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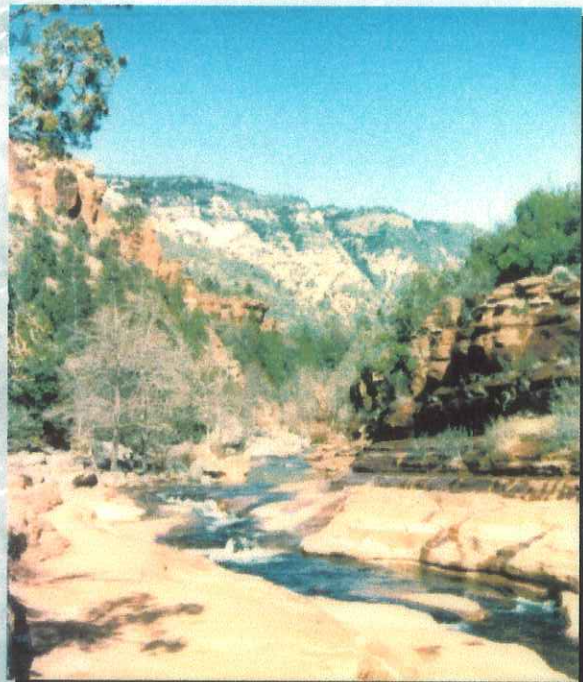
Final Report

CRITERIA FOR ASSESSING CHARACTERISTICS OF NAVIGABILITY for SMALL WATERCOURSES IN ARIZONA

Contract No. A7-0109-001



ARIZONA NAVIGABLE STREAM ADJUDICATION COMMISSION

Stantech Consulting Inc.
In Association with
JE Fuller/Hydrology & Geomorphology, Inc.
and the
University of Arizona
Water Resources Research Center

Stantech Consulting

Yuma County Small & Minor
Watercourses, 02-001-NAV

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ARIZONA NAVIGABLE STREAMS ADJUDICATION COMMISSION

FINAL REPORT

CRITERIA FOR ASSESSING CHARACTERISTICS OF NAVIGABILTIY

FOR

SMALL WATERCOURSES IN ARIZONA

CONTRACT No. A7-0109-001

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PREFACE

Pursuant to Arizona Revised Statutes, Title 37, Chapter 7, State Claims to Streambeds (ARS §37-1101 et. seq.), an administrative process is established to gather information and determine the extent of the State's claims to the beds of the watercourses within Arizona arising from a finding of navigability for title purposes. The statute's purpose is to determine a method for assessing if watercourses within Arizona were navigable for title purposes as of the date of Statehood on February 14, 1912.

The Arizona Navigable Stream Adjudication Commission (ANSAC) was established as a State Agency to gather evidence and information regarding navigability or non-navigability of watercourses within Arizona as of Statehood. There are over 13,000 documented watercourse segments within Arizona, the vast majority of which are minor or small watercourses which ANSAC has determined should be considered separately from the major river investigations. ANSAC needs to gather information and develop criteria and methods regarding the study of small and minor watercourses as of February 14, 1912. The content of this report is intended to provide the necessary tools for ANSAC to make findings as to the navigability or non-navigability of minor and small watercourses, and subsequently forward recommendations to the Legislature.

This report was prepared for ANSAC under Contract No. A7-0109-001 by Stantech Consulting Inc.(Stantech) in association with JE Fuller/Hydrology & Geomorphology, Inc. (JEF, Inc.) and University of Arizona Water Resources Research Center (WRRC). The project team consisted of Christina Waddell, MBA, ANSAC, former Executive Director; Pat Deschamps, PE, RLS, Stantech, Project Manager; George V. Sabol, PhD, PE, Stantech, Senior Technical Advisor; Carlos Carriaga, PhD, PE, Stantech, Project Engineer; Jon Fuller, PE, PH, JEF, Inc., Project Hydrologist; Barbara Tellman, University of Arizona WRRC, Project Historian; and Diana Salisbury, Database Programmer.

The progress of this project was monitored and guided by a Technical Review Committee comprised of representatives of various agencies of the State of Arizona. The Committee members included Tom Vogt, ANSAC, Acting Executive Director; John Hathaway, PE, Arizona Department of Environmental Quality; Don Gross, PE, Arizona Department of Water Resources; Bill Werner, Arizona Game and Fish Department; Bob Sejkora, Arizona State Parks; Clyde Anderson, PE, Arizona State Land Department; and Curtis Jennings, ANSAC Legal Counsel.

Executive Summary

INTRODUCTION

The Arizona Navigable Stream Adjudication Commission (ANSAC) is directed by statute to establish administrative procedures, hold public hearings, and make recommendations regarding the navigability or non-navigability of all watercourses in Arizona as of Statehood on February 14, 1912. ANSAC is to set the priorities for investigating and conducting hearings on watercourses and then to report its recommendation as to which watercourses or reaches of watercourses were navigable or non-navigable at Statehood to the Arizona Legislature. The Legislature then makes a finding upon consideration of the ANSAC recommendation and enacts appropriate legislation in response to the determination.

ANSAC is required to complete the legislatively mandated tasks described above by July 1, 2002. The watercourses currently in the process of being assessed only include the major river systems in the state. There are over 13,000 documented watercourse segments in Arizona, the vast majority of which constitute minor or small watercourses ANSAC determined should be considered separately from the major rivers. In order to expedite the evaluation process and meet the target date for completion in the year 2002, ANSAC contracted with the Stantech project team in 1997 to develop an efficient and effective evaluation system to assess the small and minor watercourses within the state for characteristics of navigability, non-navigability, or susceptibility to navigation as of statehood on February 14, 1912. The contract also includes the identification and cataloging of all small and minor watercourses to be evaluated utilizing that system.

The project work products are technical and historical criteria, the evaluation system, the catalog of small and minor watercourses, and a summary report. The application of the evaluation system to each of the small and minor watercourses cataloged is not part of this project scope. It is anticipated that all the cataloged small and minor watercourses will subsequently be assessed utilizing the criteria, the evaluation system, and the watercourse catalog developed under this contract. That work will be performed in a priority to be established in the future by ANSAC and under a separate contract.

TECHNICAL CRITERIA

Historical records of navigability are lacking for the vast majority of small watercourses in Arizona. Therefore, most navigability findings will be decided based on a stream's susceptibility to navigation, rather than its historical record. To determine susceptibility to navigation, certain technical data about the stream are required. Technical information, as defined for this project, includes data relating to the physical characteristics of a watercourse. Physical characteristics include the following interrelated variables:

- Flow rate
- Flow depth
- Flow velocity
- Flow width

For natural streams, these flow characteristics are highly variable - streamflow changes throughout the year, from year to year, and from one point along the stream to the next. Therefore, direct measurement of the changing physical characteristics of every small watercourse in Arizona is not practical or possible. Indirect methods for estimating key flow characteristics are recommended to evaluate whether a watercourse was susceptible to navigation under specific flow conditions.

Criteria and Methodology

The following recommendations are made for estimating the physical characteristics of small watercourses in Arizona:

Navigability Criteria. The navigability criteria addressed in ARS §37-1128 describe actual navigation in fact, leaving the issue of susceptibility to navigation open to interpretation. ANSAC should firmly establish criteria that define susceptibility to navigation. These criteria should include standards for type of boats to be considered, whether ordinary high water vs. ordinary low water flow conditions are to be used, a minimum flow duration for boating, the minimum degree of predictability of flows, and a minimum length of boatable stream reach.

The following are recommended by the project team for ANSAC's consideration in establishing the criteria to be used in evaluating susceptibility of watercourses to navigation:

- Boat Type. Minimum boatable conditions should be based on use of inflatable rafts or canoes, both of which were available at statehood.

- Flow Condition. Ordinary high water conditions, or the mean annual flow rate, rather than ordinary low water conditions should be used to determine susceptibility to navigation.

- Flow Duration. Boatable flows should be defined as those continuously sustained for at least one month of every year.

- Predictability. Boatable conditions should be defined as occurring annually at regularly occurring periods of the year.

- Length of Reach. A boatable reach should be defined as at least one mile in length.

Methodology. A combination of use of stream classification data, engineering methodologies, and engineering judgment is recommended to estimate physical and navigability characteristics of Arizona watercourses. Stream classification data from agency database sources is suitable for initial screening, but cannot provide the level of detail required to estimate actual flow conditions of a specific stream reach. The level of effort required to use the engineering methodologies is not appropriate or warranted for application to all 13,000 stream segments in Arizona. Therefore, a multi-level approach, with varying degrees of effort and types of analyses is recommended, as described in Section 4 of this report.

Diagnostic Technical Criteria/ Analyses

Regardless of the exact evaluation scheme adopted by ANSAC, certain technical data are required to identify non-navigable streams and to determine susceptibility to navigation.

Non-Navigable Stream Technical Criteria. The following technical data are recommended for consideration when identifying non-navigable streams:

- USGS gage data indicate that the stream is ephemeral

- Stream is listed as ephemeral in Arizona State Parks (AZSP), Arizona Game & Fish (AZGF) and U.S. Fish & Wildlife Service (USFW) databases

- Stream is not listed as boating stream by AZSP, AZGF and Central Arizona Paddlers Club (CAPD)

Navigability Susceptibility Technical Criteria. The following technical data are recommended for consideration when determining susceptibility to navigation for Arizona streams:

- Flood peak discharge rates
- Mean annual flow and median flow rates
- Mean monthly or seasonal flow rates
- Channel flow depth, width, and velocity at flow rates
- Channel slope
- Channel bed and bank material
- Channel bank vegetation characteristics

Methods for estimating these recommended technical criteria are described in detail in Section 4 of this report.

HISTORICAL CRITERIA

One objective of this study is to determine what kinds of boats were available in Arizona and vicinity circa Statehood. Investigations involved searching available literature for references to historic boating and visiting museums, libraries and historical societies. General books on the history of boating were examined, along with sources specific to Arizona. Several indexes of newspapers from the turn of the century were examined and appropriate articles located where available. Legal cases were surveyed and relevant sections from the Utah Riverbed Case copied. All of these references appear in Appendix B-1. Photographic collections were examined and relevant photos cataloged. A list organized by type of boat is contained in Appendix B-2.

Boating History

The results of the research into the history of boating in Arizona are described in Section 3.2.

Arizona has a long tradition of boating, despite its desert environment. Prehistoric peoples used boats to cross and travel along the lower Colorado and lower Gila rivers. Ferryboats were used on the Colorado, Gila, Salt, and Little Colorado rivers in historic times, especially in flood situations. Steamboats transported people and goods up and down the Colorado River until the arrival of the railroad. Recreational boating became popular on man-made lakes starting in the 1880s, and accelerated with the construction of large dams such as Roosevelt. Some daring adventurers traveled on the Gila and other rivers throughout the historic period, but rivers were not generally used for recreational travel until the development of new materials such as fiberglass and artificial rubber after World War II. The construction of Glen Canyon Dam increased the feasibility of commercial recreational rafting, boating, and kayaking through the Grand Canyon by reducing very high flood flows downstream of the dams. The sequence of man-made lakes along the lower Colorado has increased recreational use of that area by motorboats, canoes and personal watercraft.

Stream Boatability

Section 3.3 contains a discussion of the boatability of various kinds of watercourses. It is difficult to develop hard and fast rules for boatability of streams in the Arizona context. Water supply varies dramatically throughout the year, but even with enough water, a stream may not be boatable. Boatability depends on a number of factors - water supply, slope of the stream, obstacles such as boulders or sand bars, and width and depth of the channel. The draw of a boat varies with the amount of load, so that a boat used for a single run on the river carrying few supplies draws less than one loaded for a long journey. Rapids are classified on a scale of 1-6, with 6 being unrunnable. A stream with Class 6 rapids or obstacles may be boatable if it is possible to portage around the rapids. There is no simple formula which applies automatically to all streams. However, Table 3.3 provides the range of boatability for various stream types. Information is presented in Table 3.4 regarding some estimates of depth of water and width of stream needed for boating for certain watercraft types.

Court Rulings on Navigability

The U.S. Supreme Court has made rulings on navigability in over one hundred cases, but has never set hard and fast rules on what kinds of boats are needed to show navigability, what stream conditions are required or what length of flow season is necessary for a determination. Excerpts from U.S. Supreme Court rulings on navigability are presented in Section 3.4. Some trends can be determined from rulings in major cases, but any past ruling does not necessarily apply to a particular river.

WATERCOURSE EVALUATION SYSTEM

A primary work product of this project is an evaluation system for assessing characteristics of navigability, non-navigability, and susceptibility to navigation for the small and minor watercourses in Arizona at the time of statehood in 1912. That evaluation system is to be efficient and economical in application, practical in implementation by utilizing readily available information, and technically and historically sound. To that end, a three-level watercourse evaluation system is proposed as shown in Figure 4.1.

The State's definition of navigability addresses both susceptibility to navigation and actual navigation in fact. Therefore, the project team prepared a multi-level screening process designed to identify stream segments least likely to meet the statutory and legal definitions of navigability as follows:

- Levels 1 and 2 of the screening process, described in Sections 4.1 to 4.3, are intended to eliminate non-navigable streams, such as ephemeral washes with no record of historical or current boating, from further consideration by ANSAC. The Level 1 screening process is designed to be completed using only information from existing databases.

- The Level 2 screening process will be completed using a subjective quality assurance review provided by a technical working group familiar with navigability issues, as well as the characteristics of the specific Arizona watercourses identified by the Level 2 screening.

- The Level 3 screening process requires that engineering analyses be performed to estimate flow characteristics for specific watercourses. Section 4.4 summarizes the recommended Level 3 engineering analyses to be used to estimate flow characteristics on specific small watercourses in Arizona.

The multiple levels of the watercourse evaluation system comprise a series of screening tests of increasing refinement and work effort. Only those watercourses that survive the Level 1 evaluation are tested at Level 2, and so on. The benefit of this approach is the economy of effort that is realized in eliminating the need for a full, multiple-level assessment of each watercourse. Little justification exists to undertake more intensive and expensive evaluation at the next level when it is evident that the watercourse does not meet the technical criteria indicative of the susceptibility to navigation and the historical criteria indicative of navigation in fact. This is the only prudent approach to avoid unnecessary, detailed assessment of each watercourse even when basic susceptibility criteria are clearly not met.

WATERCOURSE DATABASE CATALOG

The multi-level evaluation system and the watercourse database catalog function interdependently. The database catalog was compiled from available existing watercourse databases maintained by various agencies. Section 5.4 describes the data fields populated for each documented watercourse segment.

The merged small watercourse database was customized for the Level 1 screening process by programming data queries in the database based upon the six test criteria comprising the Level 1 evaluation - river type, with dam, historical boating, modern boating, with fish, and special status. Section 5.5 contains detailed information regarding the database queries. The database is structured so as to keep a running notation of the results of the testing for each criterion in a narrative format for each stream segment. This feature will provide ANSAC with a full record of information which presents the reasons for the disposition of each watercourse segment as it proceeds through the screening process. Potentially, an individual not in agreement with the disposition of a particular watercourse at any level may challenge that finding based on submitted evidence relative to that watercourse. ANSAC has a ready resource for use in considering further evaluation of the watercourse finding being challenged.

Testing and refinement is an important element in the development of a workable, efficient, and sound evaluation system. To that end, testing was conducted for each of the of various categories of watercourses. Results were instructive in terms of needed modifications to the testing criteria at each level. Section 5.6 contains further discussion of database testing and results.

RECOMMENDED WORK PLAN

Section 6 presents a recommended future work plan for applying the multi-level watercourse evaluation system to the watercourses in the database catalog.

1.0 Project Summary

1.1 PROJECT BACKGROUND

Public Trust principles date back to English Common Law when the King held the beds of rivers affected by tides in Trust for the general public and for the public good. This provision was founded on the principle that there is a public need to use the waterways for commerce. When the United States gained independence from the British Crown, Public Trust principles were recognized so that the lands beneath navigable waters within the original thirteen states became the sovereign property of those states. The Equal Footing Doctrine provided that future states were entitled to sovereign ownership of riverbeds located within those new states on an "equal footing" with the original thirteen states.

At the time of statehood on February 14, 1912, the State of Arizona received sovereign title to the beds of navigable rivers located within state boundaries. Under the Equal Footing Doctrine, the United States government previously held these lands in Trust pending the creation and admission of the State of Arizona to the Union. Although the State owned the land, in order to perfect title to the navigable streambeds, the State was required to make its claim of ownership. From statehood until the mid-1980's, Arizona claimed only the bed of the east half of the Colorado River. The State failed to act on all other claims of streambed ownership and other parties asserted title to certain streambed lands. In assuming ownership of lands located in or near these streambeds, many of the current record title holders constructed projects and improvements to the land, paid property taxes, and altered the stream ecosystems and riparian habitat.

During recent years, the State, as well as a number of private and public entities, asserted claims of ownership of streambeds throughout Arizona. These claims turned on whether or not the streams were navigable or susceptible to being navigable at the time of statehood. The titles held by landowners whose property includes all or a portion of the streambed of potentially navigable streams are clouded. As a result of litigation addressing in-stream sand and gravel mining activities in the Verde River, the Arizona Legislature recognized the economic hardships created by the uncertainty of the State's potential future claims on streambed lands. In 1987, House Bill (HB) 2017 was passed outlining a procedure to quit claim any interest of the State in the beds of the Salt, Gila, and Verde Rivers for a nominal fee, reaffirming the State's claim to the Colorado River, and waiving any claim to all of the other streambeds in the State. A lawsuit challenging the constitutionality of HB 2017 was successful in 1991 and the Court found that one flaw in the bill was that it did not provide for an evaluation of the validity and value of the State's Public Trust interest on the individual watercourses.

In 1992, the Governor signed HB 2594, which repealed HB 2017 and established a systematic administrative procedure for gathering information and determining the extent of the State's ownership of streambeds. The main purpose of the legislation was to confirm State ownership in Public Trust lands located in the beds of streams determined to have been navigable at statehood. HB 2594 also created the Arizona Navigable Stream Adjudication Commission (ANSAC), a five-member board appointed by the Governor. ANSAC was directed to establish administrative procedures, hold public hearings, and make determinations of navigability. The legislation also directed the Arizona State Land Department (ASLD) to facilitate determination of navigability and to act as support staff for the ANSAC.

