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Water Supply Needs and Sources Assessment: Alternative Water Supply Investigation: Review of Established Minimum Flows and Levels for the Wekiva River System

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EXECUTIVE SUMMARY

This technical memorandum is a peer review of the processes applied to establish MFLs for streams and rivers in the Wekiva River basin. This review evaluates the goals, methodologies, and assumptions applied by St. Johns River Water Management District (SJRWMD) to develop the MFLs for the basin. Based on this review, the appropriateness of the established MFLs as a basis for preventing significant harm to the Wekiva River basin is evaluated.

BACKGROUND INFORMATION

SJRWMD's current MFLs program involves data collection and management; research; the establishment of MFLs; and follow-up. To be successful, the MFLs program must interface with and support other SJRWMD programs, such as water use permits, the management and storage of surface water permits, the determination of water availability for water supply planning and permitting, and the identification and management of water shortages.

To establish MFLs within the Wekiva River basin, SJRWMD establishes a minimum flow regime consisting of multiple events, rather than a single, minimum level or flow value. This flow regime approach recognizes that natural stream aquatic systems must experience a variety of flow magnitudes to maintain established biological communities and overall environmental health.

The minimum flow regime is defined as a series of flow events necessary to prevent significant environmental harm. Establishment of minimum flow criteria and values for each event constitutes the minimum flow regime and the establishment of the required minimum flow and levels. In the Wekiva River application, criteria were established for determining four hydrologic parameters: minimum flow, a minimum level, a duration, and a recurrence interval. Biological concerns are the primary driver for setting the goals and criteria for each flow event for the minimum flow regime.

ENVIRONMENTAL SETTING AND HYDROLOGY

The Wekiva River system is a highly valued natural resource. The location of the Wekiva River near Orlando provides a large urban population base with a unique opportunity for recreation. In general, the Wekiva River is wide and shallow, with the upper of the main stem fed by an array of seven named springs. Because of the springflow, the water is clear and water temperature is moderate and relatively stable. The river has large areas of wetlands, particularly along the western bank. Classified as an Outstanding Florida Water, the Wekiva River is typical of many spring-fed streams, but not of most Florida rivers.

Black Water Creek is a major tributary to the Wekiva River. The hydrologic characteristics of Black Water Creek vary considerably from the Wekiva River. Black Water Creek has no significant springflow discharge; however, the creek has a baseflow component, largely because of the natural storage provided by Lake Norris, which receives a small quantity of springflow. As the name implies, Black Water Creek is a colored water system; therefore, both the habitat and flow characteristics of the creek and the Wekiva River are dissimilar. Black Water Creek supports significant wetland and aquatic systems.

METHODS

This TM presents a peer review of the MFLs developed by SJRWMD for the Wekiva River watershed system. The goals, methodologies, and assumptions applied by SJRWMD are reviewed and a critique is offered.

There is no widely accepted, standard method for setting for MFLs on Florida streams. Thus, in large part, the review in this TM presents the application of basic principals of hydrology and ecology, and the best professional judgement and opinion of the reviewers. Our evaluation involved the review of SJRWMD reports, a site visit, and discussions with SJRWMD staff. No new analyses were conducted.

REVIEW OF BIOLOGICAL GOALS AND EVALUATION PROCEDURES

SJRWMD staff selected five components of the flow regime and defined a biological criterion for each component. Once the biological criteria were established, specific elevation benchmarks within the biological communities were developed for each criteria. Development of the MFL regime for the Wekiva River and Black Creek proceeded from objectives into criteria through a series of assumptions by Hupalo et al. (1994) and Clapp et al. (1997). Together, these assumptions provide the theoretical, practical, and methodological background for the process used to establish the biological criteria.

For each of the target MFLs, a stage, flow, duration, and recurrence interval were defined using the ecological benchmark elevations and statistical analyses of historical stage and discharge data. The MFLs were then evaluated by modeling. Based on the information obtained from modeling, it appears that SJRWMD's group of assumptions is valid as a basis for developing an MFL program.

Two other elements are essential for accurate results: consistent application of the biological criteria and the control of uncertainty. In general, the biological criteria (environmental protection goals) were consistently applied. Uncertainty associated with ecological features for infrequent low-flow events is not easily quantified. Controlling uncertainty as further data are acquired is essential so that SJRWMD can determine the success of the MFL program and other associated programs.

Undertaking any resource management program must provide some reasonable assurance that the resources intended to be protected are protected. Reasonable assurance is a combination of best available information and an adaptive assessment resource plan. Because adaptive management explicitly recognizes uncertainty and provides for structured feedback to cope with uncertainty, it has clear ties to ecosystem management and ecosystem science. Thus, we recommend an explicit adaptive management approach for managing uncertainty during the MFLs program. Such an approach recognizes sources of errors and uncertainty, but develops specific protocols for control.

REVIEW OF HYDROLOGIC AND HYDRAULIC EVALUATION PROCEDURES

Standard accepted methods of statistical hydrology were applied when analyzing the historic records available for the Wekiva River and Black Water Creek gauges. These analyses define important hydrologic characteristics on the basis of historic record.

The long-term stage hydrograph for the Wekiva River gauge shows that water levels observed at the beginning of the period are significantly higher than those observed in recent years. The cause of this shift is unknown. In future applications, the reviewers suggest testing the stage record for stability of the stage discharge relationship. If a stable or stationary system is confirmed, then the raw stage data can be analyzed directly to develop the desired stage duration relationship and stage frequency analysis. If a transition has occurred, then the current stage-discharge relationship should be used to develop a current stage-frequency-duration relationship. A transient stage discharge relationship also has implications related to proper application of the biological and environmental criteria. MFLs should be established to protect the biologic and hydrologic systems as they exist at the time that the MFLs are set, not as they existed before the transition occurred.

REVIEW OF VALIDATION STUDY RESULTS

The reviewers agree substantially with the validation study results, such as the recommendation that minimum flows rather than minimum elevations be used to evaluate hydrologic conditions in the Wekiva River. The authors of the validation study also recommend the development of a definition of significant ecological harm. We concur that this is an essential step to provide guidance for all future MFL investigations.

CONCLUSIONS AND RECOMMENDATIONS

The flow regime approach, which consists of a series of MFLs targeted at protecting key ecological functions of the stream system, is well grounded in ecological principles and is accepted as general practice in the environmental industry. The flow regime approach is also consistent with an ecosystem management approach. The group of assumptions appears valid as a basis for developing an MFL program. The goals established and procedures used by SJRWMD to determine MFLs within the Wekiva River watershed, including Black Water Creek, are comprehensive.

As part of the follow-up to these studies, SJRWMD should estimate the availability of water under likely water withdrawal scenarios without violating the multiple MFLs. This would provide insight into the usefulness of the MFLs approach as a water resource management and allocation tool. We also strongly support Clapp et al.'s (1977) recommendation to establish additional gaging stations for the Wekiva River system.

SJRWMD should adopt an explicit adaptive management approach, expanding on the flexible approach, to guide the learning process as the MFL program evolves. The process should evaluate water availability. Also, consideration should be given to establishing two MFL procedures, one screening-level and one detailed. Future MFL determinations should include a description of the significant harm expected to occur if the established MFLs are not implemented.

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INTRODUCTION

Surface waters, including lakes, streams, springs, rivers and wetlands, are some of Florida's most important and highly valued natural resources. These natural systems provide habitat for a wide variety of fish and wildlife. Some lakes and streams also provide irrigation, navigation, and potable water supplies. Balancing natural system needs with water supply and other existing and future needs is, and will continue to be, a significant water resources management challenge. The establishment of minimum flows and levels (MFLs) is an important element of good water resources management and is necessary to help meet this challenge.

The St. Johns River Water Management District (SJRWMD) is required by law to establish MFLs for the Wekiva River System (paragraph 373.415[3], Florida Statutes [F.S.]). Also, Section 373.042, F.S. requires each of the five state water management districts to establish minimum flows for surface water courses and minimum levels for both ground and surface waters, below which significant harm to the water resources or ecology of the area would result.

To date, the Wekiva River, including its tributary Black Water Creek, is the only free-flowing stream system within the District where MFLs have been established and adopted by the Governing Board. The work required to establish the Wekiva River MFLs is documented in Technical Publication SJ94-1, *Establishment of Minimum Flows and Levels for the Wekiva River System* (Hupalo et al. 1994). Review of this report is the primary focus of this technical memorandum (TM).

REVIEW SCOPE AND OBJECTIVES

This TM is a peer review of the processes applied to establish MFLs for streams and rivers in the Wekiva River basin. This review evaluates the goals, methodologies, and assumptions applied by SJRWMD to develop the MFLs for the basin. Based on this review, the appropriateness of the established MFLs as a basis for preventing significant harm to the Wekiva River basin is evaluated. Also, recommendations are made concerning the additional data collection and alternative approaches or methodologies used.

SJRWMD MFLs PROGRAM

SJRWMD's MFLs program is a continuing effort requiring the investment of significant resources. According to the Minimum Flows and Levels Project Plan (SJRWMD 1994), more than 26 person years of direct and indirect effort was budgeted in fiscal year (FY) 1994 for the MFLs program, and about 44 person years was budgeted in FY 1995. This level of investment requires continuous oversight and assessment to ensure that the effort results in adequate and useful products. Although limited to the Wekiva River Basin, this review provides a portion of the needed oversight.

SJRWMD's current MFLs program involves data collection and management; research; establishment of MFLs (based on the data base and research results); and follow-up, including reassessment and applications. The relationship among these major program components is illustrated in Figure 1.

Final application of the results is essential to the program's success. To be fully useful, the MFLs program must interface with, and support, many other SJRWMD programs, such as water use permits, the management and storage of surface water permits, the determination of water availability for water supply planning and permitting, and the identification and management of water shortages.

MINIMUM FLOW REGIME

The approach used by SJRWMD to establish MFLs within the Wekiva River basin includes establishing a minimum flow regime consisting of multiple events, rather than a single minimum level or flow value. The flow regime approach recognizes that natural stream aquatic systems must experience a variety of flow magnitudes to maintain established biological communities and overall environmental health.

The review discussed in this TM is divided into two main parts: the review of biological goals and procedures and the review of hydrologic and hydraulic evaluation procedures. Both reviews are based on the minimum flow regime defined by SJRWMD; therefore, the flow regime definition is presented below to provide a common basis for the individual review elements.

The minimum flow regime is defined as the series of flow events necessary to prevent significant environmental harm. This regime includes the following five flow events:

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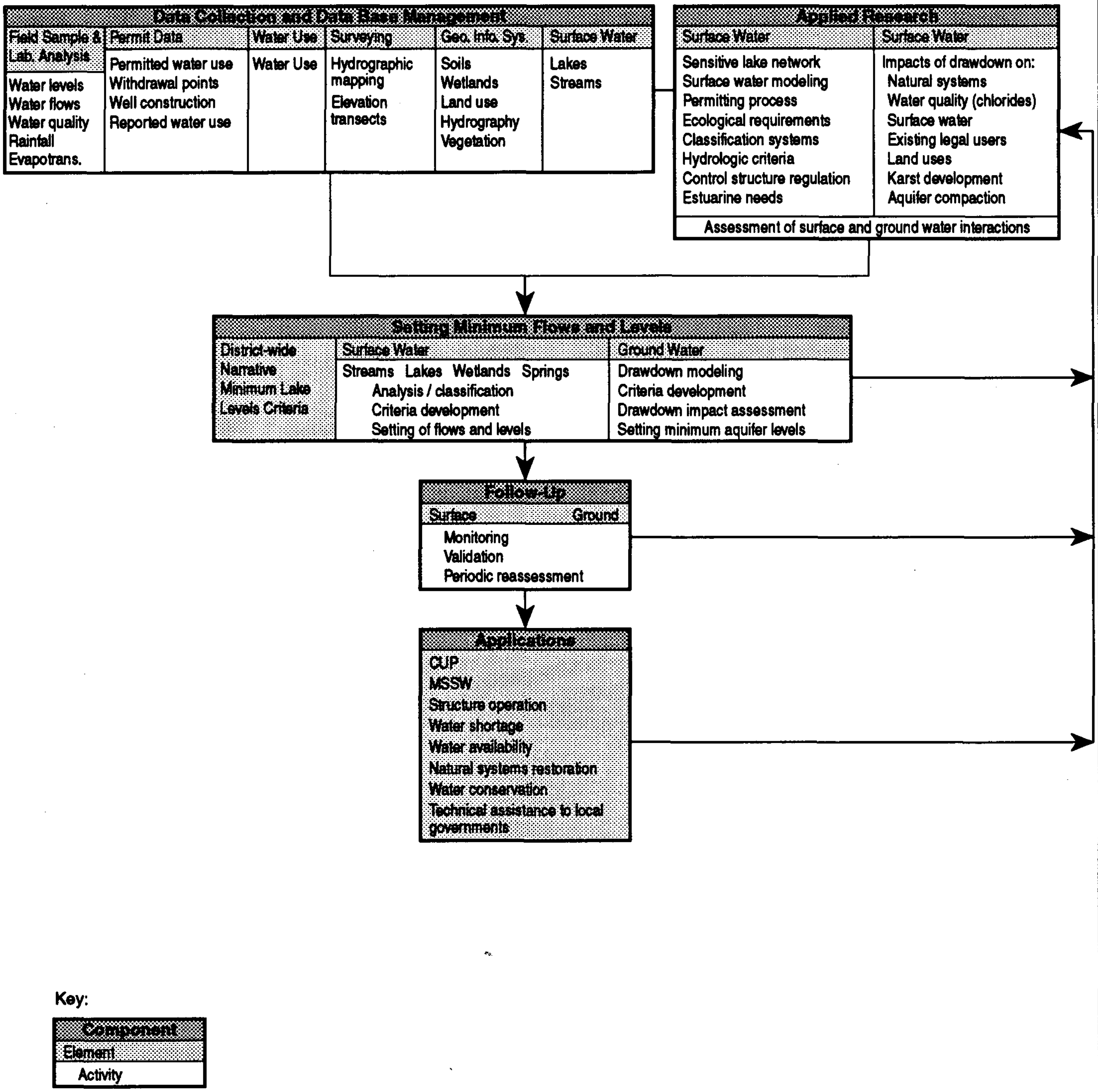

Figure 1. Minimum Flows and Levels Components and Relationships (after SJRWMD 1994).

