB structure operating criteria
- Objective 3B: Determine if the results from the base condition simulations provide an appropriate benchmark for use in the Alternative Plan Selection Process

From Loucks, et al. (2008), the following is the conclusion of the panel's review:

> "The panel finds no critical defects in the modeling and operation study completed as of this date and no critical defects in the modeling and study activities planned for the completion of this study; thus no remedies are needed. We do identify some remaining issues and opportunities that if addressed within the time and budget constraints available might further enhance the outcomes of this study.

Specific to the objectives of the second session, the following is the panel's assessment:

> Objective 3A: The selected models have been appropriately formulated and calibrated and are ready to use to evaluate existing and proposed Kissimmee Basin structure operating criteria.
>
> Objective 3B: The results from the past and future base conditions simulations provide an appropriate benchmark for use in the Alternative Plan Selection Process. The base conditions are appropriately formulated and there are no significant shortcomings.

During the peer review process, the panel had a number of comments and recommendations that were addressed either through modifications to the documentation, presentations to the panel during the final workshop, or updates to ongoing efforts. The major modification to the KBMOS, as a result of the peer review panel, was the recommendation relative to reference evapotranspiration used in the modeling effort. This recommendation, along with the need to develop a water supply planning tool, resulted in the development of the AFET-W modeling tool.

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APPENDIX A

REPORT OUTLINE SUMMARIZING REFERENCES CITED

Section ID	Section Title	Reference	Reference Topic
1	INTRODUCTION	Earth Tech 2005	comprehensive assessment of basin conditions
1.1	Purpose	Earth Tech 2005a	Task 1.9 Work Plan
1.2	Background	DHI 2007	the MIKE SHE/MIKE 11 tool
		Hydrologics 2006	the OASIS modeling code
2.1	Alternative Evaluation System	Earth Tech 2007d	Alternative Evaluation System Technical Design Document
2.1.3	Alternative Plan Selection Document	AECOM 2010	Updated PME Tool Documentation version 1.3b
3	KBMOS MODELING AND EVALUATION TOOLS	Earth Tech 2005	
3.3	OASIS Model Selection	Hydrologics 2006	OASIS modeling software
		Earth Tech 2005c	Screening Tool Proof of Concept Test Plan
4.1	Data Collection and Compilation	Earth Tech 2005	modeling strategy documented in the KB Assessment
4.1.1.1	Daily Data	Earth Tech 2005b	Interim Data Summary Table
		Earth Tech and Marco Water Engineering 2006	further review
4.1.1.2	Hourly Data Summary	Earth Tech 2006	Hourly data for event calibration/verification of AFET
4.1.2	Rainfall Data	Earth Tech 2005b	Interim Data Summary Table
		Earth Tech 2006a	Phase II, Alternate Formulation and Evaluation Tool Development - Interpolated Rainfall Grids Technical Memorandum
		Earth Tech 2007	2004 Hourly rainfall depth raster sets from 15-minute Next Generation Radar (NEXRAD) NEXRAD Rainfall Grids Technical Memorandum
		Earth Tech 2007a	Daily Rainfall:1965 through 2005 Processing of SFWMM 2mi. x 2mi. Rainfall Grids to Create AFET Input Files Technical Memorandum

Section ID	Section Title	Reference	Reference Topic
4.1.3	Topographic Data	Earth Tech 2007b	processing and creation of the DEM that describes the topography of the KB is documented in the Digital Elevation Model of the Kissimmee Basin
5.1.1	MIKE SHE/MIKE 11 Technical Design Document	Earth Tech 2006b	the Kissimmee Basin Modeling and Operations Study, Alternative Formulation Evaluation Tool (AFET) Development Technical Design Document
		DHI and GeoModel 2001	Lake Tohopekaliga Drawdown Model documented in the Integrated Surface and Groundwater Model for Lake Tohopekaliga Drawdown Project
		Earth Tech 2006c	the Kissimmee Basin Modeling and Operations Study, Alternative Formulation/Evaluation Tool Acceptance Test Plan () describes the calibration and verification time periods for continuous and event simulations and to define the statistical criteria that was to be used as the starting point to assess model calibration
5.1.2	OASIS Model Technical Design Document	Earth Tech 2006d	the Kissimmee Basin Modeling and Operations Study, Screening Tool Technical Design Document
5.2.1.1.1	MIKE SHE Model Development of the Kissimmee Basin – AFET	Earth Tech 2005	Summaries of these models are provided in the Phase I Kissimmee Basin Assessment
		Earth Tech 2006h	interim status was documented in the Alternative Formulation/Evaluation Tool Development of MIKE SHE Documentation
5.2.1.1.2	MIKE 11 Model Development of the Kissimmee Basin – AFET	Project Communication	Additional canal cross sections and hydraulic data were obtained from past modeling by the SFWMD and the USACE in UNET and HEC-RAS in the KB
		Earth Tech 2006i	interim status was documented in the Phase II, Alternate Formulation and Evaluation Tool Development – Development of MIKE 11 Documentation
5.2.1.1.3	Merged MIKE SHE / MIKE 11 Model of the Kissimmee Basin – AFET	Earth Tech 2007e	model documented in Kissimmee Basin Modeling and Operations Study, Phase II, AFET Model Documentation/Calibration Report
5.2.1.1.4.1	Initial Sensitivity Analysis of the Merged MIKE SHE/MIKE 11 Model – AFET	Earth Tech 2007e	The sensitivity analyses
5.2.1.1.4.2	Calibration and Verification of MIKE SHE/MIKE 11 Model – AFET	Earth Tech 2007e	The results of this calibration process are documented in the Kissimmee Basin Modeling and Operations Study, Phase II, AFET Model Documentation/Calibration Report
5.2.1.2	Daily Planning Model Re-calibration – AFET-W	Loucks, et al. 2008	recommendation from the Modeling Peer Review Panel
		SFWMD 2008	new reference evapotranspiration data set
		Project communication	the East Central Florida Transient (ECFT) MODFLOW Model

