Grand Canyon Monitoring and Research Center

FY 2001 Integrated Science Plan

Presentation for the Technical Work Group on Sept. 7, 1999

by

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Outline of Presentation

I. **Introduction**

- Adaptive management
- Monitoring and research - definitions

II. **Philosophy of Monitoring and Research**

- Philosophy of monitoring and research
- Role of long-term monitoring and research in the GCD adaptive management program

III. **Developing an Integrated Science Plan**

- Protocol evaluation program
- Schedule for developing all elements of the integrated long-term science plan

Outline of Presentation (con't.)

IV. **Integrated Science Plan**

- GCMRC integrated framework
- Conceptual Modeling
- Physical Resources
- Biological Resources
- Socio-cultural Resources
- Information Technologies
- Remote Sensing
- Logistics
- Independent Review Panels

Outline of Presentation (con't..)

V. **Budget**

- Bureau Support Services
- Personnel, Mgt. & Admin.
- Physical Resources
- Biological Resources
- Socio-cultural Resources
- Information Technologies
- Remote Sensing
- Independent Review Panels
- Logistics

Adaptive Management

- Begins with Vision, Goals, MOs and INs
- Monitoring for predicted ecosystem responses
- Plan future management actions/experiments around new knowledge
- Treats management actions (i.e., current dam operations, BHBFs, HMFs, SASF, TCD, etc.) as experiments
- Iterative science-based decision making
- Research cause and effect relationships
- Report evaluations of "the effects of the Secretary's Actions"

Monitoring and Research Definitions

- ***Monitoring*** - is the measurement of environmental attributes over an extended period of time (i.e., multi-generational) to determine status or trends in the environmental attribute being monitored.
- ***Research*** - is the measurement of an environmental attribute to test a specific hypothesis.

Note: *environmental attribute* is any biotic or abiotic feature of the environment which can be measured.

Philosophy of Monitoring and Research

- Linked to Goals, MOs & INs
- Based on relevant spatial and temporal scales
- Select key indicator components or processes
- Utilize consistent protocols and re-assessment
- Integrate across and within resource areas
- Funding is fixed for long-term monitoring
- Funding is flexible for research

Role of Long-Term Monitoring and Research in the GCD AMP

- Focus on prominent stressors and indicators
- Monitoring is multi-generational and built on a baseline
- Information used in ongoing synthesis
- Identifies range of variability
- Provides information to evaluate effects of management actions/experiment

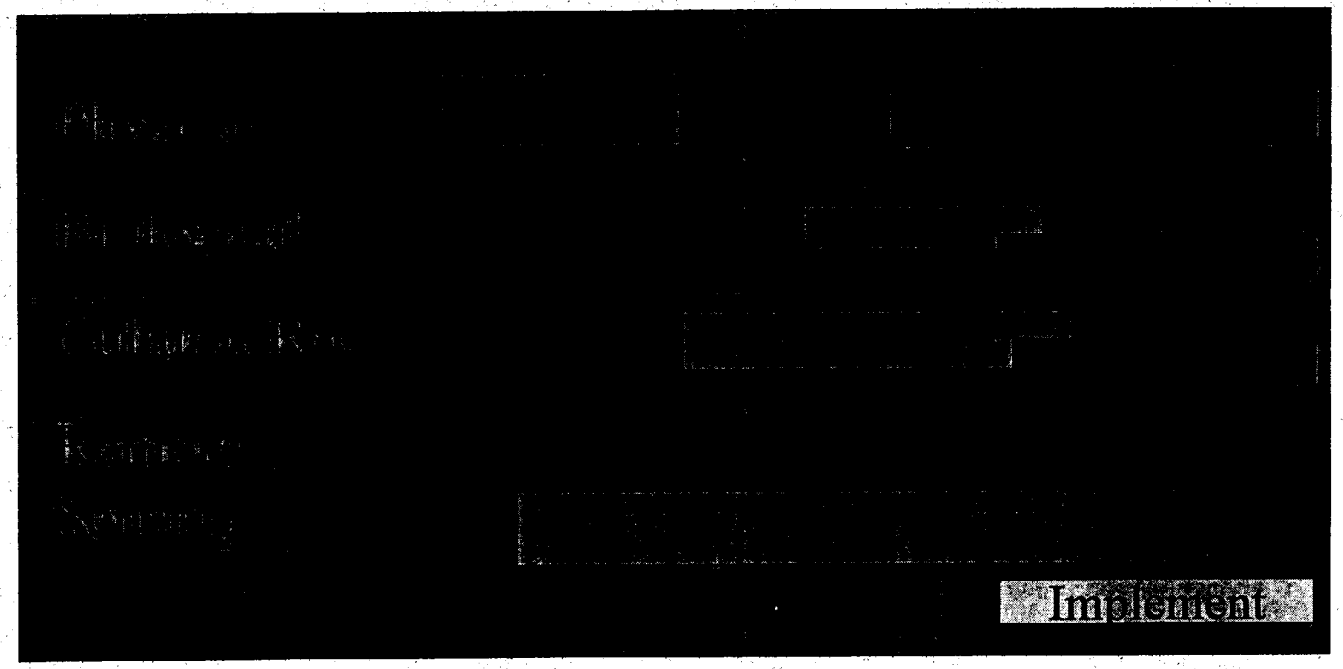
Protocols Evaluation Program (PEP)

- Begins with an articulation of MOs & INs
- Utilizes panel of independent external experts
- Systematic review of current protocols
- Scope alternatives to existing protocols
- Panel recommends protocols to be considered
- Testing of alternative protocols, as needed and appropriate
- Selection by GCMRC of protocols to implement

PEP/LTM Schedule

PEP

'98 '99 '00 '01 '02



Schedule for Developing Elements of Integrated Long-Term Science Plan

Physical Program - SEDS Workshops

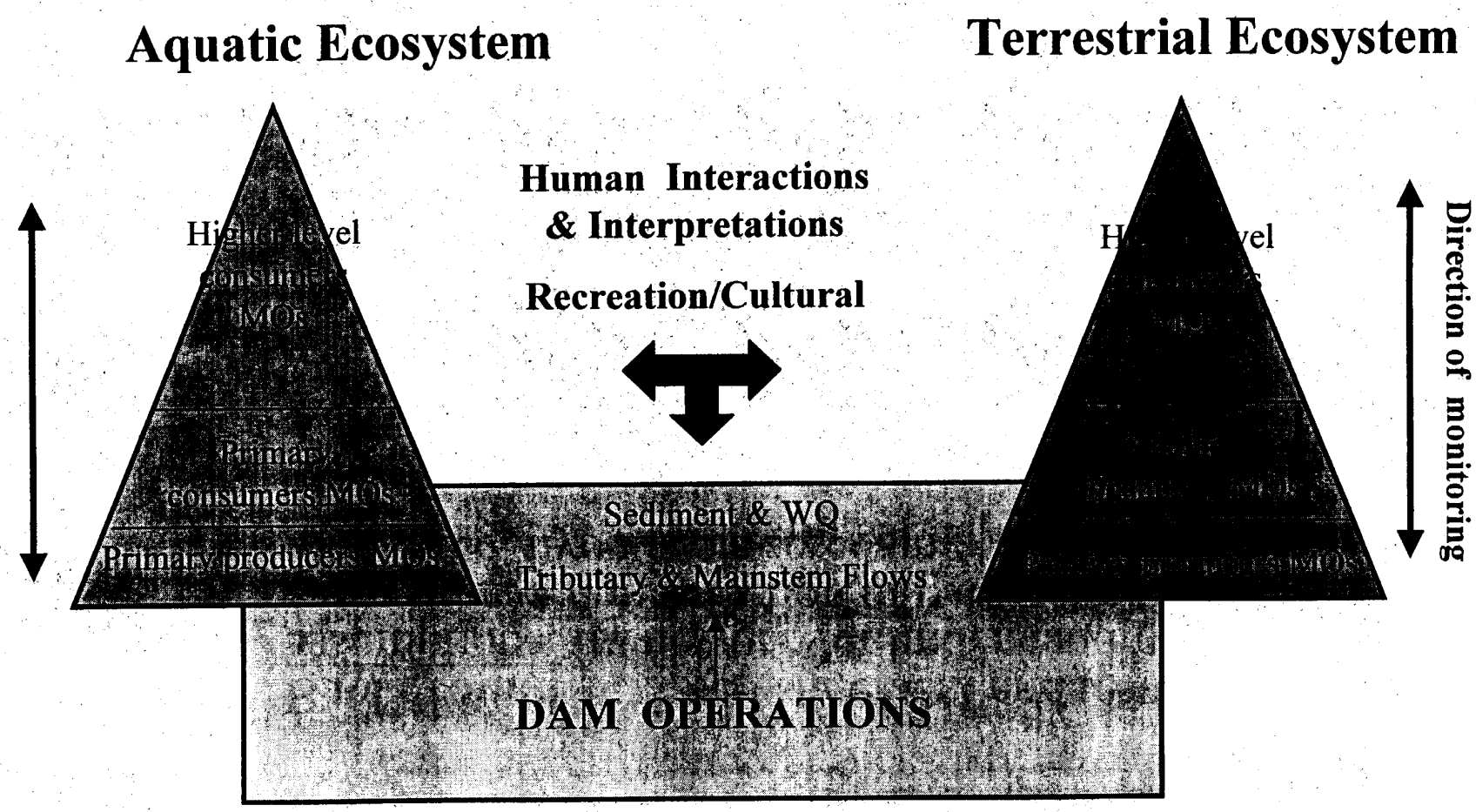
- PEP I - August 98
- PEP II - August 99
- PEP final report Oct. 1999
- Draft LTMP by Spring 2000
- LTMP guides RFPs in April 2000
- Implementation of LTMP in FY 2001
- PEP III - 2004 assesses LTMP effectiveness