- Minimum infrequent high
- Minimum frequent high
- Minimum average
- Minimum frequent low
- Minimum infrequent low

Establishment of minimum flow criteria and values for each event constitutes the minimum flow regime and the establishment of the required minimum flow and levels. In the Wekiva River application, criteria were established for determining four hydrologic parameters: minimum flow, a minimum level, a duration, and a recurrence interval. These four parameters are associated with each of the five flow events; thus, 20 numeric values are needed to define the minimum flow regime for a single control point within the watershed.

Biological concerns are the primary driver for setting the goals and criteria of each flow event for the minimum flow regime. Biological criteria, which define the specific ecological functions to be protected, are defined by a specific hydrologic regime that is presumed to protect the intended functions. These biological criteria are described later in this TM. Translation of these goals and criteria into numeric values involves quantitative hydrologic analysis, also described later in this TM.

WEKIVA RIVER SETTING AND HYDROLOGY

The Wekiva River system is a highly valued and unique natural resource. The upland portions of the watershed are located in the northern portion of the Orlando urban area. As illustrated in Figure 2, the upper reach of the main stem of the Wekiva River is fed by an array of seven named springs. These springs discharge upper Floridan aquifer water, resulting in a substantial, reliable base flow.

The location of the Wekiva River near Orlando provides a large urban population base with a unique natural recreation opportunity. For example, canoeing is a popular activity on the river and spring runs. Large portions of the river, the headwater springs, and lowland areas of the watershed are publicly owned. Also, significant wildlife habitat is provided by these adjacent lands, and the river provides an aquatic habitat dependent in large part on maintenance of historic base flow conditions.

130581.SJ.WR 7/97 GNV

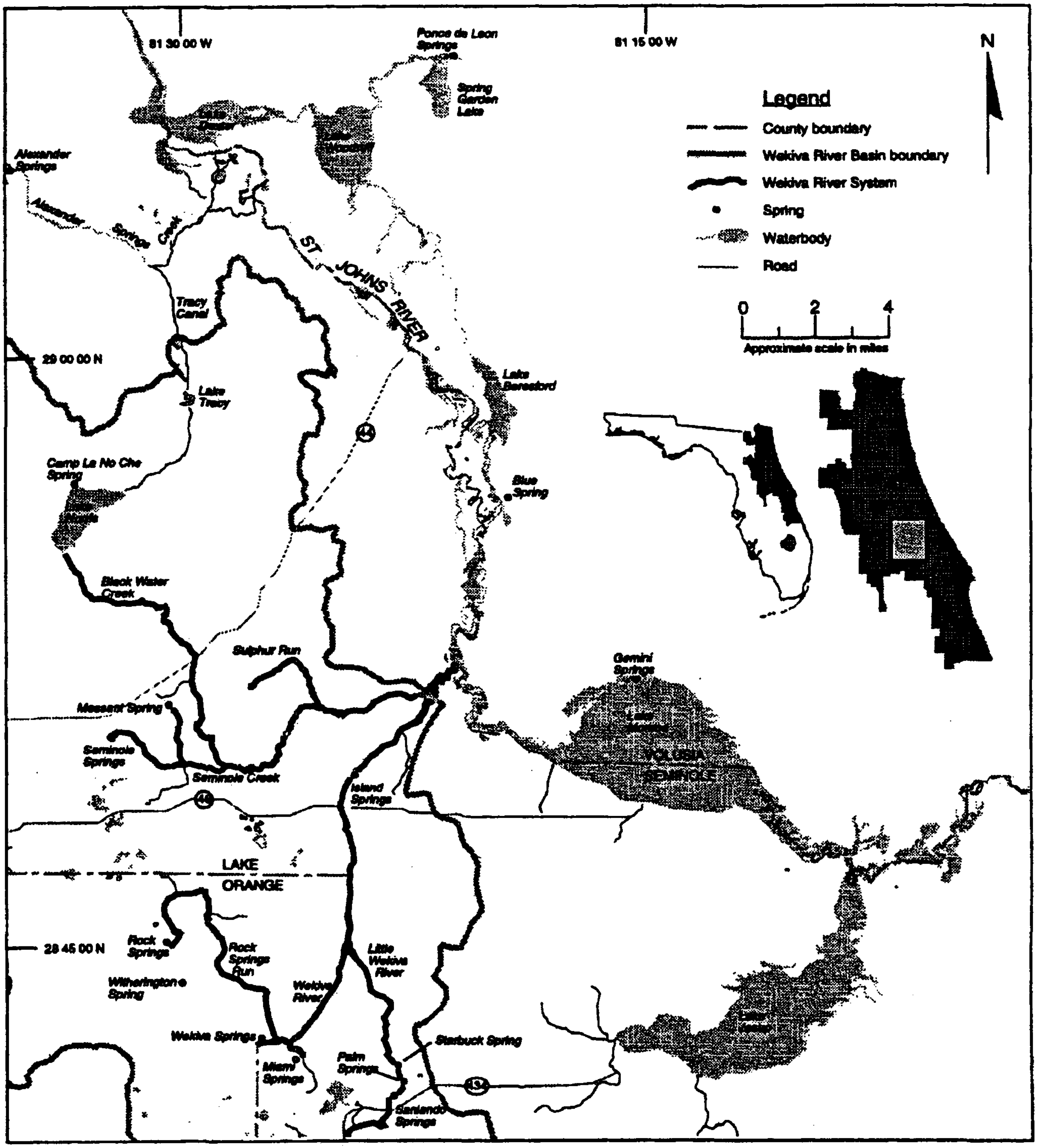

Figure 2. Wekiva River Basin ***(after Hupalo et. al. 1994).***

In general, the Wekiva River is wide and shallow, and includes both riffles and pools. Because of the large springflow contribution, the water is clear and water temperature is moderate and relatively stable. The river has large areas of wetlands, particularly along the western bank, and also contains extensive eelgrass beds. Classified as an Outstanding Florida Water, the Wekiva River is typical of many spring-feed streams, but not of most Florida rivers.

Long-term streamflow records are available for the U.S. Geologic Survey (USGS) Gaging Station No. 02235000 ("Wekiva River near Sanford Florida"). Both daily flow rates and stages provide the primary source of information for the hydrologic analysis conducted by SJRWMD.

The mean annual flow at the Wekiva River stream gauge is 285 cubic feet per second (cfs). The area drained is 189 square miles, which provides a total watershed yield of about 20.5 inches per year. This large unit yield can be attributed to significant springflow contribution. Springflow contribution above the Wekiva River stream gauge averages about 183 cfs, or about 64 percent of the total measured flow. Surface runoff is, therefore, only about 36 percent of the total flow, or 7.5 inches per year.

Observed daily flows have ranged from a low of 105 cfs to a maximum value of 2,060 cfs. Observed water surface elevations have ranged from 6.66 to 11.05 feet above National Geodetic Vertical Datum (NGVD). This range (4.39 feet) is rather small and adds practical difficulty to setting appropriate minimum levels.

BLACK WATER CREEK SETTING AND HYDROLOGY

Black Water Creek is a major tributary to the Wekiva River (Figure 2). The hydrologic characteristics of Black Water Creek are considerably different from those of the Wekiva River. Black Water Creek has no significant springflow discharge upstream of SR 44. However, the creek still has a baseflow component at this location, largely because of the natural storage provided by Lake Norris, which receives a small quantity of springflow. There are springflow contributions downstream of SR 44; however, the springflow component is much less than in the Wekiva River. As the name implies, Black Water Creek is a colored water system rather than a clear water; therefore, both the habitat and flow characteristics associated with these two streams are dissimilar.

Black Water Creek supports significant wetland and aquatic systems. In general, the creek's wetlands are adjacent hardwood floodplain/ swamp systems that depend on overbank flow for periodic hydration.

Long-term USGS streamflow records are also available for Black Water Creek. The records for USGS gaging station No. 02235200 ("Black Water Creek near Cassia Florida") provide daily flow and stage observations. The mean annual flow for the Black Water Creek gauge is 57 cfs and the drainage area is 126 square miles. The watershed yield is only 6.14 inches per year, much smaller than the total Wekiva River yield, but comparable to the Wekiva River surface runoff value.

Observed daily flow rates have ranged from 2.0 to 749 cfs, and observed daily stages have ranged from 22.87 feet above NGVD to 28.48 feet above NGVD. The Black Water Creek watershed yield, flow range, and stage range are more typical of small-to-intermediate sized Florida streams than that of the Wekiva River, which is influenced by the large springflow contribution.

SUMMARY OF MFLS

MFLs were established by SJRWMD for both the Wekiva River and Black Water Creek. These values were based on analysis of the streamflow records available from the stream gauges discussed previously and on site-specific biological investigations. The resulting flows and levels for these two gaging stations are presented in Table 1 for both the Wekiva River and Black Water Creek. These data will be referenced throughout this TM.

Table 1. Summary of Minimum Flows and Levels (MFLs) for the Wekiva River and Black Water Creek (after Hupalo et al. 1994)

Minimum Flow Regime	Level (ft. NGVD)	Flow (cfs)	Duration (days)	Acceptable Return Period (years)
Wekiva River at the SR 46 Bridge				
Minimum Infrequent High	9.0	880	> 7	< 5
Minimum Frequent High	8.0	410	> 30	< 2
Minimum Average	7.6	240	< 180	> 1.7
Minimum Frequent Low	7.2	200	< 90	> 3
Minimum Infrequent Low	6.1	120	< 7	> 100
Black Water Creek at the SR 44 Bridge				
Minimum Infrequent High	27.0	340	> 7	< 5
Minimum Frequent High	25.8	145	> 30	< 2
Minimum Average	24.3	33	< 180	> 1.7
Minimum Frequent Low	22.8	2.5	< 90	> 15
Minimum Infrequent Low	21.9	0	< 7	> 100

METHODS

This TM presents a peer review of the development of MFLs for the Wekiva River watershed system, including Black Water Creek. The goals, methodologies, and assumptions applied by SJRWMD are reviewed and a critique is offered.

The reviewed work is among the first of its kind. SJRWMD has not established MFLs on other streams, and most similar historic work has been conducted in the western United States, only. Although certain principles are transferable, little of the site-specific or species-specific analyses developed in the western United States are directly applicable to Florida's subtropical environment.

Therefore, there is no widely accepted, standard method for setting MFLs on Florida streams. In fact, it is likely that there will never be a single method applicable to all situations as each watershed and stream or river system has unique features that require individual consideration. Thus, SJRWMD staff tasked with this effort faced a formidable challenge, and the results represent the application of scientific principals, along with best professional judgment and opinion.

In large part, the review in this TM also presents the application of basic principals of hydrology and ecology and the best professional judgment and opinion of the reviewers. The effort has involved the review of SJRWMD report documents, a site visit to help understand the characteristics of the watershed, and discussions with SJRWMD staff. The site visit is documented in Appendix A. Reviews conducted previously by the USGS and the National Biological Survey are included in Appendix B to provide a complete set of review comments. No new analyses were conducted.

REVIEW OF BIOLOGICAL GOALS AND EVALUATION PROCEDURES

BACKGROUND AND ASSUMPTIONS

The MFL-setting method is based on the following two key assumptions:

- That a flow regime rather than a single flow value is required to protect the key functions of the river system.
- That for each flow condition within the regime, specific ecological benchmarks can be used to define stage, flow, duration, and recurrence interval.

As noted previously in this TM, the basis of the approach is to establish a set of MFLs, with each set associated with protection of a group of ecological functions deemed essential for function of the river system. The ecological functions can be linked to one or more community maintenance benchmarks. For example, hydric soils develop under certain conditions of saturation and/or flooding during the growing season. Therefore, to maintain a given hydric soil there is an associated hydrologic regime defining a range of conditions for depth, duration, frequency, and seasonality of flooding. In this example, maintenance of hydric soil conditions is the criterion.

SJRWMD staff selected five components of the flow regime and defined a biological criterion for each component. Once the biological criteria were established, specific elevation benchmarks within the biological communities were developed for each criteria (Table 2).