In early 1994, HB 2589, amending Arizona Revised Statutes (ARS) §37-1101 through 37-1156, was adopted. HB 2589 sets the criteria to be used for determinations of navigability and non-navigability, and establishes an ombudsman office to represent the interests of private property owners in proceedings involving governmental action. HB 2589 requires the ANSAC to set priorities for investigating and conducting hearings on watercourses within this state and then to report its recommendation as to which watercourses or reaches of watercourses were navigable or non-navigable at Statehood to the Legislature. The Legislature then makes a finding upon consideration of the ANSAC recommendation and enacts appropriate legislation in response to the determination.

1.2 PROBLEM STATEMENT

ANSAC is required to complete the legislatively mandated tasks described above by July 1, 2002. The watercourses currently in the process of being assessed only include the major river systems in the state. There are over 13,000 documented watercourse segments in Arizona, the vast majority of which constitute minor or small watercourses ANSAC determined should be considered separately from the major rivers. In order to expedite the evaluation process and meet the target date for completion in the year 2002, ANSAC contracted with the Stantech project team in

1997 to develop an efficient and effective evaluation system to assess the small and minor watercourses within the state for characteristics of navigability, non-navigability, or susceptibility to navigation as of Statehood on February 14, 1912. The contract also includes the identification and cataloging of all small and minor watercourses to be evaluated utilizing that system.

1.3 STUDY OBJECTIVES

- Develop criteria for determining navigability, non-navigability, or susceptibility to navigation for small and minor watercourses in Arizona at the time of statehood on February 14, 1912 which are supported by technical data and historic information.

- Develop and test an evaluation system which addresses the criteria as described above, in addition to the navigability criteria provided in A.R.S. §37-1128, in an efficient and economical manner.

- Identify the watercourses to be assessed utilizing the evaluation system described above and categorize according to a scheme consistent with the navigability criteria, the evaluation system, and the needs of the ANSAC to facilitate future study.

- Catalog the small and minor watercourses according to a categorization scheme including categories such as political boundaries and watershed boundaries, among others.

The project work products are the technical and historical criteria, the evaluation system, the catalog of small and minor watercourses, and a summary report. The application of the evaluation system to each of the small and minor watercourses cataloged is not part of this project scope. It is anticipated that all the cataloged small and minor watercourses will subsequently be assessed utilizing the criteria, the evaluation system, and the watercourse catalog developed under this contract. That work will be performed in a priority to be established in the future by ANSAC and under a separate contract.

1.4 PROJECT METHODOLOGY

The scope of work is comprised of three major work tasks which proceeded concurrently for this project.

Task I - Develop Minimum Criteria and Watercourse Evaluation System

General Description - Task I addresses the development of technical and historical criteria in accordance with the definition of navigability and non-navigability contained in ARS §37-1128 and such other sections of Title 37, Chapter 7, Arizona Revised Statutes, as may be applicable. The criteria are incorporated in the development and testing of an evaluation system for finding that specific minor and small watercourses have characteristics of navigability. The work product for Task I includes the technical and historical criteria and the watercourse evaluation system. The evaluation system is to be subsequently applied to each of the watercourses listed in the database catalog (Task II) as part of a separate contract.

Work Plan - The specific work tasks for Task I are listed below:

1. Literature Search/ Data Collection

Technical Data

- Identified various information sources for the hydrologic criteria.
- Completed literature search for hydrology and geomorphology criteria tasks.
- Researched engineering methodologies.

Historical Information

- Researched information sources for the historical boating criteria.
- Contacted museums and appropriate groups.
- Collected approximately 200 books and journal articles and another 25 newspaper articles dealing with boats used in or near Arizona before about 1925.
- Located and copied, or arranged for copying, close to 100 photos and drawings of boats in Arizona and vicinity before about 1925.
- Researched previous legal decisions, with emphasis on the Utah Riverbed Case (1930).
- Performed additional literature and photo searches at the University of California at Berkley.
- Completed a literature review.
- Compiled a bibliography of over 225 books, manuscripts and articles, and approximately 135 photographs dealing with boats in Arizona up to the 1920's.
- Drafted a literature search summary.

2. Criteria Development

Technical Data

- Reviewed, evaluated, and recommended appropriate methodologies.
- Prepared draft criteria and decision flow charts.
- Prepared summary of recommendations on engineering methodologies for advanced level screening of watercourses.

Historical Information

- Reviewed the findings of the preliminary research into the historical boating criteria.
- Evaluated alternatives for structure and content of historical, boating, and navigation criteria.
- Searched records to determine what kinds of watercraft were used at Statehood and under what conditions.
- Researched the criteria used for special status designations for watercourses by various entities.
- Drafted a short history of boating in Arizona, a glossary of boating terms and boat types, a list of available Arizona boating photos, a list of types of boats and classification of boating requirements for various kinds of streams.

3. Watercourse Evaluation System

- Evaluated implications of technical and historical criteria development upon the conceptual design of the watercourse evaluation system.
- Reviewed the data fields available within the existing watercourse databases for applicability to criteria and evaluation system development.
- Worked to develop a decision flow chart for evaluating watercourses using readily available data from the databases and the technical and historical criteria.
- Revised decision flow charts through several iterations of development.
- Refined the evaluation system to include three levels of screening for characteristics of navigability of watercourses.
- Determined the appropriate data fields to apply to various levels of the evaluation system.
- Programmed the database queries for the watercourse evaluation system.
- Tested the watercourse evaluation system using a sample set of watercourses.
- Modified the decision flow charts based on those sample test results.
- Further refinement of the three levels comprising the evaluation system.

Task II - Identify and Catalog Watercourses

General Description - Task II addresses the identification and cataloging of all minor and small watercourses within the State of Arizona. Watercourse databases obtained from various agencies are compiled. Data fields are selected appropriate to the technical and historical criteria and the evaluation system being developed concurrently. Data queries for the initial screening level of the watercourse evaluation system are programmed into the database catalog and a categorization system incorporated. The work product for Task II is the small watercourse database.

Work Plan - The specific work tasks for Task II are listed below:

4. Watercourse Database Catalog

- Contacted several state and federal agencies and obtained information regarding the existing databases for small watercourses in Arizona.
- Acquired the Arizona Land Resource Information System (ALRIS), Arizona State Parks (ASP), and Arizona Department of Water Resources (ADWR) watercourses databases in digital format.
- Evaluated content and format of the databases.
- Merged the databases based upon the hydrologic unit code and/or stream name data field, as available.
- Determined the data fields most applicable to the criteria under development in Task I.
- Reviewed the available, substantially populated data fields within the existing watercourse databases for use in the further refinement of the watercourse evaluation system.
- Completed the collection of all available watercourse data fields for the database catalog.
- Provided information for populating some additional data fields of the watercourse database.
- Developed a conceptual categorization system as part of the watercourse evaluation system.
- Compiled database queries for the initial Level 1 screening components of the watercourse evaluation system.
- Tested the database using sample watercourse data.

- Performed programming and data processing work tasks to merge all data tables, refine the Level 1 data queries in the database, and various data processing tasks to customize the database utility for this application.
- Tested the database using actual watercourse records.

Task III - Coordination and Reporting

General Description - Task III addresses the communication of the project work and study findings between the project team and ANSAC. The project team works in conjunction with the professional staff of ANSAC, the Commission itself, other state agencies, and the Technical Review Committee to achieve the study objectives and perform the scope of work for this project. The work product for Task III includes monthly progress reports and the final report summarizing findings.

Work Plan - The specific work tasks for Task III are listed below:

5. Coordination and Reporting

- Coordinated all project activities with ANSAC professional staff and reported project status monthly in written Progress Reports.
- Attended all ANSAC public hearings during the performance time for this project and provided informal project updates, as needed.
- Provided a prepared presentation to the ANSAC addressing project status, small watercourse database catalog, the watercourse evaluation system, upcoming work tasks, project schedule, and project deliverables. ANSAC reached consensus agreement regarding the design of the watercourse evaluation system.
- Held four Technical Review Committee Meetings to report project status, assess alternative options for the watercourse evaluation system, and review the database catalog and test results. The Technical Review Committee reached consensus agreement regarding the design of the design of the watercourse evaluation system.
- Prepared the final report.

2.0 Technical Criteria

Historical records of navigability are lacking for the vast majority of small watercourses in Arizona. Therefore, most navigability findings will be decided based on a stream's susceptibility to navigation, rather than its historical record. To determine susceptibility to navigation, certain technical data about the stream are required. Technical information, as defined for this project, includes data relating to the physical characteristics of a watercourse. Physical characteristics include the following interrelated variables:

- Flow rate
- Flow depth
- Flow velocity
- Flow width

For natural streams, these flow characteristics are highly variable - streamflow changes throughout the year, from year to year, and from one point along the stream to the next. Therefore, direct measurement of the changing physical characteristics of every small watercourse in Arizona is not practical or possible. Indirect methods for estimating key flow characteristics are recommended to evaluate whether a watercourse was susceptible to navigation under specific flow conditions.

2.1 TECHNICAL LITERATURE/DATA SEARCH

2.1.1 Reference List

A literature search was conducted to identify technical methodologies for estimating existing and historical flow characteristics. The key literature sources appropriate for Arizona streams are identified below. The following types of literature are listed:

- Descriptions of existing river uses, including boating
- Lists of Arizona streams
- Lists of Arizona boating streams
- Records of Arizona stream gaging stations
- Methods for estimating flood peak discharges
- Methods for estimating average annual flow rates
- Methods for estimating stream channel geometry

Discussion of these publications is provided in Section 2.2 of this report. A reference list is provided in Appendix A-1 of this report.

2.1.2 Definitions

In addition to the references cited above, the literature supports the following definitions of flow regime. Note that a change of regime could occur as a result of man-made or natural causes.

Ephemeral. An ephemeral stream is one that flows only in direct response to precipitation, and whose channel is at all times above the water table. An ephemeral stream has measurable discharge less than 10% of the time, no sustained snowmelt discharge, and no sustained discharge from springs or seepage (Meinzer, 1923; Hedman & Osterkamp, 1982).

Intermittent. An intermittent stream is one which flows only at certain times of the year when it receives water from springs or some surface source such as melting snow in mountainous areas. An intermittent stream experiences measurable discharges between 10% and 50% of the time (Meinzer, 1923), and has a seasonal period of continuous flow at least one month in duration (Hedman & Osterkamp, 1982).

Perennial. A perennial stream flow continuously, except during period of extreme drought, and has measurable flow more than 80% of the time (Meinzer, 1923; Hedman & Osterkamp, 1982).

Interrupted. An interrupted stream has short perennial reaches interspersed among intermittent stretches (Meinzer, 1923).

2.2 EVALUATION OF AVAILABLE METHODOLOGIES

The available methodologies for estimating the physical characteristics of Arizona watercourses were evaluated relative to the following objectives of this project:

- To identify streams that have no characteristics of susceptibility to navigation, given the broadest reasonable definition of navigability.
- To identify streams that have no characteristics of susceptibility to navigation, using the definition of navigability given in ARS §37-1128.

2.2.1 Limitations and Assumptions

Susceptibility to Navigation. The following questions have not been clearly and definitively addressed in the legislation, by court decision in Arizona, or by ANSAC:

1. *Type of Boat.* ARS §37-1128 identifies specific types of boats to be considered in obtaining evidence of navigability. However, historical research indicates that several types of boats other than those listed in ARS §37-1128 were available at the time of Arizona statehood (See Section 3.2). Also, there is some dispute whether case law supports restricting the types of boats to be considered. For instance, if all states enter on an "equal footing," can different boat types be used as the standard of susceptibility for each state (e.g., Would hard shell kayaks or inflatable rafts be the standard if Puerto Rico were to become a State?).

2. *Ordinary High Water vs. Ordinary Low Water.* Is annual low water to be considered the flow rate at which navigation must occur, or is the low water mark only to be used to define the limits of the State's claim if the stream is found to be navigable? In the latter case, should ordinary high water conditions be used to determine navigability, or should some other flow rate/condition be used?

3. *Flow Duration.* Is there a time period over which the stream must remain navigable? For example, is a stream that has regular, predictable annual high flows that could be boated a navigable stream if annual low flows on that stream are not usually boatable?

4. *Predictability.* Must regular periods of boatable flows be relatively predictable (e.g., spring snowmelt runoff) or can boating conditions be more opportunistic (e.g., boating in floods or during rainfall-runoff events)?

5. *Interrupted Streams.* Numerous streams have short reaches of perennial flow interspersed between intermittent or ephemeral reaches. Over what length of stream could boating occur to make a stream boatable? Meters? Kilometers? In Arizona, most interrupted streams have low flow rates and correspondingly low flow depths.

Existing Conditions. For most streams, the available data only describe existing or recent conditions. The assumption must be made, lacking data to the contrary, that existing conditions are representative of conditions as of the time of statehood. It is noted that, in general, this is not a conservative assumption with respect to non-navigability since many Arizona streams experienced higher average flow rates as of the time of Statehood. The exception to this assumption is for the effluent-dominated stream reaches that occur on watercourses such as the Santa Cruz River and Salt River.

2.2.2 Sources of Data

Data Source Criteria. The data used to assess the physical characteristics of a stream and its susceptibility to navigation must have the following characteristics:

1. *Available*. The data must be readily available to facilitate its practical use.
2. *Accurate.* The data must be published by an organization with internal and external quality control measures, and must reasonably depict actual field conditions.
3. *Published.* The data and methodologies used should be documented in juried publications.

Data Sources. The following data sources were identified:

1. US Geological Survey (USGS) Gage Summaries
2. USGS Topographic Maps
3. Flood Control District Streamflow Gage Records
4. Published Reports. See literature search summary (Section 2.1)
5. Boater Surveys - e.g., Central Arizona Paddlers Club Member Survey

Required Data Types. The following categories of physical data types could be required for estimating navigability criteria on different stream types:

<u>Hydrologic Data</u>.

- Streams with USGS Streamflow Summaries
- Streams Tributary to Streams with USGS Streamflow Summaries
- Sources of Flow - springs, precipitation, snowmelt, tributaries
- Flow Regime- ephemeral, perennial, and intermittent

<u>Hydraulic Data</u>

- Flow width, depth & velocity at Mean Annual Discharge
- Flow width, depth & velocity at Median Annual Discharge
- Flow width, depth & velocity at 10% & 90% discharge
- Flow width, depth & velocity at lowest monthly average discharge

- Flow width, depth & velocity at highest monthly average discharge
- Flow width, depth & velocity at 2-year peak discharge

Geomorphic Data.

- Channel Slope
- Channel Materials - bedrock, boulders, and sand
- Channel Width

Watershed Characteristics.

- Snowfall/Snowmelt Potential
- Elevation
- Watershed Area

Stream-Specific Published Information.

- USGS Studies & Engineering Reports
- Arizona State Parks Riparian Classification
- Arizona Game & Fish Stream Classification
- Fishery Designation / Fish Habitat - No fish may indicate no permanent water
- Recreational Classification - Classified for boating, swimming, or wading
- ADEQ Water Quality Classifications - Full body contact, drinking, limited use

2.2.3 Potential Methodologies

Three potential methodologies for considering the physical navigability characteristics are described and evaluated below:

Classified Streams vs. Unclassified Streams. ANSAC could simply make a policy statement that only the streams listed in some combination of lists of watercourses (ASP, USF&W, AZGF, etc) will be considered for characteristics of navigability. Any stream not listed is assumed to be too small to have characteristics of navigability, and would therefore be declared non-navigable. ANSAC could make a declaration of this statement in each county, asking for evidence of navigability for any streams not on the list. If no new evidence is received, then forward the recommendation of non-navigability to the legislature.

Advantages:

a. Limits consideration to a finite number of streams, albeit a large number.
b. Eliminates consideration of the Nth tributary, as in the Corps of Engineers definition of "waters of the United States."

c. Eliminates discussion of what constitutes a "watercourse".
d. Logical. If a stream is too small to have been noticed by any State or Federal resource agency, its probably too small to have significant flow, and therefore too small to boat. In an arid state like Arizona, any stream with significant flow is likely to have been noticed by some agency.

Disadvantages:

a. May be challenged for not explicitly considering each individual stream's public trust values, like the original Streambed Bill (HB 2017).[1]
b. Does not address the issue of boating ephemeral streams (opportunistic boating).

Data Bases:

a. AZ State Parks lists 74 stream segments in the *Arizona Rivers and Streams Guide* (1989), which includes 47 individual rivers. Of these, 9 are listed for whitewater boating, 1 for flat water boating, 10 for low water boating, 45 for cold water fishing, and 20 for warm water fishing (categories overlap).
b. AZ State Parks SCORP document (1989) lists 42 boating stream segments on 17 different rivers in Arizona. Only 13 of these stream segments (10 rivers) have not had detailed navigability reports prepared for ANSAC already, excluding the Colorado River (navigable by statute).
c. AZ State Parks (1995) lists 149 rivers in Arizona that provide sport fisheries, with another 35 rivers that have the potential for development as sport fisheries.

Template Methodology. The Arizona State Parks/ Arizona Game & Fish/ U.S. Fish & Wildlife Master List of Rivers divides streams into three overlapping categories: (1) boating streams, (2) fishing streams, and (3) streams with riparian habitat. USGS gage data and streamflow summaries are available for approximately 250 watercourses in Arizona. The USGS data are probably available for a number of watercourses within each of the three AZSP/ AZGF/ USFW categories, as illustrated in Figure 2.1. A relationship showing measured flow characteristics, such as flow duration, minimum monthly flow, seasonal flow, and flood peaks, could be established for each watercourse category. These relationships could then be applied to other listed watercourses within each category to assess their susceptibility to navigation.

[1] Although the challenger would first have to prove that a stream left off the master list exists, since there is no public record of such streams, and then that that stream had some public trust value.

