Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

Project Information

1. **Proposal Title:**

   Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

2. **Proposal applicants:**

   John Cain, Natural Heritage Institute
   James Robins, Natural Heritage Institute
   Elizabeth Soderstrom, Natural Heritage Institute
   Bruce Orr, Stillwater Sciences
   John Stella, Stillwater Sciences
   Scott McBain, McBain and Trush
   Bill Trush, McBain and Trush
   John Bair, McBain and Trush

3. **Corresponding Contact Person:**

   James Robins
   Natural Heritage Institute
   2140 Shattuck Ave, 5th Floor Berkeley, CA 94704
   510 644-2900 x111
   jrobins@n-h-i.org

4. **Project Keywords:**

   Habitat Restoration, Riparian
   Reservoirs, Management and Modeling
   Riparian Ecology

5. **Type of project:**

   Research

6. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

7. **Topic Area**:

   Riparian Habitat

8. **Type of applicant:**

Private non-profit

9. **Location - GIS coordinates:**

Latitude: 37.870

Longitude: -122.267

Datum:

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

Research sites for this project will range throughout the Central Valley (from Clear Creek to SJ). Dan Ray of CALFED suggested using the Natural Heritage Institute's location as both the centroid and the state/federal political districts.

10. **Location - Ecozone:**

3.3 Chico Landing to Colusa, 3.5 Verona to Sacramento, 4.1 Clear Creek, 12.2 Merced River to Mendota Pool, 12.4 Gravelly Ford to Friant Dam, 13.2 Tuolumne River, 13.3 Merced River, 11.1 Cosumnes River, Code 15: Landscape

11. **Location - County:**

Colusa, Fresno, Glenn, Merced, San Joaquin, Shasta, Stanislaus, Sutter, Yolo

12. **Location - City:**

Does your project fall within a city jurisdiction?

No

13. **Location - Tribal Lands:**

Does your project fall on or adjacent to tribal lands?

No

14. **Location - Congressional District:**

9

15. **Location:**

California State Senate District Number: 9

California Assembly District Number: 14

16. **How many years of funding are you requesting?**

3

17. **Requested Funds:**

a) Are your overhead rates different depending on whether funds are state or federal?

No

If no, list single overhead rate and total requested funds:

Single Overhead Rate: 25

Total Requested Funds: 1,409,529

b) Do you have cost share partners already identified?

No

c) Do you have potential cost share partners?

No

d) Are you specifically seeking non-federal cost share funds through this solicitation?

No

If the total non-federal cost share funds requested above does not match the total state funds requested in 17a, please explain the difference:

18. **Is this proposal for next-phase funding of an ongoing project funded by CALFED?**

No

Have you previously received funding from CALFED for other projects not listed above?

Yes

If yes, identify project number(s), title(s) and CALFED program.

01-N32	**Marsh Creek Wateshed Stewardship Program: A project to protect water quaility in the Western Delta**	**ERP**
99-B186	**Focused action to develop ecologically-based hydrologic models and water management strategies in the San Joaquin Basin**	**ERP**
99-B189	**Inundation of a section of the Yolo Bypass to restore Sacramento splittail and to support a suite of other anadromous and native species in dry years**	**ERP**
00 E-05	**Merced River Corridor Restoration Project-Phase III**	**ERP**

99-B152	**A Mechanistic Approach to Riparian Restoration in the San Joaquin Basin**	**ERP**

98-E09	**Merced River Corridor Restoration Project-Pase II**	**ERP**

19. **Is this proposal for next-phase funding of an ongoing project funded by CVPIA?**

    No

    Have you previously received funding from CVPIA for other projects not listed above?

    No

20. **Is this proposal for next-phase funding of an ongoing project funded by an entity other than CALFED or CVPIA?**

    No

    Please list suggested reviewers for your proposal. (optional)

Duncan Pattern	**Montana State University**	**480-965-3167**	**dtpatten@asu.edu**
Karen Holl	**University of California at Santa Cruz**	**831-459-0111x3668**	**kholl@cats**
John Sawyer	**Humbolt State University**	**707-826-3011 x3327**	**jos2@humboldt.edu**

21. **Comments:**

    Between the applicants, the Natural Heritage Institute, Stillwater Sciences, and McBain and Trush, we have a total of 26 CALFED and CVPIA funded grants and service agreements upon which one of the co-applicants is either a primary or subconstultant. Please refer to section B.4 in the main body of the text and/or the associated tables for the full listing of projects

Environmental Compliance Checklist

<u>Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation</u>

1. **CEQA or NEPA Compliance**
   a) Will this project require compliance with CEQA?

      No

   b) Will this project require compliance with NEPA?

      No

   c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

      Compliance is not required because the work described in this proposal is purely research.

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies).** *If not applicable, put "None".*

   <u>CEQA Lead Agency:</u>
   <u>NEPA Lead Agency (or co-lead:)</u>
   <u>NEPA Co-Lead Agency (if applicable):</u>

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

   CEQA
   -Categorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   Xnone

   NEPA
   -Categorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   Xnone

   If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this project.

4. **CEQA/NEPA Process**
   a) Is the CEQA/NEPA process complete?

      Not Applicable

   b) If the CEQA/NEPA document has been completed, please list document name(s):

5. **Environmental Permitting and Approvals** (*If a permit is not required, leave both Required? and Obtained? check boxes blank.*)

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land. Agency Name:	
Permission to access state land. Agency Name: California State Parks and California Department of Fish and Game	Required
Permission to access federal land. Agency Name: US Fish and Wildlife Service	Required
Permission to access private land. Landowner Name: Individual land owners	Required

6. **Comments.**

Land Use Checklist

Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

1. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

2. **Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?**

   Yes

3. **Do the actions in the proposal involve physical changes in the land use?**

   No

   If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

   research only

4. **Comments.**

Conflict of Interest Checklist

<u>Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation</u>

Please list below the full names and organizations of all individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal or who will benefit financially if the proposal is funded.
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.
- Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers for your proposal.

Applicant(s):

John Cain, Natural Heritage Institute
James Robins, Natural Heritage Institute
Elizabeth Soderstrom, Natural Heritage Institute
Bruce Orr, Stillwater Sciences
John Stella, Stillwater Sciences
Scott McBain, McBain and Trush
Bill Trush, McBain and Trush
John Bair, McBain and Trush

Subcontractor(s):

Are specific subcontractors identified in this proposal? No

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

If yes, please list the name(s) and organization(s):

Sabrina Simpson Stillwater Sciences

Comments:

Budget Summary

Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

Please provide a detailed budget for each year of requested funds, indicating on the form whether the indirect costs are based on the Federal overhead rate, State overhead rate, or are independent of fund source.

Independent of Fund Source

Year 1												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary** *(per year)*	**Benefits** *(per year)*	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Study Plan Development and Peer and Review	0	0	0	0	0	0	0	0	0.0	0	0.00
1a	Convene workshop of technical advisory committee (TAC)	80	3400	0	0	0	33950	0	0	37350.0	6270	43620.00
1b	Refine work plan	55	2338	0	0	0	9411	0	0	11749.0	1525	13274.00
1c	TAC review of work products	0	0	0	0	0	4500	0	0	4500.0	1125	5625.00
2	Site Reconnaissance, Device Installation and Basleine Data Collection	417	17723	0	4800	22550	262453	0	0	307526.0	39517	347043.00
3	Mechanistic Investigation of Pioneer Species Establishment from Seedling to Maturity	0	0	0	0	0	0	0	0	0.0	0	0.00
3a	Using climatic variables to predict seed release timing in the Central Valley	55	2332	0	0	0	83260	0	0	85592.0	8909	94501.00
3b	Development of substrate specific groundwater decline models	168	7140	0	1920	0	1280	0	0	10340.0	2585	12925.00
3c	Development of a hydrologic model to predict seedling-sapling cohort composition and survivorship	256	11072	0	3840	0	1920	0	0	16832.0	4208	21040.00

4	Developing Hydrogeomorphic and Ecophysiological Indicators to Predict Establishment Location of Mature Trees and Longer-term Vegetation Dynamics	0	0	0	0	0	0	0	0	0.0	0	0.00
4a	Forensic analysis of existing riparian stands to relate current species occurrence to one or more hydrogeomorphic measures	75	3187.5	0	0	0	67478	0	0	70665.5	7545	78210.50
4b	Develop indicators of longer-term (growing season) plant source waters, water use efficiency and physiological stress	25	1062.5	0	0	0	49363	0	0	50425.5	5202	55627.50
4c	Draft manuscript	0	0	0	0	0	0	0	0	0.0	0	0.00
5	Extrapolation from Site-Specific Intensive Studies to Corridor-Scale Planning	0	0	0	0	0	0	0	0	0.0	0	0.00
5a	Spatially explicit vegetation response model	20	850	0	0	0	30636	0	0	31486.0	3276	34762.00
5b	Applying the site-specific model across an entire river corridor	0	0	0	0	0	25081	0	0	25081.0	2508	27589.00
5c	Draft manuscript and project team coordination	0	0	0	0	0	0	0	0	0.0	0	0.00

6	Project Managment	120	5100	0	0	0	0	0	0	5100.0	1275	6375.00
		1271	54205.00	0.00	10560.00	22550.00	569332.00	0.00	0.00	656647.00	83945.00	740592.00

Year 2												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary** ***(per year)***	**Benefits** ***(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Study Plan Development and Peer and Review	0	0	0	0	0	0	0	0	0.0	0	0.00
1a	Convene workshop of technical advisory committee (TAC)	0	0	0	0	0	0	0	0	0.0	0	0.00
1b	Refine work plan	0	0	0	0	0	0	0	0	0.0	0	0.00
1c	TAC review of work products	0	0	0	0	0	4500	0	0	4500.0	1125	5625.00
2	Site Reconnaissance, Device Installation and Basleine Data Collection	0	0	0	0	0	19605	0	0	19605.0	1961	21566.00
3	Mechanistic Investigation of Pioneer Species Establishment from Seedling to Maturity	0	0	0	0	0	0	0	0	0.0	0	0.00
3a	Using climatic variables to predict seed release timing in the Central Valley	30	1380	0	0	0	40580	0	0	41960.0	4403	46363.00
3b	Development of substrate specific groundwater decline models	330	15180	0	1500	200	0	0	0	16880.0	4220	21100.00

3c	Development of a hydrologic model to predict seedling-sapling cohort composition and survivorship	438	20148	0	2580	325	3840	0	0	26893.0	6723	33616.00
4	Developing Hydrogeomorphic and Ecophysiological Indicators to Predict Establishment Location of Mature Trees and Longer-term Vegetation Dynamics	0	0	0	0	0	0	0	0	0.0	0	0.00
4a	Forensic analysis of existing riparian stands to relate current species occurrence to one or more hydrogeomorphic measures	40	1840	0	0	0	67478	0	0	69318.0	7203	76521.00
4b	Develop indicators of longer-term (growing season) plant source waters, water use efficiency and physiological stress	40	1840	0	0	0	49363	0	0	51203.0	5396	56599.00
4c	Draft manuscript	0	0	0	0	0	0	0	0	0.0	0	0.00
5	Extrapolation from Site-Specific Intensive Studies to Corridor-Scale Planning	0	0	0	0	0	0	0	0	0.0	0	0.00
5a	Spatially explicit vegetation response model	0	0	0	0	0	40848	0	0	40848.0	4085	44933.00

5b	Applying the site-specific model across an entire river corridor	0	0	0	0	0	37621	0	0	37621.0	3762	41383.00
5c	Draft manuscript and project team coordination	0	0	0	0	0	0	0	0	0.0	0	0.00
6	Project Managment	120	5520	0	0	0	0	0	0	5520.0	1380	6900.00
		998	45908.00	0.00	4080.00	525.00	263835.00	0.00	0.00	314348.00	40258.00	354606.00

Year 3												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Study Plan Development and Peer and Review	0	0	0	0	0	0	0	0	0.0	0	0.00
1a	Convene workshop of technical advisory committee (TAC)	0	0	0	0	0	0	0	0	0.0	0	0.00
1b	Refine work plan	0	0	0	0	0	0	0	0	0.0	0	0.00
1c	TAC review of work products	0	0	0	0	0	4500	0	0	4500.0	1125	5625.00
2	Site Reconnaissance, Device Installation and Basleine Data Collection	0	0	0	0	0	0	0	0	0.0	0	0.00
3	Mechanistic Investigation of Pioneer Species Establishment from Seedling to Maturity	0	0	0	0	0	0	0	0	0.0	0	0.00
3a	Using climatic variables to predict seed release timing in the Central Valley	0	0	0	0	0	57555	0	0	57555.0	5756	63311.00

3b	Development of substrate specific groundwater decline models	390	17940	0	1500	200	0	0	0	19640.0	4910	24550.00
3c	Development of a hydrologic model to predict seedling-sapling cohort composition and survivorship	518	23828	0	2580	325	3840	0	0	30573.0	7643	38216.00
4	Developing Hydrogeomorphic and Ecophysiological Indicators to Predict Establishment Location of Mature Trees and Longer-term Vegetation Dynamics	0	0	0	0	0	0	0	0	0.0	0	0.00
4a	Forensic analysis of existing riparian stands to relate current species occurrence to one or more hydrogeomorphic measures	0	0	0	0	0	0	0	0	0.0	0	0.00
4b	Develop indicators of longer-term (growing season) plant source waters, water use efficiency and physiological stress	0	0	0	0	0	0	0	0	0.0	0	0.00
4c	Draft manuscript	20	920	0	0	0	29225	0	0	30145.0	3152	33297.00
5	Extrapolation from Site-Specific Intensive Studies to Corridor-Scale Planning	0	0	0	0	0	0	0	0	0.0	0	0.00

5a	Spatially explicit vegetation response model	0	0	0	0	0	30636	0	0	30636.0	3064	33700.00
5b	Applying the site-specific model across an entire river corridor	0	0	0	0	0	62702	0	0	62702.0	6270	68972.00
5c	Draft manuscript and project team coordination	20	920	0	0	0	33941	0	0	34861.0	3624	38485.00
6	Project Managment	120	5520	0	0	0	0	0	0	5520.0	1275	6795.00
		1068	49128.00	0.00	4080.00	525.00	222399.00	0.00	0.00	276132.00	36819.00	312951.00

Grand Total=1408149.00

Comments.

Please refer to proposal Appendix A, tables 7.0-7.2 for more detailed budget information. The detailed budget tables document expenses/line item for both co-applicants (McBAin and Trush and Stillwater Sciences).

Budget Justification

Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

Direct Labor Hours. Provide estimated hours proposed for each individual.

These hours represent estimate hours over three years. John Cain (NHI) total hours = 1215 hours over three years James Robins (NHI) total hours = 1910 hours over three years Elizabeth Soderstrom (NHI) total hours = 174 hours over three years Co-applicant hours and expenses will be billed under Services/Consultants

Salary. Provide estimated rate of compensation proposed for each individual.

John Cain- $54/hour for year 1 and $58/hr for year 2 and 3. James Robins- $37/hr for year 1 and $41/hr for year 2 and 3. Elizabeth Soderstrom- $58/hr for year 1 and $61/hr for year 2 and 3. James Robins will use approximately 55% of NHI time. John Cain will use approximately 35% of NHI time. Elizabeth Soderstrom will use approximately 5% of NHI time. For budget simplicity we have used this time allocation to calculate an average NHI rate of $42.50/hour for year 1 and $46.00/hour for year 2 and 3.

