

Draft Work plan for Science Component of the Springs Protection Initiative: Springs Protection Initiative Science (SPIS)

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## I. INTRODUCTION/BACKGROUND

The Floridan aquifer is one of Florida's most significant natural resources. One of the best indicators of the status of the aquifer is the quantity and quality of water flowing from Florida's numerous springs (Copeland et al., 2009). The springs not only reflect the status of the aquifer but also influence the ecological health of many of Florida's most significant surface water ecosystems. Thus, protection of springs will serve to protect both groundwater and surface water resources.

There have been substantial changes in the ecological character of many of Florida's most significant springs. These changes include reduced flow rates, increased levels of nitrate, increased biomass and cover of algae and invasive aquatic plants, decreased abundance of native submerged aquatic vegetation, and changes in fish and invertebrate communities (Scott et al., 2004; Munch et al., 2006). These changes threaten the ecologic and economic values of the springs and of the surface water ecosystems to which they flow.

Recognizing the economic and ecological significance of springs, the St. Johns River Water Management District has developed a Springs Protection Initiative. The initiative has three major components: projects, regulation, and science. The science component of the initiative acknowledges that effective management of springs requires that we understand the relative influences and manageabilities of the numerous natural and anthropogenic forcings that affect their ecological health and that additional interdisciplinary research is needed to achieve this goal (FDEP, 2007).

**Current Understanding** - A substantial amount of work aimed at understanding the changes in springs has already been done. This work indicates that a large fraction of the decline in flow rates at some major springs is largely attributable to low rainfall. For example, Knowles (1996) estimated the water budget for the combined spring sheds of Rainbow and Silver Springs (Figure 1). This work indicates that only a small part of the recharge (averaging < 1 inch of 13 inches during 1965-1994; < 8 %) has been exported through groundwater pumping. More recent work indicates that the influence of groundwater pumping may constitute as low as 4.0% of the decline in spring flow in the Silver Springs system, with the remaining 96% due to changes in climactic conditions (Boniol, et.al., 2013). For this spring system, it appears that reduced groundwater use would not restore historic average flow rates because variation in annual spring flow was largely explained by variation in rainfall (Figure 2). However, it is still undetermined whether the

marginal effects of groundwater use could lower spring flows below important ecological thresholds (Heffernan et al., 2010). This is an area where additional investigation is warranted.

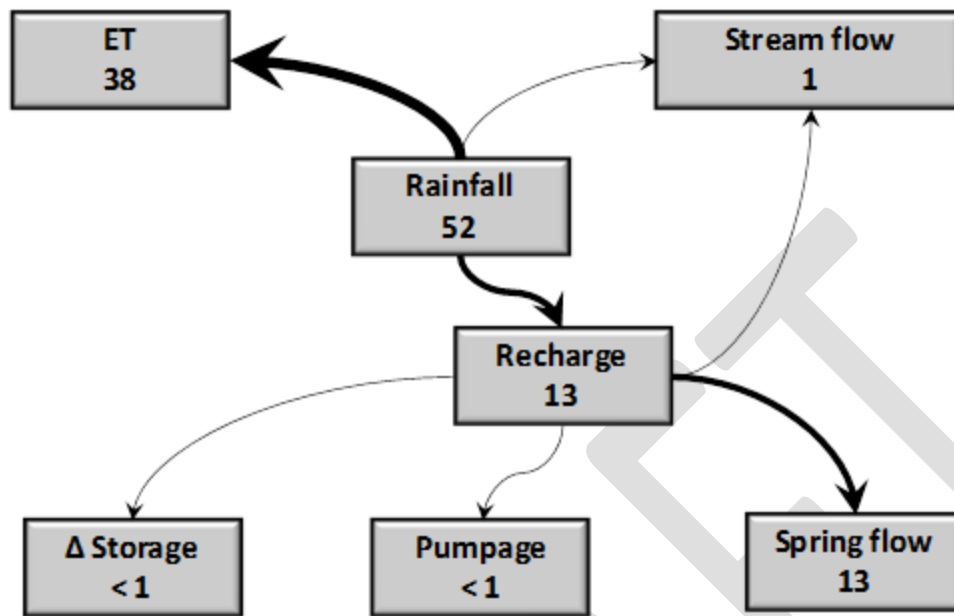


Figure 1. Estimated water budget for the Rainbow Springs and Silver Springs basin area in inches per year for 1965-1994 (Knowles, 1996).