Key Assumptions

Development of the MFL regime for the Wekiva River and Black Creek proceeded from objectives into criteria through a series of assumptions. Two sets of assumptions were developed, one set by Hupalo et al. (1994) for the MFLs establishment study and the other by Clapp et al. (1997) for the MFL validation study. Together, these assumptions provide the theoretical, practical, and methodological background for the process used to establish the biological criteria. These assumptions were as follows:

Table 2. Summary of Minimum Flows and Levels—Goals, Criteria and Values—for the Wekiva River System

Events	Minimum Infrequent High	Minimum Frequent High	Minimum Average	Minimum Frequent Low	Minimum Infrequent Low
a) Wekiva River					
Goals	Complete inundation of riparian wetlands to support ecological processes of transport of sediment, detritus, and nutrients.	Saturation or shallow flooding of hydric hammock community to serve the habitat and life cycle needs of the stream biota that use floodplain habitat for feeding, reproduction, and refuge.	Maintain water table sufficient to maintain riparian hydric soils needed to support floodplain biota and impede encroachment of upland plant species.	Maintain water level sufficient to allow boat and canoe passage without damage to eelgrass beds located in shallow riffles. This level protects the eelgrass beds and associated aufwuchs, which form the basis of the food chain.	Maintain fish passage and health of eelgrass beds to provide habitat conditions that will allow biota to recover from severe low-flow conditions during extreme drought.
Criteria	Periodic inundation of all riparian wetlands	Annual or biannual flooding to maintain floodplain plant community	Maintain water level within 0.25 feet of wetland floor for extended periods	Maintain an average depth of at least 1.67 feet (20inches) over eelgrass beds at critical sections	Maintain a minimum depth of 1.0 foot or more over at least 25 % of shallow riffles at critical sections
b) Black Water Creek					
Goals	Complete inundation of riparian wetlands	Saturation or shallow flooding of mixed swamp community	Maintain water table sufficient to maintain riparian hydric soils and impede encroachment of upland plant species	Maintain water level sufficient to allow fish passage in shallow riffles	Maintain stream biology/habitat during extreme drought
Criteria	Periodic inundation of all riparian wetlands	Annual or biannual flooding to maintain floodplain plant community	Maintain water level within 0.25 feet of wetland floor for extended periods	Maintain a depth of at least 0.6 feet, over at least 25 % of the stream width, at critical sections	Incur no flow conditions no more often than once every 100 years for no longer than 7 days duration

- Hupalo et al. (1994)
  - Use of the flow regime method is the preferred approach.
  - The threshold transect method will be used for field data collection.
  - A river system is a continuum.
  - The seasonal timing of fluctuations will follow natural patterns.
- Clapp et al. (1997)
  - A good correlation will exist between the frequency of discharges and elevations.
  - A discharge or water surface elevation with a certain duration and occurrence interval at Black Water Creek at SR 44 will protect similar environmental features on the Wekiva River at SR 46.
  - MFLs at SR 46 and SR 44 will protect similar features at locations in the river system.

A detailed summary and analysis of these key assumptions are shown in Table 3. These assumptions have been peer-reviewed by USGS and the U.S. National Biological Survey (USNBS). These reviews are included in Clapp et al. (1997) and provided as an attachment to this TM (Appendix B). In general, both these reviews concur with the flow regime approach used by SJRWMD and the key assumptions made by Hupalo et al. (1994). The USGS and USNBS reviewers also identify some of the conditions under which a given assumption may not hold, or where other issues may become a factor (Table 3).

CRITERIA APPLICATION—RESULTS AND VALIDATION

For each of the target MFLs, a stage, flow, duration, and recurrence interval were defined using the ecological benchmark elevations and statistical analyses of historical stage and discharge data. MFLs were established for the Wekiva River and Black Water Creek (Hupalo et al. 1994) and then evaluated in a validation modeling effort (Clapp et al. 1997). The report on the validation effort also contains review comments supplied by hydrologists and biologists from USGS and USNBS.

Based on this information, it appears that the group of assumptions is valid as a basis for developing an MFL program. Each assumption,

Table 3. Assumptions Used as a Basis of Setting Minimum Flows and Levels for the Wekiva River System

Wekiva River System MFL	Assumption	Results of Application	Comments
Establishment of Minimum Flows and Levels (Hupalo et al., 1994)	Define minimum flow and level regime rather than a single flow or level. MFLs associated with specific ecological criteria or benchmarks.	Flow regime concept applied. Recommended regime covers the three relevant types of flows from Hill et. al.(1992). The fourth type, the river valley maintenance flow, will occur naturally in an unregulated stream. Each MFL associated with eco-benchmark.	There was general consensus among reviewers from USGS that flow regime approach is appropriate. More than one MFL needed to protect the river ecosystem, 3 to 5 MFLs appear appropriate. Use of biological criteria is standard practice.
	Each MFL should include a duration and return interval.	Each MFL for WR and BWC are defined in terms of water surface elevation, flow rate, duration, and recurrence frequency.	Literature and USGS reviewers concur that temporal statistics are commonly utilized. Furthermore, these will allow evaluation of water use and effect of uses on the minimum flow standards.
	Intermediate flows and levels needed to maintain water table average near surface of floodplain	Intermediate flows, the MA and MFH set to protect the functions of the floodplain community and its linkage to the channel community.	USGS reviewers (Stalnaker) concur that out of bank flows essential for protection of floodplain plant communities.
	Use threshold transect method, which assumes that a defined flow is adequate for the rest of the stream as it is for the study reach.	Threshold transect method worked well for BWC, but application was more difficult for WR due to channel stability and seepage zones within the floodplain	USGS comments that threshold transect approach is commonly used. They point out however that fish passage criterion is not consistently used.
	River continuum--if a critical flow or stage is reached at a gaging station, then it is likely that other reaches in the system are in the same or similar condition.	River continuum hypothesis can be tested with HEC-2 modeling. Based on validation study SJRWMD concludes that assumption is valid.	Further refinement of concept should be part of the ongoing MFL efforts within the District.
	The seasonal timing of fluctuations within the regime of F&Ls and stage recession rates will follow natural patterns because the river system is not regulated by control structures.	Assumption not specifically testable within the context of the application.	USGS reviewers point out conditions under which the assumption may not be true:(1) changes in the hydrologic response of watershed as development occurs, (2) change in channel characteristics due to erosion, deposition or vegetative growth.

Table 3 (Continued). Assumptions Used as a Basis of Setting Minimum Flows and Levels for the Wekiva River System

Wekiva River System MFL	Assumption	Results of Application	Comments
Surface Water Modeling and Validation Study: Wekiva River Minimum Flows and Levels (Clapp et al., 1997)	A good correlation exists between the frequency of discharges and elevations: (1) discharge of given recurrence will give rise to stage of same, (2) MFs will protect ecological features associated with MLs.	Assumption tested through modeling efforts. Results are generally supportive. Exceptions to this identified for WR appear to be due to its unique characteristics (channel stability, and lateral seepage zones in floodplain).	Relationships identified for this river system may/may not provide guidance for other systems. There appears to be useful "emergent" relationships that will be useful elsewhere, such as the 60th percentile flow as estimate of MA.
	Discharges or elevations with a certain duration and occurrence interval on BWC at SR44 will protect similar ecological features on WR at SR46, since magnitude of discharge is similar.	Assumption tested through modeling efforts. Results are generally supportive. Complications identified in transferring BWC to WR appear to be due to unique aspects of the WR (i.e., channel stability, and lateral seepage zones within floodplain).	Both documents conclude that there are differences between WR and BWC, so this assumption should be applied with caution. Further guidance as to when this assumption is not appropriate should be developed.
	MFLs at SR 44 and SR46 protect similar ecological features at other location in the river system, since river systems have spatial continuity and that the defined MFLs for the study reach protect the whole river system.	Assumption tested through modeling efforts. Results are generally supportive. Complications identified for WR due to unique aspects of the WR (i.e., channel stability, and seepage zones).	Initial results generally supportive. However, as Stalnaker recommends, site specific studies still needed to verify. SJRWMD should identify conditions under which this assumption would not hold.

however, has bounds defining a range of reasonable applicability. It would be valuable to identify the conditions under which each assumption is valid.

Environmental Protection Goals

Tabular summaries of the results from Hupalo et al. (1994) and Clapp et al. (1997), including USGS and USNBS reviews, are provided in Tables 4 and 5 for the Wekiva River and Black Water Creek, respectively. In addition, comments are provided regarding consistent application of the criteria, the degree of environmental protection provided, and uncertainties in the applications.

In general, the biological criteria were consistently applied. We concur with Clapp et al. (1997), who concluded that MFLs for the Wekiva River system generally result in elevations that protect the intended ecological functions. While the studies by Clapp et al. (1997) and Hupalo et al. (1994) indicate that MFLs will protect targeted ecosystem components, the need for some of the biological criteria are not well documented. In particular, the criteria for fish passage and canoe passage are not adequately established.

Furthermore, the assumptions for recovery times from extreme low-flow events, especially minimum infrequent low, are not well documented in the report. The estimation of recovery times is by nature a difficult exercise, and may require an alternative approach from that used to set minimum biological criteria for ecosystem maintenance events. The theoretical, observational, and region-specific data to support ecosystem recovery times for rare low-flow events is based on best professional judgement and hydrologic event frequencies; however, a description of the ecological harm expected to occur and its biological basis is lacking. Thus, it appears that recovery times for rare low-flow events are deduced from the hydrologic record, without actual biological response criteria. Further analysis may show that the presumption is correct, however, the current documentation is sufficient to support a working hypothesis or presumption, not a conclusion.

Upon further review, it may be determined that the criteria for canoe and fish passage and, possibly, drought recovery are not warranted or that they require modification. Therefore, there may be an opportunity to simplify the MFL regime.

Table 4. Summary of Minimum Flows and Levels—Goals, Criteria and Values—for the Wekiva River

Events	Minimum Infrequent High	Minimum Frequent High	Minimum Average	Minimum Frequent Low	Minimum Infrequent Low
Goals	Complete inundation of riparian wetlands	Saturation or shallow flooding of hydric hammock community	Maintain water table sufficient to maintain riparian hydric soils and impede encroachment of upland plant species	Maintain water level sufficient to allow boat and canoe passage without damage to eelgrass beds located in shallow riffles	Maintain fish passage and health of eelgrass beds
Criteria	Periodic inundation of all riparian wetlands	Annual or biannual flooding to maintain floodplain plant community	Maintain water level within 0.25 feet of wetland floor for extended periods	Maintain an average depth of at least 1.67 feet (20inches) over eelgrass beds at critical sections	Maintain a minimum depth of 1.0 foot or more over at least 25 % of shallow riffles at critical sections
Values	Level = 9.0 ft. Flow = 880 cfs Duration = 7 days (min) Return Period = 5 yrs. (max)	Level = 8.0 ft. Flow = 410 cfs Duration = 30 days (min) Return Period = 2 yrs. (max)	Level = 7.6 ft. Flow = 240 cfs Duration = 180 days (max) Return Period = 1.7 yrs. (max)	Level = 7.2 ft. Flow = 200 cfs Duration = 90 days (max) Return Period = 3 yrs. (min)	Level = 6.1 ft. Flow = 120 cfs Duration 7 days (max) Return Period = 100 yrs. (min)
Results from MFL Establishment Study	This flow and level difficult to establish due to complications from channel stability and seepage. Original Criterion could not be applied, therefore recurrence interval and duration from Black Water Creek used. Elevation exceeded 1% of time over POR.	Ecological benchmark appears to be verified, will result in soils saturation or shallow flooding in hydric hammock.	Criterion difficult to use on WR due to high variance and low sample size, therefore a default criterion of the 60th percentile elevation was used. This level is 0.16 ft less than average elevation, and 0.15 ft. less than the median for the 54 yr POR.	Ecological benchmark established as average eelgrass elevation + 1 S.D., then add 20 inches. Resulting elevation is presumed to avoid damage to eelgrass from canoe paddling.	Criterion serves function, eelgrass is protected. Flow is approximately 50% of both MA and median flow over the POR. Flow has recurrence of > 100 yr.
Results from Validation Study	Default use of criterion for BWC under assumption that discharge of same duration and recurrence would protect similar features. HEC-2 generated elevation was within 0.1 ft. of the upland wetland ecotone.	Conclude that there are three benchmark elevations the MFH: (1) the Monk (1966) method, (2) obligate/non-obligate zone, and (3) ecotone between the MHS and hydric hammock. Target elevation was 1.0 ft. less than needed to meet the Monk (1966) method.	Found difficulty in applying the MA criterion on the WR to due complications from channel stability and lateral seepage zones. Validation study, however, concludes that ecological functions will be served. Deltas from modeling analysis were near zero.	Criterion for one stream reach was not necessarily appropriate for another. Flow regime, channel morphology, recreational use, and eelgrass coverage vary from location to location. Study concludes, however, that function maintained throughout system.	Good agreement found with HEC-2 values. Stolen and reproductive tubers of eelgrass will remain inundated. Results indicate that the functions of the MIL will be accomplished.

Table 4 (Continued). Summary of Minimum Flows and Levels—Goals, Criteria and Values—for the Wekiva River

Comments	Criterion applied consistently. This high flow event is the least likely to be significantly affected by allocating flows for other demands. Return period is short enough to have meaning as far as resource management is concerned.	Criterion applied consistently	Criterion applied consistently	Canoe passage criterion is not adequately supported. In fact, DNR review appears to contradict the need for this criterion. Also, projections for recovery time are not documented.	Need for fish passage criterion is not documented. Presumes that WR is more sensitive than BWC based on eelgrass community, however, drought cycle tolerance of eelgrass is not adequately supported. Return period (100yrs) is too long for valid planning.