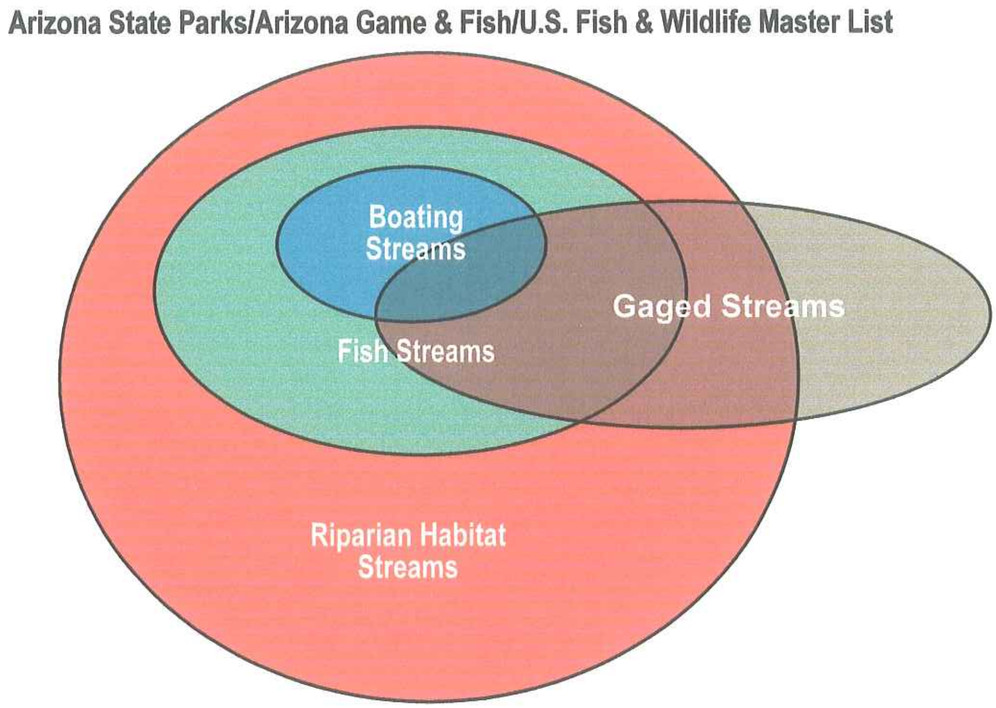

Figure 2.1 - Illustration of overlap between stream master list and gaged streams.

Advantages:

a. Uses published gage data and does not require use of regression equations for discharge and stream geometry.
b. Provides a physical description of flow characteristics of streams known to be boatable.

Disadvantages:

a. Does not address the issue of boating ephemeral streams (opportunistic boating).
b. USGS streamflow data may not be diagnostic between the three stream classifications. That is, there may be a high degree of similarity between the physical characteristics of boating, fishing, and riparian habitat streams.

Engineering Methodology. A variety of engineering methodologies are available from which physical characteristics of streams may be estimated. A list of publications potentially applicable to Arizona streams is provided in Appendix A-1. Published regression equations could be used to estimate flood peak discharge rates. Assumed peak to volume relationships could then be used to estimate average flow conditions. Finally, regression equations or regime relationships could be used to estimate flow depth, width, and velocity at specific flow rates, such as the mean annual flood or the mean annual discharge.

Advantages:

a. Provides specific numbers for specific watercourses that can be compared to boating criteria established to define susceptibility to navigation.
b. Considers physical characteristics of stream and reaches.
c. Does not rely on classification systems done by other agencies.

Disadvantages:

a. Requires many levels of assumptions to achieve an estimate of flow conditions. The accuracy of discharge regression equations is typically +/- 50%. The accuracy of regime equations typically are no better than +/- 50%. The combined accuracy estimates made using both discharge regression equations and regime geometry equations could be off by a factor of two or more.
b. Hydraulic geometry equations generally are not accurate in semi-arid regions like Arizona because: (1) they assume a relatively constant channel forming discharge, (2) they assume floods are essentially non-erosive, and (3) they are most accurate for cohesive bank materials with high silt/clay content.
c. The engineering methodology requires extensive computations and effort to obtain estimates for each stream, each stream reach, and each concentration point. Data required for each estimate could include drainage area (planimetering watersheds), mean elevation, mean annual precipitation, and/or mean annual evaporation. Given that there are more than 10,000 stream segments recognized in the available databases for Arizona, an effort as low as one hour per stream segment would take five person-years to complete.
d. The methodology requires direct knowledge of the flow characteristics of the stream (perennial, intermittent, ephemeral).
e. Regime equations generally not applicable to non-alluvial streams (bedrock channels, channels in urban areas, channels downstream of dams, etc.), and may not be appropriate for braided or distributary systems. Many Arizona streams are either bedrock controlled, or are braided/distributary systems.
f. Mean annual or peak flow data may not accurately depict boatable conditions on streams that flow for brief, regular periods, such as snow melt streams.
g. Many streams that may not be boatable due to boulders, vegetation, frequent waterfalls, or significant natural hazards may have average annual flow rates or flood peaks that, when combined with hydraulic geometry relationships, indicate that boating could occur.[2]

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[2] For example, using Thomas et. al. (1994) 2-year peak flow regression equation, a 450 acre watershed in Region 13 (Pima County) draining to a 10 ft wide ephemeral stream will indicate at 2-year flow depth of 1.7 ft, which would be boatable by a canoe. Using Hedman & Osterkamp (1982) mean annual discharge equation, the same channel would indicate a mean annual flow rate of 0.001 cfs, which would be non-navigable by any boat type. However, Hedman & Osterkamp's equation for ephemeral streams in the desert southwest, the stream would

h. Does not address the issue of boating ephemeral streams (opportunistic boating).

2.2.4 Summary

The following recommendations are made for estimating the physical characteristics of small watercourses in Arizona:

Navigability Criteria. The navigability criteria addressed in ARS §37-1128 describe actual navigation in fact, leaving the issue of susceptibility to navigation open to interpretation. ANSAC should firmly establish criteria that define susceptibility to navigation. These criteria should include standards for type of boats to be considered, whether ordinary high water vs. ordinary low water flow conditions are to be used, a minimum flow duration for boating, the minimum degree of predictability of flows, and a minimum length of boatable stream reach.

The following are recommended by the project team for ANSAC's consideration in establishing the criteria to be used in evaluating susceptibility of watercourses to navigation:

- Boat Type. Minimum boatable conditions should be based on use of inflatable rafts or canoes, both of which were available at statehood.
- Flow Condition. Ordinary high water conditions, or the mean annual flow rate, rather than ordinary low water conditions should be used to determine susceptibility to navigation.
- Flow Duration. Boatable flows should be defined as those continuously sustained for at least one month of every year.
- Predictability. Boatable conditions should be defined as occurring annually at regularly occurring periods of the year.
- Length of Reach. A boatable reach should be defined as at least one mile in length.

Methodology. A combination of use of stream classification data, engineering methodologies, and engineering judgment is recommended to estimate physical and navigability characteristics of Arizona watercourses. Stream classification data from agency database sources is suitable for initial screening, but cannot provide the level of detail required to estimate actual flow conditions of a specific stream reach. The level of effort required to use the engineering methodologies is not appropriate or warranted for application to all 13,000 stream segments in Arizona. Therefore, a

need to be 72,000 feet wide to predict a mean annual flow rate of 100 cfs. Compare these numbers to Rillito near Tucson (#09486000): (1) USGS Gage Data: Q2=5,120 cfs; Qav=14 cfs; Q50%=0.01 cfs; W=400 ft; (2) Hedman & Osterkamp Qav=0.24 cfs, (3) Thomas et. al. Q2=3,400 cfs.

warranted for application to all 13,000 stream segments in Arizona. Therefore, a multi-level approach, with varying degrees of effort and types of analyses is recommended, as described in Section 4 of this report.

2.3 IDENTIFICATION OF DIAGNOSTIC TECHNICAL CRITERIA/ANALYSES

Regardless of the exact evaluation scheme adopted by ANSAC, certain technical data are required to identify non-navigable streams and to determine susceptibility to navigation.

2.3.1 Non-Navigable Stream Technical Criteria

The following technical data are recommended for consideration when identifying non-navigable streams:

- USGS gage data indicate that the stream is ephemeral
- Stream is listed as ephemeral in AZSP/ AZGF/ USFW databases
- Stream is not listed as boating stream by AZSP/ AZGF/ CAPD

2.3.2 Navigability Susceptibility Technical Criteria

The following technical data are recommended for consideration when determining susceptibility to navigation for Arizona streams:

- Flood peak discharge rates
- Mean annual flow and median flow rates
- Mean monthly or seasonal flow rates
- Channel flow depth, width, and velocity at flow rates
- Channel slope
- Channel bed and bank material
- Channel bank vegetation characteristics

Methods for estimating these recommended technical criteria are described in detail in Section 4.4 of this report.

3.0 Historical Criteria

3.1 INTRODUCTION AND METHODOLOGY

One objective of this study is to determine what kinds of boats were available in Arizona and vicinity circa statehood. Investigations involved searching available literature for references to historic boating and visiting museums, libraries and historical societies. General books on the history of boating were examined, along with sources specific to Arizona. Several indexes of newspapers from the turn of the century were examined and appropriate articles located where available. Legal cases were surveyed and relevant sections from the Utah Riverbed Case copied. All of these references appear in Appendix B-1. Photographic collections were examined and relevant photos cataloged. A list, organized by type of boat, is contained in Appendix B-2.

The results are summarized in Section 3.2. Section 3.3 contains a discussion of the boatability of various kinds of watercourses, including some excerpts from U.S. Supreme Court cases dealing with navigability. A glossary of terms appears as Appendix B-3.

A listing of the historical information sources follows:

- **Historical Societies and Museums**

  Arizona Historical Society - Tucson, Arizona
  Arizona State Museum - Tucson, Arizona
  Caballeros Historical Museum - Wickenburg, Arizona
  Colorado River Indian Tribes Museum - Parker, Arizona
  Gila Bend Historical Society - Gila Bend, Arizona
  Mohave County Historical Society - Kingman, Arizona
  Oklahoma Historical Society - Norman, Oklahoma*
  Pinal County Historical Society - Florence, Arizona
  Quechan Indian Museum - Winterhaven, California
  Sharlot Hall Museum -Prescott, Arizona
  Utah State Historical Society - Salt Lake City, Utah*
  Yuma County Historical Society - Yuma, Arizona

- **Libraries**

  Arizona Historical Foundation - Tempe, Arizona
  Arizona State Library and Archives - Phoenix, Arizona
  Arizona State University Library, Arizona Collection and Indian Collection - Tempe, Arizona
  Huntington Research Library - San Marino, California
  National Archives and Records Administration Library - San Bruno, California
  National Guard Library - Phoenix, Arizona*
  Phoenix Historical Society - Phoenix, Arizona
  University of Arizona Library, Special Collections - Tucson, Arizona
  University of California at Berkeley, Bancroft Library - Berkeley, California
  Water Resources Center Archives, University of California - Berkeley, California

- **Other Sources**

  Arizona State Land Department - Phoenix, Arizona
  Central Arizona Paddlers' Club - Phoenix, Arizona*
  Center for Law in the Public Interest - Tucson, Arizona
  Lynne Clark Photography (Historic photos) - St. George, Utah

* Contacted by mail to obtain photos or information, not visited.

3.2 A BRIEF HISTORY OF BOATING IN ARIZONA

> *"... Then one day Montezuma's friend Coyote, came by and told him he should build a big dugout canoe. Montezuma could make anything, but didn't know why he needed a canoe. Coyote told him to build it anyway, so he did, and kept in on a mountaintop. Coyote made himself a little boat out of a hollow log.*
>
> *Before long, Montezuma found out why he needed the canoe. A great flood engulfed the land, and Montezuma and Coyote floated on its surface while everything else perished. The two friends tried to find dry land, and when they scouted out the north, they found it. The Great Mystery had already begun to make more people and animals there, and he put Montezuma in charge again, telling him to teach the people all the things they would need to know to survive. ..."*
> *Tohono O'odham Creation Story.*

3.2.1 Introduction

The following is a brief overview of the history of boating in Arizona. Appendix B-2 contains a list of boat illustrations available in libraries and museums and other sources. Appendix B-4 consists of a series of quotes describing boating in Arizona.

3.2.2 Chronological Summary

Prehistoric Boating - Flood stories are common throughout the world from the Hebrews to the Tohono O'odham, Pima and other Arizona Indian tribes. Many of those stories include boats, as does the story quoted above. The Apache flood story, on the contrary, has people going on foot to the top of the mountain to be saved. Whether or not boats were actually used by those peoples, it seems clear that the concept of boating was prevalent in some Arizona prehistoric societies.

Boats were used on the Colorado River long before the arrival of the Spaniards. One of the names the Spanish explorers gave the Colorado River was "Rio del las Balsas" because of the large number of rafts (balsas) Indians were using on the river. These rafts were made of reed-like materials, wood, or a combination. Rafts were sometimes made of bundles of reeds, agave stalks, or willows fastened together either so that one or both ends was pointed and the sides elevated - in the shape of a canoe or so the raft lay flat in the water. Such rafts are known from California, all along the coast and inland to South America. The Seri Indians who lived on the coast about 100 miles south of the Colorado River delta built reed rafts of highly sophisticated design, well suited for open-water travel on the Sea of Cortez. Rafts were propelled by paddles, poles or swimmers.

Wooden rafts were flat, made of stems or trunks attached horizontally. Both were propelled by poles or swimmers. The first Spaniards reported seeing and traveling on rafts of both types. The rafts were highly maneuverable. There is no evidence that either type of raft was used prehistorically in Arizona beyond the Colorado River and lower Gila River, although it seems possible that such rafts were used on the middle Gila and Salt at some times. Because of the perishability of the materials, proof is unlikely to be found, but archaeologist, Frank Cushing, is reported to have found remains of a canoe in a Hohokam site from the Salt River Valley.

Other prehistoric vessels were made of woven twigs (usually willow) in the shape of a basket and made waterproof with what the Spaniards described as "a bitumen-like substance." Similar boats from southern California were made watertight with tar, probably from the tar pits in the area. Sap from agaves was used to waterproof smaller baskets and may also have been used for these larger vessels. Basket-type boats are reported to have been used by Apaches on the Gila River.

The Quechan made ceramic vessels large enough to carry goods, children and even wives. These vessels were propelled by swimmers. One writer described these as nearly flat vessels, while others describe them as "ollas," rounded vessels for carrying water. There is some evidence of the use of dugout canoes, but these were never as popular as they were farther north all the way to what is now British Columbia where plenty of trees of appropriate wood of fir, cedar, or pine could be easily found.

Beaver trapper, George Yount, said that he built a dugout canoe "after the manner of the Mohave Indians" in the 1820s.

The Arrival of the Spaniards - Several groups of Spaniards arrived by sea along the California coast and the Sea of Cortez in large sailing ships. They proceeded up the Colorado River probably not much farther than the mouth of the Gila River in their ships or in smaller ship's boats of various types - rowboats or canoes. The tidal bore "burro" was often a major problem, but they were able to deal with it. The Spaniards are not known to have used boats on other Arizona rivers as their exploration inland was on horseback and on foot. Most of the missions were established and served by routes inland from Mexico and New Mexico. One description has Father Kino felling a large cottonwood tree in Caborca to provide lumber for a boat to explore the coast and to determine whether Baja California was a peninsula or an island, and determine the character of the Colorado River, but the boat was not completed.

Anglo Trappers - Anglo trappers came to Arizona from the north and east. They were traveling on horseback and on foot, but sometimes constructed boats to get across and down rivers. The most common type of boat was the "bullboat" developed by plains Indians. Originally these boats were made of one bull buffalo hide stretched over a framework of willows or similar wood. In Arizona where there were no buffalo, elk or horse hides were stitched together for this purpose. These boats were propelled with paddles or poles were sturdy but were not very maneuverable and were usually abandoned after serving a particular purpose. In one exploration from Idaho to the Sea of Cortez, two of the trappers' horses were killed for their hides on the first Colorado River crossing and another two later for the return journey. Some trappers used these boats for some distance downstream on the Colorado and Gila Rivers. Trappers sometimes built dugout canoes where they could find appropriate wood along the upper Gila and upper Colorado rivers. There are no appropriate trees in Arizona for the kinds of birchbark canoes common in the eastern parts of the continent.

American Exploration and Surveys along the Lower Colorado River - After 1850 the U.S. Government sponsored a number of surveys of the new territory. Most of these were cross-country trips involving crossing the Colorado River by ferry, but some were designed to explore the river itself by boat. Joseph Ives took a steamboat up the river in 1861 as far as Vegas Wash. The Wheeler Expedition used rowboats (with the occasional addition of sails) to explore parts of the lower Colorado River as far as what they considered the limits of practical navigability - somewhere around the present Hoover Dam. Jacob Hamblin explored the lower Colorado River in the vicinity of the mouth of the Virgin River and in the Lee's Ferry region, usually on foot, but also using rafts and rowboats over a period of about twenty years at the end of the nineteenth century. The first inflatable boat was used in Arizona in 1854 to cross the Colorado River somewhere near Needles on the second Ives Expedition. Balduin Mollhausen drew a picture of this boat and humorously described how the Indians on their easily maneuvered rafts laughed at the Anglos trying to get their clumsy raft across the river. A few years later Edward Beale used an inflatable raft with slightly more success. Use of inflatables, however, did not become common until the development of artificial rubber in the 1940s.

Godfrey Sykes spent many summers boating on the Colorado River, exploring the Delta, often with his family. He conducted scientific explorations along the Colorado and to the Salton Sea for the Carnegie Institution's Tumamoc Hill facility in Tucson. He sometimes hauled lumber to the shore and built his boat on the spot. His boats were generally rowboats or a combination of oar and sails.

Ferryboats - The California Gold Rush, California statehood and acquisition of Arizona in the 1840s and 1850s increased the demand for cross-river travel on the Colorado. At first the demand was met by Quechan and Mohave Indians who ferried travelers across the river for a fee. The business became so lucrative that Anglo entrepreneurs soon challenged Indian domination of the river. Several outright battles ensued, especially at the Yuma crossing. For a while Anglos dominated the passenger-freight business while Indians ferried and swam animals across the river. Farther north at the Mohave crossing, Indians bitterly resented Anglos who cut down their sacred and valuable cottonwood trees to build rafts for single crossings. Here, too, Indians crossed travelers for a fee, especially if convinced that the travelers were moving on, not settling nearby. In nearly all cases, wood rafts were used as ferries, though travelers report seeing Indians using reed rafts.

