Draft Work plan for Springs Initiative Investigation (SII)
February 19, 2013
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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.

Effective management of a spring requires that we understand the relative influences and manageabilities of the numerous natural and anthropogenic forcings that affect its ecological status. At present, 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. 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 growundwater use could lower spring flows below important ecological thresholds (Heffernan et al., 2010). This is an area where additional investigation is warranted.

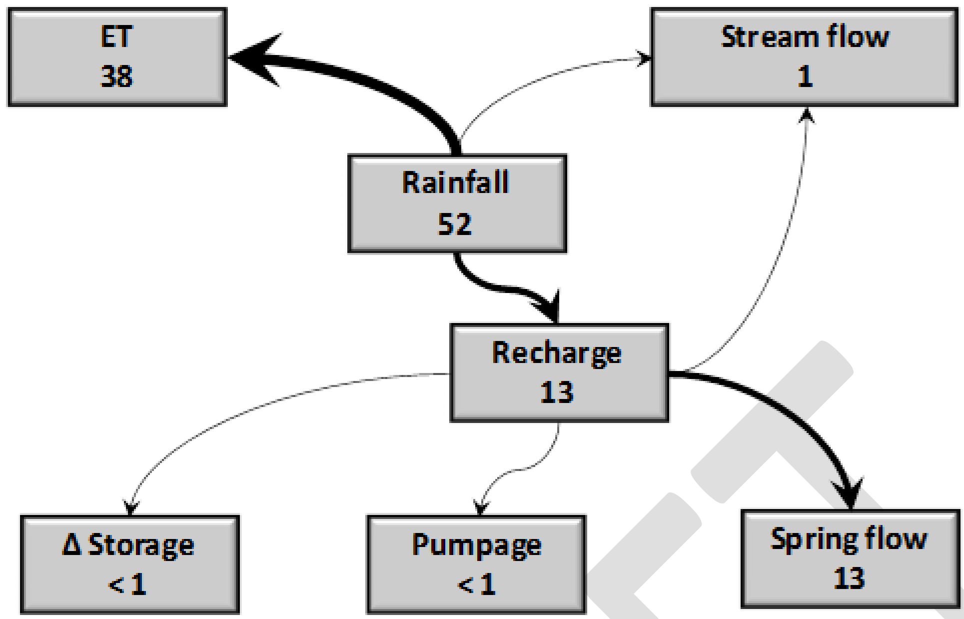


Figure 1. Estimated water budget for the Rainbow Springs and Silver Springs basin area in inches per year for 1965-1994 (Knowles, 1996).