Table 5. Summary of Minimum Flows and Levels—Goals, Criteria and Values—for Black Water Creek

Events	Minimum Infrequent High	Minimum Frequent High	Minimum Average	Minimum Frequent Low	Minimum Infrequent Low
Goals	Complete inundation of riparian wetlands	Saturation or shallow flooding of hydric hammock community	Maintain water table sufficient to maintain riparian hydric soils and impede encroachment of upland plant species	Maintain water level sufficient to allow fish passage in shallow riffles	Maintain stream biology/ /habitat during extreme drought
Criteria	Periodic inundation of all riparian wetlands	Annual or biannual flooding to maintain floodplain plant community	Maintain water level within 0.25 feet of wetland floor for extended periods	Maintain a depth of at least 0.6 feet, over at least 25 % of the stream width, at critical sections	Incur no flow conditions no more often than once every 100 years for no longer than 7 days duration
Values	Level = 27.0 ft. Flow = 340 cfs Duration = 7 days (min) Return Period = 5 yrs. (max)	Level = 25.8 ft. Flow = 145 cfs Duration = 30 days (min) Return Period = 2 yrs. (max)	Level = 24.3 ft. Flow = 33 cfs Duration = 180 days (max) Return Period = 1.7 yrs. (max)	Level = 22.8 ft. Flow = 2.5 cfs Duration = 90 days (max) Return Period = 15 yrs. (min)	Level = 21.9 ft. Flow = 0.0 cfs Duration 7 days (max) Return Period = 100 yrs. (min)
Results of Initial Study	Ecological benchmark is elevation at upland edge of mixed hardwood swamp (MHS). This elevation exceeded 1.6% of time over POR.	Ecological benchmark is 15 inches of flooding within MHS. Water marks within MHS at 26.55 NGVD.	Two options for defining ecological benchmark: (1) 0.25 ft. below soil surface in MHS, (2) 60th percentile exceedance elevation. The 60th percentile benchmark was selected; associated flow is approximately 50% of the average flow and near the median.	Ecological benchmark is fish passage. Presumption that ecology would be significantly harmed if level were reduced or were to occur for longer duration or more frequent occurrence.	Ecological benchmark is no flow condition in channel. Stream condition would be series of pools separated by exposed riffles. Extrapolated flow recurrence is >500 yrs. Presumption of significant harm if MFL is of longer duration or more frequent.
Results of Validation Study	Reasonable validation provided by HEC-2 analysis, which generated elevations that flood MHS and lower portion of hydric hammock. Conclude that IFH accomplishes intended ecological function.	Elevation of MFH is less than the ecological benchmark. Flood depth in MHS is highly variable. Flooding of 0.8 ft above near channel floodplain elevation needed to flood MHS/HH ecotone. Flooding to this depth provides out of bank flow.	Prediction is good on the basis of modeling and analysis. Results show that maintenance functions for the floodplain's wetland are with this criterion.	Study developed a complex set of alternative criteria. Application of this set of criteria is difficult. Fish passage criterion is not always applied because under some conditions canoe passage is used.	Study developed a complex set of alternative criteria. Application of this set of criteria is difficult. However, the study includes that intended ecological functions are accomplished throughout the stream system.
Comments	Criterion was applied consistently.	Criterion was applied consistently.	Criterion was applied consistently. Criterion seems to have broad application to other flowing water systems in the District.	Criterion was not consistently applied. Need for fish passage criterion is not documented.	Difficult to foresee how a criterion with a return period in excess of 100 years can be used for setting management goals.

Both the MFL establishment study and the validation study summarize useful targets for establishing the individual MFL targets. For example, Clapp et al. (1997) cite the following alternative methods for establishing a minimum frequent high: (1) the elevation at 1.25 feet above the surface of the mixed hardwood swamp, (2) the elevation of the floodplain zone with obligate and non-obligate wetland species, and (3) the elevation of the ecotone between the mixed hardwood swamp and hydric hammock communities. These methods should be formally compiled into a guidance document that provides users with insight into conditions under which these benchmark elevations are appropriate and inappropriate.

Uncertainties and Sensitivity

The development of MFLs for the Wekiva River system was a complex, detailed process that required adapting approaches developed in other parts of the country. Because of both the pioneering nature of this MFL application and the unique biological and hydrologic character of the Wekiva River, there are many uncertainties that must be recognized. Sources of uncertainty include errors associated with observations and measurements, modeling and calibration, and the establishment of ecological benchmarks, and the uncertainty associated with key assumptions and target biological criteria.

The authors and reviewers recognize that some means of managing uncertainty within the context of an evolving process is needed. Techniques for determining errors associated with observed measurements and model development and calibration are known. Unfortunately, errors associated with ecological features are not as easily quantified.

Controlling uncertainty is essential so that SJRWMD can determine the success of the MFL program and other resource management and protection programs. Undertaking any resource management program must provide some reasonable assurance that the resources intended to be protected are indeed protected. Reasonable assurance is a combination of best available information and an adaptive assessment resource plan that describes how the agency implementing the program will continue to improve the resource information base and, if needed, make structural or operational modifications if major problems are detected. Adaptive assessment is a process that integrates monitoring, modeling, research, and evaluation of scientifically sound management actions.

Several key concepts of adaptive management deal with treatment of uncertainty. The adaptive management process explicitly recognizes uncertainty in our knowledge base and, therefore, explicitly provides for structured learning. In other words, it is a formalized program to "learn as you go." Through adaptive management, one can develop policies as hypotheses and view management actions as tests and opportunities for learning.

Because adaptive management explicitly recognizes uncertainty and provides for structured learning feedback to cope with uncertainty, it has clear ties to ecosystem management and ecosystem science. Together, the three concepts (ecosystem science, ecosystem management, and adoptive management) provide a firm foundation from which to develop goals, policies, and implementation strategies for environmental resource management actions. From this foundation, we can develop management approaches that use our best scientific base, recognize uncertainty, and make it possible to adjust our actions as we learn.

For these reasons, we recommend that an adaptive management approach be used to manage uncertainty as the MFLs program evolves. Such an approach recognizes sources of error and uncertainty, but develops specific protocols for control. For example, such an approach could include the following elements:

- Identification and analysis of sources of uncertainty in setting mfls
- Development of program to address sources of uncertainty
- Ongoing data collection program
- Periodic re-evaluation of mfls
- Mechanism to revise allocation

REVIEW OF HYDROLOGIC AND HYDRAULIC EVALUATION PROCEDURES

The goals and criteria used to establish MFLs on the Wekiva River are based on biological and environmental considerations, as discussed previously in this TM. Hydrologic and hydraulic procedures are then used to translate the biological and environmental criteria into actual numeric limits, applicable at a given site.

The hydrologic and hydraulic analysis procedures used in the Wekiva River application are documented in Hupalo et al. (1994) and Clapp et al. (1997). Several hydrologic and hydraulic analyses are applicable. These include analysis of the historic hydrologic record and simulation studies. Historic record analysis includes development of flow and stage duration curves and low-flow and high-flow duration frequency analysis. Simulation studies include continuous hydrologic simulations to generate synthetic streamflow records at ungauged sites and hydraulic open channel flow analyses to estimate stage discharge relationships at these sites. Once the synthetic record is generated, (flow and stage), these records can be analyzed in a manner similar to the historic record to establish MFLs at any desired location within the watershed.

HISTORIC RECORD ANALYSIS

Standard accepted methods of statistical hydrology were applied when analyzing the historic records available for the Wekiva River and Black Water Creek gauges. These analyses include development of flow duration and stage duration curves, as well as low- and high-flow frequency duration analyses for both gauges. These analyses, which are relatively straightforward, define important hydrologic characteristics on the basis of historic record. One area of concern identified by these analyses and investigated in-depth in the validation study (Clapp et al. 1997) is the stability of the stage discharge relationship for the Wekiva River gauge. The relative stability of this relationship is essential to the application of the environmental criteria, which are largely elevation-related.

Figure 3 shows the long-term stage hydrograph for the Wekiva River gauge. In this figure, water levels observed at the beginning of the period of record are significantly higher than those observed in recent years. The analyses presented in the validation study indicate that this

130581.SJ.WR 7/97 GNV

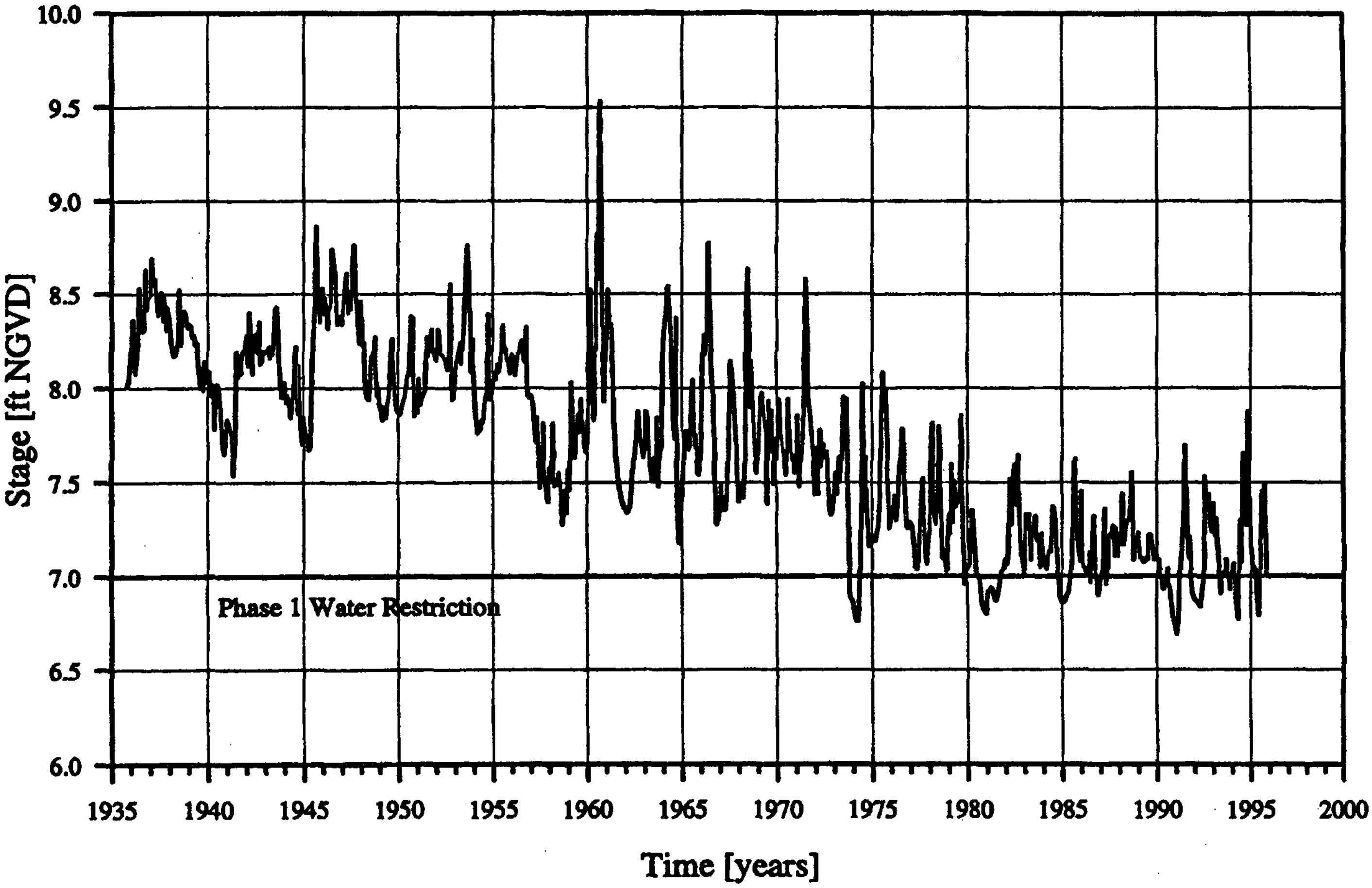

Figure 3. USGS Stage Hydrograph (ft NGVD) for Wekiva River at SR 46 from 1935 to 1994 (after Clapp et. al. 1997).

change is on the order of 1.0 to 1.25 feet, which represents a significant shift in a system with an observed daily stage range of only about 4.4 feet. In fact, some of the maximum water surface elevations observed in recent years are similar in magnitude to the minimum water surface elevations observed near the beginning of the period of record.

The cause of this shift is unknown. However, all streams tend to erode to a base level with time. The rate of erosion depends on the stream gradient, bed material, and many other factors. Shifts in a stage discharge relationship could also be caused by changes in channel vegetation, resulting in changes in stream bed hydraulic roughness. For example, eelgrass beds in the Wekiva River provide considerable hydraulic flow resistance. As the occurrence and distribution of these beds change with time, so will the open channel flow characteristics of the stream. It is likely that a combination of changes in stream morphology and channel vegetation are responsible for the observed transient stage discharge relationship. Given the large magnitude of the change, it is unlikely that changes in vegetation, alone, could be responsible.

There are some important lessons to be learned from the Wekiva River stage record case study. These lessons are related to both the analysis and interpretation of the hydrologic record and to application of the hydrologic analysis results to the biological goals and criteria. First, because shifts in stage discharge relationships are possible at any location, the stability of this relationship should be checked early in the hydrologic analysis. In this case, the large shift in the stage discharge relationship over time renders the stage frequency analysis for the Wekiva River gauge presented in the original MFL determination (Hupalo et al. 1994) of limited value at best, and misleading at worst. This is because analysis of a stationary system is implied and the system is actually in transition.

The reviewers suggest the following approach. Test the stage record for stability of the stage discharge relationship, as was done for the Wekiva River gauge in the validation study. If a stable or stationary system is confirmed, then the raw stage data can be analyzed directly to develop the desired stage duration relationship and stage frequency analysis. If, however, the system is transitory, then the stage data should be adjusted to reflect recent or current conditions. In this case, the current stage discharge relationship would be applied to the historic daily flow record to generate a quasi-historic stage record for current river hydraulic conditions. This adjusted stage record would then be analyzed to establish a current stage duration and stage frequency analysis.

A transient stage discharge relationship also has implications related to proper application of the biological and environmental criteria. If the base level of a stream is receding with time, then it follows that the adjacent natural systems, including the floodplain and floodplain wetlands, are also in transition. As the stream level is lowered, the adjacent wetlands, which depend on the stream, will also be in transition towards a somewhat dryer condition, particularly at the upper margins. However, since changes in vegetation occur slowly in response to water level changes, the adjacent wetland communities observed at the time of the analysis may well be representative of past water level regimes rather than current water level conditions. In such cases, minimum levels may be set too high relative to current maintainable conditions. MFLs should be established to protect the biologic and hydrologic systems as they exist at the time that the MFLs are established, not as they existed before the transition occurred.