Schedule for Developing Elements of Integrated Long-Term Science Plan

Remote Sensing - GARST Workshops

- PEP I - May 98
- PEP I report June 98
- Draft RS strategy document in FY 2000
- RS strategy guides FY 2000-02 testing
- Follow-on PEP workshops as needed
- Implementation of RS elements in FY 2001-03

Integrated Long-Term Science Program



Integrated monitoring and research based on MOs & INs

Conceptual Modeling

Background - explicit statement and testing of assumptions, framework for understanding ecosystem, aid in selection of parameters to be monitored, hypothesis screening

Activities -

- Vegetation trend analyses,
- Water quality linkages
- Ongoing geomorphic framework submodel
- Larval drift algorithm
- Advanced sediment budget
- Transition to in-house GCMRC support

Water and Sediment Resources

Current Knowledge -

- Fine Sediment Inputs - Residence time for main channel sand shorter than described in Final EIS
- Sediment Budgeting - Refine tracking of all sediment-size classes
- Sand Bar Morphology - Predictions of operations and sediment relative to habitat structure
- Long-Term Means - Difficult to manage on basis of means; need to manage "events"

MOs & INs - Water and Sediment Resources

- Dam Operations - Measure and report GCD flow releases relative to Record-of-Decision
- Positive Sediment Balance - Track sediment budget within context of historical synthesis results
- Monitor Sand Bars - Monitor bar responses w.r.t. changing sediment and streamflow
- Rebuild Sand Bars and Backwaters - Advise on magnitude and duration of BHBFs

Streamflow and Sediment Transport Monitoring

Linkages -

- Streamflow/sediment influences primary productivity through light attenuation during fine inputs
- Structures beaches (aquatic and terrestrial habitats)
- Nutrient budget influenced by inputs of organic carbon
- Influences camping beach availability
- In-situ preservation of cultural materials

Streamflow and Sediment Transport Monitoring (con't.)

Monitoring Activities - *FY 2001 and beyond*

- 15-min. streamflow data at 5 main channel and 2 tributaries
- Suspended and bed-sediment sampling, (daily to weekly) at 2-3 main channel and 2 tributaries
- Tracking of real-time fine inputs from flow-based models (Paria and LCR)
- Analyses for organic inputs
- Fine-sediment data for ungaged tributaries

Main Channel & Shoreline Sand Storage Monitoring

Objectives - tracking major component of fine-sediment budget system-wide

Linkages -

- Influences channel substrates (productivity)
- Aquatic and terrestrial habitats
- Sand deposition w.r.t. cultural materials
- Recreational campsite size and distribution

Monitoring Activities - (change detection)

- Bathymetry at index study reaches
- Terrestrial sand bar surveys at index sites
- Aerial overflights with system-wide coverage

Geomorphic Framework of Mainstem Monitoring

Objectives - track physical changes in the main channel caused by tributary debris flows and floods

Linkages -

- Influences primary productivity by structuring channel elements (aquatic and terrestrial habitats)
- Impacts to campsite availability and restoration

Monitoring Activities - (change detection)

- Field surveys to monitor impacts to main channel and tributary settings by debris flows
- Mapping mainstem for baseline conditions
- System-wide aerial overflights

Research Predicting Sand Bar Evolution

Objectives - reach-averaged responses of main-channel sand bars under varied operations and sediment conditions

Linkages -

- Structures aquatic and terrestrial habitats
- Related to camping beaches size and distribution
- Influences preservation of cultural sites

Research Activities - *"Empiricism & Modeling"*

- Predicted reach-by-reach responses
- Outputs based on actual channel topography
- Results are inputs for 1-D sand transport

Reach Averaged Sand Transport Research

Objectives - prediction of sand transport and export of sand storage from critical reaches following inputs

Linkages -

- Sand movement relates to conditions of storage
- Impacts on primary productivity
- Evolution of aquatic and terrestrial habitats
- Potential for campsite restoration

Research Activities - *"Empiricism & Modeling"*

- Coupling unsteady streamflow with 1-D sand transport under varied sand inputs
- Prediction of reach-averaged fine exports for actual and hypothetical dam operations
- Track sediment budget in real time for "events" after large sand inputs; measured vs. modeled

Research to Predict Channel Evolution

Objectives - predict the style of main channel changes likely to occur in specific channel settings, by reach

Linkages -

- Evolution of main channel morphology directly structures aquatic and terrestrial habitats
- Geometry of settings influences fine-sediment storage in ways uniquely related to dam operations

Research Activities - *"Advanced Simulations"*

- Based on reach physical habitat characteristics
- Long-term simulations to assess local and reach-average changes
- Link changes in physical habitat to aquatic and terrestrial habitat characteristics

Biological Resources

Current Knowledge

- KAS populations vary seasonally; Systematic relationships remain undefined.
- SWWF numbers do not appear to be affected by available habitat in Grand Canyon
- Reservoir and downstream water quality are linked and are effected by operations
- Aquatic foodbase is affected by operations and has benefited with MLFF
- Trout have benefited from IF and MLFF
- Genetics of HBC indicate that introgression has occurred and basin wide populations are not markedly different from each other.

Terrestrial Ecosystem

Management Objectives and Targeted Information Needs For FY2001

Protect, restore and enhance native and special status species.

- Define and specify ecology of native faunal component (IN 11.1).
- Determine species population characteristics to detect departures from natural range (IN 11.2).
- Identify and characterize riparian wildlife habitat types along the river corridor (IN11.4).

Vegetation/habitat monitoring

Objectives: Determining changes in community composition and structure

Linkages

- Traditional ethnobotanical resources,
- Avifaunal diversity,
- Terrestrial food base (insects),
- Camping beaches/recreation.

Monitoring Activities

- Aerial photography for vegetation mapping
- Community identification and change detection
- Evaluate remote sensing for habitat monitoring techniques
- Exotic species monitoring
- Document species occurrences - ethnobotanical inventories

Avifauna monitoring

Objectives: Determine bird community composition, occurrence and habitat requirements

Linkages:

- Vegetation resources
- Aquatic foodbase,
- Terrestrial foodbase
- Recreation

Monitoring Activities

- Seasonal surveys for waterfowl, migratory and nesting birds
- Vegetation community identification and structure
- SWWF monitoring

Kanab ambersnail monitoring

Objectives: Determine population status of KAS at Vaseys Paradise and translocated populations

Linkages

- Vegetation composition
- Available habitat
- Operations
- Recreation

Monitoring Activities:

- Surveys for snail population status
- Topographic survey of vegetation community area
- Logistic support for downstream population surveys

Aquatic Ecosystem

Management Objectives and Targeted Information Needs For FY2001

Protect, restore and enhance fish populations in Glen and Grand Canyons, and the foodbase upon which they depend.

- Determine the status and trends in foodbase composition, structure, density and distribution (IN 1.1).
- Determine foodbase composition…required to maintain fish populations (IN 1.2/2.7).
- Determine trends in fish population size... (IN 2.2, 2.5, 3/4.1-2, 8.1, 10.4).
- Determine availability and quality of spawning substrates in Glen Canyon (IN 2.4).