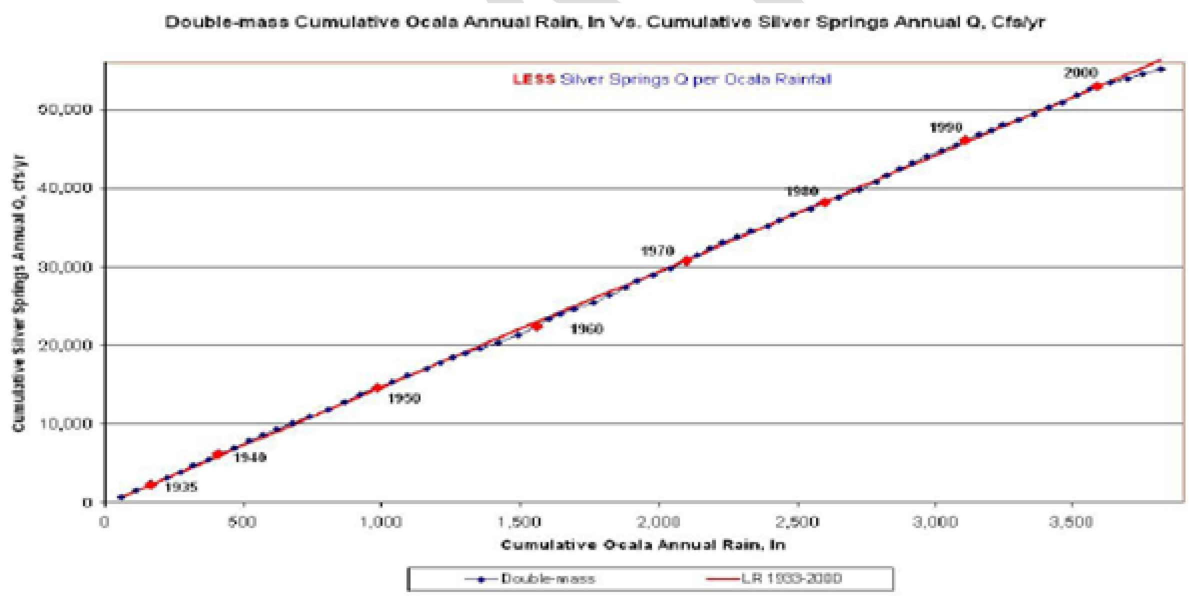


Figure 2. Cumulative discharge from Silver Springs (cfs) versus Cumulative Annual Rainfall at Ocala (inches) (from Munch et al., 2004).

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 [NOx] 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	

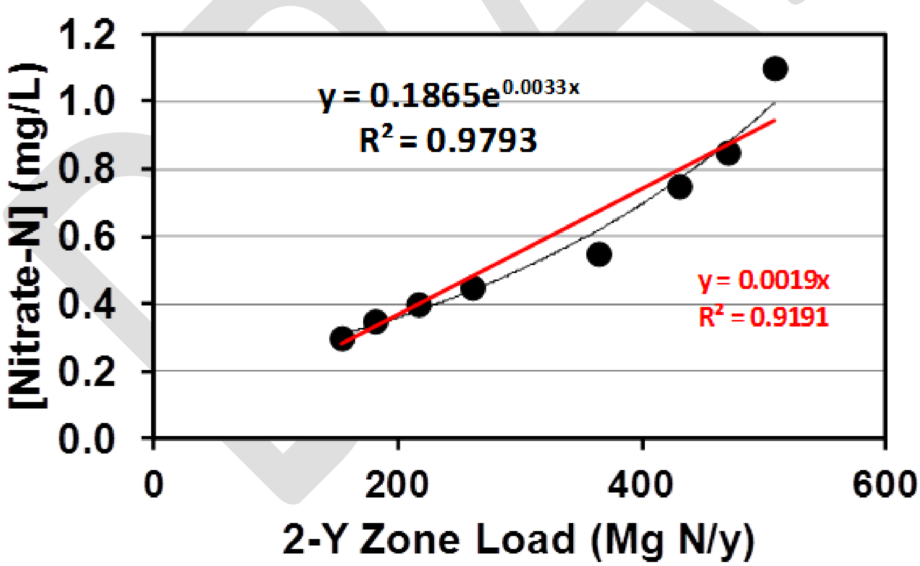
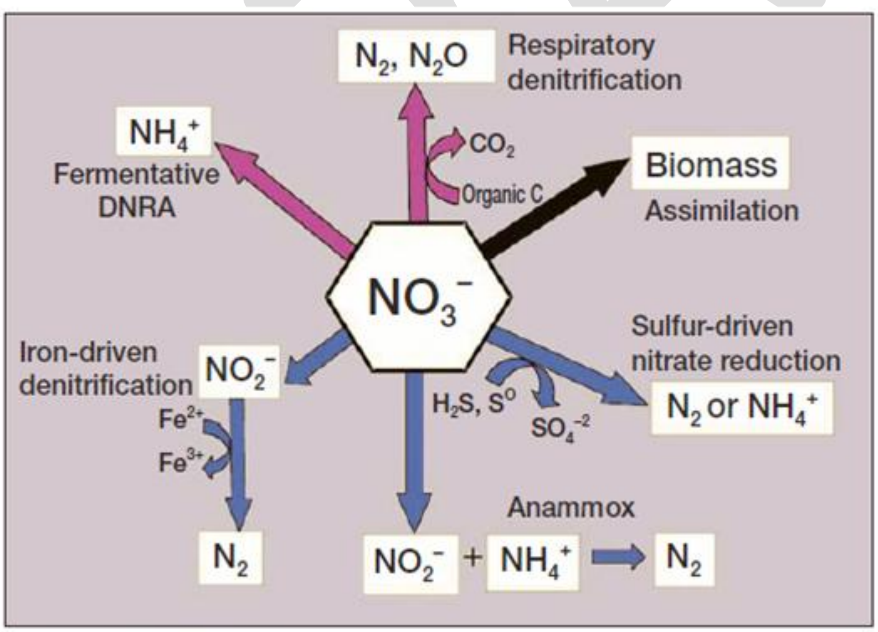