SIMULATION STUDIES

To develop MFLs for locations within a stream system other than at gauged locations, simulation studies are required. These studies include hydrologic simulation to generate synthetic streamflow records at ungauged sites and hydraulic simulation to develop stage discharge relationships to convert flow values into corresponding stage values.

Simulation studies undertaken to date in the Wekiva River watershed, including Black Water Creek, are well documented in the validation study (Clapp et al. 1997). Hydrologic simulation used the U.S. Army Corps of Engineers (COE) Streamflow Synthesis and Reservoir Regulation (SSARR) model. Hydraulic simulation used the HEC-2 models. In our opinion, these models were appropriate for this application.

SSARR Model

The SSARR model is a continuous hydrologic simulation model that generates long-term synthetic streamflow records on the basis of observed rainfall and evaporation records and watershed hydrologic parameters. A separate routine was developed to generate spring discharges on the basis of rainfall and calibrated spring discharge parameters. The model continuously tracks soil moisture, and rainfall/runoff relationships are represented as a function of antecedent soil moisture. All important surface water hydrologic processes are accounted for in this model; yet, it is relatively straightforward. The final test is calibration and the model-calibrated well. That is, the model was able to approximately reproduce observed streamflow records using realistic tributary watershed parameters and calibration parameter values all within reasonable limits.

HEC-2 and HEC-RAS Models

HEC-2 and the newer River Analysis System (HEC-RAS) model are open channel flow hydraulic models capable of developing reasonable stage discharge relationships at any ungauged site in the watershed. These models are standard accepted techniques for evaluating open channel flow in natural streams, including associated floodplains and overbank flow.

REVIEW OF RECOMMENDATIONS

The validation study addresses several important issues related to both determination of the Wekiva River MFLs and to future determinations on other systems. The reviewers are in substantial agreement with the validation study results. Some of the more important results and recommendations are discussed below.

The authors of the validation study recommend that minimum flows rather than minimum elevations be used to evaluate hydrologic conditions in the Wekiva River. This recommendation arises primarily from concerns related to the transient nature of the stage discharge relationship at the SR 46 gauge. We concur with this recommendation and further believe that consideration should be given to establishing flow (as opposed to level) as the primary indicator of hydrologic conditions for all flowing streams. This is because water is the resource directly managed. Desired levels should be used to establish the desired flow, but maintenance of the minimum flow regime, once establish, should be the primary object of water resource management strategies.

Although the legislative mandate requires the establishment of minimum flows <u>and</u> levels, it seems appropriate from a practical resource management standpoint to establish minimum flow *or* levels, depending on the type of hydrologic system under consideration. For example, when considering an aquifer, the concept of flow has little meaning. In this case, the management goal is to maintain an aquifer level, or potentiometric elevation, sufficient to protect the resource. Springs are a surface water feature supplied by ground water. Maintenance of a minimum springflow will require maintenance of an associated minimum aquifer level. Also, in the case of isolated lakes, flow has little practical meaning. Again, the management metric is maintenance of lake levels.

In flowing streams, the water resource is defined by the streamflow. Therefore, it seems appropriate to focus resource management decisions on maintenance of the minimum flow regime. Biological and environmental criteria are used to establish desirable elevations. However, once converted to flow values, the flow values should be the primary focus for water resource management decisions.

The authors of the validation study also recommend the development of a definition of *significant ecological harm*. We concur that this is an essential step to provide guidance for all future MFL investigations.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Our conclusions, based on this review of the Wekiva River MFL reports, are as follows:

- The Wekiva River is a highly valued natural resource that provides significant outdoor recreational opportunities, as well as unique natural habitat.
- The flow regime approach, consisting of a series of MFLs each targeted at protecting key ecological functions of the stream system, is well grounded in ecological principles and accepted as general practice by USGS and USNBS reviewers.
- The flow regime approach is consistent with an ecosystem management approach, with a focus on sustainability of natural systems. The MFL approach recognizes the linkages between the channel community and its adjacent floodplain community.
- The group of assumptions appear valid as a basis for developing an MFL program. Each assumption, however, has bounds defining a range of reasonable applicability. It would be valuable to identify the conditions under which each assumption is valid.
- The goals established and procedures used by SJRWMD to determine MFLs within the Wekiva River watershed, including Black Water Creek, are comprehensive. The definition of a minimum flow regime, including five minimum flow events, provides explicit consideration of important natural system in-streamflow needs.
- For the Wekiva River, the minimum frequent low flow was used to derive minimum springflows needed to protect stream system base flows
- The regime appears to protect the intended ecological functions and features.
- Overall, the biological criteria are applied consistently.
- A strong case for the necessity of the fish passage criterion is not made.

- A strong case for the canoe passage depth over eelgrass criterion is not made.
- Assumptions for recovery times from rare low-flow and no-flow events are not well documented as compared to those for intermediate-flow events. Recovery times for infrequent low-flow events are based on best professional judgement of senior project staff. These assumptions should be revised as more is learned about the Wekiva River system.
- It will be difficult for stakeholders to envision how MFL events and associated criteria with recurrence intervals of greater than 100 years, such as the minimum infrequent low, can be used in resource management planning.
- Refinement of the ecological criteria will be an ongoing process, as noted by Clapp et al. (1997).
- Adoption of an explicit adaptive management approach would be helpful because the work summarized by Hupalo et al. (1994) and Clapp et al. (1997) clearly show that the development of MFLs is a "learn as you go" process.
- The original work was performed without a formal definition of *significant ecological harm*. Without such a definition, established as a matter of SJRWMD policy, the investigators were charged with defining significant harm on a case-by-case basis. This definition will vary from investigator to investigator.
- Both the MFL establishment study and the validation study summarize useful targets for establishing the individual MFL targets; this information should be compiled and made available for future use.
- The overall approach, including, goals, criteria, and procedures used to establish MFLs on the Wekiva River system, are quite complex and, in some cases, the results may be difficult to apply. In the case of the Wekiva River, the resource management complexity is reduced to a simple function of spring discharge. In other, non-springflow-dominated systems, the method and results are perhaps too complex to serve as a model for establishing MFLs on all other SJRWMD streams.
- Each of the five minimum flow events is described by a level, flow rate, duration, and return period, resulting in 20 values to fully

define MFLs at a single point on a stream. The effort required to develop such a large array of characteristics and corresponding values is considerable and probably prohibitive, both in terms of level of effort and time needed to establish MFLs on all SJRWMD streams requiring the establishment of MFLs.

- The results of this process may also be difficult to apply to meet the needs of other SJRWMD programs (Figure 1). For example, it would be difficult for SJRWMD water supply planning staff or for a CUP applicant to determine water supply availability for a typical stream with MFLs established according to the Wekiva River model. The determination of water availability would likely require additional hydrologic simulation analysis, making regional water supply planning and CUP analysis more difficult.

RECOMMENDATIONS

For the Wekiva River watershed, including Black Water Creek, the criteria used to establish the minimum frequent low for the Wekiva River should be reevaluated. The current criteria is based on maintaining an average depth of 20 inches over eelgrass beds at critical (shallow) sections. This criteria is based on the possibility of damage to the eelgrass beds by canoe paddles at lesser depths. However, given that the minimum frequent low event is used to establish the existence of a water shortage, the selected criterion appears to be overly conservative. That is, is the possibility of some damage to eelgrass beds located in shallow sections of the river, by canoeist "significant harm" requiring the declaration of a water shortage. If it is then this criterion is appropriate. If not, than a more appropriate criterion and associated limits needs to be established.

As part of the follow-up to these studies, SJRWMD should estimate water availability under likely water withdrawal scenarios without violating the multiple MFLs. This exercise would provide insight into the usefulness of the MFLs approach as a water resource management and allocation tool. In addition, SJRWMD should consider the following recommendations related to the establishment of MFLs within the Wekiva River basin:

- Because of the unstable stage-discharge relationship within the stretch of the Wekiva River in the vicinity of the gaging station at SR46, we strongly support Clapp et al.'s (1997) recommendation to establish additional gaging stations for the Wekiva River system. A gaging station upstream of the SR46 station should provide a better location from which to monitor discharge of the Wekiva River.

- Because of the transient nature of the channel system in the Wekiva River at SR46, the application of ecological criteria should recognize conditions existing at the time that MFLs are set, not those that reflect previous states.

SJRWMD should consider the following recommendations on future MFL setting:

- SJRWMD should continue to review existing MFL determinations and attempt to formalize a consistent definition of *significant ecological harm*. This term should be used in all future MFL determinations and to reevaluate existing determinations.
- SJRWMD should establish a MFLs working group that includes end-users and the SJRWMD staff responsible for establishing the MFLs. The mission of the proposed working group is to define the format and content of MFL end products so that they meet user needs and provide efficient management of District water resources. Hopefully, this evaluation will result in refinements in the current model that enhance its utility as a water resources management tool.
- SJRWMD should adopt an explicit adaptive management approach, expanding on the flexible approach used to date, to guide the learning process as the MFL program evolves.
- The methods used to establish MFL targets should be compiled into a guidance document that provides users with insight into conditions under which these benchmark elevations are appropriate and inappropriate.
- The process should evaluate water availability. Water availability can be evaluated as part of the overall MFL analysis through simulation. For a given water body, a set of withdrawal criteria should be established for initial analysis, defining such limits as the maximum allowable withdrawal, the low-flow condition below which no further withdrawal is allowed, and other withdrawal criteria warranted for site-specific conditions.
- Consideration should be given to establishing two MFL procedures, one screening-level and one detailed. The MFL screening-level method would be based only on analysis of

streamflow characteristics (observed or synthetic), and would result in a quick assessment of MFL requirements, without detailed, site-specific biological studies. The screening method would make possible rapid MFL assessment for the entire District. This assessment would provide approximate information to support water resources planning and other activities.

The detailed, site-specific biological approach would then be applied on an as-needed basis for highly valued streams such as the Wekiva River; for investigations related to a proposed significant consumptive use; or for other projects with the potential for significant alteration of the natural streamflow regime.

An example screening-level method is illustrated in Table 6. Application of this method to a particular site would require computation of the mean annual flow, development of the flow duration curve, and performance of a flood magnitude/frequency analysis.

The criteria for the screening-level method should be developed by the SJRWMD MFLs working group after the official definition of significant ecological harm has been established.

- Future MFLs determinations should include a description of the significant harm expected to occur if the established MFLs are not implemented.

Table 6. Example Screening-Level Criteria for Determining Minimum Flows and Levels (MFLs)

Minimum Flow Event	Example Criteria for Approximate MFLs Method
Minimum Infrequent High	80 percent of natural system 5 year flood flow for all durations.
Minimum Frequent High	80 percent of natural system 2 year flood flow for all durations.
Minimum Average	85 percent of natural system mean annual flow
Minimum Frequent Low	Streamflow rate exceeded 92 percent of the time
Minimum Infrequent Low	Streamflow rate exceeded 97 percent of the time

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Appendix A

Wekiva River, Black Water Creek and Lake Dorr Site Visit

ATTENDEES:	Sonny Hall/SJRWMD Ric Hupalo/SJRWMD	Ron Wycoff/CH2M HILL Bill Dunn/CH2M HILL
FROM:	Bill Dunn	

On Thursday, October 31, 1996, CH2M HILL and SJRWMD ecologists and hydrologists met at the SR 46 bridge over the Wekiva River bordering Lake County and Volusia County in Florida. The purpose of the field meeting was to visit key sites on the Wekiva River (WR) and Black Water Creek (BWC) that were used by SJRWMD for the establishment of minimum flow regimes. The field trip was led by Ric Hupalo and Sonny Hall.

Wekiva River

Sonny Hall said there are three sections to the river:

- upper zone with braided channel
- eelgrass flats zone with unbraided channel, and
- lower, St. Johns River interface zone (braided)

The goal of our trip was to focus on the upper two zones of the river.

Wekiva River- South of SR 46 Bridge (Figures A-1 and A-2)

Floodplain forest is a mixture of hydric hammock with bay seepage swamp. According to Ric and Sonny, this latter community types proved to be somewhat problematic, because seepage zones "allow" wetland communities to move upslope of where they might otherwise occur within the floodplain.

The river channel immediately south of the bridge is very wide (Figure A-2, top). Eelgrass beds are present but have a very patchy distribution. The forested floodplain is narrow through this section to and scattered houses are visible along the edge of the floodplain.

We stopped at location of SJRWMD's Transect 2. The floodplain on the east side of the river had a very narrow forested border. The palmetto zone at the upland edge of the the floodplain was within 100 ft of the shoreline. Overall the floodplain in this section was narrow with a sharp rise to the uplands. The floodplain forest consisted of a narrow band of hydric hammock. At this location the channel was wide with very shallow depth; eelgrass beds were patchily distributed, and according to Ric the beds were not as densely distributed as they had been in previous years.

Moving south from the bridge the character of the river system changes to a braided channel zone with interspersed sand bars. The sand bars vary widely in size and vegetative cover, some are covered with emergents, others with thickets of willows, and still others with successional stages of hardwood swamp.

The floodplain proper is a dense cypress/MHS forest zone. The water appears to be darker than in downstream reaches with silt deposits on bottom (Figure A-1). We noted the canopy composition to be cabbage palm, red maple, elm, bald cypress (*Taxodium distichum*), ash (*Fraxinus caroliniana*), swamp dogwood (*Cornus foemina*), laurel oak (*Quercus laurifolia*), and blackgum (*Nyssa biflora*).