Water quality monitoring

Objectives Determine changes in parameters of water quality that effect downstream resources

Linkages

- Operations
- Foodbase productivity
- Recreation

Monitoring Activities

- Physical, chemical and biqlogical sampling of water quality parameters (nutrients, conductivity, turbidity)
- Downstream and reservoir monitoring

Aquatic foodbase monitoring

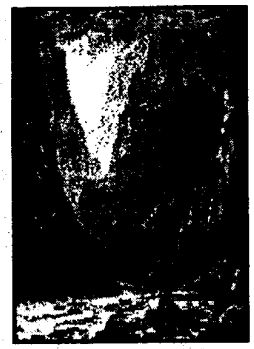
Objectives: Determine changes in composition and quality as it relates to fish and other resources

Linkages

- Fish, waterfowl
- Habitat availability (debris fans, cobble bars, sand),
- Recreational fishing,
- Tributary inputs of benthic and drift components.

Monitoring Activities

- Collect mainstem data on abundance, composition, distribution, productivity



Fisheries monitoring

Objectives: to determine trends in fish populations regarding recruitment, health and age structure

Linkages

- Habitat availability (debris fans, cobble bars, sand) for food and spawning,
- Recreational fishing,
- Predatory birds,
- Traditional cultural values of resource.

Monitoring Activities

- Long-term monitoring trout fishery
- Continued downstream monitoring of fish - condition, abundance, composition, distribution, productivity

Terrestrial and Fisheries Research

Linkages

- Food availability/dynamics,
- Population dynamics of endangered fish

Research Activities:

- Complete population genetics research of HBC
- Complete pilot study of trophic linkages on terrestrial environment
- Complete food web dynamics for aquatic food base
- Initiate research on non-native/native competitive interactions
- Evaluate spawning substrates in Glen Canyon Reach

Terrestrial and Fisheries Research - Section 8 Funds

Objectives: To evaluate effects of operations (TCD, SASF) on resources

Linkages

- Food availability/dynamics,
- Population dynamics of endangered fish.

Activities

- Baseline data collection for seasonally adjusted steady flows to augment current monitoring programs
- Baseline data collection/research for TCD prior to operation

Current Knowledge - Socio-Cultural Resources

- Archaeological sites benefit from redeposition of margin deposits
- Erosional factors at archaeological sites not clearly understood
- Ethnobotanical resources appear to benefit from high flows and high flow events
- Quantity, quality and distribution of recreational camping beaches not known

FY 2001 Management Objectives and Information Needs- Cultural Resources

In Situ conservation of resources (MO1)

- Assess impacts to cultural sites (IN1.1)
- Assess risk of damage and loss from flow regimes (IN 1.2)
- Evaluate flood terrace stability (IN 1.6)
- **Design mitigation strategies combining tribal & scientific approaches (MO2)**
- Characterize resource values to tribes and the public (IN2.1)
- **Maintain and integrate appropriate cultural data (MO 4)**
- Develop and disseminate appropriate cultural data (IN4.1)

Photographic Monitoring of Terraces With Cultural Deposits in Glen Canyon

Objective- Assess impacts to cultural sites

Linkages:

- Sediment deposits
- Terrestrial habitat
- Cultural resource INs 1.1 and 1.6

Activities:

- Monitor selected terrace sites
- Formulate and test research questions
- Study related flow impacts and ramping rates

Monitoring Isolated Occurrences (IOs)

Objective - Assess Impacts to cultural sites

Linkages:

- Sediment and geomorphic processes
- Cultural resource IN 1.1

Activities:

- Monitor IOs that represent cultural sites

Additional Flow and Deposition Model Applications

Objective - Assess risk of damage and loss from flow regimes

Linkages:

- Sediment deposits
- Terrestrial habitat
- Cultural resource IN 1.2

Activities:

- Incorporate flow and deposition data
- Determine flood frequency and triggers for remedial actions
- Apply flow deposition model to previously unevaluated resources

Tribal Monitoring And Assessment Projects

Objective - Assess Impacts to Cultural Resources

Linkages :

- Terrestrial habitat
- Sediment deposits
- Cultural resource INs 1.1 and 3.1

Activities:

- Develop monitoring paradigms with tribes to incorporate scientific, tribal and other perspectives.

Dissemination & Access to GCMRC Cultural Data

Objective- Disseminate appropriate cultural data

Linkages:

- Utilize Information Technologies Support Services
- Disseminate and interpret other resource data
- Cultural resource IN 2.1

Activities:

- Develop procedures
- Disseminate data through programs, workshops, internships and interactive educational projects.
- Training for tribal access to data and modeling information

Geomorphic Hypothesis Field Applications

Objectives - Assess risk of damage from flow regimes

Linkages:

- Sediment deposits
- Terrestrial habitat
- Cultural resource IN 1.2

Activities:

- Investigate outstanding questions
- Additional field testing

FY 2001 Management Objectives and Information Needs- Recreational Resources

Provide recreation experiences consistent with other resource objectives (MO1)

- Determine criteria for the recreational experience (IN 1.1)
- Define methods to insure quality experiences (IN1.3)
- Determine angler satisfaction, use and harvest (IN 1.4)

- **Maintain flows and sediment processes that create adequate numbers and distribution of beaches for camping (MO2)**
  - Determine camping beach number and distribution (IN 2.1)

Long-term Monitoring of Camping Beaches

Objective- Determine adequate beach quantity, quality, and distribution throughout the river system

Linkages:

- Sediment deposits
- Terrestrial habitat
- Recreation resource IN 2.1

Activities:

- Field test monitoring protocols
- Implement long-term monitoring of camping beaches

Continue Adopt-a-Beach Program

Objective- Monitor beach changes using cooperative programs with boating guides

Linkages:

- Sediment Deposits
- Terrestrial habitat
- Cultural resources at recreation locations
- Recreation Resource IN 2.1

Activities:

- Continue current monitoring program

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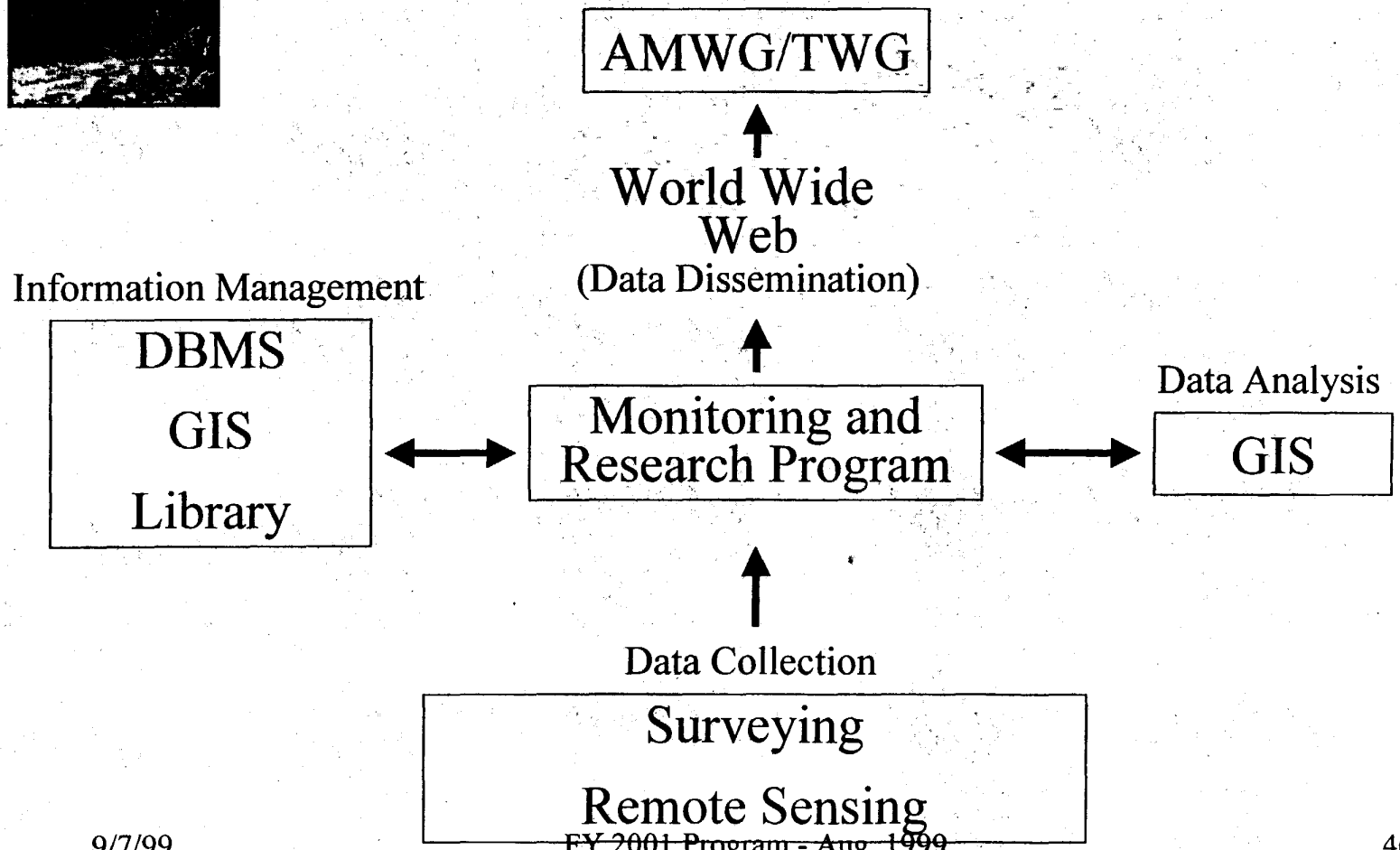
Information Technology Program