Figure 3. Relationship between [NOx] in Silver Springs discharge and estimated nitrogen loading in the two-year capture zone of the spring shed. Analysis uses data from Munch et al., 2007 and Hicks and Holland, 2012.

It appears then that in the Silver Springs system [NOx] 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 and 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 [NOx]. 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): three are physicochemical; being [DO] (Heffernan et al., 2010), nitrate enrichment (Mattson et al., 2006), and current velocity (King, unpublished) and two are biological; being competitive interactions between algae and SAV and reduced grazer abundance. In order to develop effective management approaches to reduce the abundance of benthic algae, additional research is needed to elucidate the relative influences of the multiple drivers of algal production and abundance.

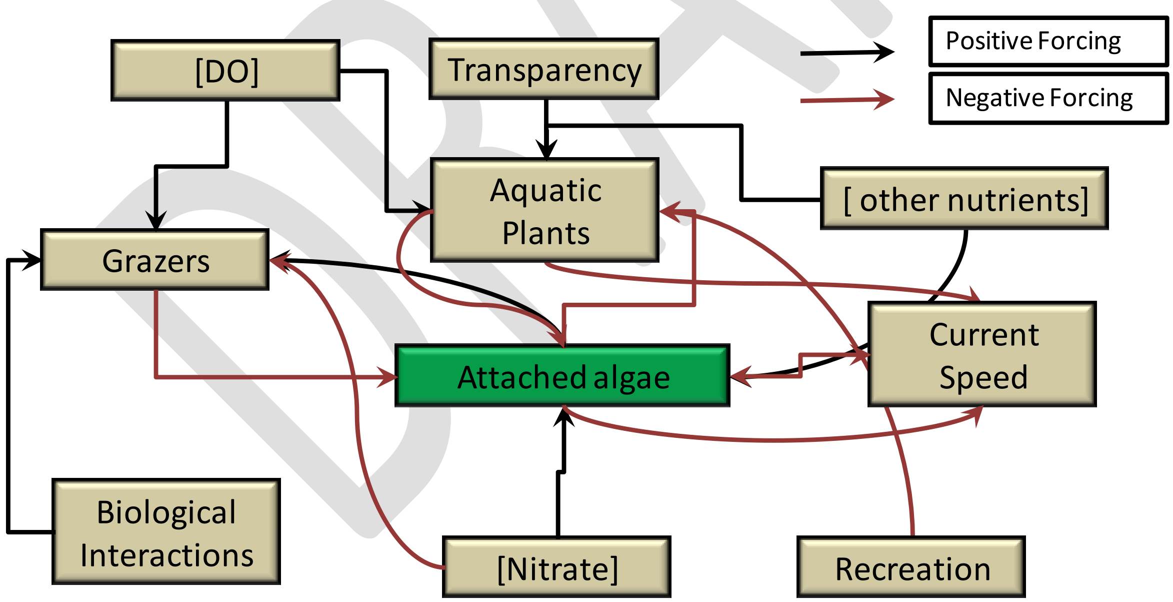


Figure 5. High nitrate, low dissolved oxygen, reduced flow velocities, and reduced grazer populations may influence the relative abundance of SAV and algae in the springs.