Bridge SR 46 (Figure A-3)

We noted staff gage reading as 2.08 ft 11:30 AM, according to Ric Hupalo the datum is 4.98. The construction was taking place on the bridge (Figure A-3, top and bottom). Mats of floating vegetation were noted at the bridge. The bridge may act as barrier to the downstream transport of these mats.

Wekiva River North of SR46 Bridge (Figures A-4, A-5, A-6)

This section of the river is characterized by:

- a wide channel with relatively shallow water depths,
- extensive and well-developed beds of eelgrass,
- a forested floodplain of hydric hammock with some mixed hardwood swamp, and
- scattered sandbars vegetated with willow and/or cattail.

At several locations we noted at least 4 inches of soft sand and/or organics within the eelgrass beds.

We visited one of SJRWMD's transects (Figure A-6). At the transect the channel is wide and shallow, so that wide ranges in flow can occur with only relatively modest changes in stage. The eelgrass beds were dense in this reach of the river. SJRWMD has classified the floodplain forest as hydric hammock floodplain on west side, hydric hammock The general character was as follows:

- canopy: red maple (*Acer rubrum*), cabbage palm (*Sabal palmetto*), (80% cover total for canopy)
- subcanopy: hornbeam (*Carpinus caroliniana*), cabbage palm, elm (*Ulmus americana*),(50% cover total for subcanopy)
- shrub: little bluestem palm (*Sabal minor*) and cabbage palm
- groundcover: <1% cover; scattered patches of grass/sedge
- soil: sandy with fines; crayfish burrows noted

We noted that hog and/or armadillo rooting activity had disturbed soils. Moving upslope, the forest canopy composition changed with increased amounts of live oak, laurel oak and sweet gum. A palmetto line is ± 150 to 200 ft from edge of upland; at edge is slight rise +1.0 ft then hardwood fringe blending into open pine overstory with oak understory

Transect had an approximate orientation of 310° (WNW). The length was approximately ± 500 to upland end of transect, with the palmetto line a ± palmetto at 441′

Black Water Creek (Figures A-7 and A-8)

We visited BWC at SR 44 bridge. There is gaging station at the bridge. According to Ric and Sonny three transects had been established in this reach of the creek. In addition, a fish study was conducted by a contractor. The study included 120 locations for fish shocking.

In contrast to the Wekiva River, the floodplain of BWC contains a well defined mixed hardwood swamp bordering the channel.

We asked Sonny and Ric--Why was this creek selected for the establishment of minimum flows? They responded with the following list of reasons:

- Legislation mandate
- It is an Outstanding Florida Water (OFW)
- lower part is an Aquatic Preserve
- watershed is not well developed
- Headwaters are within protected lands--Lake Norris & Lake Dorr in the Ocala National Forest

The general character of the floodplain forest bordering the channel is:

- Canopy/Subcanopy: cypress, red maple (*Acer rubrum*), blackgum, popash, elm, laurel oak, cabbage palm, water hickory (*Carya aquatica*), and buttonbush (*Cephalanthus occidentalis*);
- Herbaceous groundcover: maidencane (*Panicum hemitomon*), *Panicum gymnocarpon*, lizard's tail (*Saururus cernuus*), (*Bohmeria cylindrica*), cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*), woodfern (*Thelypteris sp.*), chain fern (*Woodwardia*),
- Water marks on trees corresponded to depth of approximately 1.33 ft.

General comments and observations:

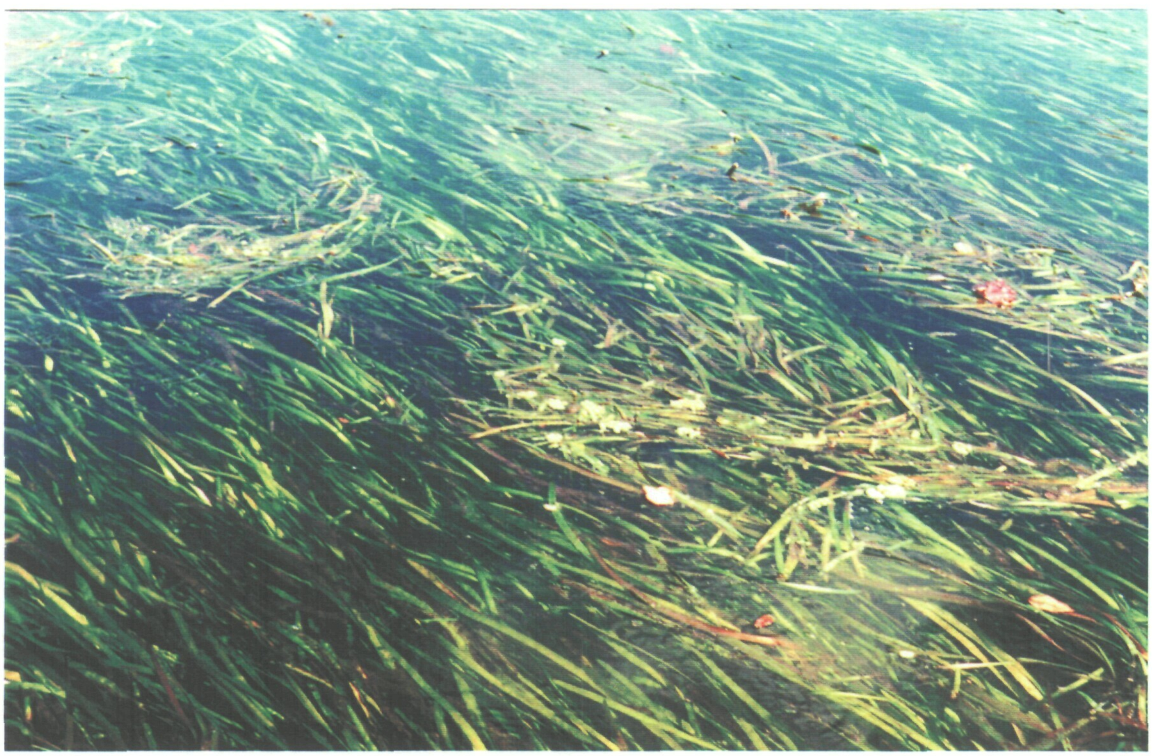
- BWC, at this location, appears to be typical of tannic, non-spring fed creeks throughout the District,
- floodplain would be inundated under 1 to 2 year recurrent event, so flooding of the swamp is nearly an annual event,
- we observed bank full flow in creek, floodplain soils were saturated, there were scattered shallow pools in low areas of the floodplain,
- regulatory issues are minimal for BWC as compared to WR.

Figure A-1. Views of the Wekiva River South of the Bridge at SR 46.

Figure A-2. Views of the Wekiva River South of the Bridge at SR 46.

Figure A-3. Views of the Bridge at SR 46 over the Wekiva River.

Figure A-4. Views of the Wekiva River North of the Bridge at SR 46



(Close up of an eelgrass bed)

Figure A-5. Views of the Wekiva River North of the Bridge at SR 46.

(Left to Right, Ron Wycoff and Rick Hupalo)

Figure A-6. Views of the Wekiva River North of the Bridge at SR 46.

(Left to Right, Field Team of Ron Wycoff, Rick Hupalo, and Sonny Hall)

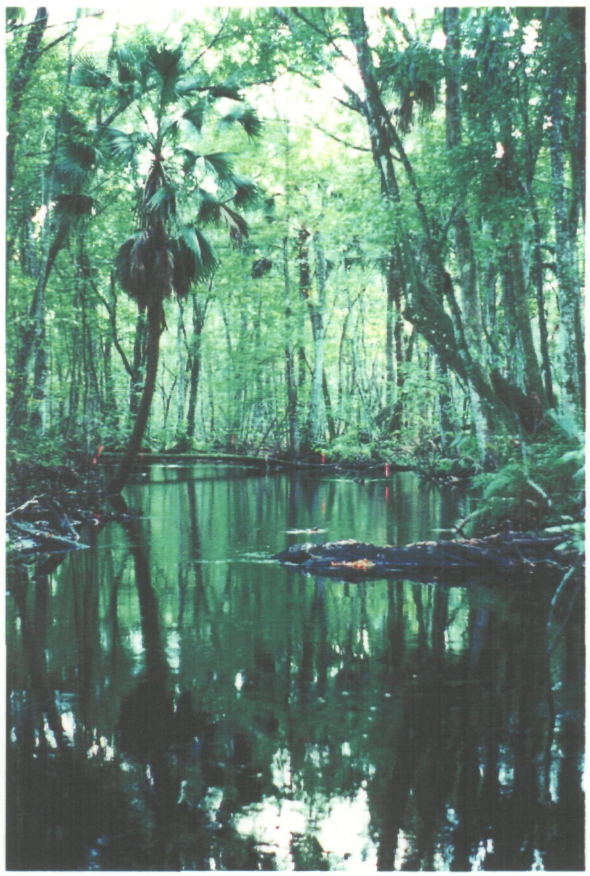


Figure A-7. Mixed Hardwood Swamp along the Channel of Black Water Creek.

Figure A-8. Mixed Hardwood Swamp along the Channel of Black Water Creek.

(Forms the Headwaters of Black Water Creek)

Figure A-9. Lake Dorr in Ocala National Forest.

Appendix B

MEMORANDUM

DATE: February 29, 1996

TO: Hal Wilkening, P.E., Assistant Director
Department of Resource Management

Ed Lowe, Ph.D., Director
Division of Environmental Sciences

Sonny Hall, Ph.D.
Division of Environmental Sciences

Cliff Neubauer, Ph.D.
Division of Environmental Sciences

Rick Hupalo
Division of Environmental Sciences

Charles Tai, Ph.D., Director
Division of Engineering

Don Rao, Ph.D.
Division of Engineering

David Clapp
Division of Engineering

FROM: Barbara A. Vergara, P.G., Director BV
Division of Needs and Sources

RE: Wekiva River system minimum flows and levels, peer review by U.S. Geological Survey

Attached is a copy of the referenced review comments. The three reports which were attached to Charles Tibbals February 26, 1996, letter to me are in my office and can be checked out from Carol Taylor. Only one copy of each was received. Please review these comments in preparation for a meeting with Hal Wilkening sometime in the next several weeks. You will be contacted concerning a time for that meeting.

BV

United States Department of the Interior

GEOLOGICAL SURVEY

WATER RESOURCES DIVISION
224 West Central Parkway, Suite 1006
Altamonte Springs, Florida 32714
(407) 865-7575

February 26, 1996

Ms. Barbara Vergara, Director
Division of Needs and Sources
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178-1429

Dear ~~Barbara~~ Barbara:

Per your request of November 28, 1995, personnel in the USGS District office in Tallahassee performed a peer review of SJRWMD Technical Report SJ94-1, "Establishment of minimum flows and levels for the Wekiva River system" and the draft technical publication titled "Surface water modeling and validation study: Wekiva River minimum flows and levels."

The following items are attached:

- February 21, 1996, Gerry Geise's review comments in letter format signed by Gerry Geise, District Surface-water Specialist.

- February 20, 1996, Helen Light's, Melanie Darst's, and Trey Grubbs' review comments in letter format signed by Helen Light, Botanist.

- February 1996, minor comments of Helen Light, Melanie Darst, and Trey Grubbs in open format.

- Copies of the 3 USGS reports referred-to in the review comments:

  Leitman, H.M., Darst, M.R., and Nordhaus, J.J., 1991, Fishes in the forested flood plain of the Ochlocknee River, Florida, during flood and drought conditions: U.S. Geological Survey WRIR 90-4202

  Light, H.M., Darst, M.R., and Grubbs, J.W., 1995, Hydrologic conditions, habitat characteristics, and occurrence of fishes in the Apalachicola River floodplain, Florida: Second annual report of progress, October 1993-September 1994: U.S. Geological Survey Open-File Report 95-167.

  Light, H.M., and Darst, M.R., U.S. Geological Survey; and MacLaughlin, M.T., and Sprecher, S.W., Florida Department of Environmental Regulation, 1993, Hydrology, vegetation, and soils of four North Florida river floodplains with an evaluation of State and Federal wetland determinations: U.S. Geological Survey WRIR 93-4033.

If you have any questions, please give me a call. Thank you.

Sincerely,

Charles

Charles H. Tibbals
Subdistrict Chief

Enclosures

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
227 N. BRONOUGH STREET, SUITE 3015
TALLAHASSEE, FLORIDA 32301

Feb. 21, 1996

Barbara A. Vergara, P.G., Director
Division of Needs and Sources
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178

Re: Peer review of Wekiva River system minimum flows and levels

Dear Ms. Vergara:

The report "Surface Water Modeling and Validation Study: Wekiva River Minimum Flows and Levels" has been forwarded to me for peer review by Charles Tibbals and John Vecchioli, Florida District Chief, Water Resources Division.

The goals, process, procedures, criteria, data, and assumptions seem generally sound, except as noted below. Other minor comments are in the text of the report.

1. p.22 says that channel downcutting is the reason for the change in the stage discharge relation at Wekiva River at SR 46, such that for a given discharge, the stage is now significantly lower than it was say, 30 years ago. It may be that channel downcutting is not the cause, or is only one of several contributing factors. It has been suggested that the application of herbicides to remove certain non-native water plants may have contributed to the decline in stage for a given discharge over the years at this station. An examination of discharge measurements over the years at this station could well reveal the exrent of any channel downcutting, but this has not been done thus far. Also, p. 33 indicates that another recent change in the stage-discharge relation may have occurred during 1993-94, as evidenced by significant variation in the stage-discharge relation. Actually, this variatiion is likely due to seasonal variation in aquatic vegetation and has been occurring continually, probably since the station was established--not just in the past several years. Within the past year, several stations have been established on the Wekiva upstream from the SR46 site which do not seem to have this problem with vegetation. However, the vegetation problem, which has both seasonal and long-term components, creates a situation where assumption 1 (p.12) may be violated. This assumption, that flows of a given recurrence interval give rise to water levels of a given recurrence interval, may be violated both seasonally and long-term. A question arises, "Which minimum levels should we be protecting now, those associated with the stage-discharge relation of 40 years ago, or that of today?" Which of the regimes is more "natural"? I can't answer

this question, but it is one which I think should be addressed.