For the most part, cross-country travelers came on horseback, covered wagons, on foot, or, later, stagecoach, fording rivers such as the San Pedro and Gila. Some travelers attempted travel down the Gila by converting their wagons to boats or by building rafts. In several cases, when the river was high, they did travel for some distance along the Gila from Gila Bend to the Colorado. One pioneer designed his wagon to be easily convertible as he crossed the country, but seldom used that feature in the West.

Anglo ferries originally were rowboats or flatboats, but later often developed into more complex structures. By the early twentieth century, boats were large enough to carry six or more automobiles. Many of the early ferries were operated by cables for stability in crossing changeable rivers. Some of these were propelled by people on the ferry pulling the cable while others were operated from the shore. In most cases the boat was in the water, but some ferries were suspended above the river. Many of the ferries were operated by Mormons to facilitate travel by Mormons between Salt Lake City and the Arizona communities. The Mormon ferries at the mouth of the Virgin River and Lee's Ferry were the most long-lived as they were major points along the Mormon Trail. The ferries at Yuma were used more than any others because of the many people wanting to cross to the gold fields. Hayden's ferry was an important crossing of the Salt River in Tempe. There were other ferries in the Phoenix area as far downstream as Maricopa. One ferry operated across Roosevelt Lake to connect with the road to Young. A suspended cable ferry crossed the Little Colorado River, serving Mormon settlers.

The arrival of the railroad and highway bridges led to the demise of the ferry business. With the development of gas engines, ferries in areas without railroads or bridges became larger and much easier to maneuver than the old ones powered by oars. In more recent times, gas-powered ferries have taken gamblers and tourists across the Colorado River to Nevada casinos.

Figure 3.1 shows a map of the major ferryboat stations in Arizona.

> *"The watercraft most commonly used in commercial navigation have been row boats of 16-18' in length, drawing 6-12"; row boats 18-22' long, drawing 14-18"; steel rowboats 18' long, drawing 7-19"; motor boats of 20-27' length drawing 10" - 2'; rowboats 16-18' length, propelled by outboard motors drawing 15-18"; scows 32'-8', and 24'-6', drawing 8"; and rafts."*
>
> *Summary from the Utah Riverbed Case (1931).*

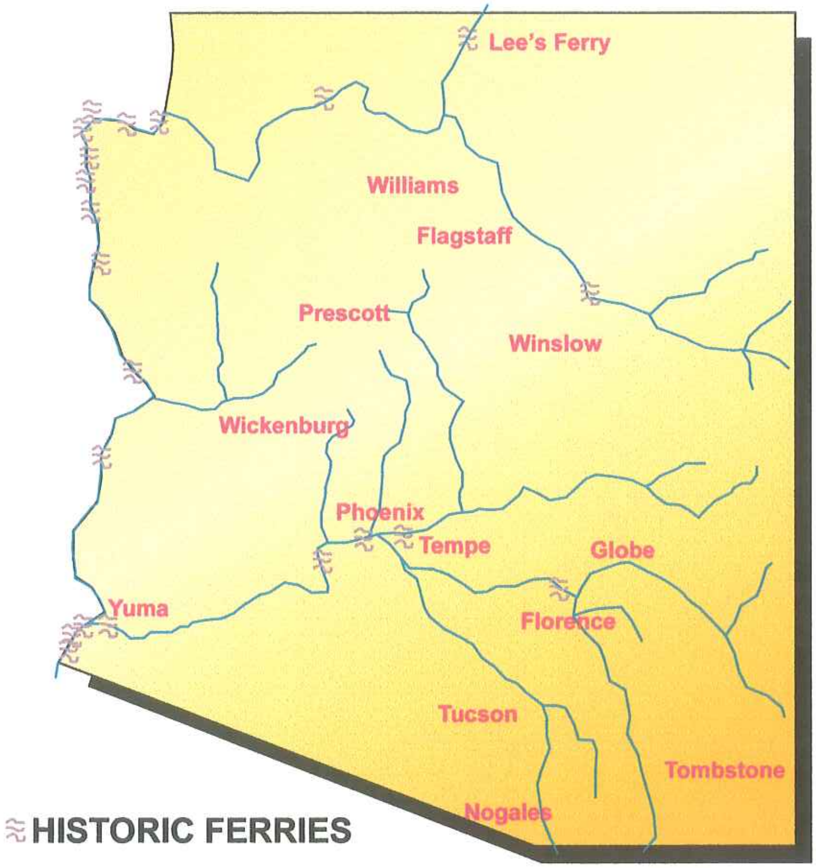


Figure 3.1 map of major ferryboat stations

The Steamboat Era - After the end of the California Gold Rush, many miners sought and found treasure along the Colorado River. After the Civil War, several forts were established along the river. Getting supplies in and ore out and supplying the forts offered new opportunities for boating entrepreneurs. Surveyors were needed to establish boundaries and explore the new territory. The history of steamboats on the Colorado is thoroughly described in Lingenfelter's *Steamboats on the Colorado*. The first steamboats were only partially successful, but were followed by a series of commercial steamboats which could travel during the high water months of spring and early summer. Captains developed techniques for getting their boats off the sandbars so common along parts of the river.

Before the arrival of the railroad, most commercial freight along the Colorado River was transported by steamboat. The limit of navigation was considered to be in the vicinity of the present day location of Lake Mead, as far upstream as the mouth of the

Virgin River (Callville and Rioville) in many years. The Mormons were interested in developing a network of communities, roads, and ferries all the way from Salt Lake City to the coast. At one time they had great hope for a steamboat-land route to carry freight from California or the East to Salt Lake City, along the Virgin River alignment.

One steamboat operated for a while in the Lee's Ferry area and others in the Upper Basin of the Colorado, but steamboats are not known to have been used on other Arizona rivers.

Boat Use by Settlers and Prospectors - People who traveled through Arizona on their way to someplace else used ferries, but were not usually involved in travel up and down rivers. Settlers sometimes used boats, especially during spring snowmelt periods or other flood times. People in rural areas depended on horses to a large extent and seldom needed boats as their horses or wagons could easily ford the rivers. In more urban areas along the Gila and Salt rivers, especially the Florence-Kelvin and Phoenix-Tempe areas, boats were slightly more common. While boats are seldom mentioned either in journals or newspapers, they were clearly available for use when needed in situations such as flood rescue, suggesting they may have been used at other times for uses such as hunting or fishing.

The Colorado River and some of its tributaries were used by prospectors in the late 19th and early 20th centuries. Various kinds of rowboats are reported traveling extensively in the Lee's Ferry area and surrounding areas, but most of the prospecting activity was in the lower Colorado from somewhere around present day Needles to Yuma. Marshall Bond, a gold prospector, was one of the few prospectors who described his travels on the Colorado River in the early years of the twentieth century. In 1912, he took his wife and children down the river from Needles to Yuma in a canoe and a 20-foot scow which he described as a "luxury." He also described travels by boat in the delta region and up the Alamo River to Imperial Valley.

Flood Rescue and Travel at Flood Time - Water flowed in the Salt and Gila rivers in urban areas almost every year until the construction of upstream dams. Regular ferry service operated during several high-water months of the year in Tempe, Phoenix on the Salt River, and Maricopa, Kelvin, Florence, Dome and other places on the Gila River. At low-water times the river could be forded. At some times, however, the rivers flowed too strongly for even the ferries to operate. At one point, cross country train travelers headed for Phoenix had to embark at Casa Grande, take the stage to Florence where they were ferried across and from then one went by stage.

During the winter and spring of 1905, heavy flooding occurred along the Gila River. Bridges went out at several places and the ferry business thrived at Florence and Kelvin. Each issue of the weekly paper described the lengths people went to transport passengers and freight and keep the Ray Mine at Kelvin supplied. Extracts from Editor Tom Weedin's humorous descriptions of the competition, and the trials and tribulations experienced are briefly excerpted in Appendix B-4. Two "navigation companies" were in fierce competition for three months until the completion of cable "cages" and subsidence of the flood waters in May. These rescue boats are seldom well described except as "rowboats" or "flatboats" sometimes large enough to transport a horse and buggy. The editor, tongue-in-cheek, spoke of the "Gila Fleet" and of an important person he called "Admiral of the fleet" that operated near Florence, but it seems probable that the fleet was much less grandiose than described. But it is clear that a number of boats, some of which were large enough to haul tons of freight were in use there.

Exploring the Grand Canyon - The history of river running in the Grand Canyon and the development of boat types and boat skills are discussed in great detail in Lavendar's River Runners of the Grand Canyon. John Wesley Powell was undoubtedly the first American to travel from the Green River through the Grand Canyon, although there are unproven reports of an earlier traveler through the Grand Canyon. Powell's first boats were made of sturdy oak of a typical rowboat design of the period. His boats were propelled by an oarsman facing backward in the traditional rowing fashion, providing power as the oars were pulled forward. Nathan Galloway changed this traditional method to one in which the oarsman faced forward going through the rapids, making it possible to clearly see exactly what the obstructions were and how the rapids were behaving. This revolutionized Grand Canyon travel at least as much as the new boat design, also developed by Galloway. He was a trapper who traveled alone in the Grand Canyon in the late 1800s and early 1900s for months at a time. His boat was lightweight and easily maneuverable - ideal for one man. Airtight compartments were built into the boat fore and aft, allowing both for waterproof storage areas and increased buoyancy.

Later explorers, especially those doing official surveys for the railroad and the government used variants on Galloway's design. In 1909 Julius Stone brought

Galloway to Ohio to design boats for a trip on the Colorado. These boats had to be larger than the traditional Galloway design to hold several men and heavy supplies, including survey and photographic equipment. Because they were much larger and heavier they were much less maneuverable in the rapids, but were adequate for the purpose as long as they were built of sturdy materials. One explorer ordered boats built in the Galloway-Stone pattern, but they were constructed of lightweight cedar which was far too fragile for the Grand Canyon and some were even broken in transit before they reached the river. From then on until the development of modern materials, Grand Canyon boats were built of oak or pine, not cedar. While later explorers modified the designs, the most successful boats were the Galloway-Stone type made of sturdy wood until the development of modern materials after World War II.

In 1938 Buzz Holmstrom took the first modern-type inflatable raft (provided by Goodyear) through the Grand Canyon with mixed results. In the 1940s the development of artificial rubber made it possible to design durable, maneuverable rafts which did well in the Grand Canyon, due largely to experiments with war surplus rafts, conducted on the river by Georgie White. It was not until after construction of Glen Canyon Dam that rafting the Grand Canyon became relatively safe and popular for tourists. Today boats of many kinds are used in the Canyon, including kayaks, canoes, inflatable rafts, and rowboats made of various materials from wood to fiberglass.

Boats in the Dam-Building Era - Boats were used in the process of building dams, first for exploring for appropriate dam sites and later for moving people and material to the sites. Such boats ranged from rowboats to barges. Dignitaries were taken to the dams by boat. Once the reservoirs were in place, the lakes became popular boating areas. Photos of boats on reservoirs are available from the 1880s and later. After construction of Roosevelt Dam, boating was a popular pastime. One photo shows a tour boat at a boat landing there, while another shows people in a tourboat on the lake. Murl Emery and others operated tunnel-stern motorized boats in the Needles/Hoover Dam area both before and after dam construction, serving both dam workers and tourists.

Recreational Boat Use - Recreational boating was popular in Arizona as early as the 1880s. The first man-made lakes made the use of boats for hunting, fishing, or daily adventures common. A picture of the lake formed by the Walnut Grove Dam near Wickenburg shows a number of boats under full sail in the late 1880s. Other photos show boats on lakes Mary and Rogers near Flagstaff in the late 1800s. The Granite Dells Lake near Prescott opened in 1907 offering both boating and swimming. A 1900 promotional pamphlet by the Phoenix Chamber of Commerce talks about opportunities for boating "nearby." One photo shows eight men in a rowboat on the San Francisco River at Clifton, while another shows men in a rowboat traveling down a Salt River canal and a third shows people in a boat on Clear Creek near Winslow in the late 1800s.

Newspapers describe several adventuresome trips down the Salt and Gila Rivers in the 1880s and 1890s. In some cases, the adventurers sent a letter to a newspaper part way through a journey reporting progress, but there is no record of whether the journey was completed. Godfrey Skyes' brother Sydney built a canvas boat around 1910 which he used for an only moderately successful winter low-water trip down the Gila from somewhere downstream of Phoenix to the Colorado, having to tow the boat much of the way.

Even in the early 1900s, people took boats down to Mexico for fishing and recreation. One description in the Florence Blade Tribune describes some men from Florence taking a "yacht" to the gulf in 1905 and not finding good hunting and fishing proceeded 500 miles to Tiburon Island.

In the 1930s Bus Hatch and Norman Nevill began commercial river trips on the San Juan and upper Colorado rivers, using wooden boats and charging $65 per trip. After World War II, inflatable rafts made of the new artificial rubber (neoprene) developed during that war, became popular on Arizona rivers. The development of fiberglass in the 1950s led to the popularity of river recreation on rivers such as the Verde, Gila, Salt and Colorado, although wooden canoes and rowboats continue to be used. More recently the development of one-person lightweight kayaks and "rubber duckies" has made it possible to boat shallow rivers previously thought unboatable.

Lake recreation also increased about the same time with the increase in large man-made reservoirs throughout the state. Today more than 150,000 boats are registered in Arizona, almost all for recreational use on lakes, for uses such as fishing and water skiing. Small "personal watercraft" have become popular on dammed rivers such as the Colorado. It is often stated that Arizona has more boats registered per capita than any other state. While Arizonans do own a large number of boats, this statistic is somewhat misleading since Arizona requires registration of all boats no matter how small, while other states such as Michigan only require registration above a minimum size, skewing the comparison. Watercraft registration increased from 20,866 in 1959, the first year registration was required, to 241,280 in 1997 (of which 161,061 are "active" registrations.) See Table 3.1 for a breakdown of registered watercraft in Arizona by boat type in 1998.

TYPE OF BOAT	ACTIVE	INACTIVE	TOTAL
Runabout	66,413	30,817	97,230
Day Cruiser	9,039	3,899	12,938
Cabin Cruiser	4453	2505	6955
Houseboat	991	433	1,424
Pontoon Boat - Cabin	8073	2141	10224
Sailboat	2,857	2,174	5,031
Catamaran	788	828	1,616
Sailboard	538	1,159	1,697
Utility	26,542	14,864	41,406
Canoe	9,154	5,460	14,614
Inflatable	3,118	3,430	6,548
Kayak	1,899	981	2,880
Personal Watercraft	26,268	10,314	36,582
Airboat	35	14	49
Hovercraft	18	30	48
Amphibious	7	2	9
Other	848	1,171	2,019
Total	**161,061**	**80,219**	**241,280**

Table 3.1 - Arizona boat registration in 1998

"Runabout" includes fishing and ski boats, usually motorized.
"Utility" includes rowboats and small outboard motor boats.
"Inactive" means that the boat was registered at one time, but the registration was not kept up. AGF does not know whether the boat is still in use in Arizona.

> *"... A desert, yes. But Arizonans own and use twice as many boats per capita as Californians. Our waterways offer exciting variety and adventure, the dramatic complement of water to an already majestic land. We're proud of our remarkable variety which ranges from quiet coves on calm lakes to the pounding excitement of white water; from the thundering might of unlimited hydroplane races to the pastoral relaxation of a solitary canoe resting in a tree-shaded lagoon. ..." Gov. Raul Castro, 1976. Introductory letter in McDannel's Guide to Arizona's Waterways.*

Summary of the Availability of Boats in the First Decades of the 20th Century - Table 3.2 provides a summary of boat types in Arizona before 1913. Prior to about 1900, most small boats were homemade from lumber or driftwood and of many shapes and sizes. Boat-building manuals gave detailed plans for making canoes, row boats, hunting boats and small sailboats. There are no commercial boat builders listed in the census for river towns such as Yuma or Phoenix but there are several examples of private boatbuilding.

Boat Type	Size Range (Length)	Materials	Primary Historic Uses in and Near Arizona	Known Areas of Use by 1912
Reed Raft	4' - 15'	Reeds, Agave, Willow	Fishing, open sea, cross and up/down river travel	Pacific coast, Baja, Colorado River, lakes, etc.
Olla Raft	3' - 5'	Ceramic	Transport goods, children across river	Colorado River
Basket Boat	3' - 5'	Willows, etc.	Transport goods, children across river	Colorado, Gila Rivers
Wooden Raft	5' - 25'	Logs	Travel across and up/down river travel	Colorado, Gila Rivers
Bullboat	6' - 25'	Hides	Cross and down river travel	Colorado River
Canoe	8' - 25'	Wood	Lakes and calm rivers for fishing, recreation, travel	Many rivers, canals, lakes.
Rowboat	6' - 22'	Wood, Steel	Lakes and calm rivers for fishing, recreation, travel up/down rivers- also ferrying	Many rivers, canals, lakes.
Canvas Boat	5' - 12'	Canvas/framework	Hunting, recreation	Many rivers, canals, lakes.
Scow	8' - 32'	wood, metal	Transport goods up/down rivers, also ferrying.	Colorado, Gila and Salt Rivers
Duckboat	4' - 6'	steel, canvas, wood	Hunting	Lakes, marshes
Flatboat	8' - 30'	wood, steel	Ferrying, transport goods up/down rivers	Colorado, Gila and Salt Rivers
Sailboat	6' - 35'	wood	Exploration, recreation	Colorado River, lakes
Dory	8' - 22'	wood	Fishing, adapted for whitewater boating	Colorado River
Aerial Ferry	6' - 35'	wood, steel	Cross-river travel	Colorado, Gila, Little Colorado Rivers
Ferry Boat	6' - 35'	wood, steel	Cross-river travel	Colorado, Gila Rivers
Steamboat	25' and up	wood, steel	Transport good and people up/down river	Colorado River
Galloway Boat	8' - 12'	wood	Whitewater travel	Colorado River
Galloway-Stone Boat	16' - 22'	wood	Whitewater travel	Colorado River
Gas-powered	10' - 27'	wood, steel	Travel up/down rivers, recreation, fishing ferrying.	Colorado River, lakes

Table 3.2 - Boat types in Arizona before 1913

By 1900 it was possible to order boats from the Sears and Wards catalogs. Rowboats, canoes, and duckboats for hunting (along with oars and other equipment) were offered at low prices for many years. These were available in wood, canvas and steel. The rowboat is the most common small boat seen in historic photos, sometimes with provisions for sails.