Study Purpose and Objectives – The SII 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 denitrificatiion) in soils and shallow aquifers.

2. Evaluate the need for management of forcings other than nitrate loading in order to reduce benthic algal abundance and restore ecological structure and function to acceptable levels.

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. Elucidate the relative influence and manageability of each driver affecting the biological structure and function of springs with special emphasis on the Silver Springs system.

The objective is to be able to rank the relative influence of primary 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 data 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 ecological structure and function of spring systems, especially the abundance of benthic filamentous algae.

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.

1) Surface water hydrology (rainfall, evapotranspiration, recharge, runoff);

2) Groundwater hydrology (aquifer storage, transmissivity, conduit flow, spring discharge)

3) Nitrogen Biogeochemistry – N sources (rates and forms), N transformation, uptake, and loss;

4) Spring System Hydrodynamics/Hydraulics – Hydrodynamic and hydraulic attributes and drivers of the spring system. In cooperation with the Physicochemistry Work Group, interrationships between H&H drivers and physicochemical attributes.

5) Spring System Physicochemistry – In cooperation with the H&H work group, interrationships between H&H drivers and physicochemical attributes. Effects of physicochemical drivers on ecological structure and function with emphasis on benthic algal abundance.

6) Spring System Biology – Biological factors influencing the abundance of benthic algae and SAV.

General Work Plan of the SII

Three workgroups working cooperatively would produce water and nutrient budgets and nutrient loadings (Figure 6). 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, two work groups would model the biological structure and function of the spring.