Data Base Management System

Linkages:

- Science program support for archiving and dissemination of tabular data

Activities:

- Populate GCMRC Oracle database
- Develop user interfaces
- Develop WWW interfaces
- Document administrative procedures

Geographic Information System

Linkages:

- Archive and disseminate spatial data
- Spatial analysis of habitat and
- Population occurrences
- Change detection of main channel elements
- Identification of areas of cultural importance

Activities:

- Service GIS map, data, and analysis requests
- Develop an Internet map server (base maps, canyon control, aerial photography, and misc. project data)
- Consult on remote sensing initiative

Library

Linkages:

• Archive and disseminate hard copy data such as reports, maps, aerial photography, slides, and videos to AMWG/TWG, resource program scientists, and the public

Activities:

• Service library requests
• Continue to catalog library contents
• Continue to make materials available on-line

Surveying

Linkages:

- Control and base maps for georeferencing remote data collection
- Terrestrial and bathymetric base maps for sediment and flow modeling
- Survey coordination and services for science programs

Activities:

- Service requests for surveying and survey data
- Continue development of a high precision control network from GCD to Phantom Ranch
- Continue development of terrestrial and hydrographic base maps of the Colorado River ecosystem
- Continue organizing legacy survey data

Systems Administration

Linkages:

- Provides infrastructure and support for office computing, networking, and automation systems
- Provides web publishing infrastructure

Activities:

- Administrate computer and networking environment
- Develop an integrated WWW publishing environment
- Enhance office automation capabilities

Remote Sensing

Linkages:

• Remote data collection for resource monitoring and research, identify and evaluate remote data collection technologies for science programs

Activities:

• Identify technologies that have the potential to meet program needs

• Conduct pilot field tests, analyze data, and evaluate results

Grand Canyon Monitoring and Research Center

Independent Review Panels

- RFPs - Panel review's for all monitoring and research proposals

- Peer-review of unsolicited & in-house proposals - minimum of 3 external reviewers for each of the above

- Technical report review - Minimum of 3 external reviewers for each report received

- Science Advisory Board (SAB) - Plan for 2 to 4 meetings plus participation in PEP, TWG, & AMWG, as appropriate.

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Logistics Program

Rationale: Consistent support to PIs, ensure compliance with NPS, cost-effective, in-house ability to respond to short lead-times

Activities:

- River logistics - Scheduling, river access permitting, logistics planning, equipment, boat men, food and emergency response. Supports 50 - 60 trips per year.

- Helicopter support - Scheduling & permitting, review of alternative support.

- Electrofishing - Boat & boatmen

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Contingency Planning

- January 2000 - Initiate process of contingency planning and receive recommendation for needed funding
- Review SCORE report
- Complete BHBF resource criteria review
- Ensure necessary compliance

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Core Adaptive Management Experiment

FY 2000:

- Agree on Vision, Goals, MOs and INs

FY 2000 / FY 2001:

- Define core adaptive management experiment

- Develop framework and decision tree for planning experimental flows (i.e., BHBFs, HMFs, SASF, and TCDs) as part of an overall experimental approach

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FY 2001 GCMRC Budget ('000s)

	AMP	O&M	Sec. 8
A. Bureau Support Services	$125		
B. Personnel, Mgt. & Admin.	$1,969		
C. Physical Resources	$950		
D. Biological Resources	$1,420	$300	$310
E. Socio-cultural Resources	$425		
F. Information Technologies	$320		
G. Remote Sensing	$400		
H. Independent Review Panels	$175		
I. Logistics	$650		
TOTAL	$6,434	$300	$310

Table 1. Schedule for developing a Research and Implementation Plan for Establishing A Second Population Of Humpback Chu

TASKS	Mar 1999	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2000	Feb
OBJECTIVE 1: DEVELOP R&I PLAN												
1A. Kickoff Meeting	5th											
1B. Develop Scope of Work	12th											
1C. Initiate/Maintain Agency Coordination	→	→	→	→	→	→	→	→	→	→	→	→
1D. SWCA Workshops		13-16th		16-18th								
1E. Develop Internal Review Draft Report		→	→	15th								
1F. Preliminary Draft Report					15th							
1G. Review of Prelim Draft by GCMRC					→	→						
1H. Meet With TWG							7th					
1I. Draft Report To Scientific Review/TWG								1st				
1J. Scientific Review of Draft Final								→	→			
1K. Develop Prelim Final Report										→		
1L. Agency Review of Prelim Final Report											→	
1M. Final Report												28th
1N. Professional Meetings a/												Aug 2001
OBJECTIVE 2: RELATE HABITAT												
2A. Determine Habitat Requirements												
2B. Determine Habitat Availability												
OBJECTIVE 3: HATCHERY REQUIREMEN												
3A. Determine Hatchery Requirements	→	→	→	→	→							
3B. Determine Hatchery Availability/Costs	→	→	→	→	→							
OBJECTIVE 4: DEVELOP STOCKING PGI												
4A. Determine No/Sizes of HBC Stocked	→	→	→	→	→							
4B. Determine Fish Marking Techniques	→	→	→	→	→							
4C. Develop Monitoring Program	→	→	→	→	→							

REQUEST FOR PROPOSALS ISSUED JULY 31, 1998

A REQUEST FOR PROPOSALS TO DESIGN A RESEARCH AND IMPLEMENTATION PLAN FOR THE ESTABLISHMENT OF A SECOND POPULATION OF HUMPBACK CHUB (GILA CYPHA) IN THE COLORADO RIVER ECOSYSTEM

- **PROJECT OBJECTIVES**
  - **Outline the steps required to establish a second humpback chub population in the Colorado River ecosystem.**
  - **Relate the available information on habitat requirements to habitat availability in the Colorado River ecosystem.**
  - **Determine hatchery requirements, availability and costs for establishment of a second population.**
  - **Develop a stocking program, including a schedule, and a monitoring program to determine the effectiveness of this effort.**

CONCEPT OF SECOND POPULATION

- **Reconsultation on 1978 BO resulted in 1987 Draft BO, Conservation Measure 7: "*Establish a second spawning population of humpback chub in the Grand Canyon*".**

- **Draft BO of 19 May 1993, Element 5 of RPA: "*Establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam*".**

- **Final BO of 21 December 1994, Element 4 of RPA: "*Establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam*".**

ASSUMED INTENT OF BIOLOGICAL OPINIONS

To establish a reproducing, self-sustaining, and genetically viable population of humpback chub geographically separate from the LCR population.