2. It can be gleaned from the discussion in 1 above that assumption 3 on p. 13 may also be questionable. If we gage a location at which there is a stable stage-discharge relationship not affected by aquatic vegetation, one may determine, for example, that because of the nature of the control there is little difference in elevation between, say, the frequent and infrequent minimum water levels and aquatic vegetation is protected even at infrequent minimum levels. However, the stage discharge relationship elsewhere may show both a wider range of stage and more variation, and may not protect similar aquatic plants at the other locations at infrequent minimum levels. Then again, if they are not protected at the other location, they might not have gained a foothold there in the first place, and thus are not there to be protected. This is not to say that assumption 3 is not a generally useful assumption, just that it may have some limitations.

3. P. 40. Equation 1 for spring flows $Qi=Qi-1 + W(Pi-Pi(average))$ seems a little too simplistic. Consider a year when each monthly precipitation hit the long term average for that month. In that case spring discharge would be constant for the year even though, presumably, the precip would vary from month to month. Also, one would imagine that precipitation reaching the aquifer system would vary from month to month as evapotranspiration varied during the year. This is not accounted for in the equation. Could multiple regression be performed, using data on soil moisture indexes, runoff percentages, and evapotranspiration, already determined for the SSAR model, to develop a better tighter predictive relationship than is given in equation 1?

I appreciate the opportunity to review this report. Overrall, I was very impressed with the thoroughness of the model analysis and with the thoughtfulness with which the minimum flows and levels have been established. If you have any questions about my comments please call me at (904)942-9500 (ext. 3007).

Sincerely yours,

Jerry Giese

Gerald L. Giese
Surface Water Specialist
USGS-WRD Florida District

cc:John Vecchioli

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
227 N. BRONOUGH STREET, SUITE 3015
TALLAHASSEE, FLORIDA 32301

February 20, 1996

Barbara Vergara, Director
Division of Needs and Sources
St. Johns River Water Management District
P.O. Box 1429
Palatka, Florida 32178-1429

Dear Ms. Vergara:

RE: Review of "Establishment of minimum flows and levels for the Wekiva River system", Technical Publication SJ94-1.

At the request of our District Chief, John Vecchioli, I have reviewed the subject report with the help of two other staff members in this office, Melanie Darst and Trey Grubbs. We think that this report contributes greatly to the complex tasks facing the water management districts in setting minimum flows and levels for Florida streams. We found the report in general to be exceptionally well written and referenced. However, we had a number of substantive comments that we hope will be useful to you. Major comments are contained in this letter; minor comments are listed separately as an attachment.

Table 19 and text p. 66-67: "A primary benefit of determining a minimum flow regime is the ability to delimit the river condition when water conservation measures should be implemented." Conservation measures will be required between the minimum frequent low and minimum infrequent low, but some explanation is needed describing what action would be taken to protect the minimum infrequent high, minimum frequent high, and minimum average. One can make assumptions about how you might either enforce the standards or use them to guide regulatory decisions, but it needs to be explicitly stated.

Passage depths on p. 19 for large trout are based on body dimensions. This may be okay in streams with moderate to dense aquatic vegetation (like the eelgrass in the Wekiva), but in the clear tannin water of Black Water Creek, we think that just enough water for their body to pass through is not enough for some species because they would feel too exposed. Charlie Mesing of the Florida Game and Fresh Water Fish Commission has told me that in clear water, striped bass need 3 feet of depth to pass into or out of a tributary because (he suspects) they feel too vulnerable if they are too close to the surface. Charlie and the fisheries biologists that work for him have done a great deal of field work on the Chipola and Apalachicola on striped bass, including many direct observations of striped bass behavior by scuba divers. I don't have a reference for you but you could call Charlie Mesing (904 487-1645) and cite "oral communication" if he doesn't have a reference either. I'm sure that striped bass get much bigger than the fish in Black Water Creek, but possibly a conversation with him could help you apply the concept to smaller species in your stream. Based on this new information, you may want to reconsider the minimum requirements for maintaining fish passage on page 30 and the Minimum Frequent Low for Black Water Creek on page 56.

Why are the acceptable return periods in your standards in Table 17 more lenient than the actual return periods? In the discussion on pages 52 to 64, there is an attempt to explain the biological basis for this difference for some of the standards. However, these explanations are a little difficult to follow (in particular, the first paragraph on page 56; consider rewording this paragraph and in the process, check your reference to Table 14). Are there underlying reasons for this difference that are not stated: 1) are biological recovery times deemed reasonable if acceptable flows are maintained, 2) has development in the basin already altered the flow somewhat and the acceptable return period is set to account for those changes that have already occurred, and/or 3) are the acceptable return periods more lenient to allow for development to alter the flow record in the future? It would help to directly state the basis for the acceptable versus actual return periods in each case, even if quantitative data is not available and they are based on best professional judgement.

This leads to another question: are there any trends in the long-term record that could be due to human impacts? We think that trends in the hydrologic record should be very carefully considered in this process of setting standards, because you are dependent on the hydrologic record to make biological inferences about the minimum flows and levels that are needed. Figure 12 shows a possible trend of lower peak flows over time that would need to be tested with trend analysis. The 1980 photorevised Forest City USGS quadrangle map (which shows all new developments in purple) indicates the potential for development impacts in the last 20-30 years in at least part of the basin. We realize that trend analyses would be time-consuming to conduct, but we think that at least some mention of whether or not your hydrologists suspect a trend in the record because of human activities would be helpful. If you do take a cursory look at the record to look for trends, be sure to look for seasonal shifts that may not be apparent in the annual statistics.

On page 52: "The seasonal timing of fluctuations within this regime of flows and levels and stage recession rates will follow natural patterns because the river system is not regulated by control structures." This statement effectively dismisses seasonal timing as an issue that needs to be addressed in criteria for minimum flows and levels. Maintenance of natural patterns of seasonal timing is very important in maintaining natural systems and needs to be addressed. Even if you determine that seasonal timing is not an issue on the Wekiva, the first objective of this study (p. 3) was to develop a conceptual model for determining minimum flows and levels that can be applied to other surface waters in SJRWMD. However, we think the statement on page 52 may not be true, even for the Wekiva. Isn't it possible for seasonal shifts to occur in unregulated streams when a large portion of the basin becomes urbanized, greatly increasing the area covered by impervious surfaces? We do not know of any studies to back this up, but in our recent study of four north Florida rivers, we wondered whether increases in runoff due to growth and development in the upper St. Marks basin portion of the Tallahassee area could change seasonal flood patterns. We speculated that when rainfall is high, water runs off impervious surfaces instead of being absorbed by the soil and percolating to groundwater, and then in subsequent dry periods, less water is available to feed base flow of the stream from natural storage.

If you have any questions about our comments, please call me at (904) 942-9500 extension 3008. We want to reiterate that this is a excellent report that contributes clear thinking and valuable information in the complex and emerging science of determining minimum flows and levels for Florida streams. We enjoyed reviewing this document very much and hope that our comments will be useful to you in your efforts to set standards for the streams in your district.

Sincerely,

Helen Light

Helen Light
Botanist

Enclosures: List of minor comments
Three USGS publications referred to in minor comments

cc: John Vecchioli
Charles Tibbals

Wekiva Minimum Flows/Levels, 2-96 Review by Light, Darst, and Grubbs, Minor comments

Figure 1 (p. 2) is entitled Wekiva River basin but does not show the whole basin. This could be simply remedied by changing the title of the figure to something like "Streams of the Wekiva River system"; however, Lake Dorr is mentioned at least a couple of times (top of p. 7, table 2, and possibly other places) but is not located for the reader on any of the figures. Consider expanding Figure 1 to include Lake Dorr.

I prefer to avoid the word hydroperiod (pages 5, 17, 70, and possibly other places) because it has been used inconsistently in the literature. Sometimes it means duration only, as you have defined it on p. 17, but I have frequently seen it used to mean something akin to "hydrologic regime", conveying a broader definition that includes timing, frequency, and range of fluctuation as well as duration. It's not in either the regular or natural history dictionaries that I checked. Throughout most of the report you use the specific terms, timing, duration, frequency, etc., and I suggest you stick with them in all cases to avoid confusion.

In the last sentence of the first paragraph on page 9, I assume that you mean Little Wekiva River Basin instead of Wekiva River Basin.

On page 14, we got confused as to whether the term Hydrobiid snails included all the snails you mentioned on the previous page or just Aphaostracon monas. On page 13, only one snail is called a hydrobe, the remaining are silt snails, and there is no definite link between the first sentence "Snails of the family Hydrobiidae..." and the list of species. We suggest you change the third sentence to read "Several aquatic species of Hydrobiid snails...".

Pages 14 and 47. "whhere" misspelled.

On page 16 you state that "...46% of the fish species occurring in the Wekiva River Basin are species that exploit inundated floodplains." Based on our work on the Ochlockonee and Apalachicola Rivers, this percentage seems low. The percentage is 81% in the Apalachicola and approximately 74% in the Ochlockonee River. See marked passages and tables in two of the attached publications. By simply comparing your species list to the species in those two reports, you may be able to document a much higher percentage of floodplain exploitative species in the Wekiva. In addition you may be interested in the list of species in both reports that inhabit the floodplain during low water (non-flooded) conditions. (See table 4 in Ochlockonee report and the first column of Appendix III in 1995 Apalachicola report, and starred text on p. 14-15 of 1995 Apalachicola report.)

Page 19. Change "navigate safely a stream channel" to "safely navigate a stream channel".

Page 34. "The missing data for Black Water Creek were estimated by linear interpolation." A brief look at the data for this station indicated that there were relatively long periods (months) of missing record from '81 to '85. How did you interpolate the missing data and what other stations did you use? Because of the large amount of missing data, a brief explanation of your methods is needed here.

Page 46, large paragraph, upper middle on page. After the second sentence, you need to say that the rating below 23 feet was inadequate and explain why. In the next sentence, delete the first part ("Although the rating curve for Black Water Creek at SR 44 is adequate,"). It doesn't seem necessary and actually confused us as to which site you were talking about later in the paragraph.

On p. 45-46 is the statement "For simplicity in the hydrologic analyses, however, the 30-day duration is used as a standard (with few exceptions) to determine flows corresponding to the minimum levels." This same approach is also described near the top of p. 47. This was confusing to us because the durations used for your standards (Table 17) were 7, 30, 180, 90, and 7 days. We were confused again on page 48: "The phased water restriction levels and flows are intended to be compared with the average daily stage or flow of the previous 30-day period." How do you use a 30-day period to compare with a 90- or 180-day standard?

On page 47 one can infer that SSARR is used for Wekiva but not Black Water Creek and there were no SSARR tables generated for Black Water Creek (similar to Tables 9 and 10 for Wekiva River). Therefore we were confused by the statement on page 42: "Long-term springflow hydrographs from the rainfall differential model were input into the SSARR model to calculate base flows for the Wekiva River and Black Water Creek." This was additionally confusing because Black Water Creek at the gaging station has no significant springflow contributing to it. Did you mean the lower Black Water Creek in that statement? If so, to avoid confusion you might point out that distinction, and explain how you used or will use the lower Black Water Creek data. Going back to the statement on p. 47, "The SSARR model results for flow were used instead of the observed flow data because SSARR data were used to calculate the minimum spring flows." A little more explanation might be needed here. After reading this we were still not sure why you felt compelled to use SSARR data instead of records computed from gage data, which are presumably more accurate.

Page 51, Table 16. The percentage of period of record flooded is very high compared to our work on four rivers in north Florida. Duration percentages ranged from 1 to 33 for floodplain communities that were not dominated by tupelo. See Appendix IIA on page 48 of enclosed report entitled "Hydrology, vegetation, and soils of four north Florida river flood plains with an evaluation of state and federal wetland determinations". The only communities inundated more than 33% were strongly dominated by tupelo in one case (Telogia Creek slough), and by tupelo and cypress in the other case (Ochlockonee River depression). Our study included plots on the St. Marks River, a spring-fed stream with a high base flow, and Telogia Creek, a blackwater stream with a low wet floodplain. I don't know enough about central Florida streams to understand why there is such a big difference in floodplain durations with many of the same species present. It is very possible that geographical location has an important effect on tree-hydrology relations for a variety of reasons that cannot always be identified. On the other hand, we may be collecting the data differently and consequently getting different results. You mention a slightly higher, discontinuous, natural streambank on Black Water Creek that has a somewhat different tree composition (p. 52). According to your methods on p 29, plots started near the stream bank and extended 20 meters into the floodplain perpendicular to the stream, implying that if there was a narrow levee, it was mixed with the low floodplain behind it on the same plot. Did you check the elevation difference between the levee and the low floodplain behind it to see how much difference in percent duration there was between the two communities? Another possibility: were the species that typically inhabit slightly drier land in the floodplain (Carpinus caroliniana, Liquidambar styraciflua, Quercus laurifolia, Ulmus americana) growing on hummocks (small raised mounds of earth)? Hummocks were common at our St. Marks site; this site had the least amount of water level fluctuation of all four sites.