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

NHI does not provide benefits in the traditional sense. The hourly rate above reflects any benefits.

Travel. Provide purpose and estimate costs for all non-local travel.

NHI per diem includes mileage, food, and lodging (if necessary). All field sites are considered non-local. For NHI travel to research sites for reconnaissance (task 2)= $1920 (8 sites, 2 people, $120 per diem) For NHI travel to and from fieldwork sites: Year 1 = $5760 (total of 48 field days @ $120 per diem for tasks 3b and 3c), Year 2 = $4080 (total of 34 field days @ $120/per diem for task 3b and 3c), Year 3 = $4080 (total of 34 field days @ $120/per diem for task 3b and 3c)

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies.

FIELD SUPPLIES Year 1 Task 2. In-Situ Corp Pressure Transducers = $22,000(24@$850 each) Task 2. Piezometer piping= $1600 (40 peizometers @ $40 each) Task 2. Soil corer = $350 Task 2. Vegetation survey supplies(tape, flagging, etc.) = $200 Year 2 Task 3b. and 3c. Annual maintenance cost of pressure transducers (fix housings, new batteries, etc) and peizometers (clean out piping, replace caps, etc)= $525 Year 3. Task 3b. and 3c. Annual maintenance cost of pressure transducers (fix housings, new batteries, etc) and peizometers (clean out piping, replace caps, etc)= $525

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

The bulk of all service/consultant dollars represent the project budgets for co-applicants, Stillwater Sciences and McBain and Trush. Due to the integral the comprehensive nature of these budgets and the nature of the relationships (co-applicants) we have attached a comprehensive budget for both organiziations in Appendix A of the proposal (Tables 10.0-10.1) For all McBain and Trush work the average hourly rate is $50/hr for the 1st and 2nd years and $55/hr for the third year. For Stillwater

Sciences, hourly rates for each task are based on a formula combining the rates for individual employees depending on the specific skill sets (ie GIS task have different average hourly than vegetation sampling) employed per task. Stillwater Science's rate schedule is attached in Appendix A as Table 10.2 All non co-applicant service/contract work is clearly delineated below. Task 1a: $9000 (people @ $1000/person) honoraria for attending two-day workshop. $4500(9 people @ an average of $500/person), for Technical Advisory Committee two-day workshop. These cost will only be incurred during year 1. Task 1b: NA Task 1c: $13500 (9 people @ $500/person/year), for time and expenses incurred reviewing work products throughout the life of the project Task 2: $12,160 ($1520/study site for 8 sites, for backhoe operator to dig and fill pits for installation of 3 pressure transducers and 5 piezometers per site. These are first year costs only. $1200 for soil and stratagraphic surveys. This cost represents one graduate student @ $150/day for 8 field days (1 day/ study site). These are first year only costs. Task 3a: NA Task 3b:$1280 for soil labratory analyses (bulk density and texture). This cost accounts for a student lab tech to help run analyses ($16/hr for 80 hrs). Task 3c: $1920 for student field assistant ($120/day/site 2x during the first year). $7680 for student field assistant ($120/day/site for 4x a year during years 2 and 3

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

We will not be purchasing any single piece of equipment that will cost more than $5000/unit in any single year.

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentatons, reponse to project specific questions and necessary costs directly associated with specific project oversight.

Project managment for task 1 will include organizing the two-day workshop, developing and agenda and producing a written summary. Project managment for all of the research tasks (2-4) will include projet team coordination, reviewing data, purchase of field equipment, inspection of installation of field data collection devices, validation of all costs and invoices from co-applicants and other service providers, development of real-time working budget, presentations at CALFED sponsored workshops and other meetings, writing quarterly/annual reports, coordination with complimentary research projects and addressing project specific questions. All of this is a necessary part of insuring that funded tasks are completed on time and that data is collected and analyze with the highest degree of accuracy.

Other Direct Costs. Provide any other direct costs not already covered.

There are no direct costs that have not already been covered

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs.

The Natural Heritage Institute's general overhead rate is 25%. This covers rent, phones, furniture, computer equipment and non-billabe staff time. For this proposal the Natural Heritage Institute will charge a reduced overhead rate of 10% for work performed by co-applicants (Stillwater Sciences and McBAin and Trush) under Services/Consultants. All other services and contracts will be be charged at the general rate of 25%. The IDC column on the budget form reflects the total overhead per task as calculated by the above criteria

Executive Summary

Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

Since European settlement of Californias Central Valley, riparian ecosystems in the San Joaquin and Sacramento basins have been severely disturbed. Many of CALFEDs priority at-risk species rely on riparian forests for a variety of essential ecosystem functions such as water temperature regulation, nutrient and sediment deposition, and allochthonous food web inputs. Thus, restoration of riparian forests and the ecological benefits they provide is a high priority for CALFED and other agencies. Restoring self-sustaining riparian forests along managed rivers will require stream flows of the appropriate timing, magnitude, and duration to foster seedling survival, plant recruitment, and succession of native woody riparian speciesand to discourage non-native invasive species. Central Valley water is a scarce and fiercely guarded resource, and thus flow regimes for restoration purposes must be carefully designed based on a solid understanding of scientific principles. The goal of this proposed research project is to develop modeling tools that are calibrated to Central Valley rivers for optimizing water use, assessing the effectiveness of environmental flow releases, and prioritizing restoration actions. While existing models provide a framework for understanding the essential environmental variables, research to date has focused on areas outside the western states. It is crucial that we develop data specific to the Central Valley to construct locally applicable models. This proposal seeks to address scientific information gaps and develop a series of management tools through a rigorous research program on Central Valley rivers designed to: ·develop critical physiological information for key native and non-native riparian plant species; ·gain a better understanding of the relationship between stream stage dynamics and groundwater levels across riparian zone substrate types; ·evaluate the influence of groundwater on seedling establishment and early life stage survivorship; ·develop hydrogeomorphic indicators to predict establishment patterns of mature trees and longer-term vegetation dynamics; ·develop isotopic indicators of plant source water and ecophysiological water relations and stress for native riparian species; and ·test methods for scaling-up from site-specific studies to reach- and river-corridor-scale modeling for restoration planning.

Proposal

Natural Heritage Institute

Making the best use of a scarce resource: Developing tools to optimize flows for restoration of Central Valley riparian vegetation

John Cain, Natural Heritage Institute
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Submitted to:
CALFED Bay-Delta Program
Ecosystem Restoration Program
October 5, 2001

Prepared by
Natural Heritage Institute
2140 Shattuck Avenue, 5th Floor
Berkeley, CA 94704

Natural Heritage Institute

A. PROJECT DESCRIPTION: PROJECT GOALS AND SCOPE OF WORK

A.1 Problem

Since European settlement of California's Central Valley over 150 years ago, riparian ecosystems in the San Joaquin and Sacramento basins have been severely altered by the cumulative effects of instream mining, dam and levee construction, farming, grazing, and urban encroachment (McBain and Trush 1998, Vick 1995). Losses over the past century are difficult to quantify accurately, but riparian forest, marsh, and seasonal wetland habitat area lost throughout the entire Central Valley is estimated to be greater than 90 percent of its historical extent (Katibah 1984). Riparian forest age and canopy structure of remaining standshas changed as older hardwood trees mature and die, and regeneration of young ones is inhibited by human and natural causes (JSA 1998, McBain and Trush 2000, Stillwater Sciences 2001).

In the southwestern United States, an estimated 60 percent of wildlife species are directly dependent on riparian areas and another 10–20 percent rely on these habitats during some stage of their life cycle (Tellman et al. 1997). Moreover, many of CALFED's priority at-risk species rely on riparian forests for a variety of essential ecosystem functions such as water temperature regulation, nutrient and sediment deposition, and allochthonous food web inputs. Thus, restoration of riparian forests and the benefits they provide to threatened and endangered species are high priorities for CALFED and other agencies (ERPP 1999, AFRP 1997, SJRMP 1994, Draft Stage 1 Implementation Plan 2001).

Restoration of self-sustaining riparian forests along managed rivers will require designing stream hydrographs with appropriate timing, magnitude, and duration to ensure that flows facilitate recruitment of riparian vegetation, foster seedling survival, maintain a diverse and complex species composition and stand structure, and support natural succession of native woody riparian species. The possibility of implementing flows for riparian restoration along Central Valley rivers is predicated on the use of controlled flow releases from terminal reservoirs. Because of the competing demands for water in the Central Valley, obtaining water for environmental purposes is a major challenge.

One of CALFED's primary objectives is to minimize conflict between competing water demands. To this end, CALFED highlights the need for "research, monitoring, and implementation of projects designed to develop a better understanding of geomorphic thresholds and hydrologic-biologic relationships that will facilitate estimating environmental flow needs, so that environmental dedications of water are effective and efficient in achieving restoration objectives, thereby minimizing potential effects on water supply and hydropower generation" (Draft Stage 1 Implementation Plan 2001).

Although there is a body of informative work that touches on the essential elements for designing flows to restore riparian habitat (McBride and Strahan 1984, Stromberg 1993, Mahoney and Rood 1993 and 1998, Auble et al. 1994, Shafroth et al. 1998, Springer et al. 1999), much of this work has not been conducted locally. Results of these studies are often not directly applicable to the Central Valley, and essential local data often does not exist. **The goal of this project is to develop modeling tools that are calibrated to the Central Valley for optimizing water use, assessing the effectiveness of environmental flow releases, and prioritizing restoration actions. The project team proposes a series of studies on a range of Central Valley rivers to collect vegetation physiological, life-history, and landscape pattern data in conjunction with various physical (hydrological, geomorphic, pedological) parameters; these data will be inputs into a suite of mechanistic and stochastic models that will be developed to assess vegetation response to short- and long-term flow conditions.**

This project seeks to address existing data gaps by conducting a multi-year, multi-disciplinary, rigorous research program to (1) sample a suite of key physical and riparian ecological parameters at a variety of scales in order to understand the range of natural variability within the Central Valley, and (2) develop analytical and predictive tools to optimize water use. Specific research objectives are to:

- develop critical physiological information for Fremont cottonwood and a variety of other key native and non-native riparian species;

- gain a better understanding of the temporal and spatial relationships between stream stage dynamics and groundwater levels across riparian zone substrate types;
- evaluate the role of groundwater flows for seedling establishment and early life stage survivorship;
- develop hydrogeomorphic indicators to predict establishment patterns of mature trees and longer-term vegetation dynamics;
- develop isotopic indicators of plant source water and ecophysiological water relations and stress for a variety of key native riparian species;
- test methods for "scaling-up" from site-specific studies to reach- and river-corridor-scale flow and vegetation modeling for restoration planning.

The project team consists of three organizations with extensive experience in the study and restoration of Central Valley riparian ecosystems: the Natural Heritage Institute (NHI), Stillwater Sciences, and McBain and Trush. This research program will work in collaboration with a variety of other riparian research initiatives currently funded by CALFED and other agencies. Our proposed research plan both complements and builds on the various riparian habitat research efforts currently underway throughout the Central Valley. Project sites will be located on up to six rivers within the Sacramento, San Joaquin, and Delta ecoregions (**Table 1**); all work will build on ongoing work by project team members on Clear Creek and the Sacramento, San Joaquin, Tuolumne, and Merced rivers (WSRCD 1996, Cain 1997, McBain and Trush et al. 1999, CALFED Bay-Delta Program 1999, McBain and Trush 2000, Stillwater Sciences 2001a, 2000b, and 2000c, NHI 2001) or will be done in coordination with agencies working on other rivers (e.g. the Nature Conservancy on the Sacramento and Cosumnes rivers). Close coordination with the other Central Valley riparian research efforts will be ensured by the project team's existing professional relationships and collaborations and by the scientific peer-review process that is explicitly incorporated into this proposed project (see Section A.3, Task 1).

The conceptual and quantitative models developed in this project will draw on existing work on riparian species recruitment, geomorphic and vegetation linkages, landscape patterns, and succession processes (e.g. Strahan 1984, Mahoney and Rood 1993 and 1998, Shafroth et al. 1998) as well as hydrodynamic modeling (Auble et al. 1994, Bendix 1999) and plant ecophysiological stable isotope studies (Dawson and Ehrlinger 1993, Busch et al. 1992), which are uncommon in riparian vegetation research but present promising applications to the problem of optimizing flows for rehabilitating vegetation processes.

A.2 Justification

Riparian Conceptual Model

Riparian zones, defined by Gregory et al. (1991) as "three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems," provide multiple benefits to instream and terrestrial ecosystems and are widely recognized as centers of biodiversity and corridors for dispersal of plants and animals in the landscape (Gregory et al. 1991, Johannson et al. 1996). Riparian forests filter nutrients and agricultural chemicals from runoff; stabilize channel banks; and provide leaf litter to aquatic food webs, large woody debris and overhead shade for fish habitat, and habitat and migratory corridors for terrestrial wildlife (CALFED 1999, Naiman and Descamps 1997, Mitsch and Gosselink 1993, Malanson 1993).

Riparian vegetation dynamics are tightly coupled with river processes. Inputs of water, sediment, nutrients, and other ecological factors provide the raw materials that are shaped by physical forces such as flooding, scour, and sediment deposition to develop channel and floodplain habitats. These inputs strongly influence riparian plant species composition, distribution, and physical structure (**Figure 1**). Vegetation structure and composition, in turn, provide habitat, shade, cover, food, energy, and debris inputs for wildlife and aquatic communities and influence their population and food web dynamics.

This proposal is specifically concerned with how hydrogeomorphic and other physical forces influence woody riparian vegetation structure, composition, and condition. Our working hypotheses assert that these forces act on vegetation by constraining conditions for certain plant life history stages such as seed release and dispersal, germination, establishment, and adult growth. Physical forces create new geomorphic surfaces, point bars, and floodplain deposits, which pioneer species require for germination. Flow magnitude, frequency, duration, timing, and other parameters affect the success of life history stages such as germination, establishment, and long-term survival, and influence to a large extent species distributions and succession patterns within river corridors. Decadal-scale disturbances such as flooding and fire clear existing vegetation, provide the substrates and growing space for new cohorts; and influence species composition, riparian stand age, physical structure, and community landscape patterns. The life history conceptual model in **Figure 1** shows a generalized riparian plant life cycle, along with key points of interaction with physical forces.

In heavily altered systems such as the Sacramento and San Joaquin basins, restoration of riparian habitats needs to be guided by the physical and biological processes that continue to shape these system (Ligon et al. 1995, Trush et al. 2000). Thus, for restoration to be successful we need to develop a more sophisticated understanding of the linkages, processes, and mechanisms that drive the successful recruitment and maintenance of desirable native plant species. In particular, our proposal seeks to address the gaps in knowledge described below

Climatic Cues and Riparian Plant Seed Phenology. Climatic and other physical factors affect the timing of seed release for pioneer riparian species such as cottonwoods and willows. Seed release timing in conjunction with flow patterns largely determine recruitment success and survival for these species, and thus affect the composition and condition of riparian forests. For cottonwoods and willows, peak seed dispersal (a function of fruit maturation and capsule dehiscence) shows strong spatial/temporal variability and is potentially affected by photoperiod, temperature, relative humidity, and/or genetics. Photoperiod and temperature change with latitude and elevation, and presumably affect the maturation of cottonwood fruit. Less clear are the influences that relative humidity exerts on fruit maturation and capsule dehiscence, or that genetics exerts on seed dispersal timing.