Kayaks, although common in the arctic regions for thousands of years, were apparently not used in Arizona until after World War II. Inflatable boats were available as early as the 1850s, but these boats were awkward, difficult to maneuver, and not very durable and it was not until artificial rubber was developed during World War II that inflatables became feasible.

Gas-powered boats were available as early as 1900, but were not very powerful or reliable until the 1920s. A major problem with gas power in sandy rivers, such as the Colorado River near Needles, was solved by the invention of the "tunnel-stern boat" which filtered the sand out so it didn't clog the motor.

By 1910 the U.S. Rescue Service (later the Coast Guard) was using gas–powered engines in its sea-going rescue boats and soon after in its inland boats. By the 1920s gasoline engines had developed so that there were choices of inboard and outboard motors and engines developed that could power larger and larger boats.

Recreational Boating after World Water II - Commercial recreational rafting started in the 1930s, but developed in the 1970s, on the Colorado River (especially upstream in Utah) and later on the Salt, Gila, and Verde Rivers. The development of durable small boats - plastic, fiberglass and other modern types of canoes and kayaks, inflatable boats for single paddlers and for groups - all contributed to the rising popularity of river running in Arizona especially on rivers not previously considered boatable, or boatable only very rarely because of low water.

Twenty rivers are reported to be used frequently in the spring high water season by boaters and a few more are boated occasionally. Use of boats on reservoirs is especially popular for speedboating, water skiing, fishing and other recreation. Boats became popular and boat registration climbed rapidly. Arizona is reported to have more boats per capita than any other state, but this statistic is misleading since Arizona requires registration of smaller boats than many other states, skewing the statistics.

In 1994, Arizona State Parks surveyed the popularity of various recreational activities by residents and found that boating was practiced at least occasionally by more than

25% of the population, with rafting and motorboating being the most popular. They also found that out-of-state tourists boated in Arizona in significant numbers, especially on the lower Colorado River and through the Grand Canyon. More than 15,000 people raft the Grand Canyon annually and more would undoubtedly participate if the numbers were not limited by the Park Service to protect the Park.

3.2.3 Conclusions

Arizona has a long tradition of boating, despite its desert environment. Prehistoric peoples used boats to cross and travel along the lower Colorado and lower Gila rivers. Ferryboats were used on the Colorado, Gila, Salt, and Little Colorado rivers in historic times, especially in flood situations. Steamboats transported people and goods up and down the Colorado River until the arrival of the railroad. Recreational boating became popular on man-made lakes starting in the 1880s, and accelerated with the construction of large dams such as Roosevelt. Some daring adventurers traveled on the Gila and other rivers throughout the historic period, but rivers were not generally used for recreational travel until the development of new materials such as fiberglass and artificial rubber after World War II. The construction of Glen Canyon Dam increased the feasibility of commercial recreational rafting, boating, and kayaking through the Grand Canyon by reducing very high flood flows downstream of the dams. The sequence of man-made lakes along the lower Colorado has increased recreational use of that area by motorboats, canoes and personal watercraft.

3.3 WHEN IS A STREAM BOATABLE?

Historically, people have used boats in Arizona for many purposes, such as exploration, transport of goods, travel, fishing and trapping. Today, however, the primary reasons for boating in Arizona are recreation-related. Whitewater boating was practiced only by a small number of explorers and adventurers before 1912, but is commercially important today in some areas, such as the Grand Canyon and Salt River Canyon. Canoeing and kayaking on rivers have gained in popularity in the past ten to twenty years, but many people canoed even before 1912. Lakes are used for motorboating, water skiing, fishing and other recreational purposes today as they were in 1912.

When determining boatability, the intended kind of boat and purpose need to be considered. A river that is boatable by a neoprene raft or fiberglass canoe may not be boatable by wooden rowboats, for example. Man-made lakes in Arizona are boatable by sailboats, but small streams are not. Table 3.3 shows the range of boatability of streams in terms of their suitability for different kinds of boating.

It is difficult to develop hard and fast rules for boatability of streams in the Arizona context. Water supply varies dramatically throughout the year, but even with adequate water, a stream may not be boatable. Boatability depends on a number of factors - water supply, slope of the stream, obstacles such as boulders or sand bars, and width and depth of the channel. The draw of a boat varies with the amount of load, so that a boat used for a single run on the river carrying few supplies draws less than one loaded for a long journey. Rapids are classified on a scale of 1-6, with 6 being unrunnable. A stream with Class 6 rapids or obstacles may be boatable if it is possible to portage around the rapids. (Figure 3.2.) There is no simple formula which applies automatically to all streams.

3.3.1 Water Supply

Water supply varies greatly by season, usually being highest in the spring when snow melts in the mountains. Some rivers are only boatable for a few weeks a year while others may be boatable for several months. Amounts also vary from year to year. Estimates vary on the amount of water needed for boating. The usual measure of water supply is in cubic feet per second (cfs). The amount of water needed depends primarily on the width and depth of the channel and danger from obstacles such as rocks. For example, BLM estimates that the Virgin River is runnable by rafts in some segments with 1,000 cfs, but in another segment, 2,000 - 3,000 cfs is required. In one segment BLM considers 400 cfs minimal for kayaks, while 500 cfs is needed in the rest of the river. Having enough water, however, is not the entire picture. Too much water can also cause problems. Generally above certain flow levels, rivers can become hazardous, although that too is not the entire picture. At low water, a rock may be clearly seen and avoided; at somewhat higher levels it may be possible to float over the rock; at really high levels the rock may create a reversal (hole) that must be avoided; and at maximum levels, the rock may again become insignificant as a barrier.

3.3.2 Channel Configuration

All natural rivers curve and twist to some extent, but some are so contorted as to make river running very difficult if not impossible. A narrow winding stream , especially if strewn with boulders, may be boatable by personal inflatable watercraft but nothing larger, for example, or it may be completely unboatable.

Stream description	Example	Boatability
Not Boatable		
In high mountain regions, small watershed, less than 5' wide in many places, very steep slope, major rapids, major obstacles, rocky bottom.	Minor creeks high in the White Mountains.	Not boatable and not boated historically.
In low desert regions, small low elevation watershed, usually dry except in rare flood events, sandy or rocky bottom, very shallow, low slope, possible sand bars.	Washes in the Cabeza Prieta.	Not boatable except possibly briefly with inflatables or kayaks during very rare and unpredictable flash floods. Probably never boated historically.
Boatable Occasionally Under Highly Unusual Circumstances		
In mid-to-high mountain regions with moderate watershed, steep slope in places, major rapids, no more than 6' wide in most places, adequate water during snowmelt periods.	Clear Creek	Not boatable except very rarely for brief stretches during rare flood events with very skilled paddlers in 1-person boats such as modern inflatable kayaks or plastic canoes. Probably never boated historically.
Boatable Seasonally		
Mountain stream, mid elevation, more than 6' wide in most places, moderate rapids (Class 1-3), few major obstacles, rocky or gravelly bottom, at least 6" of water most places for at least 1 month of the year.	San Francisco River	Boatable for several weeks most years, with some possible portages in kayaks, canoes, inflatables by skilled boaters. Probably never boated historically.
Mid to low elevation stream, more than 10' feet wide, no major rapids, at least 12" of water for at least one month of the year.	Gila River below Coolidge Dam	Easily boatable in wooden rowboat, skiff, flatboat, canoe. Probably boated historically.
Mid to low elevation stream, more than 8' wide in most places, occasional Class 1-3 rapids, sandy or gravelly bottom, only occasional obstacles, at least 5" of water most places for at least one month of the year.	Verde River below Camp Verde	Easily boatable for at least one month of the year with canoes, kayaks, inflatables, rowboats. Possibly boated historically in rare situations
Mountain stream, mid elevation, more than 8' wide in most places, major rapids (Class 3-5), rocky or gravelly bottom, few major obstacles, at least 3" of water most places for at least 1 month of the year.	Burro Creek	Boatable for several weeks possible some years, with portages in 1 person inflatable kayaks or canoes, by highly skilled boaters. Probably never boated historically.
Boatable Most or All of the Time		
Mid to low elevation stream or lake, more than 10' wide, low slope, at least 24" of water most of the year, no rapids, no major obstacles, sandy or gravelly bottom	Lower Colorado River from Needles to Yuma	Easily boatable by rowboats, motorboats, sailboats, canoes, kayaks, inflatables year round.

Table 3.3 – Range of boatability of streams

Class I Still or moving water with few (if any) riffles or obstructions
Class II Small rapids with waves up to 3 feet high and obvious clear channels not requiring scouting.
Class III Powerful rapids with waves up to 5 feet high. Some maneuvering required to miss obstacles. Generally speaking Class II is the upper limit for open canoes.
Class IV Long difficult rapids requiring intricate maneuvering in turbulent waters. Scouting often necessary. Rescue difficult.
Class V. Extremely difficult, extremely violent rapids, requiring difficult and precise maneuvering to avoid numerous serious obstacles. Rescue difficult at best, impossible at worst.
Class VI The most extreme whitewater, generally synonymous with unrunnable. It is a common practice to upgrade to Class V if someone succeeds in running it.
All classes can change depending on season.

Figure 3.2 – The international whitewater rating scale

"There is a bit of revolution in river running going on in the state that makes it hard to give definitive information.. Boaters who aren't content to resign themselves to a few days of fun per year on most of the state's rivers have started using durable plastic canoes and single person inflatables to run them at levels well below what in the past has been considered boatable. These seemingly stubborn individuals may end up dragging their boats over a riffle too shallow to float once in a while but to pay that small inconvenience for the reward of a day in the river is well worth it in their eyes." Arizona State Parks (1989)

3.3.3 Width and Depth

Charts are available which indicate minimum width and depth for various kinds of boats, but there is little agreement on the actual figures. Arizona State Parks, for example, considers that a canoe or kayak needs 6" in depth and 4' in width, while Jim Slingluff, of the Central Arizona Paddler's Club, claims that 2-3" in depth is adequate. Professional river guides with High Desert Adventures, St. George Utah, say they would not choose to take a canoe very far in less than one foot of depth because of the need to control the boat by dipping the paddles deeply into the water without obstructions. They also point out that depth needed depends on how heavily the boat is loaded. With two paddlers and some goods, a canoe can sink 6" deeper than with one paddler and few supplies. See Table 3.4 for some claims on width and depth. See the Appendix B-4 for quotes from the Utah Riverbed Case and other sources on how much "draw" various kinds of boats had (i.e., how far they sank when fully loaded). Draw is a good indication of required depth, but not equivalent to it, as the needs of the paddler must be considered as well as the ability to avoid rocks on the bottom.

3.3.4 Slope

The slope (determined by average number of feet per mile the river drops) determines how fast the river flows downstream - the faster the flow, the more difficult rapids are to maneuver. The slope of rivers usually changes throughout the river, with nearly flat calm areas intermixed between moderate or extreme rapids. Where a slope suddenly becomes close to vertical, a waterfall occurs which few would dare to run. While average slope gives quite a bit of information, it does not tell the whole story since sharp drops in a river with low average gradient can make a river hazardous.

3.3.5 Rapids

Rapids occur when the slope of the river suddenly increases, often because of increased slope, decreased width, and/or the presence of rocky areas (sometimes due to landslides). Rapids increase the excitement and thrill of river running, but can be so dangerous as to make a river unrunnable. The International Whitewater Rating Scale in Figure 3.2 was developed to give river runners guidelines for difficulty of various rivers. In Arizona, the amount of water in the stream can vary so greatly throughout the year that the scale is difficult to apply, as a river may be Class I at some times of year and Class II - IV at others, for example, while at some times there is little or no water at all. The scale in Figure 1. is only a general guideline to boatability.

3.3.6 Obstacles

Obstacles include boulders, overhanging branches, beaver dams, sand bars or man-made obstacles such as dams or barbed wire fences. Some of these obstacles are more of a problem at some times of year than others. On the Virgin River, for example, whether or not one large boulder is visible or submerged is considered a test of boatability during spring runoff. Boulders that are fully submerged by plenty of water can be avoided, while boulders emerging from the water can lead to crashes. Sandbars can make the river unrunnable if too extensive. Even a small man-made dam can be a severe hazard to boats.

Boat type	Depth (ft.)	Width (ft.)	Source	Other
Canoe	0.5	4.0	USFWS[1]	
Canoe	0.3 - 0.5		Slingluff[2]	4" for flatbottomed; 6" for round-bottomed
Canoe	3.0 - 6.0	25.0	Cortell[3]	
Canvas Boat	0.2		Sears Catalog 1910	Hunting in calm water
Drift Boat	1.0	50.0	Cortell	
Duck Boat	0.2	3.0	Sears Catalog 1910	
Innertube	1.0	15	Cortell	
Innertube	1.0	4.0	USFWS	
Kayak	0.5	4.0	USFWS	
Kayak	0.15	4.0	Brosius[4]	Can go anywhere there's a little water.
Low-power boat	1.0	25.0	Cortell	
Plastic canoe/ 1-person inflatable	Very shallow		ASP[5]	Can go places previously thought nonboatable.
Neoprene Raft	1.0	6.0	USFWS	
Neoprene Raft	1.0	50.0	Cortell	
Rowboat/Drift Boat	1.0	6.0	USFWS	

Table 3.4 - Some estimates of depth of water and width of stream needed for boating

1. U.S. Fish and Wildlife Service (1978): Methods of Assessing Instream Flow for Recreation. FWS/OBS
2. Slingluff, Jim (1987): Testimony in Maricopa County et al. v State of Arizona et al.
3. Cortell and Associations (1977): Recreation and Instream Flow Vol. 1 Flow Requirements BORD6429
4. Brosius, Jack (1978): Canoes and Kayaks: A Complete Buyer's Guide.
5. Arizona State Parks (1989): Arizona Rivers and Streams Guide. Phoenix.

3.3.7 Portages

Obstacles can be surmounted in many cases by portaging the boat around the obstacle. This is possible where the floodplain is wide enough, and clear enough of vegetation and rocks to make walking possible. If there are only a few portages needed, the river remains boatable. When, however, the canyon walls rise steeply from the river, the area is too rocky or vegetation too dense for long stretches, the river becomes unboatable. "Lining" is similar, except that boatmen attach ropes to the boats and let them float while the people keep hold of it from the shore, walking the boat down the river. Lining can be difficult and dangerous in strong currents.

3.4 SOME PAST SUPREME COURT RULINGS ON NAVIGABILITY

3.4.1 General Rulings

The U.S. Supreme Court has made rulings on navigability in over one hundred cases, but has never set hard and fast rules on what kinds of boats are needed to show navigability, what stream conditions are required or what length of flow season is necessary for a determination. The following are excerpts from U.S. Supreme Court rulings on navigability. Some trends can be determined from rulings in major cases, but any past ruling does not necessarily apply to a particular river.

In U.S. v Utah extensive research was done into past boating on the Colorado River and its Utah tributaries. Many people who had boated the rivers appeared as expert witnesses. Boating history was summarized by Frederick Dellenbaugh who had himself boated the Colorado and had thoroughly researched other boating for his two books on the subject. The range of boats described by witnesses appears as Table 3.5.

U.S. v. Utah - Non-navigability of a river is not established by comparison of conditions with those of other rivers which have been held to be non-navigable, but each determination as to navigability must stand on its own facts.

U.S. v Holt State Bank - Streams and lakes which are navigable in fact must be regarded as navigable in law

U.S. v The Montello - The capability of use by the public for purposes of transportation and commerce affords the true criterion of the navigability of a river, rather than the extent and manner of that use. If it is capable in its natural state, of being used for purposes of commerce, no matter in what mode the commerce may be conducted, it is navigable in fact, and becomes at law, a public river or highway.

U.S. v Appalachian Elec. Power Co. - The navigability of a stream is not depended upon the continuity or extent of its use for navigation, although these factors must be considered in determining, on all the facts, the question of navigability.

U.S. v Appalachian Elec. Power Co - .The navigability of a stream is to be determined on the basis, not only of its natural condition, but also of its possible availability for navigation after the making of reasonable improvements, and it is not necessary that such improvements should be actually completed or even authorized.

U.S. v Appalachian Elec. Power Co - Lack of commercial traffic does not negate navigability where personal or private use by boats demonstrates the availability of a stream for the simpler types of commercial navigation.

U.S. v Utah - Absence of existing commerce does not show a river not to be navigable, but its susceptibility in it ordinary condition to use as a highway of commerce, rather than the real manner and extent of actual use if the test. The question remains one of fact as to the capacity of the river to meet the needs of commerce as they may arise in connection with the growth of the population, the multiplication of activities, and the development of natural resources; and this capacity may be shown by physical characteristics and experimentation as well as by the uses to which the stream has been put.

3.4.2 Physical conditions of rivers

U.S. v. Utah - The mere fact of presence of sand bars causing impediments to navigation does not establish the character of a river as non-navigable.

U.S. v Cress - The test of navigability in fact is to be applied to a stream in its natural condition, not as artificially raised by dams or similar structures.

Economy Light & P. Co. v. U.S. - The fact that artificial obstructions in a stream exist, capable of being abated by due exercise of the public authority, does not prevent the stream from being regarded as navigable in law, if, supposing them to be abated, it be navigable in fact in its natural state.

Economy Light & P. Co. v. U.S. - Navigability in the sense of the law is not destroyed because the watercourse is interrupted by occasional natural obstructions or portages, nor need the navigation be open at all seasons of the year or at all stages of water.

U.S. v. Holt State Bank - A lake 3 to 6 feet deep which is an expansion of a river connected with navigable water, and which is used by merchants and settlers in transportation of persons and supplies by boats is navigable, although in times of drought navigation is difficult, and sand bars and vegetation at times interfere with navigation.