Section ID	Section Title	Reference	Reference Topic
		AECOM. 2008	AFET-W
5.2.1.2.1	AFET-W Calibration App	AECOM 2008	proposed calibration approach
5.2.1.2.2	AFET-W Acceptance	AECOM 2008	
5.2.2.	Kissimmee River Floodplain Hydraulic Model	Earth Tech | AECOM 2008	MIKE 11 network and cross sections of the Kissimmee River floodplain currently in the KBMOS future condition model
		Earth Tech | AECOM. 2008	refine and validate the river evaluation performance measure targets at key locations in Pool B-C-D
		Earth Tech | AECOM. 2008	'With-Project' Base Condition Model
5.2.4.1.1	OASIS Model Development of the Kissimmee Basin	Earth Tech 2006e	The development of O-KCOL OASIS KCOL Model Report
		Earth Tech 2006k	update to include the Kissimmee River
		Earth Tech 2006d	established in the Screening Tool TDD
		Earth Tech 2007f	compare OKISS to measured data OKISS Model Development and History Matching Report
		Earth Tech 2007e	additional history matching in KBMOS AFET (MIKE SHE/MIKE 11)
5.3.1	Operating Criteria Framework	Konyha 2005	Operating Criteria Framework Document
5.3.2	Initial Comparison of Modeling Tools	Earth Tech 2006e	OASIS KCOL Model Report proof-of-concept testing
		Earth Tech 2006f	Operating Criteria Simulation Engine Proof of Concept Approach - compare OASIS and MIKE11 OPERATIONS
		Earth Tech 2006g	Alternate Formulation and Evaluation Tool Development – AFET Operating Criteria Simulation Engine OCSE Demonstration Report
5.3.3	Demonstration of Transition Rules	Konyha 2006	Proposed Operational Rules KR_Transition_Rules- The SFWMD created a white paper entitled Kissimmee Basin Modeling and Operations Study
		Earth Tech 2007c	Demonstration of Transition Rule Operating Criteria Technical Memorandum
5.3.4	Development of the PME Tool	Earth Tech 2007d	Design according to Alternative Evaluation System Technical Design Document
		AECOM 2010	implementation of the AES as a modeling tool is described in the Updated PME Tool Documentation, Version 1.3b

Section ID	Section Title	Reference	Reference Topic
5.4	Application of the Modeling Tools	AECOM 2009	development, implementation and results obtained from the base condition are documented in the Evaluation of "With Project" Base Conditions Report
5.4.1	Development of Base Condition Models	Earth Tech 2007g	features of the fully implemented Kissimmee River Restoration Project including the Headwater Revitalization Project. Base conditions are summarized in the KBMOS Base Conditions Summary Report
		AECOM 2009a	updated to reflect the ongoing KB water reservations activities and described in the Kissimmee Chain of Lakes Surface Water Supply Availability Study, Summary of "With Project" Base Conditions - Technical Memorandum
5.4.1.1	Downstream Boundary Condition – Lake Okeechobee	Earth Tech 2007h	The KBMOS Draft Evaluation of Downstream Boundary Conditions Technical Memorandum describes the evaluation that was performed to define this boundary condition.
5.4.1.2	Interim Operation of the S-65D Structure	Earth Tech 2007i	proposed interim operating criteria was documented in the KBMOS Draft Operating Criteria for Modeling S-65D Future Conditions Technical Memorandum
5.4.1.2.1	Future Condition Water Use	Earth Tech 2008	Technical Approach to create the Existing Legal Users database included in the "With Project" base condition model
5.4.2	Validation and Testing of the Modeling Tools	AECOM 2009	demonstrate that the KBMOS modeling tools produce comparable component values for the EPMs. Evaluation of Base Conditions Report – AFET-W
5.5.1	Environmental Peer Review Panel	Karr, et al. 2007	The Environmental Peer Review Panel was convened to review the EPMs and EPIs in March and April 2007
		Wetzel 2008	To confirm revisions were consistent with peer review panel recommendations, the SFWMD conducted a third party review of the Draft Alternative Plan Selection Document that included the revised measures
5.5.2	Modeling Peer Review Panel	Loucks, et al. 2008	modeling peer review assessed the quality and credibility of the science used to develop the OKISS and the AFET models and their applicability to decision-making for operational management of structures in the KB
5.5.3	Modeling Peer Review Activities	Loucks, et al. 2007	Peer review report
		Loucks, et al. 2008	Peer review panel conclusions