Photoperiod, latitude/elevation, and relative humidity are all linked to temperature, which controls the development of many organisms. Plants and some animals require a certain cumulative quantity of heat to develop from one life stage to another (e.g., the amount of heat required to flower and develop and disperse seeds). The measure of accumulated heat is known as “physiological time” and is a common developmental reference for plants because the amount of heat required to reach the next life stage does not vary (Wilson and Barnett 1983, Zalom et al 1983). Physiological time is often quantified using the degree day, which is a measure of the departure of the mean daily temperature from a lower and sometimes upper developmental threshold. Each species has its own unique number of degree days that it requires to reach another developmental stage (e.g., fish emergence, insect pest emergence, or seed dispersal [Wilson and Barnett 1983, Zalom et al 1983]).

The high demand and cost of water in the Central Valley necessitates that biological responses to environmental conditions be understood adequately to ensure the most efficient allocation and timing of flows. The intent of this research is to correlate seed dispersal timing with variables—temperature and relative humidity—that are widely monitored, are established as mechanisms for biological development, and can be measured and evaluated remotely (by following weather station data). The result will be an accurate predictive seed dispersal model that can be remotely applied so that simulated spring snowmelt streamflows can be released with the highest certainty that regeneration and subsequent recruitment will occur on contemporary floodplains.

Surface Flow and Groundwater Dynamics. Although successful germination of native riparian seedlings depends on a variety of hydrologic and geomorphic variables, seedling survival following germination appears to be contingent on constant contact with the water table and/or its capillary fringe throughout the growing season (Mc Bride and Strahan 1984, Stromberg et al. 1991). Research indicates that when the water table decline is more rapid than the rate of root growth, cottonwood seedlings become isolated from their water source, resulting in increased mortality (McBride et al. 1989, Stromberg 1996). In the Central Valley, where instream flows on the mainstem Sacramento and San Joaquin rivers and their tributaries have been highly regulated, the receding limb of spring floods is often abrupt, and therefore precludes successful establishment of native riparian seedlings.

Standard approaches for designing environmental flow releases for habitat restoration assume that groundwater levels fall at the same rate as surface water stage, and use river stage patterns to assess groundwater availability for seedlings. Although this assumption may be valid in certain circumstances, it is not likely to be the case along all Central Valley stream reaches where heterogeneous alluvial stratification and complex channel-floodplain geometry makes the relationship far more complex. Preliminary data from the mainstem San Joaquin River below Friant Dam illustrates the complexity of this relationship and clarifies the need for further research (NHI 2001). In order to design environmental flow releases that optimize both water use and the establishment and maintenance of native riparian species, we need to better understand groundwater dynamics across a variety of different river flow conditions, substrates, and floodplain configurations.

Groundwater and Seedling/Sapling Survivorship. In addition to the importance of groundwater levels for seedling survival, research indicates that groundwater levels play an integral role in determining post-seedling survivorship and riparian community composition (Smith et al. 1991). The role of dry-season groundwater in plant demography is of particular interest along the highly modified rivers of the Central Valley, where in-stream flow alterations have reduced overbank flows and the resulting floodplain recharge, and modified growing season base flows that often support local groundwater.

Research indicates that across native riparian taxa, seedlings are significantly more susceptible to mortality induced by water stress than were mature trees, especially during the first few growing seasons (Smith et al. 1991, Sacchi and Price 1992, Stromberg 1996, Stromberg et al. 1998). Plants whose evaporative water demands are met during the first three growing season are more likely to join the population of reproductively mature plants. Furthermore, comparative studies indicate that some non-native invasive plant species tend to be more vigorous and drought-tolerant than natives, and thus better able to compete along reaches with extreme inter- and intra-annual water table fluctuations (Smith et al. 1991, Freidman et al. 1995, Shafroth et al. 1998 and 2000, Horton et al. 2001). Thus, in order to restore self-sustaining hardwood riparian forest, we need to better understand the role of groundwater in species survivorship across time and across species.

Plant Species Distributions and Hydrogeomorphic Parameters. In many riparian ecosystems, vegetation along river banks demonstrates non-random patterns of species distributions, which are the result of complex interactions between physical disturbance regimes and species' individual tolerances (e.g. to flooding and scour) and life history characteristics (e.g., phreatophytes), and competitive interactions (**Figure 2**). Many studies have documented associations between riparian vegetation assemblages and fluvial landforms in an attempt to provide templates for gradient analysis or restoration (Harris 1987, Hupp and Osterkamp 1985, Osterkamp and Hupp 1984). However, classifying plant habitats by geomorphic surface can be somewhat arbitrary and observer-dependent, and in heavily modified rivers such as in the Central Valley, fluvial landforms may be relicts of past hydrogeomorphic regimes.

Previous work by project team members document elevational zonation of riparian plant species on Central Valley rivers, and pilot analyses indicate that these differences can be quantified in terms of hydrologic variables that translate across sites and potentially across rivers (Stillwater Sciences 2001a and 2001b, and **Table 2**). These variables can be powerful general predictors of long-term vegetation response to flow conditions and can be useful guides for prescribing flow regimes and designing floodplain restoration projects. Inundation duration, a physical variable which can be calculated for individual tree locations from site hydraulic modeling and historical hydrologic data, is a particularly promising and robust measure to quantify species' occurrences within riparian zones (Auble et al. 1994). Other variables that have been defined include elevation above summer baseflow (Mahoney and Rood 1998) and shear stress or stream power (Bendix 1994). The project team proposes to expand the pilot work it has conducted to sites with more varied hydrologic conditions to assess the suitability of these parameters as general predictors of vegetation response to long-term flow conditions. One of the necessary subtasks of this approach will be to determine the age of the riparian vegetation studied to ensure that it established under the current flow regime.

Plant Water Relations and Species Life History Strategies. Some riparian plant physiology studies within the last decade have employed stable isotope analyses (e.g. hydrogen, oxygen, carbon) as useful tools for understanding differences in species' water relations, including reliance on various water sources (river vs. groundwater), and differences in water use efficiency and carbon assimilation (Dawson and Ehrlinger 1991 and 1993, Busch et al. 1992, Busch and Smith 1995). Unlike traditional ecophysiological methods that use instantaneous measures of physiological parameters such as xylem water potential and photosynthetic rate to understand water relations (e.g. Abrams et al. 1994), stable isotope studies integrate a plant's physiological conditions over longer periods (e.g. an entire growing season), and can be used to assess coarse differences in source water use, water use efficiency, and response to drought stress between individuals and species. This approach integrates physiological processes across large time scales and is a better measure of longer-term water status than instantaneous measurements, which can vary widely diurnally and seasonally, and require frequent and intensive sampling methods. We will build on the species-specific studies to date to investigate comparative life-history water-use traits of several native riparian trees that show different habitat preferences (described above); one research goal is to explain species' landscape distribution patterns in terms of physiological traits and life-history strategies. This research will be useful in understanding different species' site needs for each species, for optimizing flow prescriptions to benefit desired species, and for designing floodplain revegetation efforts.

Though various ecophysiological isotopic analyses have been done individually for Fremont cottonwood, Goodding's black willow, and box elder (Dawson and Ehrlinger 1993, Busch et al. 1992), a comparative analysis of source water use and ecophysiological attributes has not yet been conducted for a range of native Central Valley riparian species. Analyses to date using δD and $\delta^{18}O$ indicate that at a particular site, riparian trees can utilize different source waters such as surface water, shallow groundwater, and deeper aquifer, depending on species, age/size, and, to a lesser degree, on proximity to the stream (Dawson and Ehrlinger 1991, 1993 and 1998). Species-specific variations in source water use are linked to differences in plant ecophysiological traits such as water use efficiency and competitive ability in riparian environments, and in some cases explains the success of invasion by non-native riparian species (Busch and Smith 1995).

Developing Site-Based and Corridor-Scale GIS models. Existing GIS-based restoration models for riparian ecosystems (see for example, O'Neill et al., 1997, Russell et al, 1997) have incorporated geomorphic, hydrological and vegetation data to guide restoration efforts. Various parameters have been used to rank sites according to their restoration potential, including combinations of relative soil moisture, disturbance regime, and vegetation characteristics (O'Neill et al, 1997), and development of a synthetic wetness index (Russell et al, 1997).

In contrast to earlier efforts referenced above, the project team will develop site-based and corridor-scale models that will take a mechanistically-based approach to explore various spatial and time-dependent restoration scenarios by integrating spatial information collected at both site and reach scales. The advantages of this approach are the ability of GIS tools to stratify and extrapolate data, and employ site-based measurements at representative locations within the riparian zone to explore broader scale relationships that are important for riparian ecosystem functioning. The proposed GIS modeling approach will be a valuable evolution from earlier studies because information used to construct the model will be derived in part from relationships elucidated from the site-based studies. Existing data sets for the San Joaquin and Sacramento tributary systems (much of it developed by project team members as part of other projects) are already at a sufficiently high resolution to allow for initial exploratory analyses; available digital data sets are listed in **Table 3**. The site-based surveys outlined in Tasks 2-4 will be important in guiding additional data gathering efforts at the coarser modeling scale. The combination of existing project team expertise with Central Valley GIS data sets, a mechanistically-based GIS approach, and the intensive site-based research outlined in Tasks 2-4 afford a unique opportunity to build comprehensive models of ecosystem linkages and responses to potential flow restoration scenarios.

Project Hypotheses
The conceptual models elucidated above form the scientific basis from which we advance the follow hypotheses:

1. (Task 3a) The onset of seed maturation and dispersal for riparian pioneer species is determined by species-specific physiological threshold responses to local climate factors such as seasonal temperature and relative humidity patterns. Seeding phenology can be predicted by monitoring and modeling these local environmental factors.
2. (Task 3b) The relationship between stream stage and groundwater level is not uniform within alluvial riparian zones, but varies in rate of change and subsurface flow direction (i.e. gaining versus losing reaches) depending on substrate conditions and channel-floodplain geomorphology.
3. (Task 3c) Inter- and intra-annual patterns of streamflow and groundwater influence the composition, distribution, and success of riparian hardwoods and during the first several growing seasons, these patterns can prevent or facilitate establishment of native and non-native seedlings.
4. (Task 4a) Mature riparian trees vary by species in their establishment position on geomorphic surfaces and river banks. These differences can be quantified in terms of hydrogeormorphic parameters derived from physical site conditions and hydrologic history (e.g., inundation duration) and these patterns can be generalized across sites, river systems, and spatial scales.
5. (Task 4b) Patterns of source water use and ecophysiological parameters such as relative water use efficiency vary for riparian tree species with different life history strategies and different hydrogeomorphic habitat preferences (e.g., inundation duration).
6. (Task 5a) A site-based, predictive model of vegetation response to changes in flow and other physical conditions can be constructed by integrating site hydrodynamics and plant species' life history traits, establishment patterns, and ecophysiological tolerances.
7. (Task 5b) Site-base studies of vegetation response to hydrogeomorphic conditions can be scaled up to provide a predictive spatial model of vegetation composition and distribution patterns throughout a river reach or corridor.

A.3 Approach

We propose a multi-scale, multi-disciplinary approach, described in Tasks 1-5 below, to test our research hypotheses. In order to develop information and build models that are applicable across the Central Valley, we propose conducting our research at sites in both the Sacramento and San Joaquin basins (see **Table 1** for list of potential sites). In light of the extensive experience of the project team members on the proposed study rivers (**Table 1**), research in all tasks will be designed to maximize information value to water and land managers and optimize applicability across rivers throughout the Central Valley and by coordinating with relevant existing research efforts, standardizing methods with previous and on-going studies, augmenting existing data sets and digital GIS resources, and conducting joint analyses to leverage current understanding.

Task 1. Study plan development and peer review
The purpose of this task is to convene a Technical Advisory Committee (TAC) to review project hypotheses and approaches, refine the work plan, and provide peer review of technical deliverables. The TAC will be made up of experts in a variety of fields related to our proposed research. **Table 4** lists scientists who have agreed to serve on the project TAC. Many of these scientists currently work with the project team members in advisory capacities.

1a. Convene a workshop of scientific advisors. Project team members will identify gaps or inconsistencies within their research tasks and identify potential methods and parameters to test task hypotheses and measure the greatest range in natural conditions and data variability. Based on these results, the project team and the TAC will hold a two-day workshop to discuss the proposed research and develop a comprehensive study plan with consistent metrics, and coordinate existing research efforts.

1b. Refine study plan. Based on the results of the workshop and TAC member input, the project team will refine the study plan and standardize methods.

1c. TAC review of draft manuscripts._The TAC will provide peer review of the refined work plan and draft deliverables, particularly technical manuscripts being prepared for publication.

Task 2. Site reconnaissance and baseline data collection
This task encompasses all of the sub-tasks required for selecting our study sites, installing field measurement devices, and collecting baseline topographic and vegetation data. Due to the overlap in field data needs between tasks (3b, 3c, 4a, 4b, 5a), we will be able to maximize project feasibility and economy by coordinating the majority of the field work set-up costs (**Table 5**).

In this task the project team will conduct field reconnaissance to review potential study sites. Study sites will be located on 4-6 rivers (**Table 1**) and will be selected to capture the largest range of natural variability in the Central Valley for the research questions of interest. Following final site selection, the project team will collect baseline data at each site that will include: (1) installing piezometers, continuous water level recorders (transducers), and a staff gauge to monitor river and groundwater levels over time; (2) topographic surveys at 3-7 cross-sections for use in hydraulic models and vegetation studies; (3) baseline vegetation transects of mature trees and seedling recruitment; and (4) data entry and quality control. **Figure 3** shows a preliminary site sampling design; final design is contingent on TAC review and site logistical issues. The staff gauge and river transducer data will be used within a hydraulic model to derive stage-discharge relationships for study site cross sections. Floodplain piezometer and transducer arrays will be used to monitor spatial and temporal groundwater dynamics at each site; these instruments will be installed in excavated pits via backhoe. A representative sample of these pits will be used for soil stratigraphic analysis at each site (as described in Task 3b). An auto level or total station instrument will be used to survey topography, device locations, and monitoring station locations (e.g. transects and quadrats) at each site. Baseline vegetation surveys (described in detail in Tasks 3c and 4a) will also be carried out at each site.

All data will be entered into appropriate computer databases and quality control and quality assurance measures will be carried out.

Task 3. Mechanistic investigation of pioneer species establishment from seedling to maturity
The objective of this task is to develop biological and hydrological information to increase the potential for successful establishment of native pioneer species in riparian ecosystems. This research builds on a large body of riparian research in other alluvial river basins (e.g. Mahoney and Rood 1998, Auble et al. 1994) as well

as on-going work by project team members (e.g. CALFED grant ERP/#99-B152; A Mechanistic Approach to Riparian Restoration in the San Joaquin Basin). This task consists of three components:

- Task 3a: phenological studies to increase the precision of flow releases to better correspond with seed dispersal of desirable species,
- Task 3b: groundwater and surface water investigations to refine standard ramping flow designs to better reflect substrate-specific sub-surface hydrology, and
- Task 3c: hydrological and biological studies to explore the relationship between inter- and intra-annual groundwater levels and seedling to sapling survivorship.