U.S. v Utah - A finding that a particular stretch of river is non-navigable is not sustainable where it does not differ in characteristics from the streams which unite to join it, which are found to be navigable above the point of confluence.

U.S. v Appalachian Elec. Power Co. - A stream may be navigable despite the obstruction of falls, rapids, sand bars, carries or shifting currents.

3.4.3 Characteristics of boats

U.S. v The Montello - Vessels of any kind that can float upon the water, whether propelled by animal power, by the wind, or by the agency of steam, may be the instruments of such commerce, although in order to give it the character of a navigable stream, it must be generally and commonly useful for some purpose of trade or agriculture.

U.S. v Rio Grande Dam & Irrig. Co. - The mere fact that logs, poles, and rafts are floated down a stream occasionally and in times of high water does not make it a navigable river.

Leovy v U.S - The mere capacity to pass in a boat of any size, however small, from one stream or rivulet to another, is not sufficient to constitute a navigable water of the United States.

U.S. v Utah - The true test of navigability of a stream does not depend on the mode by which commerce is, or may be, conducted, nor the difficulties attending navigation. It would be a narrow rule to hold that in this country, unless a river was capable of being navigated by steam or sail vessels, it could not be treated as a public highway.

U.S. v Holt State Bank - navigability does not depend on the particular mode in which such use is or may be had - whether by steamboats, sailing vessels, or flatboats.

Year	Person	Boat Type	Length	Width	Draw	Other
1869	John Wesley Powell	rowboat	21'			
1869	John Wesley Powell	rowboat	16'			
1881	Frederick Dellenbaugh	rowboat	22'	18"		
1889	Franklin Nims/Stanton	rowboat	16'	3.5'	keel bottom	
1889	Joseph Ross	skiff	15'16'	6"	flat bottom	
1891	John Best	rowboat	22'	4.5		
1893	Joseph Ross	flatbottom	16'	5-6"		500 lb. load
1893-1895	William Nix	rowboat	22'	3.5'	24"	
1896	George Flavell	flatbottom				
1900	A.V. Stevenson	rowboat	18'	5'	8"	
1900	Edward Wolverton	rowboat			9"	
1901	Edward Wolverton	rowboat	18'	3'	24"	fully loaded
1902	W.F. Reeder	rowboat	16'	4'		
1903	H.T. Yokey	rowboat	15'	3.5'		
1901-1902	A.L. Chaffin	rowboat	28'	8'	2 cylinder auto engine	
1907	Bert Loper	rowboat	16'	4'	7"	steel
1908	M. Oppenheimer	motorboat	30'	5'	18"	gasoline propeller
1908	Albert Anderson	rowboat			10-12"	
1909	Julius Stone	rowboat	16'	4'	6'8"	Galloway
1910	Henry Howland	rowboat	18'		12-14"	
1911	Ellsworth & Emery Kolb	rowboat	16'	4'	8"	Galloway
1914	Bert Loper	rowboat			7"	steel
1921	George Frantz	motorboat	24'	5-6'		6 hp engine
1921	Leigh Lint	rowboat	16'			
1921	Leigh Lint	motorboat	16'	4'	10"	Evinrude motor
1921	Frederick Dellenbaugh	rowboat	22'	5'	14-18"	Galloway type
1921	Frederick Dellenbaugh	rowboat	16'		14-18"	Galloway type
1926	John Galloway	rowboat	16'	5'	4"	
1925-1928	Virgil Baldwin	motorboat	27'	5'	10'	6 cylinder auto engine
1925-1928	Virgil Baldwin	motorboat	20'	4'	6-8"	Ford motor
1925-1928	Virgil Baldwin	rowboat	18'	3.5'	10'	
1926	Carroll Dobbin	motorboat	16'			

*Includes tributaries, mostly in Utah from the Green River many going through the Grand Canyon. where information is not listed, that information was not provided in the evidence.

Table 3.5 Examples of the small boats described as evidence of navigability in U.S. v Utah*

4.0 Watercourse Evaluation System

4.1 OVERVIEW OF THE 3-LEVEL WATERCOURSE EVALUATION SYSTEM

A primary work product of this project is an evaluation system for assessing characteristics of navigability, non-navigability, and susceptibility to navigation for the small and minor watercourses in Arizona at the time of statehood in 1912. That evaluation system is to be efficient and economical in application, practical in implementation by utilizing readily available information, and technically and historically sound. To that end, a three-level watercourse evaluation system is developed as shown in Figure 4.1.

The State's definition of navigability addresses both susceptibility to navigation and actual navigation in fact. Therefore, the project team prepared a multi-level screening process designed to identify stream segments least likely to meet the statutory and legal definitions of navigability as follows:

- Levels 1 and 2 of the screening process, described in Sections 4.1 to 4.3, are intended to eliminate non-navigable streams, such as ephemeral washes with no record of historical or current boating, from further consideration by ANSAC. The Level 1 screening process is designed to be completed using only information from existing databases.

- The Level 2 screening process will be completed using a subjective quality assurance review provided by a technical working group familiar with navigability issues, as well as the characteristics of the specific Arizona watercourses identified by the Level 2 screening.

- The Level 3 screening process requires that engineering analyses be performed to estimate flow characteristics for specific watercourses. Section 4.4 summarizes the recommended Level 3 engineering analyses to be used to estimate flow characteristics on specific small watercourses in Arizona.

Three-Level Watercourse Evaluation Procedure

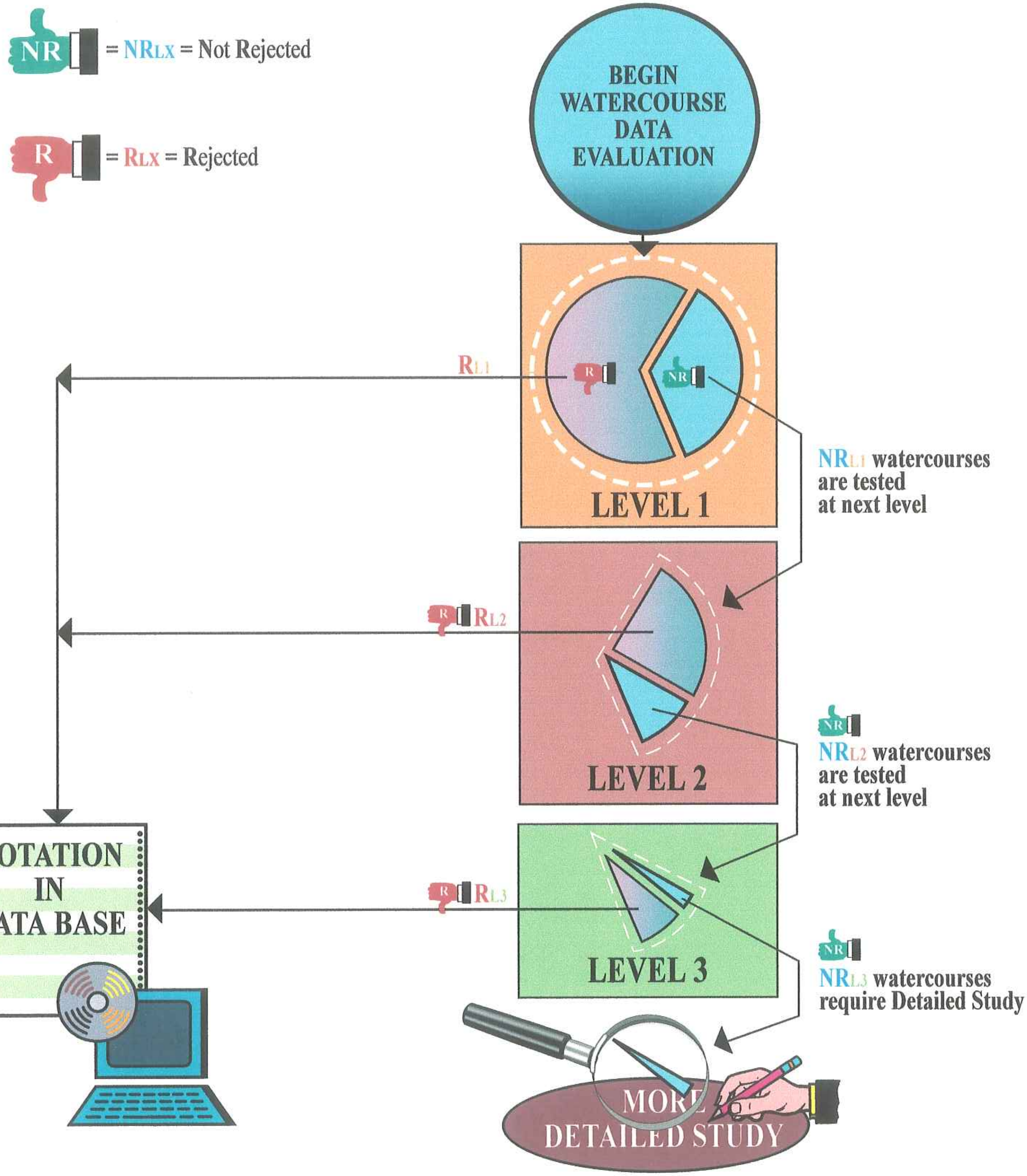


Figure 4.1
Three- Level Watercourse Evaluation Procedure

The multiple levels of the watercourse evaluation system comprise a series of screening tests of increasing refinement and work effort. Only those watercourses that survive the Level 1 evaluation are tested at Level 2, and so on. The benefit of this approach is the economy of effort that is realized in eliminating the need for a full, multiple-level assessment of each watercourse. Little justification exists to undertake more intensive and expensive evaluation at the next level when it is evident that the watercourse does not meet the technical criteria indicative of the susceptibility to navigation and the historical criteria indicative of navigation in fact. This is the only prudent approach to avoid unnecessary, detailed assessment of each watercourse even when basic susceptibility criteria are clearly not met.

The multi-level evaluation system and the watercourse database catalog function interdependently. The data fields of the database catalog are populated only enough to make the necessary decisions for each test. The database is structured so as to keep a running notation of the results of the testing for each criterion in a narrative format for each stream segment. This feature will provide ANSAC with a full record of information which presents the reasons for the disposition of each watercourse segment as it proceeds through the screening process. Potentially, an individual not in agreement with the disposition of a particular watercourse at any level may challenge that finding based on submitted evidence relative to that watercourse. ANSAC has a ready resource for use in considering further evaluation of the watercourse finding being challenged.

Testing and refinement is an important element in the development of a workable, efficient, and sound evaluation system. To that end, testing was conducted for each of the various categories of watercourses. Results were instructive in terms of needed modifications to the testing criteria at each level. Section 5.6 contains further discussion of database testing and results.

4.2 LEVEL 1

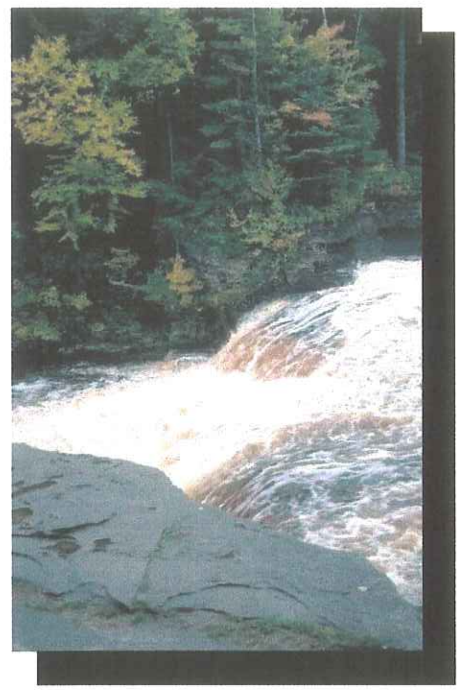
Figure 4.2 summarizes the pertinent features of the Level 1 screening of stream segments for characteristics of navigability.

Goal - The goal of Level 1 of the watercourse evaluation procedure is to perform a first-cut screening of the catalog of stream segments. The purpose is to eliminate the watercourses most likely to be non-susceptible to navigation and which exhibit no evidence of actual navigation in fact.

Level 1 Evaluation

Goal

- Coarse Sort
- Eliminate Watercourses Most Likely to be Non-Susceptible to Navigation



Methodology

- Quantitative Screening Analysis
- Binary Database Queries

Data Requirements

- Stream Type
- Dam Information
- Historical Boating
- Modern Boating
- Fish
- Special Status

Application

- Apply full test to all watercourses in the database catalog

Resulting Datasets

- R_{L1}: Watercourses which are most likely non-susceptible to navigation
- NR_{L1}: Watercourses which require qualitative evaluation at Level 2

Methodology - The Level 1 analysis is a binary, quantitative sorting process utilizing the data queries programmed into the database catalog. Those data queries are the digital expression of the technical and historical criteria considered diagnostic for evaluating watercourses for susceptibility to navigation and navigation in fact, respectively.

Data Requirements - Figure 4.3 shows the decision flow chart for the Level 1 watercourse evaluation. All watercourse segments are tested against the full set of data queries. A text record of the results of the testing for each segment is so noted in the database catalog. Only one affirmative answer to any one data query test is enough justification to advance that segment to Level 2 evaluation. A watercourse must test negative for all six queries to be eliminated at Level 1. A brief description of the content of each of the data queries follows.

Stream Type - The typical flow characteristics for a stream segment are highly significant in addressing susceptibility to navigation. As previously described in Section 2.1.2, the categories of possible stream type include ephemeral, intermittent, interrupted, and perennial. Based upon the criteria used to categorize stream type in the source databases, the Level 1 stream type data query is programmed to separate all non-perennial stream segments from the perennial ones. Perennial segments are tested for the remaining five queries, but they will advance to Level 2 evaluation regardless since they already test to the affirmative for stream type.

Non-perennial segments include those that are ephemeral, intermittent, and interrupted. These watercourses are still tested for all remaining five screening tests. However, if they do not result in the affirmative to any other tests (i.e. dam, historical or modern boating, fishery, and/or special status), they are considered unlikely to support navigation and do not advance to Level 2 evaluation.

The statutory justification for the elimination of non-perennial segments with no other features tested at Level 1 lies in the interpretation of ARS §37-1128 C. The legislation states:

> *"The Commission shall find and recommend that a watercourse was non-navigable if, as of February 14, 1912, the watercourse either: 1) Was not used or susceptible of being used for both commercial trade and travel. 2) Flowed only in direct response to precipitation and was dry at all other times."*

Level 1 Screening Procedure

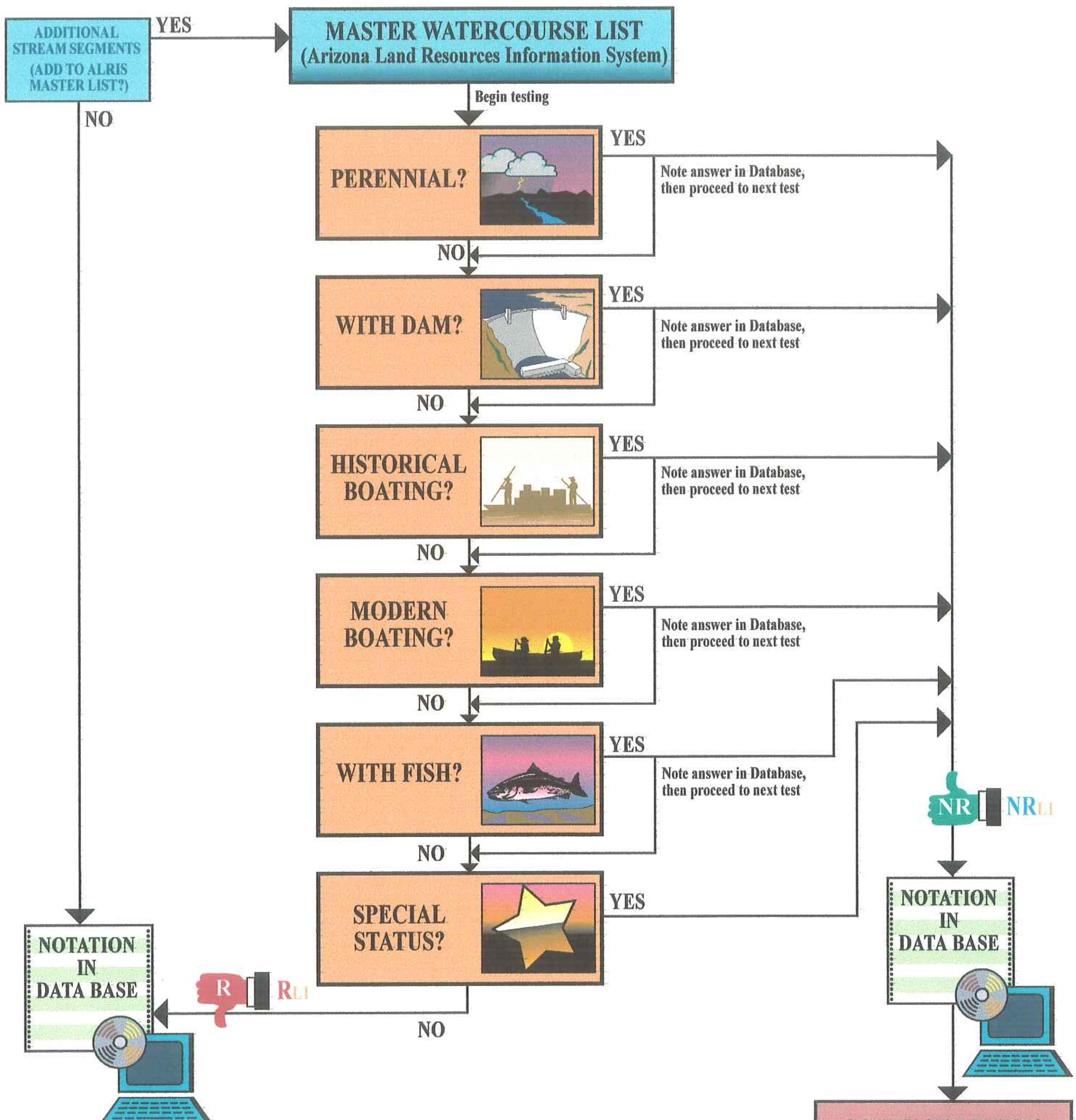


Figure 4.3
Level 1 Screening Procedure

ARS §37-1128 C.2. is the classic definition of ephemeral streams, justifying the screening out of the segments designated ephemeral in the database. Watercourses which are temporally varied in flow (intermittent) or are spatially varied in flow (interrupted) are unlikely to be navigated for commercial purposes. ARS §37-1128 C.1. addresses susceptibility to commercial trade and travel justifying the elimination of intermittent and interrupted segments.