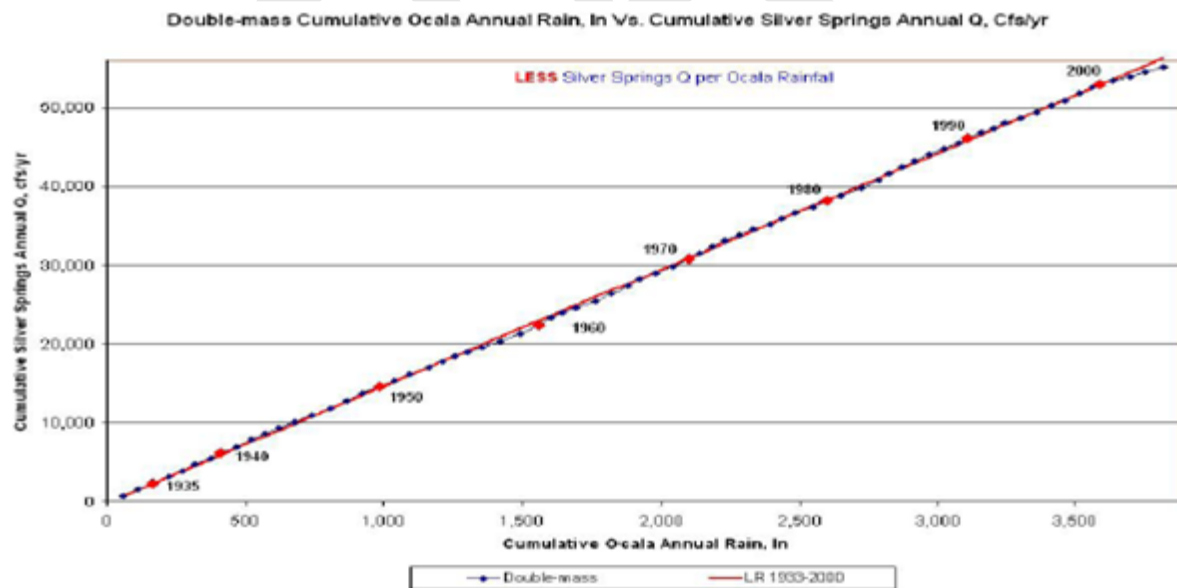


Figure 2. Cumulative discharge from Silver Springs (cfs) versus Cumulative Annual Rainfall at Ocala (inches) (from Munch et al., 2004).

Although discharge rates appear to be driven primarily by climate, which cannot be controlled, it appears that the increase in springs nitrate concentrations has been driven largely by changes in land use/land cover (LULC) within the spring sheds. Munch et al. (2004) showed that forested LULC in the 2-year capture zone of the Silver Springs spring shed decreased by approximately 13,400 acres (about 40 % of the total area) between 1949 and 2005; it was replaced by more intensive land uses (Table 1). Over the same period, estimated total N loading increased from 0.339 million lbs/y to 1.121 million lbs/y. Using data from Munch et al. (2004) in a regression analysis indicates that the nitrate concentration [NO<sub>x</sub>] in Silver Springs was strongly correlated with estimated spring shed nitrogen loading (Figure 3).

Table 1. Land use/land cover in the two-year capture zone of Silver Springs (data from Munch et al., 2004).

Land Use/ Land Cover	1949 Acres	2005 Acres	Change in Acres
Urban	144	7081	+6937
Agriculture/Pasture	6060	8235	+2175
Forested/Vegetated	24178	10755	-13423
N/A	3300	7610	+4310
Total	33682	33681	