Page 52 and Tables 3-6. The period of record on Black Water Creek (12 years) is too short to predict 100-year events. However, it seems justified in this particular case because streamflow dropped to 0.1 cfs during the period of record (fig. 9) and it seems likely that zero flow would occur at least every 100 years, probably much more frequently. It might be helpful to state that normally 100-year events cannot be predicted with 12 years of data but that it was appropriate in this case because the stream has been very close to zero flow during the 12 years of record.

Page 56, first sentence at top of page. I could not get the same answer (24.3) when I interpolated from Table 4. Wouldn't that number have to be something slightly less than 24.17?

Page 60-61, Figure 12. Aren't the 5-, 10-, and 25-year return interval flows shown in Figure 12 (and discussed at the top of page 60) based on instantaneous peak flows? If so, it seems misleading to compare them in the same graph with the Minimum Infrequent High Flow which is a 7-day duration. At the very least, you need some qualifiers in the figure caption and in the text before this comparison can be made. A Minimum Infrequent High Flow of 880 cfs for seven consecutive days includes instantaneous peak flows that are much higher than 880 cfs. In the process of revising this comparison, however, please don't abandon the conclusion at the end of the paragraph on page 60. We think the point made about flood events of greater magnitude that may be required occasionally is a good one. Very high floods are important in shaping many characteristics of a river and floodplain system.

Page 70. The large paragraph in the middle of the page referencing Hill et. al. should be moved or copied to page 22. It refers to conceptual information that formed the basis of the minimum flows and levels criteria development and is out of place being first mentioned in the summary.

MEMORANDUM F.O.R. 94-1514

DATE: May 20, 1996

TO: Hal Wilkening, Assistant Director
Resource Management Department

THROUGH: Edgar F. Lowe, Ph.D., Director
Environmental Sciences Division

G.B. (Sonny) Hall, Ph.D., Technical Program Manager
Environmental Sciences Division GBH

FROM: Clifford P. Neubauer, Ph.D., Supervising Environmental Specialist CPN
Environmental Sciences Division

RE: Peer Review comments from National Biological Service, River Systems Management Section (instream flows group), Midcontinental Ecological Science Center, Fort Collins Colorado.

The purpose of this memorandum is to forward "peer" review comments of Dr. Claire B. Stalnaker and Mr. Ken Bovee, both of the National Biological Service, on SJRWMD Technical Report (SJ94-1) titled, "Establishment of Minimum Flows and Levels for the Wekiva River System, Florida" to listed staff.

Attached is a copy of the above referenced reviewers' comments. Additional "penciled-in" comments were made in a copy of the report. This reviewer's copy of the report is available in my office until June 1, 1996; the copy with original letter containing comments will be forwarded to Central Files.

CPN:bs

c: Wayne Flowers
Charles A. Padera
Barbara Vergara
Chris Sweazy
Larry Battoe
Price Robison
David Clapp
Sandy McGee
MFL-REG Tech

United States Department of the Interior

NATIONAL BIOLOGICAL SERVICE

Midcontinent Ecological Science Center
4512 McMurry Avenue
Fort Collins, Colorado 80525-3400

In Reply Refer To:
NBS/MESC/82020

May 8, 1996

File: 302.01

Dr. Clifford P. Neubauer
Supervising Environmental Specialist
St. John's River Water Management District
P.O. Box 1429
Palatka, FL 32178-1429

Dear Dr. Neubauer:

We have reviewed your Technical Report SJ94-1, "Establishment of Minimum Flows and Levels for the Wekiva River System, Florida."

Overall the needs and objectives for establishing minimum flows and levels are clear, attainable and justified via Florida statutes. The real strength of this approach is the consideration of the temporal aspects of the water supply as reflected in the magnitude, frequency and duration of streamflow.

Your specific questions are addressed below and some specificl comments are penciled throughout the document and in the attached memo from Ken Bovee of my staff.

1) Is more than one minimum flow or level appropriate to protect an ecosytem?

    Yes, we have long advocated setting instream flow standards for wet, dry and average water supply conditions as a way of "sharing the supply and losses" among multiple uses of water and to maintain the temporal patterns of biological responses (some species flourish in flood years and some other species do well during droughts and many do best during average years).

    If so, are the five levels we set sufficient?

    From looking at the flow duration curves it appears that the inflection points are at approximately the 10% and 90% exceedence levels. Certainly three levels are necessary. Going to 5 levels may be extremely useful from a policy consideration because you can provide more certainty to the consumptive water users by defining the extremes (infrequent high and infrequent low) in water supplies and having different levels of protection for enforcement. As a policy for protection of the existing biological resources the 5 levels based upon historical flow duration seems reasonable. If you cannot distinguish a significant difference in plant or animal response to the infrequent high flows from the frequent high flows, then shifting to the frequent high rules may be all that is justified. Likewise for the difference in protection to instream biota between the infrequent low and the frequent low flows. You should define your 5 flow levels in terms of exceedence and reconstruct the flow duration plots as they would appear if all flow was removed down to the minimum flow level(s). The difference between these sets of duration plots identifies the water available for future consumptive use.

2) Is using biological criteria and setting standards a conventional and appropriate means for protecting an ecosystem from unacceptable harm?

Yes, this approach is used routinely. Also the flow necessary for canoeing and other recreational use may form the basis for criteria for setting instream flow standards. This is not addressed in your analysis but recreation is recognized by statute as an instream value on page 1.

3) Please comment on the use of threshold transects when determining minimum flows and levels for river systems.

Transects used to collect data to apply a set of <u>preselected</u> <u>criteria</u> are very useful and often applied techniques. The wetted perimeter vs. flow plot for riffle transects is used by Montaná to set minimum standards. They use the breakpoint in the plot at the criterion to selecting the flow. Your approach to maintain wetted areas to protect weland plants, seems reasonable if your stated objective is to protect the existing resource. Your discussion of fish passage criteria does not appear to be used in setting the 5 level flows. Rather the computed water depth over 25% of the channel is simply reported. If a minimum passage depth of 0.6 ft over 35% of the channel was your biological criteria for passage you would see it become overriding in selecting the minimum infrequent low flow in Black Water Creek in Table 17. This would result in the same flow standard for the two low flow standards. As presented now the water depth in Table 17 goes to 0.0, meaning that passage is not an important biological criteria during extreme droughts.

Your Methods section does not present the biological criteria you choose to use for setting the 5 levels. Rather the methods describe the hydrological analyses for describing frequency and duration of flow using the historical records. Your criteria need to be clearly described for each level of flow and include the logic for choosing each criterion. Some of the biological logic (criteria) are buried in our results section. Some of these appear to be average elevation of the upland/wetland ecotone, 15 inches as minimum wet-season flood depth for mixed swamp habitat along with a duration of 30 days; the 60% exceedance elevation to maintain average hydric soil conditions; 0.6 ft depth over 255% of the wetted stream width for fish passage; and the flow level associated with a duration of ≤ 7 days and recurrence interval of > 100 years. These appear to be the rules (criteria) chosen for the infrequent high, frequent high, average, frequent low and infrequent low flow levels. If so, these need to be pulled out into a separate discussion of the criteria chosen and the biological protection they are assumed to provide. The results section then should present the calculated flows and the resulting frequency expected to occur and the proposed policy for curtailing water use and issuing new permits, etc.

4) Is the inclusion of a duration and return interval (frequency) with a flow or level, more appropriate than setting levels or flows with no temporal statistics?

By all means this is the best way of presenting the standards. The water user should be able to determine how often their use may be curtailed under these flow protection standards.

5) Is our consideration of out-of-bank flows to protect associated wetland function appropriate?

Yes, this seems to be the best developed set of biological reasoning provided. You should make explicit that the objective is to protect the existing wetland vegetation.

6) Is the inclusion of Phased Water Shortage Restrictions within the defined hydrologic regime a reasonable way to conserve water during period of low rainfall or drought?

Yes, this is very useful. It shows that the historical pattern is to be preserved. You could compare the historical record with the restrictions assumed to be in place and calculate the frequency of curtailment and the amount of flow available above the proposed minimum levels.

7) Is in-stream, aquatic habitat sufficiently protected by the method we used?

Without site specific analyses this question cannot be precisely answered. If the aquatic species present over the period of time used in the flow frequency analyses are the desired species to maintain for the future then your approach looks very reasonable. The conventional thinking among biologists is that preserving the shape of the historical hydrograph will protect the aquatic organisms. The only hydrologic rule of thumb that has any biological monitoring to support it is the "good" to "optimum" range from the Tennant method. For stream fishes several studies have reported healthy fish populations when Tennant's rule of 40%-60% of the mean annual flow is present (as a minimum). The unanswered question is what level of aquatic species/community would be present if less water were set as the minimum. On the other extreme the water quality based rule of $7Q_{10}$ has been shown to be detrimental to stream fishes if selected as an instream flow standard and allowed to be reached as the minimum with increased frequency. The $7Q_{10}$ could be the basis for your infrequent low flow for instance but not for the other levels.

8) Are there any outstanding deficiencies that our staff may have overlooked in our application?

Just clarification by separating the criteria from the results and by presenting an analysis of the effect of imposing the proposed standards to the existing historical record.

The report appears complicated but the logic is quite simple. From a policy view you need to suggest what you would do if a proposed water use comes along in the future that would obviously violate the 5 level standards. Under what conditions would you deny outright the request versus requiring some more detailed site specific analyses, etc.

You are to be commended on setting forth a mechanism to allocate water use while protecting both the instream and riparian habitats.

Sincerely,

Clair B Stalnaker

Clair B Stalnaker, Leader
River Systems Management Section

Attachments

April 1, 1996

To: Section Leader, RSMS
From: Ken Bovee, Hydrologist KB
Subject: Wekiva River System Instream Flow Study

As requested, I have reviewed the Wekiva River System Instream Flow Study conducted by the St. Johns River Water Management District. My comments follow:

- I liked the way the authors defined new terms and acronyms the first time they were introduced. However, I also felt that sometimes the definitions got in the way of the message that the authors were trying to convey. For example, they would start off describing how they used duration statistics to define an instream flow requirement, and in mid-paragraph, diverge to define what a flow duration curve is all about. I have mixed emotions about this, because it is important for a lay audience to be able to understand the fundamental concepts, but I felt that the format tended to clutter up the message...often to the point that I could not follow their methods. A glossary would be useful, but in keeping with having concepts and terms defined near where they are first used, I suggest they use text boxes for definitions. This would make the definition convenient and accessible to the reader who needed them, but would not interfere with the flow of information for those that don't.

- A similar concept should apply to acronyms, which in government publications seem to take up most of the content of the manuscript. The authors are correct to use the full name of an organization or concept the first time it is used, followed by the acronym in parentheses (except for NGVD, for which I had to look all over the paper to find the definition). They would do their readers a big favor, however, by providing a list of acronyms at the beginning or end of the manuscript...perhaps associated with the glossary.

- I really liked the way they defined and justified their multiple instream flow requirements, especially those for their minimum high flows. This is right on the mark. Unfortunately, I had a difficult time understanding the methods used to make the recommendations. I read the methods section twice, and I'm still not sure I know what they did. The high flow recommendations seem to be the most straightforward...at least if I understand them correctly. For example, they say that a minimum infrequent high flow is designed to inundate riparian wetlands for a specific time period. Apparently, they used a hydraulic model to predict the flow necessary to inundate the floodplain and then looked up how often that flow had occurred historically. If that is in fact the method they used, they should say so just that simply. This business about finding the flow level, looking up the stage duration, and then correlating that to a flow seems to have at least one unnecessary and obfuscatory step in it.

- The relations between the methods and the recommendations became even more confusing to me when discussing the minimum average, the minimum frequent low, and minimum infrequent low flows. I think the reasons for these flows are adequately described on page

23 of the report. However, the threshold transect method described on pages 25-30 does not seem to have much relevance to the criteria for defining the various stages of minimum flows. For example, the rationale for the minimum average flow is to maintain riparian hydric soils and to impede encroachment of upland plants into the wetland community, but the method used assesses fish passage through the reach. I noted several disconnections of this sort, and they all caused me to re-read extensive portions of the report to see if I'd missed something. It turns out that I did miss something, but it was because the material wasn't in the report.

- I'd be real careful about relying on Annear and Conder (1984) to justify the threshold transect approach. Please note that I do not object to the approach, but to the citation. The Annear and Conder (1984) paper is a good example of lousy research making it into a respected publication. I suggest they stick with the Thompson (1972) and Stalnaker and Arnette (1976) citations. More importantly, however, they need to make sure that their methods are consistent with their criteria. If the reason for a minimum flow is for canoe passage, don't use migration criteria for Pacific salmon. Indeed, I'm not sure anyone has ever established the necessity for short-term passage in warm water fish communities.

I guess my biggest concern is the apparent complexity of the methods used by the authors. I say apparent complexity, because I'll bet what they really did wasn't nearly as complicated as the way it was written up. I do not want to sound overly-critical, because I know from experience how hard it is to explain things like this. There's a tendency in us science types, however, to spend words roughly in proportion to the difficulty of a particular step in an analysis rather than in proportion to its importance. For example, the process of translating stage-discharge-habitat characteristics from a study site to a gaging station was probably quite ingenious. But is it important for the reader to slog through it? I found myself asking why they bothered to do it in the first place. It would make more sense to me to develop a synthetic duration curve for the site if it wasn't the same as for the gaging station. My point here is that the authors should be ruthless in their discussion of criteria, methods, and results. Anything that does not obviously connect should be: (a) obviously connected, (b) removed from the text and explained in an appendix, or (c) eliminated completely.

This pretty much concludes my review. If you have any questions, please feel free to call on me.