With Dam - The location of a dam on a watercourse is significant in addressing susceptibility to navigation and navigation in fact. A dam can impact that stream segment and adjacent upstream and downstream segments to the extent that the flow regime is altered making it non-susceptible to navigation. In addition, certain dams can present impediments to actual navigation in fact. It is noted that the database catalog contains information for dams which are within the jurisdiction of the Dam Safety Section of the Arizona Department of Water Resources (ADWR). Small irrigation diversion works and stock ponds which do not meet the jurisdictional criteria of the ADWR dam safety program are not included. This is justified based on the fact that the smaller diversion dams can probably be portaged and that most stock ponds are located on ephemeral or intermittent streams. Additionally, no complete inventory of these smaller structures exists and the effort to compile one is impractical to consider.

Historical Boating - The project team researched several historical sources as described in Section 3.1. One work product of that research is the population of the data field which contains the record of documented cases of historical boating. An affirmative test result for the historical boating data query is very significant since it documents actual navigation in fact. A segment which tests affirmatively will advance to Level 2. A segment with no documented accounts of historical boating is assumed to have not been historically navigated, resulting in a negative test result for that query. Even though the segment tests negatively for historical boating, it will still be tested for the other five Level 1 data queries.

Modern Boating - Modern boating is considered of sufficient importance as to be included in the initial Level 1 screening. An inventory of watercourse segments considered boatable is readily available from various sources. Modern boating is indicative of susceptibility to navigation. Generally speaking, the changing conditions along Arizona's rivers and streams have decreased their susceptibility to navigation with time as a result of the construction of engineering works and the overdraft of the groundwater table. If a watercourse is boatable in recent time, it is possible that it would also have been susceptible and even actually boated in historic time as well. An affirmative test result for a modern boating account will advance that watercourse to Level 2 evaluation which will verify the type of boating and the conditions under which such boating occurred. A segment with no documented accounts of modern boating is assumed to not be currently boatable, resulting in a negative test result for that query. That segment will still be tested for the other five Level 1 data queries.

With Fish - While the biological factor of documented evidence of the existence of fish in a particular segment is not salient to the navigability question, their presence is generally indicative of a dependable supply of water. Watercourses with dependable water are more likely to be susceptible to navigation. An affirmative test result for the existence of fish will advance that watercourse to Level 2 evaluation which further addresses the presence and duration of dependable flow on the basis of the species of fish which are present. A segment with no documented accounts of the presence of fish is assumed to be currently not considered a fishery, resulting in a negative test result for that query. That segment will still be tested for the other five Level 1 data queries.

Special Status - The last data query considers whether or not a segment is listed by various agencies for a special class or special watercourse designation. The data query for special status designations includes Instream Flow Rights, Unique Waters, Wild and Scenic Rivers, Riparian Areas, and Preserved Areas such as Wildlife Refuges and State Parks, among others. This information is significant to the navigability question in that it is indicative of a watercourse segment with a set of special characteristics such that it should be evaluated at a more refined level of inspection. A segment which tests affirmatively for special status designation advances to Level 2 analysis which is a review of the basis of the particular special status designation for that segment relative to any bearing it may have on the issue of navigability. A segment with no documented special status is assumed to have no unique or outstanding characteristics that would require a more detailed check at the next level. That segment will still be tested for the other five Level 1 data queries.

<u>Application</u> - The data queries are applied to the entire catalog of watercourses contained in the database master list. That list is a compilation of several already existing watercourse databases from various agencies, as described in more detail in Section 5.2 of this report. A watercourse not listed in the database catalog may be

brought before ANSAC for consideration. That watercourse may be reviewed by a technical review committee for verification of documented evidence. It can either be added to the list for Level 1 evaluation, or determined insignificant and so noted in the database catalog.

Resulting Datasets - The Level 1 screening process results in two datasets of watercourses. The segments that have negative responses to all six of the data queries are most likely to be non-susceptible to navigation and; therefore, are considered low priority for further review. Those segments form dataset RL1(i.e., Rejected Level 1). The segments that have one or more affirmative responses to the any of the data queries require further evaluation at Level 2. Those segments form dataset NRL1 (i.e., Not Rejected Level 1).

4.3 LEVEL 2

Figure 4.4 summarizes the pertinent features of the Level 2 screening of stream segments for characteristics of navigability.

Goal - The goal the Level 2 watercourse evaluation procedure is to perform a more refined screening of the catalog of stream segments to eliminate the watercourses unlikely to be susceptible to navigation.

Methodology - The Level 2 screening process is completed using a subjective quality assurance review provided by a technical working group familiar with navigability issues, as well as the characteristics of the specific Arizona watercourses identified by the Level 2 screening.

Data Requirements - Level 2 review involves the qualitative review of watercourse segment location, typical watershed characteristics, typical watercourse characteristics, among other features, for verification and interpretation of the reason(s) which caused them to advance from Level 1. The following are examples of the type of quality control checks envisioned.

Fish Categories - The segments with documented fisheries are further investigated as to the fish species present. Arizona Game & Fish Department (AZGF) input is sought to categorize fish by species which require a certain volume and duration of flow to survive. This information is used to assess the potential flow characteristics for that watercourse that are indicative of susceptibility to navigation.

Level 2 Evaluation

Goal

- Refined Sort
- Eliminate Watercourses Unlikely to be Susceptible to Navigation

Methodology

- Qualitative Approach
- By Inspection
- Quality Control Check

Data Requirements

- Fish Categories
- Boating Account Verification
- Special Status Specifics
- Outlier Verification

Application

- Apply to NR_{L1} watercourses in the database catalog

Resulting Datasets

- R_{L2}: Watercourses which are unlikely to be susceptible to navigation
- NR_{L2}: Watercourses which merit quantitative engineering analysis at Level 3

Boating Account Verification - The documented evidence of actual navigation of any of the segments is verified as whether or not the boating was opportunistic (during a high flow event) or was a regular occurrence. If available, the purpose of the boating occurrence is also investigated.

Special Status - The segments of special status are reviewed to determine if the particular designation for each watercourse relates to navigation in any way. For example, a watercourse with a Unique Water classification on the basis of exemplary water quality alone does not relate to navigability question.

Outlier Verification - The Level 2 review also looks for inconsistencies in the results of the Level 1 screening process between adjacent segments of a watercourse. The database can be searched on the basis of the hydrologic unit code to obtain a count of segments by river type (or any data field) to facilitate outlier verification.

<u>Application</u> - The Level 2 quality assurance review is applied only to the watercourses contained in the database catalog that advanced from the Level 1 screening process (NRL1 dataset). As in Level 1, a text notation is made in the database as to the disposition of the watercourse following Level 2 analysis.

<u>Resulting Datasets</u> - The Level 2 evaluation results in two datasets of watercourses. The segments that are unlikely to be susceptible to navigation form dataset RL2 (i.e. Rejected Level 2). The watercourses which merit quantitative engineering analysis at Level 3 form dataset NRL2 (i.e. Not Rejected Level 2).

4.4 LEVEL 3

Figure 4.5 summarizes the pertinent features of the Level 3 screening of stream segments for characteristics of navigability. The Level 3 screening process requires that engineering analyses be performed to estimate flow characteristics for specific watercourses. This Section summarizes the recommended Level 3 engineering analyses to be used to estimate flow characteristics on specific small watercourses in Arizona.

Level 3 Evaluation

Goal

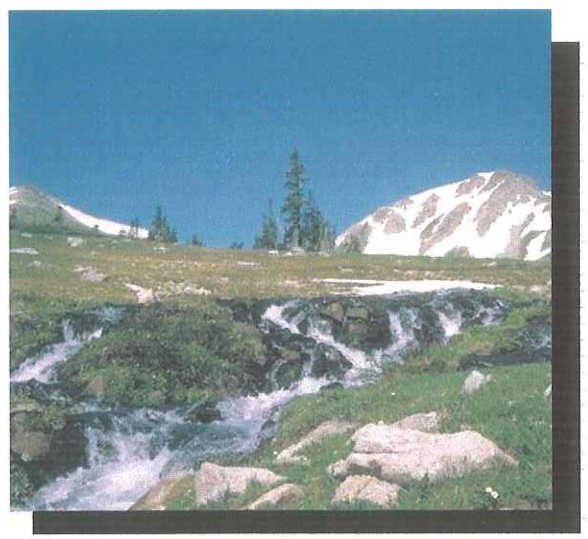
- Fine Sort
- Eliminate Watercourses Non-Susceptible to Navigation

Methodology

- Quantitative Engineering Methodologies
- Detailed Hydrologic and Hydraulic Analysis

Data Requirements

- Flow Rate
- Flow Characteristics
- Obstacles



Application

- Apply to NR_{L2} watercourses in the database catalog

Resulting Datasets

- R_{L3}: Watercourses which are not susceptible to navigation
- NR_{L3}: Watercourses which are susceptible and merit more detailed study

Stantech Consulting

Goal - The objective of this project is to develop minimum criteria for determining navigability, non-navigability, or susceptibility to navigation for small and minor watercourses in Arizona as of the time of statehood. The primary objective of the Level 3 engineering methodologies is to provide technically sound data from which typical channel characteristics and flow rates for each stream segment can be estimated and used to determine *susceptibility* to navigation.

Simply stated, the objective of the recommended engineering analyses is to provide enough information to answer the following question: "Could this stream be boated?"

Methodology - To answer the question, "Could someone boat this stream?" the following questions must also be answered:

- What type of boat(s) are to be considered? Different boats have different minimum flow depth and width requirements.
- What flow frequency or recurrence interval is to be considered? Streamflow on every natural stream varies considerably throughout the year, as well as from year to year.
- Over what time period(s) must the stream be boatable? Many Arizona streams dry up completely during the summer and fall, but support commercial boating operations in the winter and spring.
- What is the expected flow depth, width, and velocity at the specified flow rate(s)?
- What obstacles exist that might prevent boating? Permanent high flow conditions do not guarantee that a stream can be boated.

Engineering methodologies cannot provide answers to the first three questions. The Arizona legislature has provided limited guidance regarding the types of boats to be considered. However, the boats specified in ARS §37-1128D.3 exclude certain low-draft boat types known to be in use as of the time of statehood, and exclude all modern low-draft boats from consideration. Consideration of only the types of boats specified in this legislation may not be supported by most navigability case law.

Flow Rate - ARS §37-1101ff (HB 2589) provides no guidance on a flow frequency or flow duration that defines susceptibility to navigation, except that ephemeral streams[3] are non-navigable. Lacking statutory guidance, the following are flow rates and/or flow frequencies that could be used to estimate flow characteristics to determine susceptibility to navigation:

[3] HB2589:37-1127.C.2 - "flowed only in direct response to precipitation and was dry at all other times."

- *Average Annual Flood Peak.* The average annual flood has a recurrence interval of about 2.3 years, and represents the largest peak flood flow rate in an average year.
- *Average Annual Flow Rate.* The average annual flow rate in cubic feet per second, or mean annual flow, is estimated by dividing the average total flow volume in cubic feet by the number of seconds in a year.
- *50% Flow Duration Rate.* The 50% flow duration rate, or median flow rate, is the flow rate that is exceeded 50% of the time.
- *Monthly Average Flow Rates.* Monthly flow data reflect the average seasonal variation in flow rate due to watershed conditions such as snowmelt or monsoon rainfall.

Table 4.1 summarizes possible sources of methodologies or data from which to estimate the flow rate and frequency information summarized above.

Evaluation. As shown in Table 4.1, there are several possible flow frequencies that could be used to estimate flow characteristics and navigability criteria.

Table 4.1
Level 3 Engineering Methodology - Flow Rate Methodologies & Sources of Data

Flow Rate Frequency	Source of Estimate
Average Annual Flood	USGS Regression Equations - USGS OFR 93-419 USGS Gage Records – USGS OFR 91-4041
Average Annual Flow	USGS Publications - USGS OFR (Not numbered, 1970) USGS OFR 87-535 USGS WRIR 90-4053 NRCS - ARS Publications Renard, 1977 USGS Gage Records – USGS OFR 91-4041
50% Flow Duration	USGS Gage Records – USGS OFR 91-4041
Monthly Average Flow Rates	USGS Gage Records – USGS OFR 91-4041

References Cited:

1. Thomas, B.E., Hjalmarson, H.W., & Waltemeyer, S.D., 1994, Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States, USGS Open File Report 93-419.
2. Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.[4]
3. Mooseburner, O, 1970, A Proposed Streamflow-Data Program for Arizona, USGS Open File Report, Tucson, Arizona (unnumbered).
4. Krug, W.R., Gebert, W.A., Graczyk, D.J., 1989, Preparation of Average Annual Runoff Map of the United States, 1951-80, USGS Open File Report 87-535.
5. Baldys and Bayles, 1990, Flow Characteristics of Streams That Drain the Fort Apache and San Carlos Indian Reservations, East-Central Arizona, 1930-1986, USGS Water Resources Investigations Report 90-4053.
6. Renard, K.G., 1977, "Past, Present, and Future Water Resources Research in Arid and Semiarid Areas of the Southwestern United States." Australian Institution of Engineers 1977 Hydrology Symposium, p. 1-29.

[4] An updated version of Garrett and Gellenbeck (1989) is expected for release by the USGS in October 1998. The most recent version of the USGS streamflow summary should be used.

- *Average Annual Flood.* The average annual flood peak is the easiest flow rate to estimate most accurately, given the number of methodologies available and the large number of crest stage gauges compared to continuous flow record stations. However, because of the nature of floods on most Arizona streams, the average annual flood peak rate usually does not reflect "typical" flow conditions. Therefore, if the average annual flood rate is used to estimate flow characteristics, most streams will appear to have flow depths and widths that could support navigation by a wide variety of boat types.[5] To estimate the average annual flood, the following methodologies are recommended:

  1. Ungaged Streams:
     Thomas, B.E., Hjalmarson, H.W., & Waltemeyer, S.D., 1994, Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States, USGS Open File Report 93-419.[6]

  2. Gaged Streams:
     Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.

- *Average Annual Flow.* Several methodologies have been developed to estimate the average annual flow rate on ungaged streams in Arizona. With the exception of the flow estimates based on the regional maps shown in Krug et. al. (USGS OFR 87-535), none of the available methodologies are applicable to the entire state of Arizona. Because of the large volume of runoff that occurs during floods compared to low flow events, average annual flow rates tend to be skewed upward on many Arizona streams. This tendency can be illustrated by comparing average annual and median (50%) flow rates.[7] Therefore, flow characteristics estimated

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[5] For example, the average annual flow peak for an ephemeral wash with a 5.0 square mile watershed in eastern Yuma County would be about 300 cfs, using the USGS regression equations for Arizona Region 13. Assuming a roughly rectangular channel with a 20 foot topwidth, a Manning's N of 0.035, and a slope of 0.01 ft/ft., the estimated flow depth and velocity would be 2.3 feet and 6.5 ft/sec., respectively.

[6] This methodology may not be appropriate for streams in urbanized or agricultural watersheds, on alluvial fans or distributary flow areas, or downstream of dams.

[7] For example, the estimated long-term average annual and median flow rates for the Salt River at Granite Reef Dam are 1,689 cfs and 1,230 cfs, respectively (Thomas, B.W. & Porcello, J.J., 1991, Predevelopment Hydrology of the Salt River Indian Reservation, East Salt River Valley, Arizona. USGS Water Resources Investigations Report 91-4132.)

using the average annual flow rate may tend to overestimate typical flow depths and widths. The average annual flow rate may be estimated using the following methodologies:

1. Ungaged Streams.

   Mooseburner, O, 1970, A Proposed Streamflow-Data Program for Arizona, USGS Open File Report, Tucson, Arizona (unnumbered). Applicable to most of Arizona.

   Krug, W.R., Gebert, W.A., Graczyk, D.J., 1989, Preparation of Average Annual Runoff Map of the United States, 1951-80, USGS Open File Report 87-535. Applicable to all of Arizona.

   Baldys and Bayles, 1990, Flow Characteristics of Streams That Drain the Fort Apache and San Carlos Indian Reservations, East-Central Arizona, 1930-1986, USGS Water Resources Investigations Report 90-4053.

   Renard, K.G., 1977, "Past, Present, and Future Water Resources Research in Arid and Semiarid Areas of the Southwestern United States." Australian Institution of Engineers 1977 Hydrology Symposium, p. 1-29.

2. Gaged Streams

   Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.

- *50% Flow Rate*. The median flow rate may be the most representative flow rate for use in estimating flow characteristics since it is not skewed by floods and occurs (or is exceeded) at least half of the time. Unfortunately, flow duration data are not available for most stream segments in Arizona, and methodologies to generate flow duration data from watershed characteristics have not yet been developed.[8] However, there are 138 continuous record USGS gaging stations in Arizona that have sufficient data from which average flow duration statistics can be derived. These continuous-record stations are spread throughout the State. Therefore, existing methodologies could be used to transfer gaged flow records to the adjacent ungaged watersheds, although extrapolation of flow data between

[8] The USGS-Phoenix is currently considering a proposal to develop methodologies for estimating mean annual flow and median flow for Arizona streams.

watersheds significantly increases the level of uncertainty in the estimated flow rates. The median flow rate may be estimated using the following methodologies:

1. Ungaged Streams

   Obtain Streamflow (Gauge) Data from: Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.

   Transfer Methodology from: Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., 1982, *Hydrology for Engineers, 3rd Edition*. McGraw Hill Book Company, New York.

2. Gaged Streams

   Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.