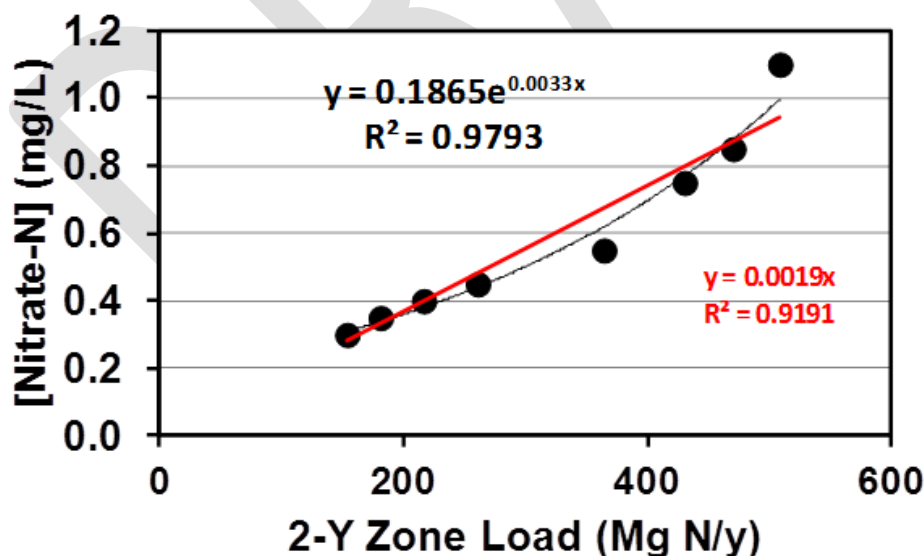
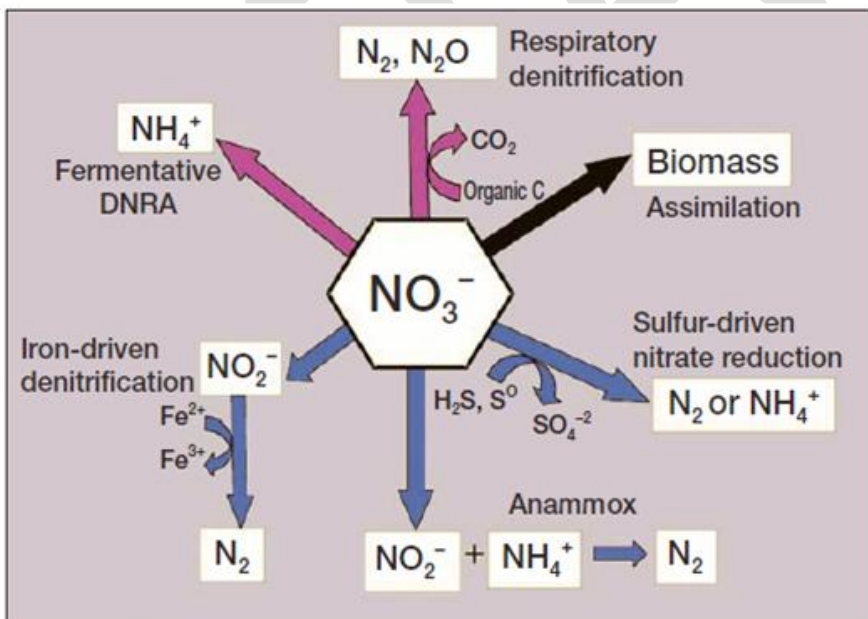


Figure 3. Relationship between [NO<sub>x</sub>] in Silver Springs discharge and estimated nitrogen loading in the two-year capture zone of the spring shed. Analysis uses data from Munch et al., 2007 and Hicks and Holland, 2012.

It appears then that in the Silver Springs system [NO<sub>x</sub>] is largely controlled by anthropogenic forcings. In order to cost-effectively manage these forcings, it is important to have a good understanding of the spatial variation over the springshed in N loading rates to the spring.

The biogeochemistry of nitrogen is complex and there is uncertainty regarding the transformations and transport of nitrogen as it passes through the groundwater system to the spring. Nitrate can be transformed through many different biogeochemical pathways (Burgin and Hamilton, 2007; Cohen et al., 2007; Figure 4). Transformation and sequestration or loss will influence the ratio of surface N source rates to spring system loading rates by influencing nitrogen transport rates. The form of a nitrogen source, the hydrogeological transit time to the spring, and biogeochemical processing of the N source prior to reaching the aquifer are important factors in determining how important an area may be in contributing to the N load of a spring (Brown et al., 2008). A substantial fraction of the nitrogen load to the upper Florida aquifer may be lost through denitrification (Heffernan et al., 2012). Thus, it cannot be assumed that N sources are simply passed through to the springs. It is necessary to improve our understanding of the fate and transport of nitrogen in soils and groundwater as a foundation for development of cost-effective allocations in the TMDL/BMAP process.



From Burgin & Hamilton 2007

Figure 4. Pathways for nitrate transformation, sequestration, and loss in aquatic ecosystems (from Burgin and Hamilton 2007).

In addition to the uncertainty associated with nitrogen transformation, sequestration, and loss rates, there is uncertainty regarding the significance of nitrate concentration as a driver of benthic algal abundance. Experiments in microcosms indicate that filamentous algal growth and biomass increase with the concentration of nitrate. Field experiments have supported the laboratory findings. Field observations, however, indicate a poor correlation between benthic algal abundance and [NO<sub>x</sub>]. Taken together, the experimental and observational data indicate that benthic algal abundance is influenced by multiple drivers.