- **CRITERIA**
  - **Genetic Viability**
  - **Demographic Viability**
  - **Habitat Suitability**
  - **Geographic Separation from LCR**

GENETIC VIABILITY

CONCEPTS

- **Establishing a second population requires a pool of genetic diversity:**
  - **that reflects adaptive physical, physiological, and behavioral traits that enable individuals to survive the rigors of their environment,**
  - **adequate to allow the population to survive environmental pressures that exceed the limits of development plasticity**

GENETIC VIABILITY

CONSIDERATIONS

- **Inbreeding rate**
- **Genetic effective population size**

INBREEDING RATE

Rate of Inbreeding (ΔF) = $1/2N_e$ (Simberloff 1988)

N_e	ΔF
10	**5.0%**
50	**1.0%**
100	**0.5%**
500	**0.1%**
1,000	**0.05%**

GENETIC EFFECTIVE POPULATION SIZE (N_e)

500/1,000 RULE

- $N_e \leq 50$ will experience short-term inbreeding depression (Soule 1980)
- $N_e \geq 500$ will maintain long-term genetic diversity (Franklin 1980)
- $N_e > 1{,}000$ will not further enhance genetic variation (Lynch 1996)

GENETIC EFFECTIVE POPULATION SIZE

1) $C = N_e/N_m$; $N_m = N_e/C$

Where: N_e = number of adults contributing genes to next generation

N_m = total number of adults in population

2) Assume N_e = 1,000 adults and C = 0.100-0.333

Then $N_m = N_e/C$ = 1,000/0.100-0.333

N_m = 3,003 - 10,000

3) Microsatelite genetic analysis of 35 LCR adult HB yielded N_e = 1,970 (Unpublished data: M. Douglas and M. Douglas 1999)

Size of LCR population (N_m) = 4,346

Then C = 1,970/4,346 = 0.453

$N_m = 1,000/0.453 = 2,208$ adults

Table 1. Locations of nine mainstem aggregations of humpback chub with numbers of fish captured and estimated numbers of adults, 1990-93 (Valdez and Ryel 1995).

Aggregation	Kilometers From Glen Canyon Dam	Number Captured, 1990-93				Estimated Number of Adults[2] (95% confidence interval)
		YOY[1]	Juveniles	Adults	Totals	
1. 30-Mile	73.7-75.8	14	0	26	26	52 (28-136)
2. LCR Inflow	117.1-130.6	1,830	1,293	1,524	4,647	3,482 (2,682-4,281)
3. Lava to Hance	131.1-148.2	778	226	15	1,019	no estimate[3]
4. Bright Angel Inflow	160.2-173.7	13	2	9	24	no estimate
5. Shinumo Inflow	199.3-200.1	4	13	27	44	57 (31-149)
6. Stephen Aisle	210.3-218.6	0	7	17	24	no estimate
7. Middle Granite Gorge	228.3-233.0	1	4	124	129	98 (74-153)
8. Havasu Inflow	276.1-277.5	0	0	7	7	13 (5-70)
9. Pumpkin Spring	367.3-368.4	0	0	6	6	5 (4-16)

[1] YOY = Young-of-year
[2] Based on Chao (1987, 1989) closed population estimator.
[3] No estimate possible because of small numbers of captures and recaptures.

Table 8. Genetic effective population size and potential rates of inbreeding for mainstem aggregations in Grand Canyon.

Mainstem Aggregation – Estimated Number of Adults	**Genetic Effective Population Size[1]**	**Rate of Inbreeding $\Delta F = 1/2N_e$**
30-Mile – 52	24	2.00%
LCR Inflow – 3,482	1,577	0.03%
Shinumo Inflow – 57	26	1.92%
Middle Granite Gorge – 98	44	1.14%
Havasu Inflow – 13	6	8.33%
Pumpkin Spring – 5	2	25.00%

[1]Assume that only 45.3% of adults are contributing genes to next generation; e.g., $N_e = N_m \times C = 52 \times 0.453 = 24$.

HABITAT SUITABILITY

LIMITING FACTORS

- Temperature
- Non-Native Fishes (predators, competitors)
- Physical Structure (shorelines, backwaters, eddy complexes, tributary inflows)
- Flows (reduced runoff, high base, fluctuations)
- Food Base
- Parasites, Disease

Table 7. Criteria matrix for mainstem aggregations.

Aggregation	HABITAT CONSIDERATIONS					GENETIC CONSIDERATIONS (Fatal Flaw)	Total Score	Rank
	Physical Habitat Quality/Quantity	Distance from Dam (km)	Proximity to LCR	Non-Native Predators/ Competitors	Proximity to Existing Aggregations	Potential Inbreeding Rate of Existing Fish[1] (est. pop. size)		
30-Mile	2	1 (74)	5	2	0	2 (52)	12	**3**
Lava to Hance	3	2 (131)	1	3	4	excessive (no est.)	-	-
Bright Angel	2	2 (160)	4	2	3	excessive (no est.)	-	-
Shinumo Inflow	2	3 (199)	5	2	3	3 (57)	18	**2**
Stephen Aisle	4	3 (210)	5	4	4	excessive (no est.)	-	-
Middle Granite Gorge	4	3 (228)	5	4	4	4 (98)	24	**1**
Havasu Inflow	2	4 (276)	5	4	2	excessive (13)	-	-
Pumpkin Spring	2	5 (367)	5	4	0	excessive (5)	-	-

[1]based on numbers from Table 2.

Table 10. Criteria matrix for tributaries.

Tributaries	Habitat Suitability	Water Quality	Fatal Flaw	Temperature	Fish Barrier	Non-Native Predators/ Competitors	Human Disturbance	Total Scores	Rank
			Water Quantity						
Paria	2	3	-	5	0	5	3	-	-
Bright Angel	2	4	2	5	0	2	2	17	5
Shinumo	2	3	1	5	5	5	5	26	2
Deer	2	3	1	5	0	5	4	20	3
Tapeats	2	3	2	4	0	4	4	19	4
Kanab	2	2	-	4	0	3	4	-	-
Havasu	4	4	4	5	5	4	2	28	1
Spencer	2	3	2	5	0	3	4	19	4

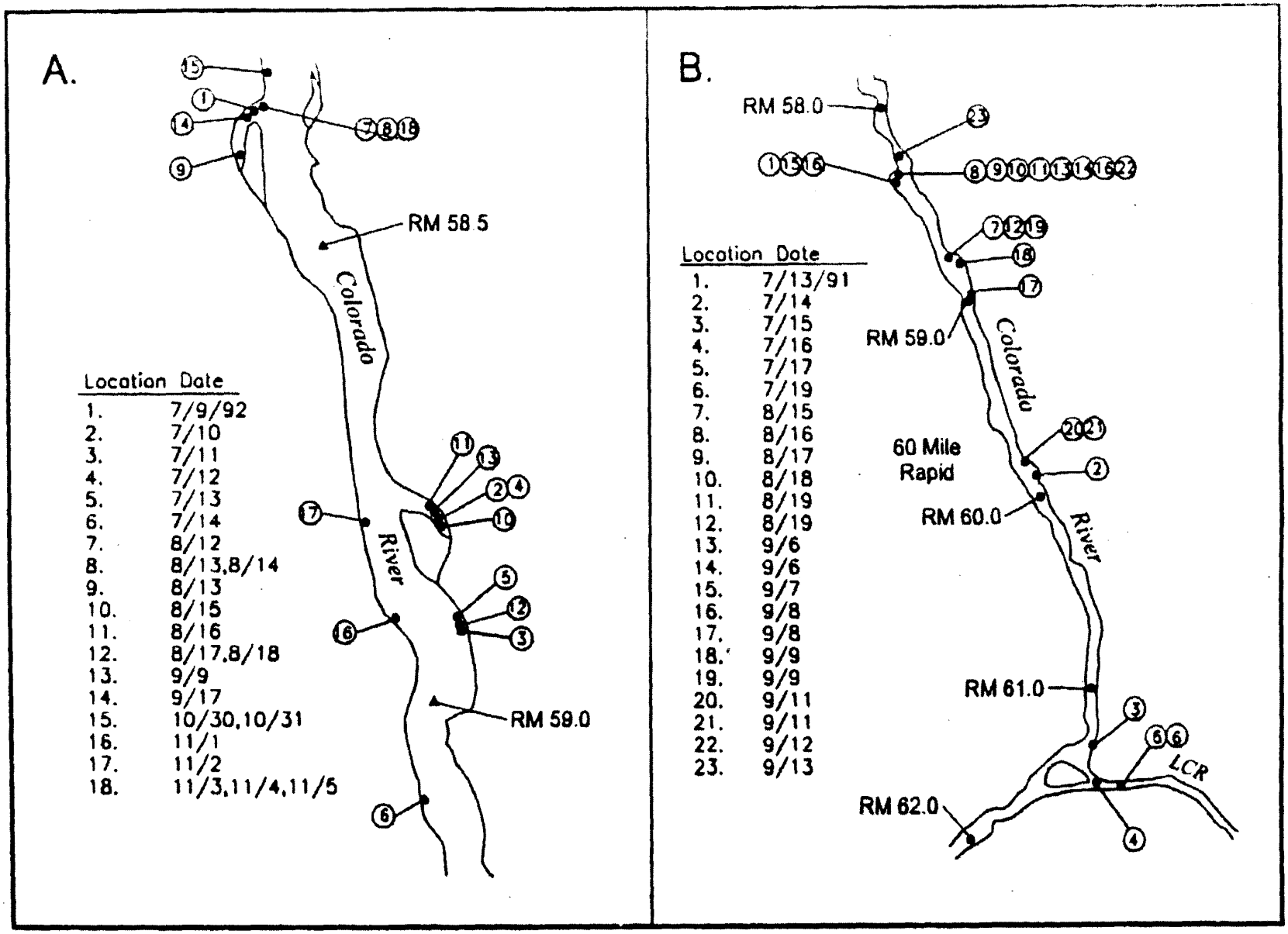
Table 9. Suitability criteria for tributaries in Grand Canyon as sites for a second population of humpback chub, compared to the Little Colorado River (LCR).