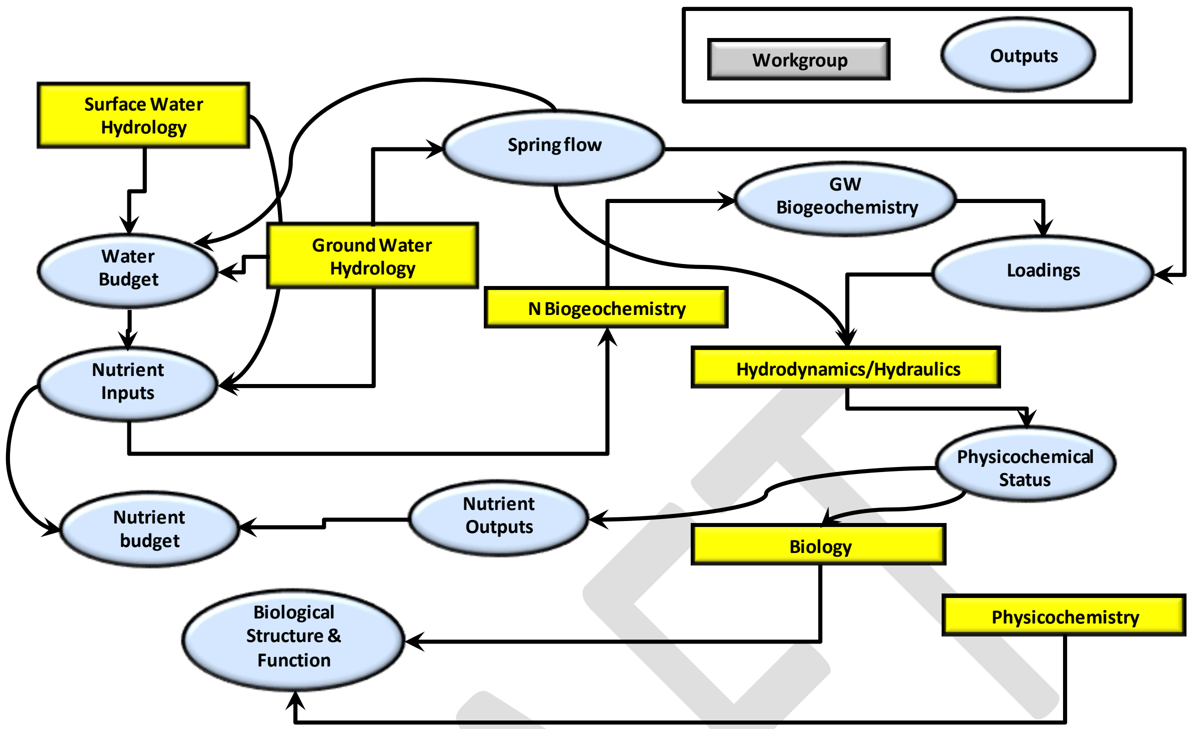


Figure 6. A general schema for the interdisciplinary study. Yellow boxes represent individual workgroups and blue ovals represent outputs.

Watershed and groundwater models would delineate the spatial variation in the hydrologic forcings (Q/m^2) for spring hydrology and hydrodynamics: recharge, consumptive use, evapotranspiration, and runoff (Figure 7). The forcing for each driver would be a function of rainfall, temperature, season, and LULC.

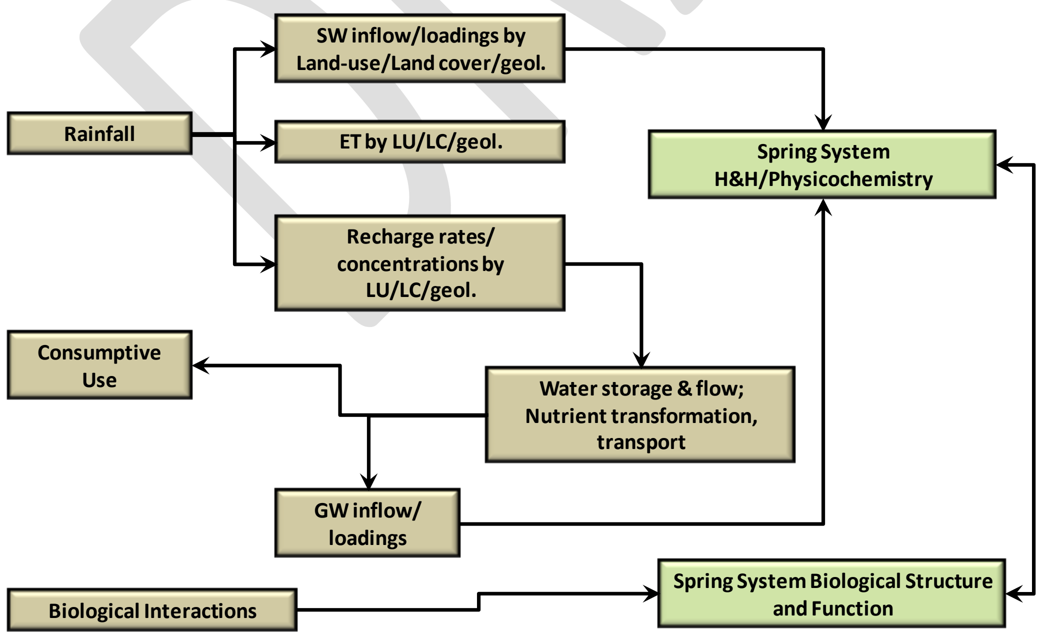


Figure 7. General conceptual model of the major forcings influencing the physical, chemical, and biological status of a spring.

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 (m^3/s), flow velocities (m/s), depths (m), nutrient concentrations (g/m^3), and dissolved oxygen concentrations (g/m^3).

Finally, a suite of ecological models would relate physicochemical forcings to effects on biological structure and function with special reference to PPCS. In addition, the biological groups would assess the potential effects of biological interactions on PPCS.

<u>SII Organization and Personnel</u> – 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).