There are several hypothetical drivers of increased algal abundance/reduced SAV (Figure 5): seven are physicochemical; being water transparency (Stevenson et al., 2007), [DO] (Heffernan et al., 2010), nitrate enrichment (Mattson et al., 2006), enrichment with other elemental nutrients, such as phosphorus and iron (Stevenson et al. 2007), current velocity (King, unpublished), nitrate induced stress to submersed aquatic vegetation (SAV), and physical disturbance caused by recreational use (Pandion, 2003) while one is biological (reduced grazer abundance; Heffernan et al., 2010). In order to develop effective management approaches to reduce the abundance of benthic algae, additional research is needed to elucidate the relative influences of these multiple drivers of algal production and abundance.

***Conceptual Model of Potential Primary Drivers of Biological Structure and Function***

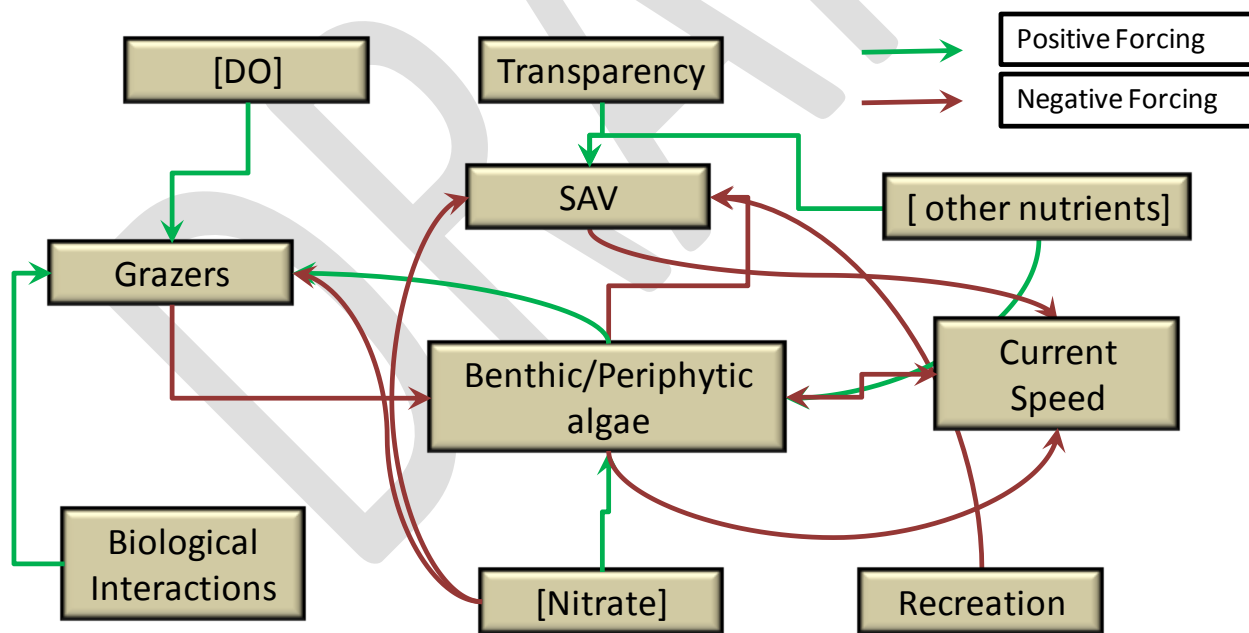


Figure 5. Potential drivers of the relative abundance of benthic filamentous algae and submersed aquatic vegetation. Changes in the status of a driver constitutes a forcing that can alter the balance. Positive forcing increase the level of the affected ecological attribute while negative forcings decrease its level.

## II. STUDY PURPOSE AND OBJECTIVES

The SPIS aims to provide a sound scientific foundation for development of cost-effective approaches for management of forcings (variations in environmental drivers) influencing the hydrology, hydrodynamics, physicochemistry, and biology of spring ecosystems.

There are three primary objectives.

### **1. Improve the scientific foundation for management of nitrate loading to springs using the Silver Spring System as the primary study site.**

This objective requires good delineation of the spatial variation in the springshed of three primary characteristics: 1) hydrologic conveyance rate to the spring system; 2) sources of nitrogen (rates and forms); and 3) nitrogen loss rates (primarily through respiratory denitrification) in soils and shallow aquifers.

### **2. Evaluate whether nitrate reduction alone will be sufficient to restore the balance between benthic filamentous algae and native aquatic plants.**

This objective requires development of a predictive model(s) relating benthic algal abundance and, perhaps, other aspects of ecological structure and function to nitrate concentration.

### **3. Assess the relative influence and manageability of each of the various drivers controlling the balance between benthic filamentous algae and native aquatic plants.**

The objective is to be able to rank the relative influence of the primary physicochemical and biological drivers of benthic algal abundance.