Tributary	Habitat Suitability	Water Quantity[1]	Water Quality[1]	Water Temperature[1]	Fish Barrier	Non-Native Fishes	Human Disturbance
Paria River	Pools, runs, riffles, medium size stream	0 - 16,100 cfs; Avg. 30.1 cfs	High sulfate, gypsum contaminated with magnesium; upstream urban/agric. use	Warm - Suitable	No fish barriers in lower reaches	None in tributary; large number of rainbow trout at outflow	Moderate use by hikers
Bright Angel Cr.	Deep pools, runs, riffles, medium size stream	10 - 4,400 cfs; Avg. 35.4 cfs	Calcium-magnesium carbonate	Cool - Suitable 1-24°C	No fish barriers in lower reaches	Large number of brown and rainbow trout in tributary and near outflow	Heavy use by hikers, river runners, fishermen
Shinumo Cr.	Deep pools, runs, small stream	5 - 15.5 cfs; Avg. 9.1 cfs	Calcium-magnesium carbonate	Cool - Suitable 1-23°C	Fish barrier ~200 m above outflow	Brown and rainbow trout near outflow; rainbow trout above barrier	Very light use by river runners above falls
Deer Cr.	Deep runs, small stream	5.4 - 8.2 cfs; Avg. 7.2 cfs	Calcium-magnesium carbonate	Cool - Suitable	Fish barrier ~50 m above outflow	Brown and rainbow trout near outflow	Light use by river runners and hikers above falls
Tapeats Cr.	Pools, runs, riffles, medium size stream	51.4 - 283 cfs; avg. 100.1 cfs	Calcium-magnesium carbonate	Cold - Limited	No fish barriers in lower reaches	Brown and rainbow trout in tributary and near outflow	Light use by river runners, fishermen
Kanab Cr.	Pools, runs, riffles, medium to small size stream	0 - 4,360 cfs; Avg. 5.7 cfs	High nutrient load, low dissolved oxygen, upstream urban/agric. use	Warm - Suitable 0-35°C	No fish barriers in lower reaches	Fathead minnow, green sunfish, carp, Plains killifish	Light use by river runners and hikers
Havasu Cr.	Deep pools, runs, riffles–similar to LCR	59.3 - 74.5 cfs; Avg. 63.8 cfs	Magnesium-calcium carbonate with large amounts of sulfates, chloride, and sodium; upstream urban/agric. use	Warm - Suitable 9-23°C	Fish barrier ~200 m above outflow	Brown and rainbow trout in tributary and near outflow	Heavy use by river runners and hikers 1-2 km above falls; moderate use above that point
Spencer Cr.	Deep pools, runs, riffles, stream small and habitat limited	1.1 - 4.4 cfs; Avg. 2.7 cfs	No information available	Warm - Suitable 2-24°C	No fish barriers in lower reaches	Plains killifish, red shiner, carp, fathead minnow	Light use by river runners
LCR[2]	Deep pools, runs, riffles, stream size medium to large	240-24,900 cfs; 205 Avg. (about 250 cfs base flow)	Sodium chloride plus significant calcium carbonate; upstream urban/agric. use	Warm - Suitable 2-25°C	Fish barrier 14.5 km upstream	Carp, channel catfish, plains killifish, red shiner, fathead minnow, black bullhead	Heavy use by river runners 1-2 km above confluence; moderate use above that point

[1] Source: Kubly and Cole 1979

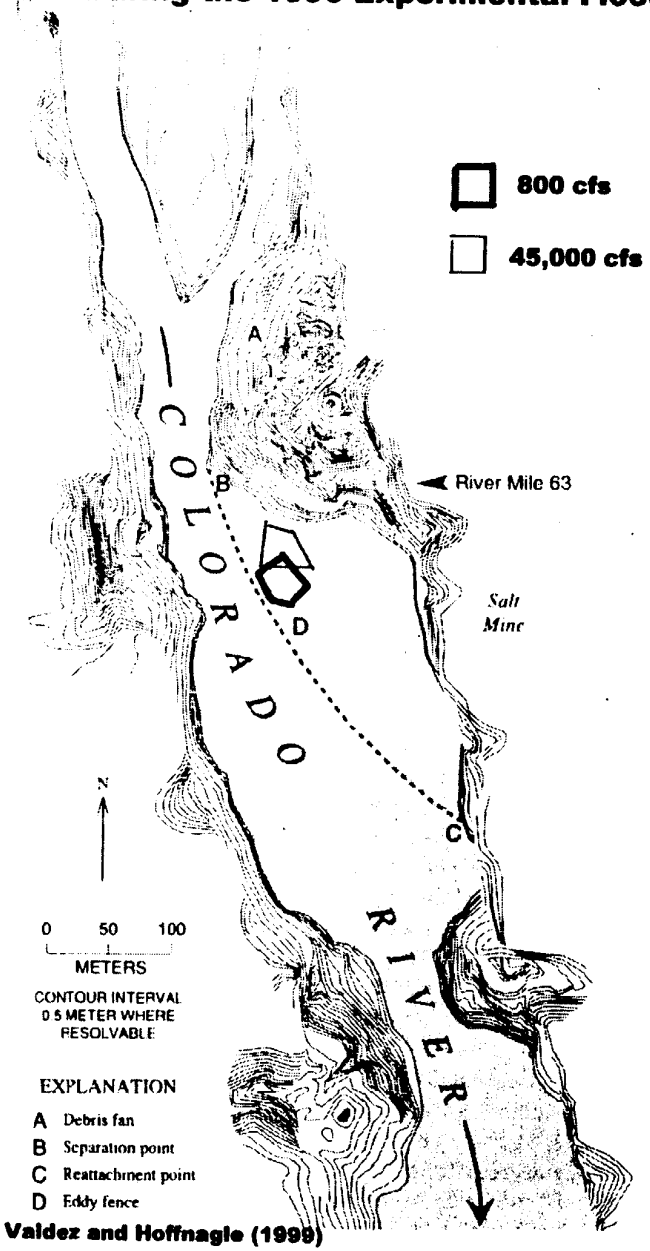
[2] The LCR is included for comparison purposes