3a. Using climatic variables to predict seed release timing in the Central Valley. Elucidating the relationship of physiologic heat accumulation and the morphologic development of flowers fruits and seeds will require intensive data collection at study sites distributed over a wide geographic and elevational range. Under the preliminary study plan, one study site will be established in each river reach listed in **Table 1**. Approximately half of the study sites spread over the widest geographic region will be used to develop the phenologic model, and the remaining ones will be used to test the model's predictive strength. Topographic surveys and hydraulic modeling conducted in Task 2 will facilitate the hydrologic analysis. Wherever possible, previously established study sites will be used.

At each site, several individuals of study species will be identified and continuous data loggers deployed in proximity to record ambient temperature and relative humidity conditions throughout the fruit maturation and seed dispersal period. Detailed observations of morphological development milestones (e.g. bud break, flowering, fruit development and dehiscence, following methods by Beck et al. 1991) and seed dispersal for each species will be made periodically (e.g. weekly). Seed dispersal densities will be quantified from seeds collected in sticky trap arrays at each site during each period. These data will define time periods for each stage of development observed. Species considered for study include a range of native and non-native riparian species: white alder (*Alnus rhombifolia*), Fremont cottonwood (*Populus fremontii*), arroyo willow (*Salix lasiolepis*), narrowleaf willow (*Salix exigua*), box elder (*Acer negundo*), mulberry (*Morus alba*), eucalyptus (*Eucalyptus* sp.), and tamarisk (*Tamarisk* sp.).

From data recorded and the observations of morphologic development made at the initial study sites, a degree-day model will be developed and evaluated. Several degree-day modeling methods have been described and evaluated (Arnold 1960, Baskerville 1969, Allen 1976, Wilson and Barnett 1983, Zalom et al 1983, Roltsch et al. 1999). We will apply available degree-day estimation models to the remaining sites and determine which is the most accurate model for this use.

3b. Developing groundwater and surface water decline models. In order to evaluate surface and groundwater relationships, the project team will install a series of replicate groundwater sampling transects at each study site. Sample sites will be stratified to reflect a suite of substrate and geomorphic conditions. The preliminary experimental design (**Figure 3**) will use data gathered in Task 2 to maximize data collection efficiency with other tasks; sample sites will be located and organized in coordination with on-going projects to complement existing research efforts (e.g. locating groundwater instruments along existing project transects). This overlap will both augment existing data sets and increase the potential for abiotic-biotic statistical correlations.

As described in Task 2, study site topography will be surveyed and piezometers, pressure transducers, and a staff gauge installed in arrays with a common datum to continuously monitor relative surface and groundwater levels. Hydraulic modeling used for Tasks 2 and 4a will be used to establish stage-discharge relationships at each cross section. Groundwater transducers will be installed at elevations ranging from 60 cm to 200 cm above mean daily summer base flow, representing the Fremont cottonwood establishment band observed by McBride and Strahan (1984) and Stromberg et al. (1991). All transducers will collect data at hourly intervals and data periodically downloaded. At non-instrumented piezometers, groundwater depth will be manually documented approximately four times between April and October and twice between November and March. Piezometer observations will be integrated with ground and surface water transducer data to construct temporally and spatially explicit groundwater profiles for each site. Data analyses will characterize inter- and intra-year patterns of groundwater and surface water levels, including maxima, minima, and recession rates.

At a subset of groundwater observation sites, soil pits dug during piezometer installation will be used to collect soil stratigraphic data, including soil horizon and capillary fringe depths, and substrate texture. Bulk soil samples will be cored and analyzed for particle size using visual estimation for particles > 2 cm, sieving for particles between 2mm and 2 cm, and hydrometer methods for sand, silt and clay (Shaforth et al. 2000, Day 1965).

Comparative groundwater and surface water recession rates will be analyzed to determine the nature of the relationship for various substrate types and channel/floodplain morphologies.

3c. Evaluating the influence of groundwater dynamics on seedling/sapling cohort composition and survivorship. This subtask will be directly integrated into the study design described in the previous section. Vegetation band transects will be established in conjunction with site topographic and hydrologic data to characterize riparian seedling reliance on groundwater for establishment and survival through the first several growing seasons. First-year seedlings recruiting within the band transects will be sampled using standardized quadrats (exact size subject to TAC input). If the majority of seedlings occur outside of this area, random sampling will be conducted across the floodplain. Quadrat data will be used to characterize seedling composition, abundance, and seedling density across each site. Physical locations of seedling patches/zones will be mapped using GPS and aerial photographs and specific individuals will flagged and tracked over the period of research. Various measures of growth and vigor will be recorded for each individual. Seedlings in the first-year cohort will be tracked for three years (through sapling stage), while seedlings from second- and third-year cohorts will be tracked for the duration of the study. Vegetation will be sampled approximately three times annually to capture two spring/summer germination periods as well as late season (fall) survivorship. Subject to logistical and budget constraints, limited destructive sampling will be conducted to ascertain seedling belowground biomass, rooting depth and lateral root extension of living and dead individuals. Statistical analysis will be conducted to correlate species demography in the first three growing seasons with groundwater parameters quantified in Task 2b.

Task 4. Developing hydrogeomorphic and ecophysiological indicators to predict species distributions of mature trees and longer-term vegetation dynamics

This task investigates landscape distribution patterns of adult riparian tree species in relation to hydrogeomorphic site conditions and seeks to link those relationships to ecophysiological differences between species. This research will utilize much of the data collected in Tasks 2 and 3 and will complement those analyses with investigations into the hydrologic and physiological factors that drive adult species patterns, habitat preferences, and long-term vegetation dynamics in riparian zones. This task consists of two components:

- Task 4a: Relating adult tree species distributions to site-specific hydrogeomorphic measures; and
- Task 4b: Developing isotopic indicators of plant water relations and life history strategies

4a. Relating adult tree species distributions to site-specific hydrogeomorphic parameters. The objective of this task is to relate current position of mature vegetation within the riparian zone to one or more hydrogeomorphic factors that can be measured or modeled at the site, in order to develop parameters across rivers that can predict vegetation distribution patterns and guide future flow prescriptions and other restoration efforts within the Central Valley and on other alluvial river systems. This approach has been used successfully on other river systems (Hupp and Osterkamp 1985, Auble et al. 1994, Shafroth et al. 1998, Bendix 1999, Horton et al. 2001), and in preliminary work on the Merced River (**Table 2**; Stillwater Sciences 2001b). Results from these efforts indicate that hydrologic factors such as inundation duration and depth to groundwater are good predictors of species occurrence, and may be powerful proxies that integrate the complex hydrological and ecophysiological factors determining riparian species zonation patterns.

In order to identify relationships that are generally applicable to rivers in the Central Valley, vegetation and hydrogeomorphic data will be collected at the sample sites identified in Tasks 2 and 3. Band transects will be established along surveyed cross sections, and adult trees within the transect will be documented for species, size class, substrate and rooting elevation (conducted as part of the site topographic surveys in Task 2). Combined with the stage-discharge relationships modeled at each cross section and historical hydrologic data, a variety of hydrologic parameters will be calculated (e.g. elevation above summer base flow, inundation duration, flood recurrence, depth to groundwater, and site-specific boundary shear stress or streampower) and tested statistically for between-species and within-species variation.

Because this approach employs the use of historical hydrologic data to explain current species distributions, an important issue to resolve is that the vegetation sampled established under the current hydrologic regime. To that end, the project team will core a sample of the largest trees sampled for the various species to determine their age relative to the hydrologic history (e.g. pre- vs. post-dam) for that river. Trees that established during a previous flow regime will be separated in the analyses from those that established afterward.

4b. Developing isotopic indicators of plant water relations and life history strategies. In this subtask, the project team will use stable isotope analyses to investigate ecophysiological mechanisms of water uptake and carbon fixation in several riparian tree species that may explain the distribution of riparian species on hydrogeomorphic surfaces (Task 4a). Physiological field studies are necessary to address the gap in understanding of processes needed for long-term establishment of seedlings and growth of adult plants. Leveraging work by TAC members and others (Dawson and Ehrlinger 1991, 1993, and 1998, Busch et al. 1992), research efforts will focus on (1) determining if different species use different source waters (e.g., channel, near-surface, or deep groundwater), and thus demonstrate different life history strategies and are differentially vulnerable to surface flow alterations, and (2) developing an indicator of seasonally-integrated water use efficiency and plant water stress, using carbon isotope ratios. Because isotope data are scarce for Central Valley ecosystems and regional water chemistry is relatively unknown, these investigations will be designed as pilot studies to sample the range of natural variability and to investigate promising analytical approaches.

For the source water analysis, the project team will first need to determine if isotopic signatures ($\delta^{18}O$ and δD) are differentiable between river and groundwater sources. Water samples will be obtained from river channels, piezometer wells, and unsaturated zone groundwater extracted from soil cores taken at different depths along a floodplain trench. Source waters will be sampled monthly along with xylem tissue samples from organisms of interest, which will include up to four native Central Valley riparian tree species with different life history traits and floodplain elevational distributions. Preliminary species of interest include Fremont cottonwood, Oregon ash, box elder, and valley oak; species selection and sampling design will be finalized in coordination with the TAC. Using trained staff in the UC Berkeley mass spectrometer laboratory, water samples will be processed initially and analyzed for oxygen and/or hydrogen isotope ratios. If source waters demonstrate differentiable isotopic signatures, tissue samples will be analyzed as well, and patterns of source water use assessed throughout the growing season.

Carbon isotope analysis is a useful tool to investigate different species' water use efficiencies and relative degree of longer-term drought stress (Erlinger 1991). The objective of this research is to investigate whether relative water use efficiency and drought stress is consistent with variations in hydrogeomorphic parameters (e.g., inundation duration at bank position) between species. Using the same trees sampled for the source water analysis, carbon isotope ($\delta^{13}C$) analysis will be performed on plant tissue to evaluate differences in water use efficiency and physiological drought stress between species. Isotope sampling will be accompanied by periodic field measurements of xylem water potential to calibrate relative water use patterns with conventional instantaneous physiological measurements. Carbon isotope analysis is predicated on the phenomenon that fractionation of isotopes occurs as CO_2 enters plant tissues through stomata in the leaves, and that the ratio of heavy to lighter isotopes records an integrated measure of stomatal conductance (and therefore water stress) over longer time frames (e.g growing season). General principles and methods are described in Ehrlinger (1991). Differences in isotope ratios between riparian species will be compared to their geomorphic habitat preferences (quantified in Task 4a) to evaluate species' differences in physiological response to seasonal flow and soil water conditions. Because this research will be conducted in conjunction with Task 4a, this approach has the potential to link landscape patterns of species distributions to specific physiological mechanisms and thus better predict the effect of flow releases on individual riparian species.

4c. Draft manuscript. Analyses conducted in Tasks 4a and 4b will be developed as a technical memorandum or manuscript for a peer review journal. The document will describe relationships between vegetation distribution patterns to site-based hydrogeomorphic parameters and the appropriateness of applying these parameters across landscape scales and river systems. The second part of the manuscript will describe the range of variability in stable isotope signatures across river basins and assess differences between riparian tree species in source water use and water use efficiency in explaining landscape distribution patterns.

Task 5. Extrapolation from site-specific intensive studies to corridor-scale planning

5a. Spatially explicit vegetation response model. In this subtask, the physical and biological parameters quantified in Tasks 2, 3 and 4 will be integrated into a general site-based model for predicting the composition, distribution, and succession of vegetation on geomorphic surfaces, both naturally-formed and created as part of restoration efforts. The objective is to develop a set of parameters that can guide both corridor-scale and site-specific restoration efforts. For example, where the topography and general hydraulics of a river corridor are known, modeled parameters will predict vegetation response (in terms of spatial extent and location) to prescriptions in flow magnitude, duration and timing. Likewise, where a flow regime is known, the vegetation response model can guide site-specific channel reconstruction projects to optimize desired outcomes, such as vegetative cover or particular species distributions.

Starting with available GIS data sets of geomorphic and hydrologic conditions on the study rivers (**Table 3**) and topographic survey data collected in Task 2, the project team will construct a three dimensional digital elevation model (using CAD or other spatial software) at 1–2 selected floodplain study sites. The objective of this model is to link the physical and biological parameters quantified in Tasks 3 and 4 to local topographic and hydrologic attributes. New coverages for high resolution topography, hydrogeomorphic attributes (such as inundation duration and ground-water contours), and vegetation characteristics (such as community type, canopy and age structure, recruitment zones, and risk areas for invasion by non-native species) will be developed using the GIS. New sites where the topography and hydrogeomorphic characteristics are known will be used to test model predictions. Predictions will link vegetation species distributions and characteristics such as cover type, seedling recruitment, and adult species density to physical factors such as groundwater depth, inundation duration, or floodplain elevation. Following model development, predictions will be tested using ground-truthed surveys of vegetation characteristics at the model sites. Model sites will be chosen in conjunction with the TAC and local agencies and organizations (see **Table 1**), and will be partly determined by the availability of existing detailed topographic and geomorphic information. Several potential model sites exist on the Merced River, including the CDWR/CDFG Robinson/Gallo Salmon Enhancement Project and the CALTRANS/CDFG Merced River Ranch restoration project. Both of these projects include revegetation (both passive and active) following floodplain reconstruction and are good settings to utilize existing physical data and test model predictions.

Task 5b. Applying site-specific GIS models to reach and corridor scales. As we better understand vegetation relationships with hydrogeomorphic factors at the site scale, it will be appropriate to apply this information to an entire river corridor, to assess landscape patterns and restoration strategies and priorities. Using a process-based GIS approach and the site-based model developed in Task 5a, the project team will develop landscape tools that can (1) assess the distribution and intensity of processes such as scour, floodplain inundation, and potential recruitment within an entire river corridor; (2) predict the distribution, condition, and life history response of vegetation types under various flow and floodplain restoration scenarios; (3) predict areas at risk of invasion by exotic species; and (4) predict areas of potential forest regeneration. The preliminary study design calls for detailed analyses to be conducted on 1–2 selected river reaches where good GIS data sets exist, and conduct more cursory pilot analyses on 1–2 other reaches where less comprehensive information is available. The final study approach for this task will be developed in conjunction with TAC member input and preliminary results from the site-based analyses in Tasks 2-4.

Both the site-based and corridor-scale GIS models will adopt physically-based schemes (e.g. stratifying topography, geomorphic surfaces, substrate characteristics, and groundwater flow regimes). At the same time, we recognize that both flood hydrology and riparian community dynamics are inherently stochastic in nature. As a consequence, reach- and corridor-scale GIS model predictions will need to provide a distribution of possible outcomes based on a given set of initial conditions. For example, floods corresponding to different recurrence intervals will necessarily have different impacts on the spatial extent of inundation, the disturbance potential of different flows, and the duration of flooding. Riparian community response to this flooding regime will be manifold and thus best framed within a stochastic scheme. Part of the GIS modeling effort will involve integrating the temporal and spatial components of the hydrological and disturbance regimes to produce riparian opportunity 'surfaces' which will describe potential for different riparian species to colonize, establish, and recruit within different areas of the riparian zone. These opportunity surfaces will be the basis of a stochastically-based model to predict species distributions in relation to alternative flow regimes or floodplain reconstruction projects. Testing the model can be conducted on parts of the GIS data set previously sequestered from the data used to construct the model, or on other data sets that become available.