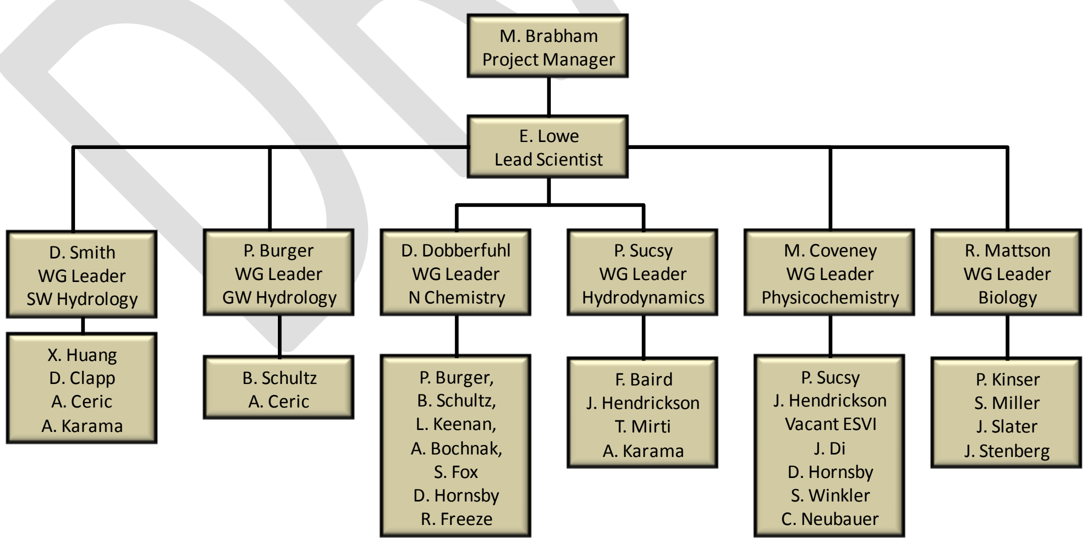


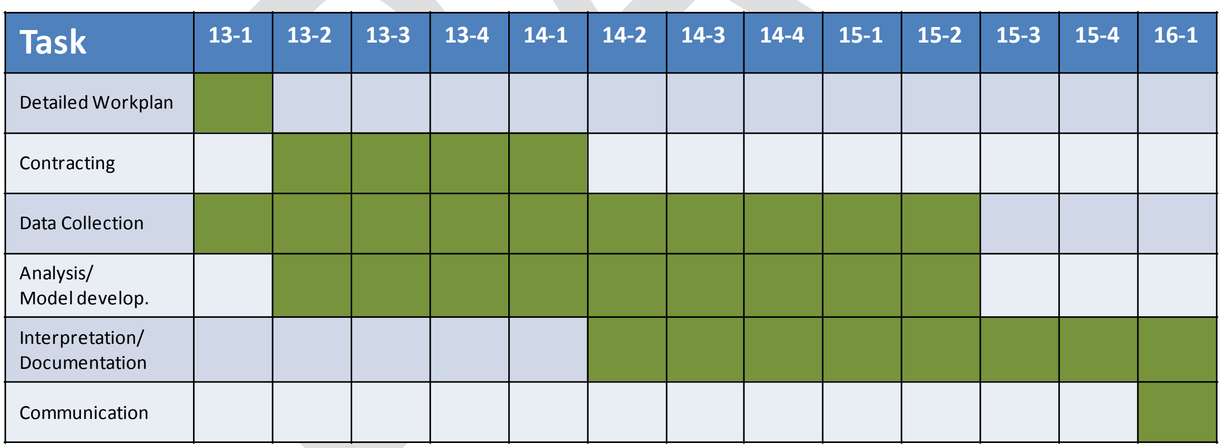
Figure 7. SII project structure and staff.

Overall Schedule and Budget

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 first quarter of 2013. Procurement of contractual support will be initiated during the second quarter of 2013 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. Communication of findings would begin with completion of reports.

Peer Review – Peer review will be an important component of the SII. 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 springs initiative.



Overall Budget -

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Individual Workgroup Work Plans