**General Approach** - The study purpose will be met through an in-depth investigation of the Silver Spring System as the primary object of study. The Wekiva System will be a secondary system for in-depth analysis. In addition, cross-system analyses for all springs with sufficient data will be used to explore the interrelationships among environmental drivers and ecosystem attributes. The unifying focus of the work is the influence and controllability of forcings affecting the primary producer community structure (PPCS) of spring systems, especially the relative abundance of benthic filamentous algae, native aquatic plants, and invasive exotic aquatic plants.

The study will be highly interdisciplinary in order to address the various environmental drivers influencing spring hydrology, hydrodynamics, water quality, and biological structure and function. Surface water hydrology, groundwater hydrology, land use, consumptive use, nutrient transformation and transport in the groundwater system, and biological interactions all influence the physical, chemical, and biological status of a spring.

In order to address the complexity of forcings, the investigation staff will be organized as six work groups. The six workgroups constitute two supergroups that will work cooperatively to address the study objectives for the springshed and for the springs ecosystem.

#### Springshed Supergroup

- 1) Surface water hydrology** (rainfall, evapotranspiration, recharge, runoff quantity and quality);
- 2) Groundwater hydrology** (aquifer storage, transmissivity, conduit flow, spring discharge);
- 3) Nitrogen Biogeochemistry** – N sources (rates and forms), N transformation, uptake, and loss;

#### Springs Ecosystem Supergroup

- 4) Spring System Hydrodynamics/Hydraulics** – Hydrodynamic and hydraulic attributes and drivers of the spring system. In cooperation with the Physicochemistry Work Group, interrelationships between H&H drivers and physicochemical attributes.
- 5) Spring System Physicochemistry** – Interrelationships between H&H drivers and physicochemical attributes. Effects of physicochemical drivers on PPCS with emphasis on benthic algal abundance.
- 6) Spring System Biology** – Biological factors influencing PPCS with emphasis on benthic algal abundance.

### **III. SCOPE OF WORK**

The Springshed Supergroup, working cooperatively, will produce water and nutrient budgets and nutrient loadings (Figure 6). The Springs Ecosystem Supergroup will elucidate the relative influences of the ecological drivers of PPCS. From the loadings of water and nutrients, the Hydrodynamics/Hydraulics and Physicochemistry workgroups would model the physicochemical status of the spring system. From both physicochemical and biological forcings, the Springs Ecosystem Supergroup will assess the relative influence of the various drivers on PPCS.