This task will take advantage of currently available electronic databases recording vegetation and physical conditions for San Joaquin Basin rivers developed primarily by project team members (**Table 3**). Data sets for the Tuolumne River (mapped in 1995-1999) and Merced River (mapped in 1999-2000) are currently available to the project team. Another data set is potentially available for the San Joaquin River; digital topography was developed by the U.S. Army Corps of Engineers' Comprehensive Study of the Hydrology of the San Joaquin and Sacramento Rivers, and in 2000, the California Department of Water Resources mapped vegetation communities along the San Joaquin River between Friant Dam and the Merced River. These data sets provide a unique opportunity to maximize existing information use and project data-gathering efficiency. A further benefit will be to compare the data value and model precision between data sets with different methods of mapping vegetation and hydrogeomorphic parameters, as is the case for the Merced and Tuolumne data sets. This comparison will be of value to water and land managers in defining environmental information needs in evaluating restoration strategies that optimize flows or consider other corridor-scale restoration strategies.

Task 5c. Draft manuscript. The project team will produce a technical memorandum or publication manuscript assessing the potential of scaling up site-based study parameters to reach-scale spatial models that relate landscape vegetation patterns to hydrogeomorphic conditions, and the applicability of these models to corridor planning, flow management, and restoration efforts. This document will include a discussion on the most appropriate and cost-effective methods recommended for future work.

Task 6. Project Management

Project management costs will be associated with the following responsibilities: (1) project team coordination; (2) communication with CALFED contracting agency regarding quarterly and annual reports, finances, and general grant administration; and (3) project oversight.

A.4 Feasibility

The proposed project takes a mechanistic approach to identifying the physical and biological mechanisms affecting initial establishment, seedling survivorship, and long-term vegetation dynamics of riparian vegetation in both the Sacramento and San Joaquin Basins. The tools developed through our research will be invaluable for identifying the most cost-effective and successful strategies for using environmental flow releases to ensure riparian protection and restoration.

The partnership of the Natural Heritage Institute, Stillwater Sciences, and McBain and Trush brings together a diverse array of existing professional relationships with locally active non-profit organizations, landowning agencies, and private landowners **(Table 1).** These established relationships will be integral to guaranteeing site access, access to existing datasets, and coordinating local involvement.

Additionally, this proposal has been designed to maximize feasibility via overlap between data needs in Tasks 3, 4, and 5. For example, groundwater data collected in Task 3a will compliment groundwater data collect in 3b and those data will also be used in Task 4a and 4b. See **Table 5** for detailed information on data overlaps.

The timing of this project depends on the seasonality of flows and seed release. Approval of funding during the CALFED funding cycle in early fall would allow the project team to mobilize in time for study site establishment by the early spring of 2002.

No CEQA/NEPA or other environmental compliance documents will be required to perform this project.

A.5 Performance Measures

Specific performance measures will be developed in conjunction with the TAC during Task 1. These measures will ensure that research is carried out as defined in the final work plan and that methods and results are effectively communicated at the end of the project. Performance measures will also be used to track the progress of experiments and analyses as well as assess the validity of implemented experimental designs for testing specific research hypotheses. In specific, the performance measures adopted for this proposal include yearly progress reports for each research task. These reports will be designed for both review of preliminary data and to highlight technical problems or questions that need be addressed. TAC members and representative project team members will review yearly progress reports to ensure that issues are addressed and remedied. In addition to the yearly reports, the final deliverable for each of the research tasks will be a “publication ready” manuscript that has been peer reviewed by the appropriate TAC members and project partners. Please refer to **Table 6** for a listing of deliverables and products for each task.

A.6 Data Handling and Storage

This project will result in the collection and development of large quantities of data and information. The data will be used to perform analyses and generate tables, figures, and maps necessary to support and create the various regulatory reports and presentation material. Electronic data will be stored in database or similar format, and the project team will retain all data at the Natural Heritage Institute’s (NHI) Berkeley office. NHI will submit all data required for public record to the appropriate party and shall retain copies of all project files, including data, metadata, maps, and other information for a period of five years upon completion of the work. Where field data collection is necessary, the Project Team will use standard quality assurance and control methods in designing sampling protocols and in obtaining, recording, and analyzing data. All field data will be recorded on standard data sheets and in field books. Field crews will review current data and notes collected at the end of each day for completeness and clarity, and will photocopy all data upon return to the office. The original field books and data sheets as well as one set of photocopies will be stored at the appropriate task leaders' office.

Copies of all raw and final data sets will translated into a format appropriate for integration into an existing publicly accessible data clearinghouse such as ICE, AFRP, or CALFED.

A.7 Expected Products/Outcomes

The technical analyses from this research project will be delivered to CALFED as technical memoranda or manuscripts for submittal to peer review journals. Other deliverables include quantitative models of vegetation and environmental linkages, site-based topographic and hydrodynamic models, and GIS maps documenting the reach vegetation analyses. Specific task products and outcomes for each task are listed in **Table 6.**

Project products will be made available to other scientists, restoration planners and managers so that current and future riparian restoration programs in the Sacramento and San Joaquin basins will benefit from improved understanding of the mechanisms driving vegetation distribution and life history processes such as recruitment, survival, and succession of native riparian hardwood species.

A.8 Work Schedule

The project schedule, indicating milestones and anticipated start and completion dates, is shown in **Table 7**. The anticipated time to complete all tasks is 3 years from the onset of funding. Payment shall be in arrears on a monthly basis. The Natural Heritage Institute will act as fiscal agent and will invoice on a monthly basis.

Certain tasks presented in this proposal are integral to the success of subsequent task. In particular, Task 1 (a,b, and c) and Task 2 form the basis of our entire research program. The 2-day workshop with our technical advisory committee (Task 1), essential for developing the most effective work plan possible and coordinating with other research efforts. Where Task 1 represents the intellectual foundation of our research program, Task 2 represents the physical foundations. In this task we will select research sites, carryout topographic surveys, install groundwater and surface water monitoring devices, and collect baseline environmental data. The work performed under Task 2 is essential for Task 3 (b and c), Task 4 (a), and Task 5 (a and b).

Although we strongly encourage CALFED to fund all tasks in this proposal, *portions* of Tasks 5a and 5b build off of information developed in Tasks 3 and 4 and thus could be phased or funded incrementally if necessary.

B. APPLICABILITY TO CALFED ERP AND SCIENCE PROGRAMS GOALS AND IMPLEMENTATION PLAN AND CVPIA PRIORITIES

B.1 ERP, Science Program and CVPIA Priorities

The Draft Stage 1 Implementation Plan identifies a series of strategies and goals for rehabilitating the Bay-Delta ecosystem. The essence of the second strategic goal is that through the restoration of natural flow regimes reflective of historic patterns, many geomorphic and ecological processes will be supported. Within the second strategic goal, flow evaluation and simulation modeling are addressed as a primary focus to "develop a better understanding of geomorphic thresholds and hydrologic-biologic relationships that will facilitate estimating environmental flow needs, so that environmental dedications of water are effective and efficient in achieving restoration objectives, thereby minimizing potential effects on water supply and hydropower generation" (Draft Stage 1 Implementation Plan 2001). Our proposed work investigates the relationship of riparian vegetation to the climatic, geomorphic and hydrologic environments in which it grows. Furthermore, based on these investigations, we intend to build a series of models that not only facilitate the self-regeneration of a multitude of hardwood species, but also optimize flow release schedules to provide the water necessary to achieve these goals. The specific relationships of each proposed task to the Multiregion, Sacramento region, the San Joaquin region and the Delta region priorities are listed in **Tables 8.0-8.3.**

B.2 Relationship to Other Ecosystem Restoration Projects

Throughout the Central Valley, numerous projects focus on the restoration of ecosystem processes. These projects can take the form of physical restoration (active) or hydrologic restoration (passive), or both. Our project focuses on the efficient usage of water to establish a wide range of riparian hardwood species at channel locations appropriate for their ecological niches.

All current and future riparian restoration programs in the Sacramento and San Joaquin basins will benefit from an improved understanding of the mechanisms behind successful recruitment of native riparian hardwood species. In addition, not only will our work provide valuable information for designing restoration project that facilitate self-sustaining native hardwood populations, but our research should also provide insights into controlling further establishment of non-native invasive species and restoring already invaded sites.

Our research will also be directly applicable to ongoing research and restoration efforts along the proposed study reaches. Study sites will be located as to maximize benefits of past data collection efforts by project team members and coordinating agencies. **Table 1** lists the organizations and agencies that project partners are currently working or coordinating with along each study reach.

Moreover, the research proposed herein compliments on-going CALFED and CVPIA funded research and restoration efforts for each of the project partners (**Table 9).**

B.3 Requests for Next-phase Funding

N/A

B.4 Previous Recipients of CALFED Program or CVPIA Funding

All the applicants have been involved in projects implementing the goals and priorities established as part of the CALFED and CVPIA programs. **Table 9** lists all projects in which team members have participated, the nature of that participation, project status, and achieved milestones.

B.5 System-wide Ecosystem Benefits

The goal of the proposal is to develop a series of riparian hardwood recruitment models that incorporate groundwater, inter- and intra-annual flow variation, seed dispersal, and other factors to optimize the effectiveness of ecological flow releases from regulation facilities on the tributaries and mainstem reaches of the San Joaquin and Sacramento rivers. Thus, this research proposal is specifically designed to provide Central Valley-wide ecosystem benefits.

Our models rely on the restoration of certain ecosystem processes (e.g., restoration of key components of natural snowmelt hydrographs and inundation frequencies) for the benefit of riparian hardwoods. Several of CALFED's priority at-risk species including Chinook salmon, steelhead, riparian brush rabbit, California red-legged frog, and a suite of neotropical migratory birds will benefit from restoring those processes necessary for riparian hardwood recruitment. Not only will our work suggest management opportunities for releasing streamflows in patterns that reflect less disturbed hydrology, the formation and development of more extensive self-sustaining riparian stands will also result. The combination of self-sustaining riparian hardwood stands and proposed streamflow releases will provide cooler temperatures, greater in-channel and off-channel habitat complexity, and reduce future maintenance/management costs.

B.6 Additional Information for Proposals Containing Land Acquisition

N/A

C. QUALIFICATIONS

Natural Heritage Institute (NHI) is a non-governmental, non-profit organization founded in 1989.Often in partnership with community groups and government agencies, NHI has led efforts to restore such natural systems as wetlands, floodplains, and riparian habitat, including several large-scale restoration projects throughout the Central Valley. **McBain & Trush** is a professional consulting partnership applying fluvial geomorphic and ecological research to river preservation, management, and restoration. **Stillwater Sciences** is a firm of biological, ecological, and geological scientists specializing in developing and implementing new scientific approaches and technologies for problem-solving in aquatic and terrestrial systems. NHI will be the CALFED contractee responsible for payments, reporting, and accounting. NHI will serve as the project manager, and will oversee all field investigations conducted by McBain & Trush and Stillwater Sciences.

Natural Heritage Institute

John Cain (M.L.A., B.A. University of California at Berkeley) is an environmental scientist who specializes in river restoration and water resources management. His recent research focused on historical geomorphic and hydrologic changes to the San Joaquin River and their implications for fisheries restoration. As a planner with the Nature Conservancy, he developed an aquatic species conservation plan for the San Joaquin Valley. He served as staff scientist for the Mono Lake Committee, where he prepared evidence for the Mono Lake water rights hearings and served on the committee overseeing restoration of Rush and Lee Vining Creeks. At NHI, he is currently developing a restoration plan for the Sacramento/San Joaquin Delta.

James Robins (M.S., University of California at Berkeley, B.A. Vassar College) is a resource scientist who specializes in plant ecology, stream restoration, and invasive species. His research efforts include analysis of the relationship between livestock grazing and both vernal pool biota and hydrology, co-development of a model to predict riparian vegetation potential in dewatered stream reaches, and evaluation of habitat restoration potential via historical ecology. As a graduate student, Mr. Robins was involved in various research projects focused on competition between exotic-invasive and native flora.

Elizabeth Soderstrom (Ph.D., University of California at Berkeley, M.S. Stanford University) is a resource scientist who focuses on water resources. Dr. Soderstrom has extensive experience in water resources management in the international and domestic arenas. Until recently, she served as the lead position in water resources management at USAID's Regional Center for Southern Africa. She has received a Switzer Environmental Fellowship and a Science, Engineering and Diplomacy Fellowship for the American Association for the Advancement of Science.

McBain & Trush

Bill Trush (Ph. D. University of California, M.Sc. Virginia Tech, B.A. Penn State) is a river ecologist specializing in integrating fluvial geomorphic processes and river ecosystem processes. He is the director of the Institute of River Ecosystems and adjunct professor in the Fisheries Department at Humboldt State University. His recent interests include fish passage and routing through forested watersheds, instream flow needs in small watersheds, and process-based stream restoration.

Scott McBain (M.S. University of California at Berkeley, B.S. Humboldt State University) is a hydraulic engineer specializing in fluvial geomorphology, river restoration, and alternative management of regulated rivers. Mr. McBain prepared a report titled "A Spawning Gravel Database for the McCloud River" for his Senior Project in the Environmental Resources Engineering Department undergraduate program at Humboldt State. His recent interests include restoration approaches with a foundation in improved fluvial geomorphic processes, stream channel reconstruction, flow and gravel management on regulated rivers, and large watershed restoration planning and implementation.

John Bair (M. A., B.S. Humboldt State University) is a riparian botanist specializing in riparian interactions with geomorphic processes, riparian restoration, and riparian physiology. He completed his Master of Science under Dr. John Sawyer studying riparian initiation and establishment processes on the Trinity River, a highly regulated river in northern California. His special interests include the effect of dams on riparian species and community structure.

Stillwater Sciences

Bruce Orr (Ph.D. University of California at Berkeley, B.A. University of California at Santa Barbara) is a Senior Ecologist and Principal at Stillwater Sciences. Dr. Orr has over 20 years experience in aquatic and terrestrial ecology of California and the western U.S. He has conducted numerous ecological investigations and restoration and mitigation design projects for river, wetland, and riparian systems in California, Oregon, Washington, and Montana. Dr. Orr is currently serving as project director for two CALFED funded projects in the Central Valley: Phase III of the Merced River Corridor Restoration Plan and Phase I of A Mechanistic Approach to Riparian Restoration in the San Joaquin Basin.

John Stella (M.S. University of California at Berkeley, B.A. Yale University) is a riparian ecologist at Stillwater Sciences. Mr. Stella specializes in the fields of riparian plant physiology and community ecology, and the geomorphologic, hydrologic, and nutrient dynamic processes that occur in riparian zones. During the development of the Merced River Corridor Restoration Plan, a project funded by CALFED and AFRP, he mapped vegetation and designed and conducted baseline evaluations of existing riparian vegetation conditions and processes on the lower Merced River. He has also managed stream restoration projects for several northern California agencies.