Local Movement and Habitat Use of Humpback Chub



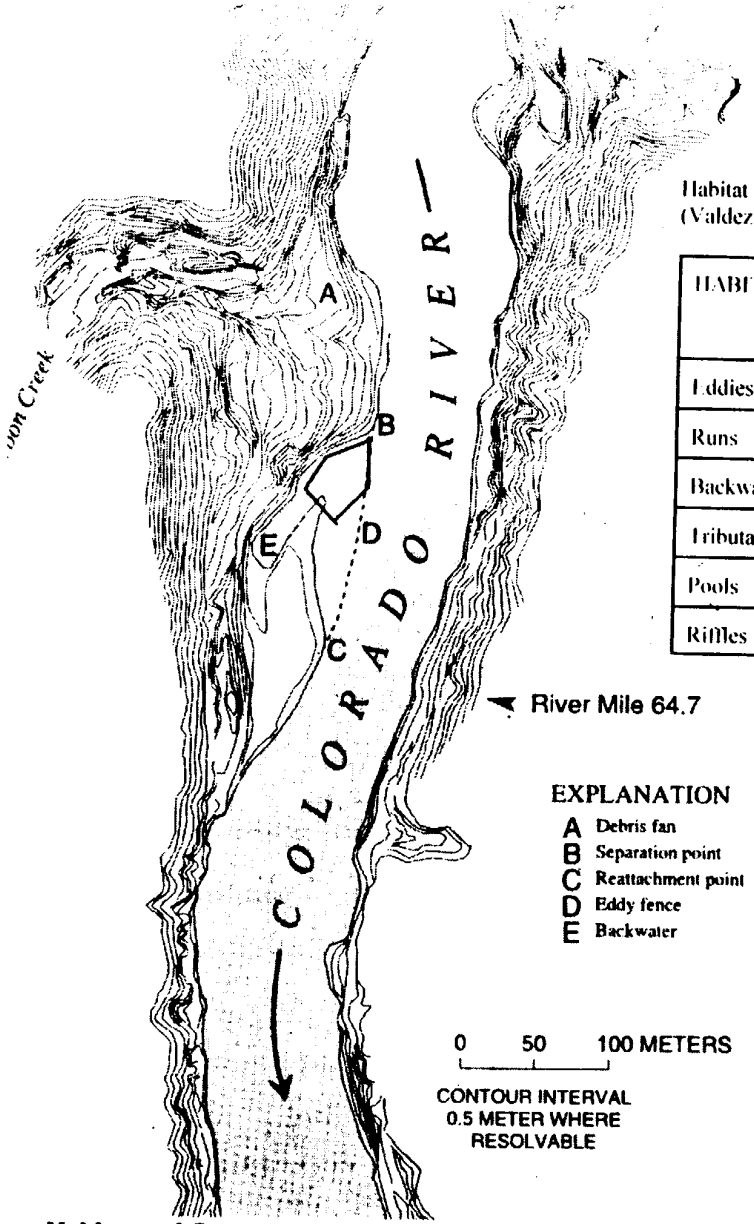
Valdez and Ryel (1995)

Movement and Habitat Use of Two Radiotagged Humpback Chub During the 1996 Experimental Flood



Valdez and Hoffnagle (1999)

Movement and Habitat Use of a Radiotagged Humpback Chub During the 1996 Experimental Flood



Valdez and Cowdell (1996)

Habitat Use by Radiotagged Humpback Chub (Valdez and Hoffnagle 1999)

HABITAT	INTERIM FLOWS (n = 69)	1996 EXP. FLOOD (n=10)
Eddies	74%	73%
Runs	12%	19%
Backwaters	7%	0
Tributary Inflows	6%	8%
Pools	1%	0
Riffles	<1%	0

Table 4. Estimated numbers of adult and sub-adult humpback chub that can be supported in the Stephen Aisle/Middle Granite Gorge (SA/MGG) region, based on current estimated densities of fish per debris fan-eddy complex in the Colorado River near the Little Colorado River (LCR) inflow.

Region	Number of Debris Fans-Eddy Complexes/km	Number of Adults	Number of Adults--No./Complex (No./km)	Number of Sub-Adults
LCR Inflow[1]	27/13.5	3,482	129 (258)	384,887[3]
SA/MGG	28/25	3,611[2]	129 (144)	396,433[4]

[1] Data source: Valdez and Ryel 1995
[2] Assumes a density of 129 adults per debris fan
[3] Computed as average of three estimates of sub-adults (Valdez and Ryel 1995)
[4] Computed as proportion of available habitat from number of sub-adults in LCR Inflow

Table 5. Estimated numbers of adult and sub-adult humpback chub that can be supported in Havasu Creek and Shinumo Creek, based on current estimated densities of fish per kilometer in the Little Colorado River (LCR).

Tributary	Reach of Available Habitat (km)	Number of Adults/km	Total Number of Adults in Tributary[4]	Number of Sub-adults/km	Total Number of Sub-adults in Tributary
LCR	14.9	292	4,346[1]	33,570	500,000[2]
Havasu Cr.	12	74[3]	888	8,560	102,720[3]
Shinumo Cr.	15	12[3]	180	1,343	20,145[3]

[1] Estimates by Douglas and Marsh (1996)
[2] Based on potential reproduction and survival (Valdez and Ryel 1995)
[3] Based on proportion of stream flow relative to LCR flow and fish density
[4] Inbreeding rates: LCR: N_e = 4,346 x 0.435 = 1,891; $\Delta F = 1/2N_e = 0.02\%$
HVC: N_e = 888 x 0.435 = 386; $\Delta F = 1/2N_e = 0.13\%$
SHC: N_e = 180 x 0.435 = 78; $\Delta F = 1/2N_e = 0.64\%$

DEMOGRAPHIC VIABILITY

- Minimum numbers of individuals
- Successful reproduction
- Recruitment to all ages
- Cross section of all ages
- Long term population stability

Table 3. Numbers of humpback chub by age group necessary to maintain a population of 2,208 adults with a minimum effective population size (N_e) of 1,000 adults under two assumed survival scenarios for ages 1 to 2, 2 to 3, and 3 to 4; survival of ages 0 to 1 and 4+ from Valdez and Ryel (1997).

Age	Lower		Upper	
	Survival	Number	Survival	Number
0	0.1	90,128	0.1	360,505
1	0.3	9,013	0.1	36,051
2	0.4	2,704	0.3	3,605
3	0.5	1,082	0.5	1,082
4+	0.755	2,208	0.755	2,208

Table 6. Ranges in predicted age structure for humpback chub in a 25-km reach of the mainstem Colorado River (Stephen Aisle and Middle Granite Gorge) and a 12-km reach of Havasu Creek.

Age	Mainstem (Stephen Aisle/MGG)				Havasu Creek			
	Lower		Upper		Lower		Upper	
	Survival	Number	Survival	Number	Survival	Number	Survival	Number
0	0.1	147,430	0.1	589,700	0.1	36,270	0.1	145,000
1	0.3	14,743	0.1	58,970	0.3	3,627	0.1	14,500
2	0.4	4,423	0.3	5,897	0.4	1,088	0.3	1,450
3	0.5	1,769	0.5	1,769	0.5	435	0.5	435
4+	0.755	3,611	0.755	3,611	0.755	888	0.755	888

POTENTIAL SECOND POPULATIONS

	Stephen Aisle/MGG	Havasu Creek
Genetic Stability	2,208	2,208
Habitat Capacity		
Adults	3,611	888
Subadults	396,433	102,720
Demographic		
Adults	3,611	888
Subadults	168,365 - 656,336	41,420 - 161,385

HATCHERY REQUIREMENTS AND AVAILABILITY

Hatcheries can play a role in establishing a second population of humpback chub in Grand Canyon, but they should not be used as a primary tool. A hatchery program should be implemented for the following purposes:

- **As a refuge for unique genetic stocks if they are identified.**
- **To develop a brood stock of humpback chub to be used as a contingency if primary efforts to establish a second population fail.**
- **To produce fish for supplementation. Supplementation is defined as "the use of artificial propagation in an attempt to maintain or increase natural production while maintaining the long-term fitness of the target population, and keeping the ecological and genetic impacts on nontarget populations within specified biological limits" (Regional Assessment of Supplemental Project 1992).**

Maintaining hatchery stocks was listed as the second item in a set of conservation measures developed after the U.S. Fish and Wildlife Service issued their draft Biological Opinion in 1987. Fish and/or gametes from at least the 30-mile aggregation should be taken into a hatchery refuge in the first year of the plan for genetic assessment and to protect unique genetic material if it is found. Genetic profiles should be developed to determine if significant genetic differences exist among the nine aggregations in Grand Canyon, and if transfer of fish among aggregations or use of hatchery products is feasible. If various genetic markers show no significant differences, a brood stock can be developed from progeny of LCR fish.

The brood stock should be developed by transferring randomly captured young-of-year wild fish from the LCR. The brood stock must be sufficiently large to annually produce about 200,000 young; approximately 100 females and 100 males are required. Proper paired mating crosses (25x25) should be made to ensure maximum genetic diversity in the progeny (F1). The number of adults required to start the program will be determined from analysis of genetic characteristics of each aggregation. The progeny are able to reproduce as age 3+. Hatchery-reared fish of that age should be available in case attempts to move LCR fish to tributaries fail.