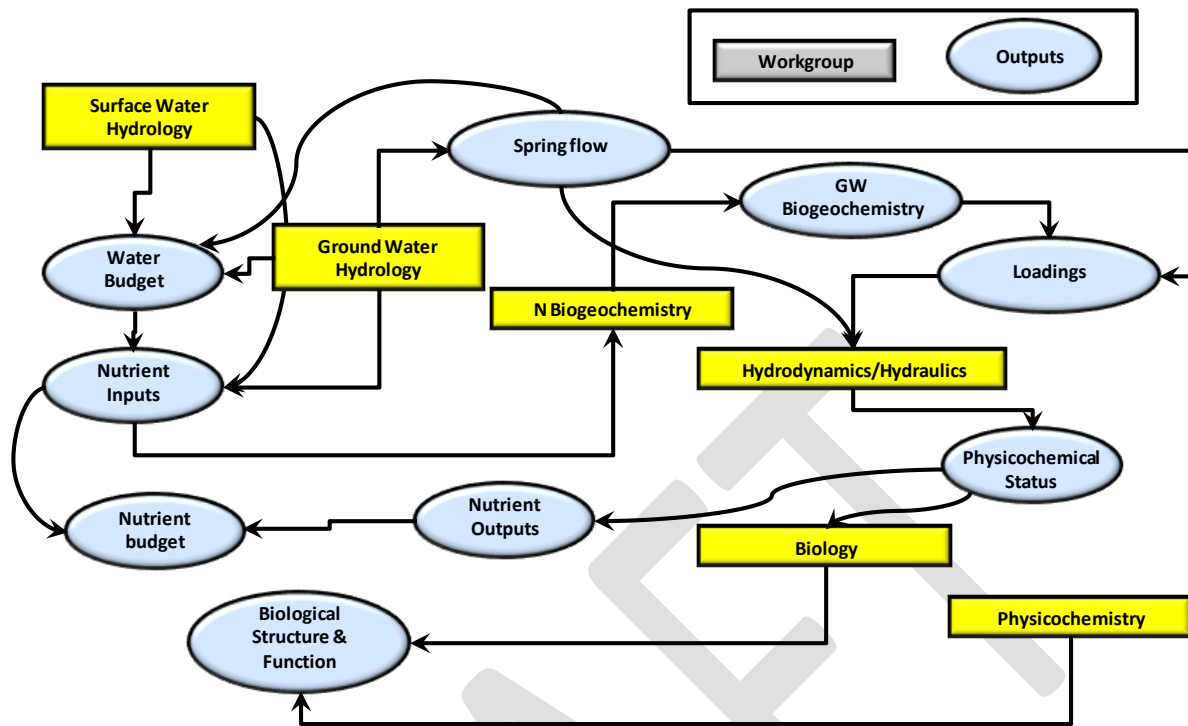


Figure 6. A general schema for the interdisciplinary study. Yellow boxes represent individual workgroups and blue ovals represent outputs.

Watershed and groundwater quantity and quality models would delineate the spatial variation in the hydrologic and nutrient loading forcings to the springs ( $Q/m^2$  and  $kg/Q$ ). These forcings affect spring discharge, water quality, and hydrodynamics. Modeling of these forcings will consider the spatial variation in evapotranspiration, recharge, consumptive uses, runoff, and nitrogen source forms and rates (Figure 7). These forcings will be related to rainfall, geology, soils, temperature, season, and LULC.



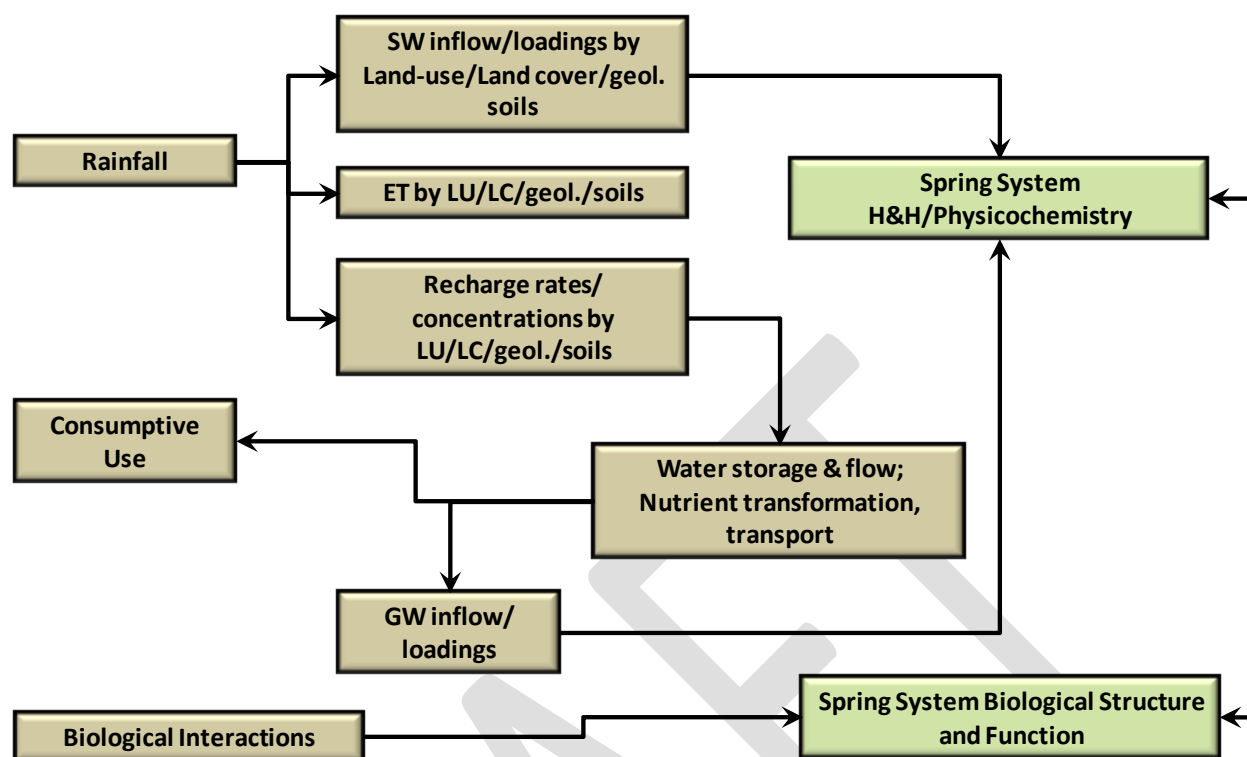


Figure 7. General conceptual model of the major forcings influencing the physical, chemical, and biological status of a spring.