D. COST

D.1 Budget

The Natural Heritage Institute (NHI) will act as fiscal agent for this project. Co-applicants, Stillwater Sciences and McBain and Trush, will invoice NHI for services completed under line items in the budget. NHI's overhead costs include costs associated with general office requirements (e.g., rent; computer hardware, software, and usage; corporate insurance; utilities, furniture, and supplies) as well as unbillable labor of support staff. NHI will employ a two-part overhead compensation package that will include: (1) a regular overhead rate of 25% on NHI billable staff time and expenses and all non-co-applicant subcontracting; and (2) a reduced overhead rate of 10% for all co-applicant invoices. In addition to the summary budget provided on Form VI and the budget justification Form VII of the electronically submitted forms, we have provided more detailed project budgets for co-applicants, Stillwater Sciences and McBain and Trush (**Tables 10.0-10.2**). These budget compliment the electronically submitted budget information and provide essential information for understanding the large consultant/services budgets on Form VI.

D.2 Cost-sharing

Significant cost-sharing is incorporated into this proposal because it builds directly upon past and ongoing projects conducted by Project Team members on the Tuolumne River, Merced River, San Joaquin River, and Clear Creek.

E. LOCAL INVOLVEMENT

Table 1 lists all the study reaches and the existing relationships with local landowners. The project team will coordinate with the Tuolumne River Technical Advisory Committee and the Merced River Technical Advisory Committee. and. Our research will also be coordinated with the ongoing Merced River Corridor Restoration Plan project, jointly conducted by Stillwater Sciences and Merced County, and partially funded in 1998 by CALFED and the U.S. Fish and Wildlife Service's Anadromous Fisheries Restoration Plan (AFRP) and the San Joaquin River Riparian Habitat Restoration Program, of which the Natural Heritage Institute is involved in technical oversight.

The project team has contacted the Cosumnes Science Consortium to coordinate study design, data collection, and analysis on its Cosumnes River research. We have also contact the Nature Conservancy regarding coordination with the Sacramento River Corridor Program. Ongoing coordination will occur through data exchange and mutual study plan review, informal meetings, and field visits.

McBain and Trush has a long standing relationship with stakeholders in Clear Creek and research along this creek will be coordinated to compliment existing data collection efforts.

F. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

The applicants have reviewed and are able to comply with the terms and conditions set forth in Attachments D and E of the Proposal Solicitation Package.

G. LITERATURE CITED

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Appendix A: Tables and Figures

Table 1. Potential study reaches where intensive study sites will be established. Study sites will be located as to maximize past data collection efforts by project team members and coordinating agencies.

River	Reach	Direct project team experience	Project team coordination with other agencies
San Joaquin River	Gravelly Ford to Mendota Pool and/or Merced River to Vernalis	Cain, J. 1997, NHI 2001	US Bureau of Reclamation Friant Water Users Authority Natural Resources Defense Council
Merced River	Dredger Tailing Reach and/or Confluence Reach	Stillwater Sciences 2001a, 2001b, 2001c	Merced River Stakeholder Group Merced Irrigation District Merced County USFWS, CDFG (and AFRP Program)
Tuolumne River	Spawning Reach and/or Lower Sand-bedded Reach	McBain and Trush 1998 and 2000	Tuolumne and Modesto Irrigation Districts City and County of San Francisco USFWS, CDFG (and AFRP Program) Friends of the Tuolumne Tuolumne River Preservation Trust
Sacramento River	Red Bluff to Colusa	CALFED Bay-Dalta Program 2000 (McBain and Trush participation)	The Nature Conservancy (coordination on-going)
Clear Creek	Reading Bar to Confluence	McBain and Trush et al. 1999	US Bureau of Reclamation USBLM, USFWS, CDFG Western Shasta Resource Conservation District
Cosumnes River	Michigan Bar to Confluence		The Nature Conservancy (coordination on-going)

Table 2. Hydrogeomorphic Parameters Associated with Plants Species' Establishment Locations at the Snelling Site, Merced River (data from Stillwater Sciences 2001b).

Species	Elevation above baseflow[1] (ft)		Inundation duration (%)		Mean recurrence interval (yrs)[2]	
	n	mean±s.e.[3]	n[4]	mean±s.e.[3]	n[4]	mean±s.e.[3]
Silver maple (*Acer saccharinum*)	9	0.2±0.7	4	38.7±5.5	4	1.1±2.4
White alder (*Alnus rhombifolia)*	56	1.2±0.3	37	27.3±1.8	37	1.2±0.8
Button willow (*Cephalanthus occidentalis* var. *californicus)*	53	1.8±0.3	40	23.0±1.7	40	1.3±0.8
Oregon ash (*Fraxinus latifolia*)	99	3.0±0.2	89	16.3±1.2	89	3.1±0.5
Narrow-leaf willow (*Salix exigua*)	102	3.7±0.2	91	8.9±1.2	91	3.1±0.5
Arroyo willow (*Salix lasiolepis*)	39	3.8±0.3	39	12.6±1.8	39	2.4±0.8
Box elder (*Acer negundo*)	31	3.8±0.4	31	13.9±2.0	31	2.3±0.9
Fremont cottonwood (*Populus fremontii*)	9	4.4±0.7	9	7.7±3.7	9	2.6±1.6
Valley oak (*Quercus lobata)*	138	6.8±0.2	137	3.7±0.9	137	9.6±0.4
Edible fig *(Ficus carica)*	20	7.7±0.5	20	5.0±2.5	20	10.5±1.1
California buckeye (*Aesculus californica*)	26	7.9±0.4	26	0.4±2.2	26	12.9±0.9

[1] Baseflow on the Merced River was defined as 205 cfs (measured at Snelling), which was calculated as the average of the mean monthly flows for July, August and September for the post-New Exchequer period (1968 to present).

[2] Recurrence intervals are calculated based on annual peak flow data for the post-New Exchequer Dam period (1968-1999).

[3] Standard Error uses a pooled estimate of error variance.

[4] Sample sizes used for the inundation duration and recurrence interval analyses were different than elevation sample sizes for some species because the rating curve formulas used in the data analysis were too coarse at the low end of the elevation data set to resolve flows.

Table 3. GIS data available for the proposed study rivers.

River	Hydrology/Geomorphology		Vegetation	
	Digital data type	**Data source**	**Data type**	**Data source**
San Joaquin River	2-foot channel bathymetry and floodplain DTM	USCOE Comprehensive Study	~15 cover types (Hink and Ohmart 1984)	CDWR
Merced River	4 mapped geomorphic surfaces (active channel, current floodplain, former floodplain, terrace)	Stillwater Sciences	13 cover types (sensu Holland 1986)	Stillwater Sciences
Tuolumne River	5 inundation outlines from air photos (620, 1000, 3100, 5300, 8400 cfs)	Stillwater Sciences	22 vegetation series (Sawyer and Keeler-Wolf 1995)	McBain and Trush
Sacramento River	2-foot channel bathymetry and floodplain DTM	USCOE Comprehensive Study	riparian corridor maps	The Nature Conservancy
Clear Creek	2-foot contour DTM's for selected segments within floodway; bathymetry in a 2-mile project reach only	McBain and Trush	no digital data; 20 vegetation series documented in the field (Sawyer and Keeler-Wolf 1995)	McBain and Trush
Cosumnes River	flood inundation maps and water surface profiles for selected recurrence interval flows	USGS	unknown	The Nature Conservancy (potentially)

Table 4. List of preliminary Technical Advisory Committee members. The following scientists have been invited and have agreed to serve as TAC members and peer technical reviewers.

Name	Affiliation	Scientific and technical expertise
Dr. Todd Dawson	University of California at Berkeley	Plant Physiology
Dr. William Dietrich	University of California at Berkeley	Fluvial Geomorphology and Hydrology
Dr. Tom Dudley	U.S. Department of Agriculture	Invasive Riparian Flora
Dr. Steven Greco	University of California at Davis	Remote Sensing and Modeling
Dr. Mathias Kondolf	University of California at Berkeley	Fluvial Geomorphology and Hydrology
Dr. Joseph McBride	University of California at Berkeley	Riparian Plant Ecology
Dr. Stewart Rood	University of Lethbridge, Alberta	Plant Physiology and Ecophysiology
Dr. Juliet Stromberg	Arizona State University	Riparian Plant Ecology

Table 5. Areas of task overlap which increase overall project efficiency.

Task Number	Line item	Overlap with relevant tasks
Task 2a	Site reconnaissance	Tasks 3a, 3b, 3c, 4a, 4b, 5a
Task 2b	Peizometer installation and groundwater and stream stage monitoring	Tasks 3b, 3c, 4a, and 5a
Task 2c	Survey channel and floodplain cross sections	Tasks 3b, 3c, 4a and 5a
Task 2d	Vegetation transects	Tasks 3c, 4a and 5a
Task 3a	Seed release phenology	Tasks 3c and 4a
Task 3b	Surface/groundwater analysis	Tasks 4a, 4b, and 5a
Task 3c	Recruitment surveys	Tasks 4a, 5a
Task 4a	Stream stage hydraulic modeling	Tasks 3b, 3c, 4b, and 5a
Task 5a	Site-based digital terrain model	Tasks 3b, 3c, and 4a
Task 5b	GIS vegetation and geomorphic mapping	Tasks 5a

Table 6. Expected products and outcomes for each project task.

Task	Products and Outcomes
Task 1.	Refined study plan and technical notes
Task 2.	Elevation plots for cross sections at each study site.
Task 3a.	Phenologies for the study species; a technical memorandum/manuscript evaluating relationships of climatic factors and seed dispersal and the effectiveness of using a degree-day model to explain the variability in peak seed dispersal timing for applicable species.
Task 3b.	A technical memorandum/manuscript describing the relationship of surface water to groundwater dynamics within a variety of substrates and floodplain morphologies.
Task 3c.	A technical memorandum/manuscript describing the role of groundwater dynamics on seedling establishment and survival for a range of native and non-native invasive species.
Task 4a.	A technical memorandum/manuscript relating position of mature vegetation within the riparian zone to site-based hydrogeomorphic parameters and assessing their appropriateness for use across landscape scales and river systems.
Task 4b.	A technical memorandum/manuscript describing the range of variability in stable isotope signatures across river basins and differences between riparian tree species in source water use, water use efficiency, and long-term carbon assimilation.
Task 5a.	A technical memorandum/manuscript evaluating the feasibility and data needs for modeling vegetation response to environmental factors using a site-based, digital elevation model (DEM) approach; DEM files of model sites.
Task 5b.	A technical memorandum/manuscript assessing the potential of scaling up site-based study parameters to reach-scale spatial models that relate landscape vegetation patterns to hydrogeomorphic conditions (e.g. landforms or areas of hydrologic similarity), and the applicability of these models to corridor planning and restoration efforts.

Table 7. Work Schedule

Task	Year 1												Year 2												Year 3											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Task 1: TAC workshop and review																																				
1a. Convene a workshop of scientific advisors	2-day workshop in Jan. 2003																																			
1b Refine work plan			Workplan completed																																	
1c TAC review of work products																																				
Task 2. Site Reconnaissance, Device Installation and Basleine Data Collection																																				
field reconnassaince				8 study site selected																																
install pressure transducers and staff gauge		Pressure transducers and staff gauges installed																																		
install piezometers						Piezometers installed																														
topographic surveys					Total-Station surveys completed																															
vegetation surveys							Vegetation surveys completed																													
soil and stratigraphy surveys			Soil properties and stratigraphy completed																																	
data entery and QA/QC								Basic site topo maps completed																												
Task 3. Mechanistic investigation of pioneer species establishment from seedling to maturity																																				
3a. Using climatic variables to predict seed release timing in the Central Valley																																				
site setup (install temp sensors, seed catchers etc.)			Sub-sample plots established																																	
phenology development, data collection																										Data collection effort completed by July 2005										
peak seed dispersal, data collection																												Data collection effort complete								
test preliminary degree day model																														Trial run complete						
refine degree day model																																	Degree day model			
temperature, relative humidity, seed dispersal, and phenology analysis and annual report																															Annual reports and final manuscript					
3b. Development of substrate specific groundwater decline models																																				
substrate analyses				Stratigraphy maps and soil analysis complete																																
collect data from transducers																																				
data analysis and write-up									Annual research summary											Annual research summary													Manuscript produced			
3c. Development of a hydrologic model to predict seedling-sapling cohort composition and survivorship																																				
collect piezometer data																																				
collect seedling/sapling data																																				
data analysis and write-up									Annual research summary											Annual research summary													Manuscript produced			

Table 7. Work Schedule

	Year 1												Year 2												Year 3											
Task	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**
Task 4: Developing Hydrogeomorphic and Ecophysiological Indicators to Predict Establishment Location of Mature Trees and Longer-term Vegetation Dynamics																																				
4a. Forensic analysis of existing riparian stands to relate current species occurrence to one or more hydrogeomorphic measures																																				
aerial photo analysis																																				
tree coring (field work)																																				
tree ring analysis																																				
hydraulic model and rating curve calculation																																				
data integration																																				
vegetation data analysis																																				
4b. Develop indicators of longer-term (growing season) plant source waters, water use efficiency and physiological stress																																				
sample collection									Samples collected monthly for one year																											
sample processing																																				
data entry, QC, analysis																											Analyses completed									
4c. Draft manuscript																														Manuscript produced						
Task 5:Extrapolation from Site-Specific Intensive Studies to Corridor-Scale Planning																																				
5a. Spatially explicit vegetation response model.																																				
collating/assembling GIS data*							Initial data exploration complete																		Integration of field data and GIS											
CALFED deliverables																																	GIS data files			
5b. Applying the site-specific model across an entire river corridor																																				
collating/assembling GIS data*							Initial data exploration complete																													
generating derived thematic maps**																									Integration of field data and GIS											
CALFED deliverables***																																	GIS data files			
5c. Draft manuscript and project team coordination																														Manuscript produced						
6. Project Management				Quarterly reports, annual reports, presentations, talks, and coordination																Quarterly reports, annual reports, presentations, talks, and coordination																

Table 8.0. Multiregion Priorities relationship to proposed subhypothesis

	Hyopthesis number and Task						
	#1 Task 3a	#2 Task 3b	#3 Task 3c	#4 Task 4a	#5 Task 4b	#6 Task 5a	#7 Task 5b
Priority 1: Prevent the establishment of additional non-native species and reduce the negative biological, economic and social impacts of established non-native species in the Bay-Delta estuary							
Prevention	**X**	**X**	**X**	**X**	**X**	**X**	**X**
NIS control and eradication projects	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Reducing Impacts		**X**	**X**	**X**		**X**	**X**
Nonnative invasive species surveys and studies	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Initiate a comprehensive system wide annual survey							
Support a cost benefit analysis of eradication			**X**			**X**	**X**
Hydrilla eradication							
Zebra Mussel eradication							
Build on existing CALFED loosestrife mapping							
Work with indurstry and stakeholders							
Develop cost/benefit risk evaluations for biocontrol agents							
Implement NIS detection, monitoring and control programs	**X**					**X**	**X**
Investigate the use of multispecies assessment and mapping methods							
Assess NIS biology	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Develop and evaluate integrated methods of NIS control							
Assess success and impacts of control efforts	**X**	**X**	**X**				
Develop aggressive public information program							
Invesigate the use of imported baits							
Priority 4: Ensure restoration and water management actions through all regions can be sustained under future climatic conditions.							
Climatic and hydrologic variability	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 5: Ensure that restoration is not threatened by degraded environmental water							
DO and Oxygen depleting substances							
Mercury							
Pesticides							
Selenium							
Other pollutants							
Pollutant effects							
Fine sediment (sedimentation)			**X**			**X**	**X**
Toxicity of unknown origin							
Priority 6: Ensure recovery of at risk species by developing conceptual understanding and models that cross multiple regions.							
Salmonid studies integrated across the system							
Knowledge for conceptual models that illustrate linkages within the systems	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Develop performance measures	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Table 8.1. Sacramento River Region Priorities relationship to proposed subhypothesis