HATCHERY REQUIREMENTS AND AVAILABILITY

Available Hatchery Facilities

1. **Willow Beach NFH – presently hold ~300 juvenile HBC for experimentation; taken as YOY at random from LCR**

2. **Dexter NFH – no HBC on site at this time; have held HBC in past; space available if planned ahead**

3. **Bubbling Pond SFH – no HBC on site at this time; have held HBC in past; space available if planned ahead**

4. **Grand Junction EFH – no HBC ever on site; currently rearing RZB and CPM; physical facilities at capacity, but can expand; water not limiting**

5. **San Luis Valley SFH – currently starting construction; planned as a "native fish facility for Colorado"; in operation ~2002**

6. **Utah SFH – currently in planning stages; no construction schedule**

Table 11. Transfer schedule of humpback chub from the LCR to Havasu and Shinumo creeks.

Size Fish (mm TL)	Marking Method	Havasu Creek	Shinumo Creek
50-100	Latex injection[1]	500	500
100-250	PIT tag[2]	100	100
250+	Radio[3]/Sonic tag[4] PIT tag	5	0

[1] Haines and Modde (1996)
[2] Burdick and Hamman (1993)
[3] Valdez and Ryel (1997)
[4] McIvor and Thieme (1999)

STEPS REQUIRED FOR ESTABLISHING A SECOND POPULATION OF HUMPBACK CHUB IN GRAND CANYON

This plan assumes that a fish monitoring plan will be in place and on-going in Grand Canyon.

PHASE I: Primary Efforts

1. **Identify and address all administrative and legal requirements.**
2. **Initiate genetic assessment of all aggregations of humpback chub in Grand Canyon.**
3. **Assess suitability of habitat in Havasu Creek and Shinumo Creek.**
4. **Initiate a hatchery program for unique genetic stocks if they exist and to start a brood stock.**
5. **Establish a Mainstem Population. Following installation of a temperature control device on Glen Canyon Dam, monitor mainstem aggregations to determine if natural reproduction and recruitment are taking place in one or more mainstem aggregations. If 5 years of monitoring show no response, implement Phase III; if response is inadequate, evaluate criteria for a metapopulation and consider supplementing with transfer of fish from the LCR or from hatcheries.**
6. **Establish a tributary population. Assuming genetic profiles show no significant differences in genetic markers, transfer fish from the LCR to Havasu Creek and Shinumo Creek to conduct experiments on best release methods. Repeat for 3 years, closely monitoring the introduced fish. If release methods are successful in tributaries, evaluate the degree of success to determine if additional transfers are necessary. If release methods are unsuccessful, implement Phase III.**

PHASE II: Contingency Measures

1. **Transfer hatchery-reared fish to one or more tributaries on an experimental basis first. If transfer and survival of fish are successful, continue stocking for supplementation of the new population. If unsuccessful, re-evaluate program.**
2. **Consider supplementing one or more mainstem aggregations with hatchery-reared fish.**

PHASE III: Re-Evaluation

1. **If Phase I or Phase II efforts are unsuccessful, the concept of a second population should be re-evaluated.**

PRELIMINARY FINDINGS

SECOND POPULATION OF HUMPBACK CHUB

- Greatest chance of success for a second population is a "metapopulation response" in the mainstem, esp. Middle Granite Gorge/Stephen Aisle

- Populations in Havasu Creek and Shinumo Creek are possible and valuable as backup populations, but would not meet guidelines for long-term genetic viability (N_e>1,000)

- Temperature Control Device on Glen Canyon Dam is presently only known means for reducing limiting factor of water temperature

Grand Canyon Monitoring and Research Center

FY 2001 GCMRC Budget ('000s)

	AMP	O&M	Sec. 8
A. Bureau Support Services	$125		
B. Personnel, Mgt. & Admin.	$1,969		
C. Physical Resources	$950		
D. Biological Resources	$1,420	$300	$310
E. Socio-cultural Resources	$425		
F. Information Technologies	$320		
G. Remote Sensing	$400		
H. Independent Review Panels	$175		
I. Logistics	$650		
TOTAL	$6,434	$300	$310

Grand Canyon Monitoring and Research Center

Bureau Support Services

FY 2001 Proposed Budget

• Contracting	$70,000
• Personnel	$25,000
• Computer Support	$25,000
• Property Management	$ 4,000
• Finance	$ 1,000
TOTAL	$125,000

Physical Resources Program

FY 2001 Proposed Budget

Monitoring	
• Streamflow & Sediment Transport	$520,000
• Main Channel & Shoreline Sand Storage	$150,000
• Geomorphic Framework of Mainstem	$ 30,000
Sub-total	$700,000
Research	
• Predicting Sandbar Evolution	$150,000
• Reach Averaged Sand Transport	$ 50,000
• Channel Evolution	$ 50,000
TOTAL	$950,000

Biological Resources Program

FY 2001 Proposed Budget

AMP Funds

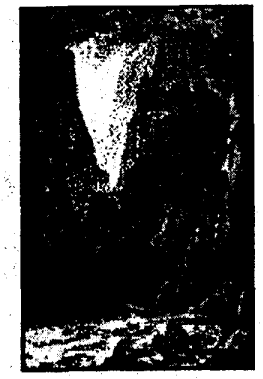
Monitoring		
• Terrestrial		
(Vegetation, Avifauna, KAS)		$170,000
• IWQP		$50,000
• Aquatic Foodbase		$190,000
• Lees Ferry Trout		$130,000
• Native Fish		$470,000
	TOTAL	$1,010,000

Biological Resources Program

FY 2001 Proposed Budget

AMP Funds

Monitoring	
• Terrestrial (Vegetation, Avifauna, KAS)	$170,000
• IWQP	$50,000
• Aquatic Foodbase	$190,000
• Lees Ferry Trout	$130,000
• Native Fish	$470,000
TOTAL	$1,010,000



Biological Resources Program

FY 2001 Proposed Budget

AMP Funds

Research	
• HBC Population Genetics	$50,000
• Terrestrial Trophic Linkages	$30,000
• Aquatic Foodbase Foodweb Dynamics	$40,000
• Native / Non-native Fish Interactions	$Pending Available Funds
• Spawning Substrates in Glen Canyon	$Pending Available Funds
Other	
• Unsolicited Proposals	$100,000
• In-house Research	$100,000
• TWG Requests	$ 50,000
• PEP	$ 40,000
TOTAL	$410,000

Biological Resources Program

FY 2001 Proposed Budget

O&M and Sec. 8

Activities	O&M	Sec. 8
• IWQP	$300,000	$ -0-
• Baseline data collection / research for SASF and TCD	$ -0-	$310,000
TOTAL	$300,000	$310,000

Socio-Cultural Resources Program

Cultural Resource Projects

FY 2001 Proposed Budget

•Photographic Terrace Monitoring	$35,000
•Monitoring Isolated Occurrences	25,000
•Additional Flow/Deposition Applications	25,000
•Tribal Projects	125,000
•Data Dissemination & Access	35,000
•Geomorphic Field Application	65,000
•PEP	35,000
•Unanticipated Information Requests	5,000
TOTAL	$350,000

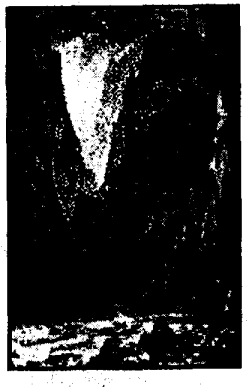
Socio-Cultural Resources Program

Recreational Resource Projects

FY 2001 Proposed Budget

•Long-term Monitoring of Camping Beaches	45,000
•Adopt-a Beach Monitoring Project	5,000
•PEP (Angler Satisfaction)	20,000
•Unanticipated Information Requests	5,000
Total	$75,000

Total Socio-Cultural Program **$425,000**



Information Technology
FY 2001 Proposed Budget

•DBMS:	$160,000
•GIS:	$12,000
•Library:	$12,000
•Survey:	$16,000
•Systems Administration:	$120,000
Total	$320,000

Information Technology
FY 2001 Proposed Budget

- Remote Sensing Initiative: $400,000

Independent Review Panels
FY 2001 Proposed Budget

• RFP Review	$65,000
• Unsolicited & In-House Proposal Review	$ 5,000
• Technical Report Review	$25,000
• Science Advisory Board	$80,000
TOTAL	$175,000

Logistics
FY 2001 Proposed Budget

• River Logistics	$475,000
• Equipment Maintenance	$ 30,000
• Equipment Replacement	$ 30,000
• Supplies	$ 25,000
• Emergency Evacuations	$ 6,000
• Helicopter Support	$ 30,000
• NPS Permitting	$ 54,000
TOTAL	$650,000