Watershed and groundwater models also would simulate forcings for drivers of nutrient loading: fertilization, stormwater treatment, septic systems, point sources, and atmospheric deposition. Each forcing would need to be a function of rainfall, temperature, season, and LULC. Importantly, the groundwater model would need to incorporate improved understanding of conduit flows and of nitrogen transformation and transport through the groundwater system.

A hydrodynamic model of the spring, coupled with biogeochemical models, would use forcings from the groundwater and watershed models to simulate effects on various attributes of the physicochemistry of the spring: flow rate ( $\text{m}^3/\text{s}$ ), flow velocities ( $\text{m}/\text{s}$ ), depths ( $\text{m}$ ), nutrient concentrations ( $\text{g}/\text{m}^3$ ), and dissolved oxygen concentrations ( $\text{g}/\text{m}^3$ ).

Finally, a suite of ecological models would relate physicochemical and biological forcings to effects on PPCS with emphasis on the abundance of benthic filamentous algae.

**SPIS Organization and Personnel** – As described above, personnel will be organized into six workgroups: surface water hydrology, ground water hydrology, N biogeochemistry, spring system hydrodynamics/hydraulics, spring system physicochemistry, and spring system biology (Figure 7).

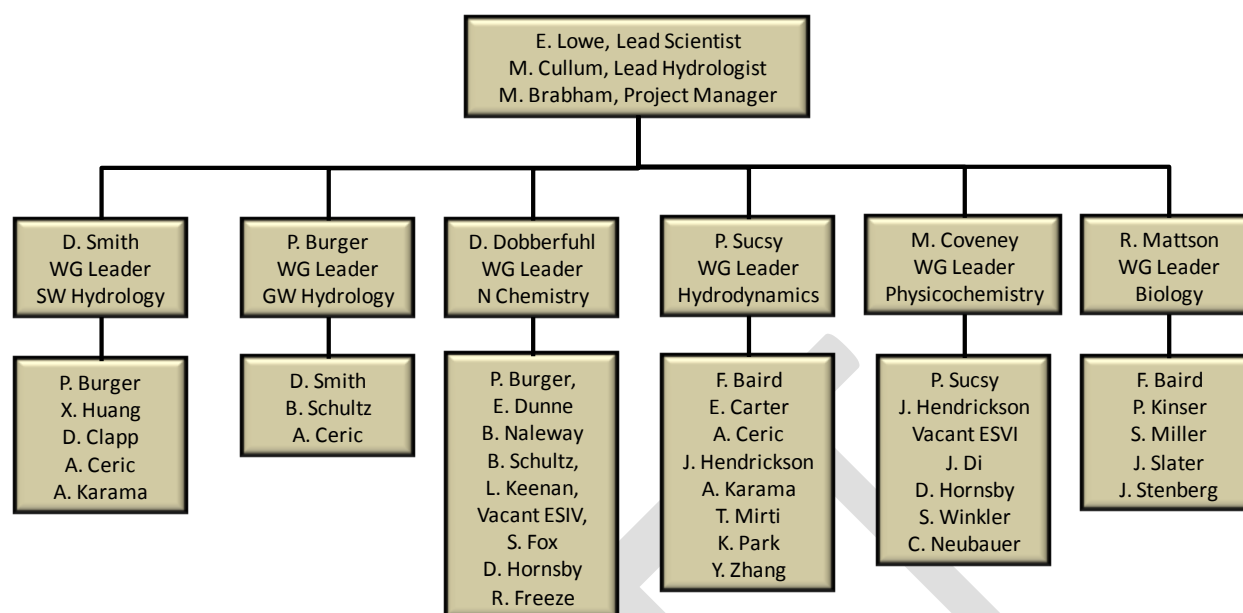


Figure 7. SPIS project structure and staff.

#### IV. BUDGET/ SCHEDULE

Overall Schedule - As shown below (Table 2), the first task for the workgroups was development this detailed work plan with schedules and budgets. This work was completed during the second quarter of 2013. Procurement of contractual support will be initiated during the third quarter of FY2013 and completed by the end of the first quarter of 2014. A two-year period for collection of additional data is anticipated, ending in the second quarter of 2015. Analysis of data and model development will overlap with the data collection but extend approximately three quarters beyond termination of new data collection. All subsequent technical analysis and writing will conclude in the first quarter of 2016. There will be a number of interim deliverables, as defined in individual workgroup plans (e.g. a HECRAS model).