	Hyopthesis number and Task						
	#1 Task 3a	#2 Task 3b	#3 Task 3c	#4 Task 4a	#5 Task 4b	#6 Task 5a	#7 Task 5b
Priority 1: Develop and implement habitat management and restoration actions in collaboration with local groups such as the Sacramento River Conservation Area Non-profit Organization.							
Riparian habitat and channel meander	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Sutter bypass							
Protect and manage gabbro-soil chapparral habitat							
Evaluate restoration in the Sacramento River Corridor	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 2: Restore fish habitat and fish passage, particularly for spring-run Chinook and steelhead trout, and conduct passage studies.							
Replenish spawning gravel							
Monitor and reduce fine sediment loads			**X**			**X**	**X**
Facilities improvments and fish passage programs							
Monitor passage flow							
Fish stranding studies							
Priority 3: Conduct adaptive management experiments in regard to natural and modified flow regimes to promote ecosystem functions or otherwise supports restoration actions.							
Mechanistic models as restoration tools	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Instream flow programs							
Effects of managed flow fluctuations	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 4: Restore geomorphic processes in stream and riparian corridors.							
Riparian vegetation research project	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Natural floodplains and flood processes	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 5: Implement actions to prevent, control, and reduce impacts of non-native invasive species in the region							
Manage *Arundo donax* and *Tamarix* spp.	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Support investigation and evaluation	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Prioirity 7: Develop conceptual models to support restoration of river, stream, and riparian habitat.							
Compare conceptual models and develop restoration performance measures for tributary streams and rivers	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Annual population estimates							
Understand and compare salmon/steelhead life histories, needs, responses to restoration							
Genetic assessments							
Juvenile life history requirements							
Implications of mine wastes for restoration							
Pilot projects for mine waste control							
Pesticides							
Develop research and pilot/demonstration projects							
Knowledge for conceptual models that illustrate linkages within the systems							
Analyze historic data							

Table 8.2. San Joaquin River Region Priorities relationship to proposed subhypothesis

	Hyopthesis number and Task						
	#1 Task 3a	#2 Task 3b	#3 Task 3c	#4 Task 4a	#5 Task 4b	#6 Task 5a	#7 Task 5b
Priority 1: Continue habitat restoration actions including channel-floodplain reconstruction projects and habitat restoration studies in collaboration with local groups.							
Channel floodplain reconstruction projects	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Gravel augmentation projects							
Non-native invasive species	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Riparian and riverine aquatic habitat restoration and research	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 2: Restore geomorphic processes in stream and riparian corridors.							
Hydrologic and sediment transport models as restoration tools for the mainstem San Joaquin River and its tributaries below Friant	**X**	**X**	**X**	**X**	**X**	**X**	**X**
San Joaquin floodplain evaluation		**X**	**X**	**X**	**X**	**X**	**X**
Biological value of floodplain habitats		**X**		**X**	**X**		
Priority 4: Implement actions to improve understanding of at-risk species in the region.							
Resource assessments and monitoring programs	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Salmonid life history studies							
Protect and better understand at-risk species in the region		**X**	**X**	**X**	**X**	**X**	**X**
Other at-risk species life history studies	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 6: Conduct adaptive management experiments in regard to natural and modified flow regimes to promote ecosystem functions or otherwise supports restoration actions.							
Mechanistic models as restoration tools	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Instream flow programs							
Effects of managed flow fluctuations	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Table 8.3. Delta Region Priorities relationship to proposed project hypotheses

	Hyopthesis number and Task						
	#1 Task 3a	#2 Task 3b	#3 Task 3c	#4 Task 4a	#5 Task 4b	#6 Task 5a	#7 Task 5b
Priority 1: Restore habitat corridors in the North Delta, East Delta and San Joaquin River.							
North Delta habitat corridor				**X**		**X**	**X**
East Delta habitat corridor				**X**		**X**	**X**
San Joaquin River				**X**		**X**	**X**
Restore tidal marsh and mid-channel island littoral zone (shoreline, marsh and shallow water) habitats in the central and west Delta							
Acquire, protect and restore habitat				**X**		**X**	**X**
Restore inland dune scrub habitat							
Priority 2: Restore and rehabilitate floodplain habitat in eastside tributaries and the lower Sacramento and San Joaquin rivers.							
Improve floodplain habitat	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Floodplain management plans and actions	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Yolo bypass		**X**	**X**	**X**	**X**	**X**	**X**
Priority 4: Restore habitat that would specifically benefit one or more at-risk species; improve knowledge of optimal strategies for these species.							
Adaptive experimentation with species specific restoration approaches	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Restoration of Sacramento splittail and Delta smelt							
Life histories and restoration or habitat requirements of at-risk species	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Changes in species abundance on a landscape basis				**X**		**X**	**X**
Priority 5: Implement actions to prevent, control, and reduce impacts of non-native invasive species in the Delta.							
Support the formation of a Delta wide multi county interagency co-ordinating council							
Develop pilot projects							
Research	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Document the distribution and abundance of *Corbicula fluminea*							
Revaluate the relationship between DO and *Egeria densa*							
Response of NIS	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Methods for NIS							
NIS education							
Mechanistic understanding	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Priority 8: Ensure restoration and water management actions through all regions can be sustained under future climatic conditions.							
Studies to better understand climatic variability	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Table 9. Previous receipt of CALFED or CVPIA funding

Organization*	Project title	Project Number	Current status	Project milestones
CALFED funded projects				
Natural Heritage Institute (p), McBain and Trush (s)	Focused action to develop ecologically-based hydrologic models and water management strategies in the San Joaquin Basin	ERP/ #99-B166	in progress	(1) completed Indicators of Hydrologic Alteration (IHA) analysis on the Tuolumne, Stanislaus, Merced, and San Joaquin; (2) completed Hydrograph Component analysis (HCA) on the Tuolumne, Stanislaus, Merced, and San Joaquin.
Natural Heritage Institute (p)	Inundation of a section of the Yolo Bypass to restore Sacramento splittail and to support a suite of other anadromous and native species in dry years	ERP/ #99-B189	in progress (1 yr extension)	(1) completed inventories of existing information, conditions and constraints; (2) developed and analyzed project alternatives; (3) completed detailed design of final alternative
Natural Heritage Institute (p)	Marsh Creek Watershed Stewardship Project	ERP/ #01-N32	in progress	(1) completed inventories of historic and existing conditions (2) implemented high school student run water quality monitoring program
Stillwater Sciences (p), McBain and Trush (s)	Merced River Corridor Restoration Plan-Phase II	ERP/ #98E-09	complete	(1) social, institutional, and infra-structural opportunities and constraints to restoration analysis; (2) baseline evaluations of geo-morphic and riparian vegetation conditions
Stillwater Sciences (p), McBain and Trush (s)	Merced River Corridor Restoration Project-Phase III	ERP/ #2000 E-05	in progress	development of (1) geomorphically functional channel and flood-plain design guidelines; (2) the Merced River Corridor Restoration Plan; (3) conceptual designs for 5 top-priority restoration projects

Table 9. Previous receipt of CALFED or CVPIA funding (continued)

Organization*	Project title	Project Number	Current status	Project milestones
CALFED funded projects				
Stillwater Sciences (p)	A Mechanistic Approach to Riparian Restoration in the San Joaquin Basin	ERP/#99-B152	starting-up/in progress	(1) literature and existing data review; (2) development of conceptual model and study plan
Stillwater Sciences (s)	Tuolumne River Coarse Sediment Management Plan	Service Agreement #010801	in progress	(1) fine sediment report; EACH and stock recruitment modeling underway
Stillwater Sciences (s)	M&T Ranch Pump Intake Assessment	Contract 01A120210 D	complete	developed mitigating techniques for sediment burial of pump intake
Stillwater Sciences (s)	Saeltzer Dam Removal Analysis	Contract B-81491	complete	(1) application of sediment transport model to a dam removal project; (2) pre- and post-dam removal channel monitoring
McBain and Trush (s)	Tuolumne River channel restoration (Spec Run Pool 9).	H134	design and permitting complete, under construction	(1) evaluated and assisted in geomorphic and riparian revegetation designs for filling instream gravel mining pits and constructing ecologically functional floodplains. (2) assist in environmental permitting (3) developed and implemented fisheries monitoring program
McBain and Trush (s)	Tuolumne River setback levees and channel restoration	H136	design and permitting complete, under construction	(1) evaluated and assisted in geomorphic and riparian revegetation designs for levee setbacks and functional floodplain construction. (2) assist in environmental permitting (3) developed and implemented fisheries monitoring program
McBain and Trush (s)	Grayson River Ranch perpetual easement and restoration	ERP/ #98-C1003	project complete	(1) evaluated and assisted in geomorphic and riparian revegetation designs for restoration of a frequently inundated agricultural field to a functional floodplain

Table 9. Previous receipt of CALFED or CVPIA funding (continued)

Organization*	Project title	Project Number	Current status	Project milestones
CALFED funded projects				
McBain and Trush (s)	Lower Clear Creek floodway restoration project	ERP/ #98-C1024	permitting complete. Phase 1and 2a complete; Phase 2b under construction	(1) completed geomorphic and riparian revegetation designs for filling instream gravel mining pits and constructing ecologically functional floodplains. (2) assisted in environmental permitting (3) developed geomorphic and revegetation monitoring programs
McBain and Trush (s)	Tuolumne River restoration: Special Run Pool 10	ERP/ #01-B201	design and permitting complete, under construction	(1) evaluated and assisted in geomorphic and riparian revegetation designs for filling instream gravel mining pits and constructing ecologically functional floodplains. (2) assist in environmental permitting (3) developed and implemented fisheries monitoring program
McBain and Trush (s)	Tuolumne River Fine Sediment Management	ERP/ #01-C208	starting-up/in progress	(1) design and construct fine sediment basin (2) design and construct Gasburg Creek restoration (3) watershed assessments of fine sediment sources in three tributaries

Table 9. Previous receipt of CALFED or CVPIA funding (continued)

Organization*	Project title	Project Number	Current status	Project milestones
CVPIA funded projects				
Stillwater Sciences (p)	Merced River Corridor Restoration Plan-Phase I	AFRP	complete	formation of the Merced River Stakeholder Group and Technical Advisory Committee
Stillwater Sciences (p)	Merced River: Ratzlaff Project	AFRP/CVPIA 11332-9-MO79	complete	provide comments on existing and proposed restoration efforts; coordinate with Merced River Restoration Project
Stillwater Sciences (p)	Stanislaus River: 2 Mile Bar	AFRP/CVPIA 11332-9-MO80	complete	prepare summary of restoration potential and strategies, focusing on geomorphic opportunities and constraints
Stillwater Sciences (p)	Stanislaus River: Smolt Survival	AFRP/CVPIA 11332-0-MO09	complete	prepare assessment of coded wire tag and multiple mark-recovery smolt survival assessment programs
Stillwater Sciences (p)	Calaveras River Spawning Habitat Evaluation	AFRP	complete	conduct reconnaissance-level evaluation of steelhead and salmon habitat conditions and population dynamics
Stillwater Sciences (p)	Calaveras Salmonid Limiting Factors Study	AFRP/CVPIA 11332-1-GO06	starting-up/in progress	reconnaissance surveys are underway.
McBain and Trush (s)	Tuolumne River mining reach restoration project no. 3 Warner-Deardorff Segment	CVPIA 2001-C209	permitting complete, 30%design complete	(1) evaluate and assist in geomorphic and riparian revegetation designs for levee setbacks and functional floodplain construction. (2) assist in environmental permitting (3) developed and implemented fisheries monitoring program

* (p)=primary contractor and (s)=sub contractor

Table 10.0. Form VI Summary for McBain & Trush

	Direct Hours	Salary	Benefits	Travel	Supplies & Expendibles	Services / Consultants	Other Direct Costs	Total Direct Costs	Indirect Costs	Total Costs
Year 1										
1a. Convene a workshop of scientific advisors	40	$ 2,000	$ -	$ 438	$ -	$ -	$ -	$ 2,438	$ -	$ 2,438
1b. Refine work plan	40	$ 2,000	$ -	$ -	$ -	$ -	$ -	$ 2,000	$ -	$ 2,000
Total cost Task 1 Year 1	**80**	**$ 4,000**	**$ -**	**$ 438**	**$ -**	**$ -**	**$ -**	**$ 4,438**	**$ -**	**$ 4,438**
2a. site reconaissance	64	$ 3,200		$ 1,200	$ -	$ -	$ -	$ 4,400		$ 4,400
Total cost Task 2 Year 1	**64**	**$ 3,200**	**$ -**	**$ 1,200**	**$ -**	**$ -**	**$ -**	**$ 4,400**	**$ -**	**$ 4,400**
3a. Degree-day										
Site setup (install temp sensors, seed catchers etc.)	272	$ 13,600	$ -	$ 3,850	$ 12,600	$ -	$ -	$ 30,050	$ -	$ 30,050
Phenology development, data collection	544	$ 27,200	$ -	$ 13,460		$ -	$ -	$ 40,660	$ -	$ 40,660
Peak seed dispersal, data collection	96	$ 4,800	$ -		$ 500	$ -	$ -	$ 5,300	$ -	$ 5,300
Temperature, relative humidity, seed dispersal, and phenology analysis and annual report	145	$ 7,250	$ -	$ -	$ -	$ -	$ -	$ 7,250	$ -	$ 7,250
Total cost Task 3 Year 1	**1057**	**$ 52,850**	**$ -**	**$ 17,310**	**$ 13,100**	**$ -**	**$ -**	**$ 83,260**	**$ -**	**$ 83,260**
Year 2										
3a. Degree-day							$ -			
Phenology development, data collection	272	$ 13,600	$ -	$ 6,730	$ 500	$ 800	$ -	$ 21,630	$ -	$ 21,630
Peak seed dispersal, data collection	48	$ 2,400	$ -	$ -	$ 500	$ 800	$ -	$ 3,700	$ -	$ 3,700
Preliminary degree day model development	160	$ 8,000	$ -	$ -	$ -	$ -	$ -	$ 8,000	$ -	$ 8,000
Temperature, relative humidity, seed dispersal, and phenology analysis and annual report	145	$ 7,250	$ -	$ -	$ -	$ -	$ -	$ 7,250	$ -	$ 7,250
Total cost Task 3 Year 2	**625**	**$ 31,250**	**$ -**	**$ 6,730**	**$ 1,000**	**$ 1,600**	**$ -**	**$ 40,580**	**$ -**	**$ 40,580**
Year 3										
3a. Degree-day										
Phenology development, data collection	272	$ 14,960	$ -	$ -	$ 500	$ 800	$ -	$ 16,260	$ -	$ 16,260
Peak seed dispersal, data collection	48	$ 2,640	$ -	$ -	$ 500	$ 800	$ -	$ 3,940	$ -	$ 3,940
Test preliminary degree day model	216	$ 11,880	$ -	$ 6,775	$ -	$ -	$ -	$ 18,655	$ -	$ 18,655
Refine degree day model	160	$ 8,800	$ -	$ -	$ -	$ -	$ -	$ 8,800	$ -	$ 8,800
Temperature, relative humidity, seed dispersal, and phenology analysis and final report	180	$ 9,900	$ -	$ -	$ -	$ -	$ -	$ 9,900	$ -	$ 9,900
Total cost Task 3 Year 3	**876**	**$ 48,180**	**$ -**	**$ 6,775**	**$ 1,000**	**$ 1,600**	**$ -**	**$ 57,555**	**$ -**	**$ 57,555**

Table 10.1. Form VI Summary for Stillwater Sciences

Year 1	Direct Labor Hours	Salary	Benefits	Travel	Supplies & Expendables	Services / Consultants	Equipment	Other Direct Costs	Total Direct Costs	Indirect Costs	Total Costs
1a. Convene a workshop of scientific advisors	195	$ 5,853	$ 1,977	$ 100	$ 500	$ -	$ -	$ 271	$ 8,700	$ 9,312	$ 18,012
1b Refine work plan	80	$ 2,491	$ 841	$ -	$ -	$ -	$ -	$ 140	$ 3,472	$ 3,939	$ 7,411
1c TAC review of work products		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total cost Task 1 Year 1	**275**	**$ 8,344**	**$ 2,818**	**$ 100**	**$ 500**	**$ -**	**$ -**	**$ 411**	**$ 12,172**	**$ 13,251**	**$ 25,423**
2a Site reconnaissance	350	$ 11,826	$ 3,994	$ 2,000	$ 500	$ 6,000	$ -	$ 490	$ 24,810	$ 19,537	$ 44,347
2b Install water pressure transducers (PT) and peizometers (PZ)	640	$ 14,489	$ 4,893	$ 5,840	$ -	$ -	$ -	$ 1,120	$ 26,341	$ 26,787	$ 53,128
2c topographic survey	1200	$ 26,122	$ 8,821	$ 14,240	$ 800	$ -	$ -	$ 2,104	$ 52,087	$ 42,883	$ 94,970
2d vegetation transect	480	$ 11,696	$ 3,950	$ 3,840	$ 800	$ -	$ -	$ 840	$ 21,126	$ 18,982	$ 40,108
2e survey and veg data entry and QA/QC	560	$ 11,084	$ 3,743	$ -	$ -	$ -	$ -	$ 984	$ 15,811	$ 17,567	$ 33,378
2f follow-up topo surveys (if necessary)		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total cost Task 2 Year 1	**3230**	**$ 75,216**	**$ 25,401**	**$ 25,920**	**$ 2,100**	**$ 6,000**	**$ -**	**$ 5,538**	**$ 140,175**	**$ 125,757**	**$ 265,932**
4a Forensic analysis	770	$ 21,537	$ 7,273	$ 182	$ 400	$ 2,400	$ -	$ 1,313	$ 33,105	$ 34,373	$ 67,478
4b Isotope indicators pilot study	359	$ 7,991	$ 2,699	$ 3,175	$ 1,175	$ 18,750	$ -	$ 608	$ 34,397	$ 14,965	$ 49,363
4c draft manuscript		$ -	$ -						$ -	$ -	$ -
Total cost Task 4 Year 1	**1129**	**$ 29,529**	**$ 9,972**	**$ 3,357**	**$ 1,575**	**$ 21,150**	**$ -**	**$ 1,920**	**$ 67,503**	**$ 49,339**	**$ 116,841**
5a Site-based vegetation prediction model	294	$ 9,925	$ 3,352	$ -	$ 450	$ 900	$ -	$ 210	$ 14,837	$ 15,799	$ 30,636
5b Reach-based GIS analysis and model	260	$ 8,349	$ 2,820	$ -	$ 200	$ 400	$ -	$ 84	$ 11,853	$ 13,228	$ 25,081
5c draft manuscript and project team coordination		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total cost Task 5 Year 1	**554**	**$ 18,275**	**$ 6,172**	**$ -**	**$ 650**	**$ 1,300**	**$ -**	**$ 294**	**$ 26,690**	**$ 29,027**	**$ 55,717**

Table 10.1. Form VI Summary for Stillwater Sciences (continued)

Year 2

2a Site reconnaissance		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2b Install water pressure transducers (PT) and peizometers (PZ)		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2c topographic survey		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2d vegetation transect		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2e survey and veg data entry and QA/QC		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2f follow-up topo surveys (if necessary)	300	$ 6,530	$ 2,205	$ -	$ -	$ -	$ -	$ 525	$ 9,261	$ 10,344	$ 19,605
Total cost Task 2 Year 1	**300**	**$ 6,530**	**$ 2,205**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 525**	**$ 9,261**	**$ 10,344**	**$ 19,605**

4a Forensic analysis	770	$ 21,537	$ 7,273	$ 182	$ 400	$ 2,400	$ -	$ 1,313	$ 33,105	$ 34,373	$ 67,478
4b Isotope indicators pilot study	359	$ 7,991	$ 2,699	$ 3,175	$ 1,175	$ 18,750	$ -	$ 608	$ 34,397	$ 14,965	$ 49,363
4c draft manuscript		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total cost Task 4 Year 1	**1129**	**$ 29,529**	**$ 9,972**	**$ 3,357**	**$ 1,575**	**$ 21,150**	**$ -**	**$ 1,920**	**$ 67,503**	**$ 49,339**	**$ 116,841**

5a Site-based vegetation prediction model	392	$ 13,234	$ 4,469	$ -	$ 600	$ 1,200	$ -	$ 280	$ 19,783	$ 21,065	$ 40,848
5b Reach-based GIS analysis and model	390	$ 12,524	$ 4,229	$ -	$ 300	$ 600	$ -	$ 126	$ 17,780	$ 19,841	$ 37,621
5c draft manuscript and project team coordination		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total cost Task 5 Year 1	**782**	**$ 25,758**	**$ 8,699**	**$ -**	**$ 900**	**$ 1,800**	**$ -**	**$ 406**	**$ 37,563**	**$ 40,907**	**$ 78,469**

Table 10.1. Form VI Summary for Stillwater Sciences (continued)

Year 3											
4a Forensic analysis		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4b Isotope indicators pilot study		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4c draft manuscript	344	$ 9,803	$ 3,310	$ -	$ -	$ -	$ -	$ 602	$ 13,715	$ 15,510	$ 29,225
Total cost Task 4 Year 1	**344**	**$ 9,803**	**$ 3,310**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 602**	**$ 13,715**	**$ 15,510**	**$ 29,225**

5a Site-based vegetation prediction model	294	$ 9,925	$ 3,352	$ -	$ 450	$ 900	$ -	$ 210	$ 14,837	$ 15,799	$ 30,636
5b Reach-based GIS analysis and model	650	$ 20,874	$ 7,049	$ -	$ 500	$ 1,000	$ -	$ 210	$ 29,633	$ 33,069	$ 62,702
5c draft manuscript and project team coordination	360	$ 11,516	$ 3,889	$ -	$ -	$ -	$ -	$ 350	$ 15,756	$ 18,185	$ 33,941
Total cost Task 5 Year 1	**1304**	**$ 42,315**	**$ 14,290**	**$ -**	**$ 950**	**$ 1,900**	**$ -**	**$ 770**	**$ 60,226**	**$ 67,053**	**$ 127,279**

Table 10.2. Stillwater Ecosystem, Watershed & Riverine Sciences Rate Sheet

STILLWATER ECOSYSTEM, WATERSHED & RIVERINE SCIENCES
2532 DURANT AVENUE, SUITE 201
BERKELEY CA 94704
PHONE (510) 848-8098 FAX (510) 848-8398

Name	Rate
Allen, Douglas	$95.19
Baker, Peter	$100.20
Bell, Ethan	$64.20
Braudrick, Christian	$70.68
Champe, Christine	$115.56
Cheang, Tom	$72.12
Cosio, Tamara	$42.00
Cui, Yantao	$141.18
Diggory, Zooey	$52.56
Dusek, Lauren	$43.50
Earl, Holly	$69.24
Fainter, Michael	$101.40
Falzone, Anthony	$63.00
Fanslow, Greg	$77.28
Fixler, Craig	$135.00
Greaves, Mary	$43.50
Hume, Noah	$108.24
Keith, AJ	$73.56
Khandwala, Sapna	$63.00
Kramer, Sharon	$123.36
Kramer, Steve	$84.60
Ligon, Frank	$134.16
Lopez, Christie	$62.04
Mason, Maureen	$39.00
Orr, Bruce	$123.60
Pedersen, Dirk	$80.28
Percival, Angela	$80.28
Real de Asua, Raf	$84.72
Reuter, Ron	$75.00
Simpson, Sabrina	$79.68
Sklar, Leonard	$116.88
Sparks, Whitney	$42.00
Stallman, Jay	$54.00
Stella, John	$75.36
Strauss, Emilie	$68.52
Trso, Martin	$81.96
Vick, Jennifer	$116.28
Wilcox, Scott	$129.84

Rates listed above are for calendar year 2001. This will be a labor-hour level-of-effort contract with reimbursement for expenses (including travel expenses) at cost plus 10%. Hourly rates will be adjusted on January 1st of each year. Computer usage will be charged on 25% of the hours invoiced, at $7.00 per hour.

Figure 1. General Riparian Conceptual Model. Left side: simplified conceptual model of the physical and biological linkages in riverine ecosystems. Right side: riparian vegetation life history stages (ovals) and processes (arrows). Processes in bold are subjects of investigation in this proposal.

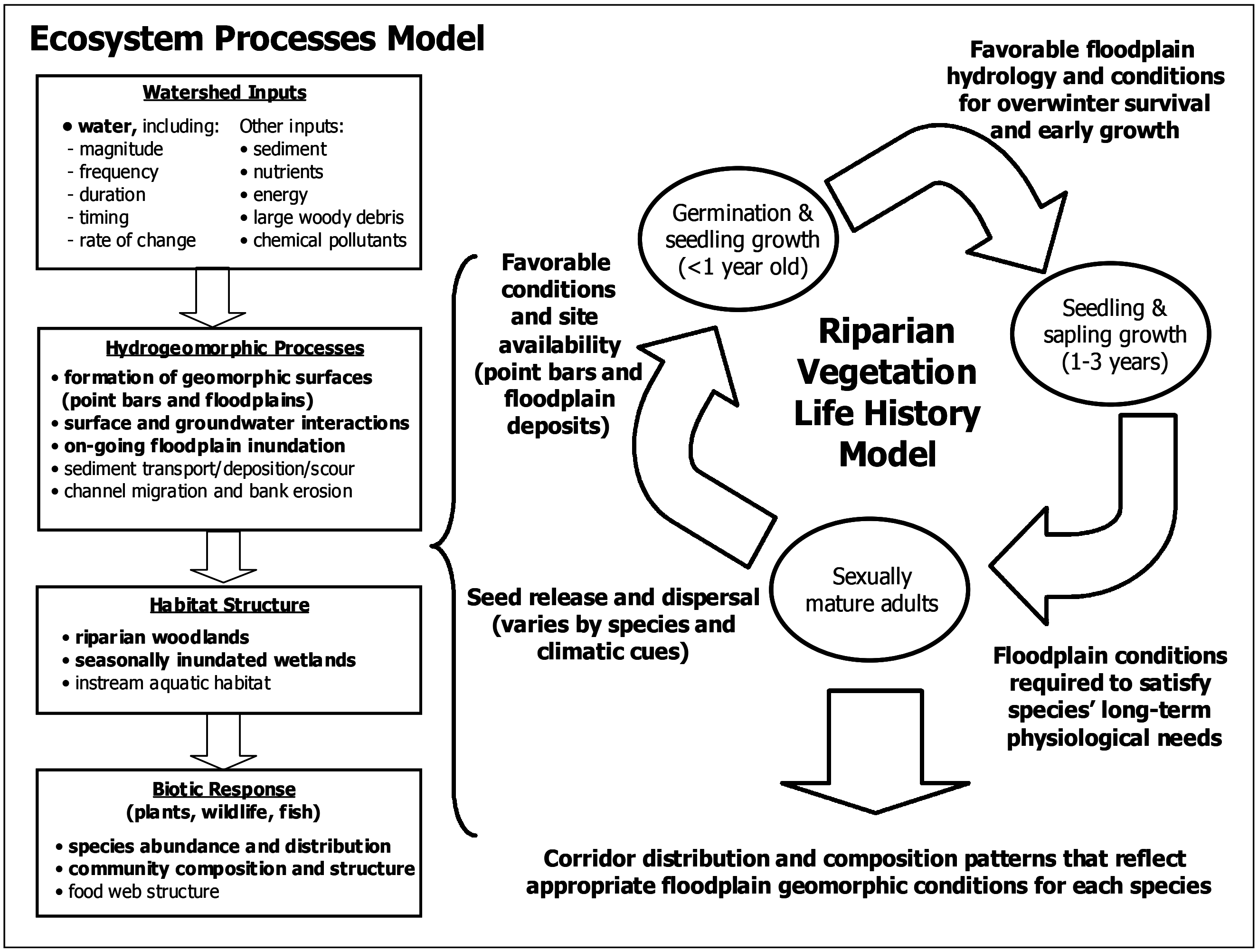

Figure 2. Conceptual cross section illustrating the relationship of sediment, channel migration and channel geomorphology to riparian stand development and fish habitat.

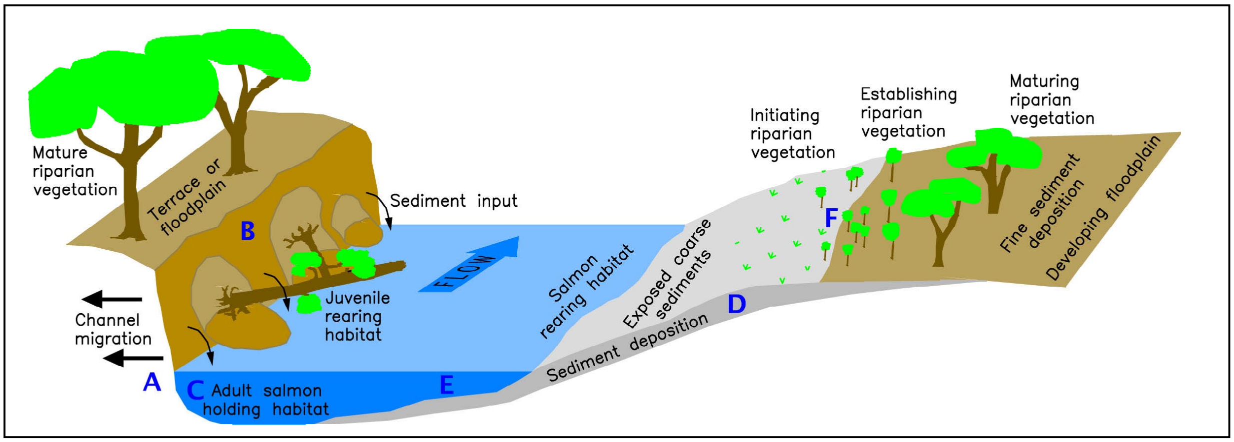

Figure 3. Preliminary general site sample design. The sampling design will be refined in coordination with the Technical Advisory Committee and subject to logistical and budgetary constraints.