Peer Review – Peer review will be an important component of the SPIS. As with the Water Supply Impact Study previously performed by the SJRWMD (Lowe et al., 2011), peer review should begin early in the work schedule so that the scope and methodology of the study can benefit from the recommendations of the review panel.

Table 2. General proposed schedule for the science component of the Springs Protection Initiative.

Task	13-1	13-2	13-3	13-4	14-1	14-2	14-3	14-4	15-1	15-2	15-3	15-4	16-1	16-2
Workplan														
Contracting														
Peer Review														
Data Collection														
Analysis/ Model develop.														
Interpretation/ Documentation														
Workshops/G.B. Presentations														

Overall Budget – The estimated cost of the investigation is approximately \$3 M, with the highest expenditures in the second year (Table 3).

Table 3. Estimated budget.

Work group	FY12-13	FY13-14	FY14-15	FY 15-16	Totals
Surface Water Hydrology	0	0	0	0	0
Groundwater Hydrology	200	400	200	50	850
Nitrogen Biogeochemistry	0	196	196	0	392
Hydrodynamics and Hydraulics	77	160	160	65	462
Physicochemistry	0	376	76	38	490
Biology	0	312	300	150	763
Peer Review Panel	0	20	20	15	55
<b>Totals</b>	<b>277</b>	<b>1,444</b>	<b>932</b>	<b>303</b>	<b>2,956</b>

The estimated staff allocation for the study varies from a maximum of 13.5 FTE in FY13-14 to a minimum of 5.5 FTE for FY15-16 (Figure 8).

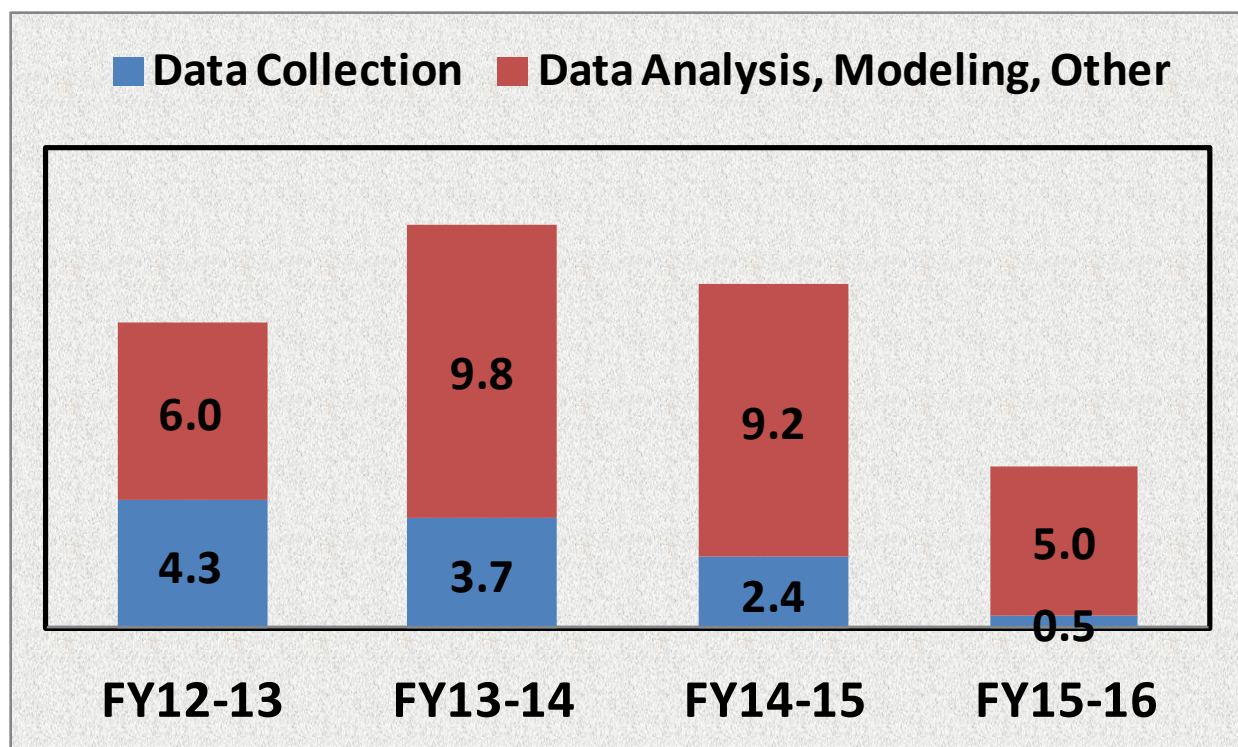


Figure 8. Estimated staff allocations for the science component of the Springs Protection Initiative.

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