- *Monthly Average Flow Rate*. Monthly average flow rate data are particularly useful for intermittent and perennial streams which flow seasonally and reliably at navigable rates, due to snowmelt or seasonal precipitation, but are dry or are not boatable during other seasons. Unfortunately, monthly average flow data are not available for most stream segments in Arizona, and methodologies to generate flow duration data from watershed or stream characteristics have not yet been developed. However, there are 138 continuous record USGS gaging stations in Arizona that have sufficient data from which monthly average flow statistics can be derived. These continuous-record stations are spread throughout the State. Therefore, existing methodologies could be used to transfer gaged flow records to the adjacent ungaged watersheds, although extrapolation of flow data between watersheds significantly increases the level of uncertainty in the estimated flow rates. Monthly average flow rates may be estimated using the following methodologies:

1. Ungaged Streams

   Gage Data from: Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.

Transfer Methodology from: Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., 1982, *Hydrology for Engineers, 3rd Edition*. McGraw Hill Book Company, New York.

2. Gaged Streams

   Garrett, J.M., & Gellenbeck, D.J., Basin Characteristics and Streamflow Statistics in Arizona as of 1989, USGS Water Resources Investigations Report 90-4041.

- *Other Methodologies*. The USGS has developed methodologies for estimating average flow rates from stream channel or watershed characteristics in other western states. The following publications are examples of these methodologies:

  Hedman, E.R., and Osterkamp, W.R., 1982, Streamflow Characteristics Related to Channel Geometry of Streams in Western United States. USGS Water-Supply Paper 2193.

  Parrett, C., and Carter, K.D., 1990, Methods for Estimating Monthly Streamflow Characteristics at Ungaged Sites in Western Montana. USGS Water-Supply Paper 2365.

  Parrett, C., Omang, R.J., and Hull, J.A., 1983, Mean Annual Runoff and Peak Flow Estimates Based on Channel Geometry of Stream in Northeastern and Western Montana. USGS Water-Resources Investigations Report 83-4046.

  Parrett, C., Hull, J.A., and Omang, R.J., 1987, Revised Techniques for Estimating Peak Discharges from Channel Width in Montana. USGS Water-Resources Investigations Report 87-4121.

In general, these types of channel characteristic methodologies are not accurate when applied to most streams in Arizona because the influence of floods (rather than median flow) on channel geomorphology, low unit water yields, and unique soil and vegetative characteristics along Arizona streams. A nationwide study[9] of these methodologies concluded:

> *"Results of the regression analyses indicate that streamflow characteristics can be defined more accurately in the humid Eastern and Southern regions than in the more arid Western and Central regions, that medium flows can be more accurately defined than high flows, and that low flows can be only weakly defined."*

[9] Thomas, D.M., and Benson, M.A., 1970, Generalization of Streamflow Characteristics From Drainage-Basin Characteristics, USGS Water-Supply Paper 1975, p. 1.

Therefore, the channel and watershed characteristic methodologies cannot be relied on to universally provide the level of accuracy required for making navigability or non-navigability decisions.

Recommended Flow Rate Methodology. The following methodologies are recommended to estimate a flow rate from which navigability flow characteristics may be estimated:

1. Ungaged streams.

   Step 1 - Estimate the mean annual flow using one of the publications cited above. Compare the flow estimate to the mean annual flow rate for similar nearby gaged watersheds.

   Step 2 - Extrapolate nearby gaged watershed data to obtain likely median (50%) flow rate.

   Step 3 - Extrapolate nearby gaged watershed data to obtain likely monthly fluctuation in flow rates.

   Step 4 - Use engineering judgment to select the median (50%) and/or seasonal average flow rates to estimate "typical" flow characteristics, depending on stream characteristics.

2. Gaged streams.

   Step 1 - Collect the USGS streamflow statistics summarized in Garrett and Gellenbeck (1990)[10] to obtain estimates of the median (50% duration) and monthly average flow rates

   Step 2 - Use engineering judgment to select either the median (50%) and/or seasonal average flow rates to estimate "typical" flow characteristics, depending on stream characteristics.

The flow rates obtained from the methodologies listed above should be used to estimate flow characteristics, as described below.

Flow Characteristics - The primary objective of identifying a representative flow rate for each stream segment is to estimate the following flow characteristics, which can then be compared to specific navigability criteria:

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[10] An updated version of Garrett and Gellenbeck (1989) is expected for release by the USGS in October 1998. The most recent version of the USGS streamflow summary should be used.

- Flow Depth
- Flow Width
- Average Velocity

Two alternative methodologies are typically used to estimate flow characteristics

1. *Regime Equations*. Regime, or regime-type, equations relate channel geometry to flow rate. For the purposes of the Level 3 navigability screening, regime equations could be used to estimate the expected channel width, depth and velocity for a given flow rate. However, regime equations are most accurate for steady flow conditions, where the "channel-forming" discharge can be readily identified. Most streams in Arizona cannot be considered as "in regime" due to the influence on stream geomorphology of flood flows, historic watershed changes, urbanization impacts, episodes of channel entrenchment, or upstream impoundments and diversions. Attempts by the USGS and others to develop reliable regime-type equations relating channel characteristics to discharge or to watershed characteristics have not been successful for most streams in Arizona (cf. Hedman & Osterkamp, 1982) or have resulted in unacceptably large standard error.[11,12]

   Therefore, application of regime-type equations is not recommended for Arizona stream navigability adjudication.

2. *Manning's Ratings*. Use of Manning's equation to perform hydraulic ratings of channel cross sections is standard engineering practice in Arizona, and is the basis of most floodplain mapping and hydraulic analyses performed in the United States. To apply Manning's equation to a given stream reach, the information summarized in Table 4.2 is needed.

As shown in Table 4.2, use of Manning's equation to estimate flow characteristics for a stream segment requires a significant level of effort. To reduce the number of streams that the full level of effort is required, the following approach is proposed:

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[11] Methodologies have been proposed to estimate bankfull width and depth, and average width and depth, from mean annual discharge, peak discharge, or bankfull discharge on Arizona streams. However, given the error inherent in these methodologies, in conjunction with the error possible in the discharge estimates, the resulting predicted flow characteristics probably would not be accurate enough to withstand legal scrutiny, and may not meet the Arizona Supreme Court's requirement that each stream be analyzed to determine the public trust value and navigability characteristics.

[12] For example, Hedman & Osterkamp's (1982) equations indicate that standard error of estimate for ephemeral sand channels in the desert Southwest is approximately 75%, compared to 28% for perennial alpine channels. Average annual flow data from the USGS Rillito Creek near Tucson station indicate that an active channel width of 1,224 feet would be required to obtain the gaged average annual discharge of 14 cfs. The actual natural active channel width at this station was generally less than 400 feet.

Step - 1. Estimate the average annual flood discharge using the USGS regression equations using the procedures outlined above.

Step - 2. Estimate the mean annual discharge using the procedures outlined above. If the mean annual discharge is less than 15 cfs and the average annual flood discharge is less than 250 cfs, proceed to Step 3. If the mean annual discharge is greater than 15 cfs or the average annual flood discharge is less than 250 cfs, a full analysis of discharge and a Manning's rating is required.

Step - 3. Estimate an average channel width and slope from a USGS topographic map. Estimate a conservative Manning's 'n' value based engineering judgment.

Step - 4. Perform a Manning's rating using the mean annual discharge, and the channel width and slope from the USGS topographic map, assuming a rectangular channel.

Step - 5. Compute the flow depth for the assumed conditions. If the calculated depth is less than 0.5 foot (the minimum canoe threshold depth), the stream probably is not navigable at the estimated flow rate. If the calculated depth is greater than 0.5 foot, a more detailed cross section should be obtained from field data, detailed topographic mapping, or other sources.

Table 4.2
Level 3 Engineering Methodology - Flow Characteristic Data Needs

A	B	C	D
Flow Characteristic	**Data Needed For Column A**	**Data Needed For Column B**	**Data Needed For Column C**
Flow Depth Flow Width Velocity	Discharge	Gage Records Extrapolation of Gage Data Regression Equations	Topographic Map - Watershed Annual Precipitation Map Annual Evaporation Map Miscellaneous Watershed Data
	Cross Section	Field Survey Topographic Map - Channel Aerial Photographs USGS Rating Curves	
	Channel Slope	Field Measurement Topographic Map - Channel Aerial Photographs	
	Manning's N	Field Photograph Topographic Map - Channel Aerial Photographs	
Natural Obstacles	Aerial Photographs Topographic Map Field Inspection		
Man-made Obstacles	Aerial Photographs Topographic Map Field Inspection List of Dams		

Note: For streams gaged by the USGS or other agencies, obtain the most recent rating curve to relate discharge to flow depth for the stream reach with the gaging station.

Obstacles - The following may constitute obstacles to some forms of commercial boating:

- Diversion dams
- Rapids (steep slope)
- Waterfalls
- Shallow Water
- Fences

The following do not constitute obstacles that would completely prevent use of modern boat types:

- Diversion dams
- Waterfalls
- Rapids
- Shallow Water
- Fences

All boating must become impracticable at some threshold of channel slope, although this threshold has never been defined, either by case law or by boaters.[13] Some kayak specialists combine paddling and rappelling techniques to traverse reaches with tall waterfalls. Therefore, obstacles cannot adequately be defined by engineering methodologies.

Summary - A review of the available methodologies for estimating flow characteristics indicates that a choice must be made between readily-applied, low level of effort, inaccurate procedures and more accurate procedures that require a significant level of effort. For the Level 3 screening process, the higher level of effort approach is recommended to meet the requirements of the adjudication process. The following methodologies are recommended:

- *Discharge*. The mean annual flow, median flow and monthly average flow should be estimated using USGS streamflow records, or USGS regression-type methodologies based on streamflow records.

- *Flow Characteristics*. Flow depth, width and velocity should be estimated using USGS rating curves or Manning's ratings.

<u>Resulting Datasets</u> - The Level 3 analysis results in two datasets of watercourses. The watercourses which are not susceptible to navigation form dataset RL3 (i.e. Rejected

[13] The steepest slope of the Arizona boating streams listed by Arizona State Parks is about 1.5% (79 ft/mi).

Level 3). The watercourses which are susceptible and merit more Detailed Study form dataset NRL3 (i.e. Not Rejected Level 3).

4.5 DETAILED STUDIES

Figure 4.6 summarizes the pertinent features of the Detailed Studies of stream segments for characteristics of navigability.

Goal - The goal of the Detailed Studies component of the watercourse evaluation procedure is to perform a final sort of the stream segments remaining following Level 3 evaluation. The purpose is to perform a detailed fact-finding study addressing both susceptibility and actual/historic navigation.

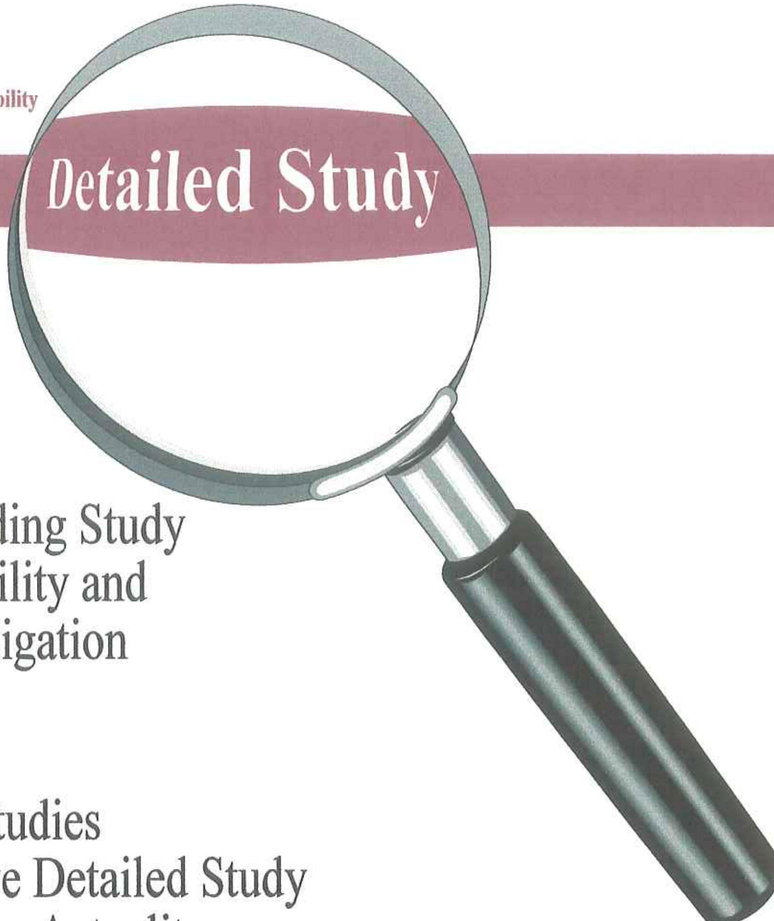
Methodology - The methodology for the Detailed Studies are similar to that used for the previously studied major river navigability studies. The previous major river studies employed qualitative and quantitative methods for evaluating susceptibility to navigation and actual navigation in fact. However, since the Level 3 quantitative analysis investigates watercourse susceptibility, the Detailed Studies for small watercourses under this watercourse evaluation system test for actual navigation in fact.

Data Requirements - ARS §37-1128 D. presumes a watercourse to be non-navigable unless there is clear and convincing evidence that it was navigable. The statute lists test criteria to be applied for a finding of non-navigability. An affirmative response to any one criterion is enough to support a recommendation by the Commission of non-navigability. Available technical data and historical information are required of sufficient detail to test the statutorily mandated criteria; the data requirements and the level of effort are extensive.

Application - The Detailed Studies are applied only to the watercourses contained in the database catalog that advanced from the Level 3 analysis (NRL3 dataset). As in Level 3, a text notation is made in the database as to the disposition of the watercourses following Detailed Studies.

Resulting Datasets - The Detailed Studies evaluation results in two datasets of watercourses. The watercourses which, upon further evaluation, are not susceptible to navigation, and support no evidence of actual/ historical navigation form dataset RDS (i.e. Rejected Detailed Study). The watercourses which are susceptible and/or show evidence of actual/ historical navigation form dataset ADS (i.e. Accepted Detailed Study).

Detailed Study



Goal

- Final Sort
- Perform Detailed Fact-Finding Study Addressing Susceptibility and Actual/Historical Navigation

Methodology

- Same as for Major River Studies
- Qualitative and Quantitative Detailed Study
- Test for Navigation In Fact - Actuality
- Apply the criteria contained in ARS 37-1128 (D)

Data Requirements

- Extensive
- Technical Data
- Historical Information

Application

- Apply to NRL3 watercourses in the database catalog

Resulting Datasets

- RDS: (Rejected Detailed Study)- Watercourses which are not susceptible to navigation, and with no evidence of actual/historical navigation
- ADS: (Accepted Detail Study)- Watercourses which are susceptible and/or show evidence of actual/historical navigation

Figure 4.6
Detailed Study

5.0 Watercourse Database Catalog

5.1 OVERVIEW OF THE DATABASE ORGANIZATION

5.1.1 Hardware and Software Requirements

In order to access the ANSAC database (file size: 4898 KB), the following are the minimum hardware and software system requirements:

- Personal or multi-media computer with a 486 or higher processor.
- 12 MB of memory for use on Windows 95 or 16 MB of memory for use on Windows NT Workstation.
- VGA or higher-resolution video adapter (Super VGA, 256-color recommended).
- Microsoft Mouse, Microsoft IntelliMouse, or compatible pointing device.
- Microsoft Access 97 database software
- Microsoft Windows 95 operating system or Microsoft Windows NT Workstation 3.51 Service Pack 5 or later (will not run on earlier versions).

5.1.2 Application Capabilities and Features

The ANSAC database of small watercourses was developed with built-in queries capable of analyzing, evaluating, and classifying the data in the database. The database has front-end interfaces that were developed for the purpose of aiding the user in navigating or browsing through the results of the analysis. In conjunction with these interfaces, the built-in queries are designed to provide the following information:

- Statistical summaries of the records in the database
- NRL1 data set
- RL1 data set

Also, the ANSAC database is designed with a main switchboard form that provides users various options as follows:

- Enter and Edit Data
- View Data and Query Results
- Show Query Results
- Preview Reports
- Change Switchboard Items

5.1.3 Compatibility Issues

Data formats that are supported by Microsoft Access provide direct import, export and links to the following application softwares:

- Microsoft Excel (Version 3.0 or later)
- Microsoft FoxPro (Version 2.x or later)
- Microsoft SQL Server
- Borland dBASE III Plus
- Borland dBASE IV
- Borland dBASE Version 5.0
- Borland Paradox (Version 3.0 to 5.0)
- ASCII text
- All ODBC-compliant databases.

In addition, the database can be directly imported and exported to Microsoft Visual FoxPro (Version 3.0) and Lotus 1-2-3.

5.1.4 Application Limitations

The database of small watercourses cannot be accessed by earlier version of Microsoft Access 97 (i.e., Microsoft Access Version 7.0 or earlier). This indicates that the database file, which was developed using Microsoft Access 97, is not downward-compatible.

5.1.5 Recommended Future Improvements of the Database

- Full and complete population of all defined fields in the ANSAC database.
- Addition of some useful *'for information only'* fields such as: LATITUDE and LONGITUDE, SECTION, TOWNSHIP, and RANGE to identify watercourse locations.
- Incorporation of dam-impacted segments field into the database to evaluate watercourses that are impacted by dams. This information may resurrect some watercourses from RL1 data set to NRL1 data set for evaluation in Level 2.
- Quality control capability to check every watercourse against nearby watercourses for consistency in river type classifications.
- Forms to list and provide statistical and summary information for all watercourses in a given hydrologic unit or county.
- Improvement of front-end interfaces to provide summary results of various queries or analyses.
- Add previous items created for reports.

5.2 DATABASE SOURCES

The main sources of data for the ANSAC database include existing watercourse databases from the Arizona Department of Water Resources (ADWR), U.S. Army Corps of Engineers, Arizona Land Resources Information System (ALRIS), and Arizona State Parks (ASP). Some additional data that cannot be supplied by above databases were gathered and collected from private, federal, and state agencies by the project team to complete the data set required for Level 1 Evaluation.

The Arizona Department of Water Resources (ADWR) maintains the databases for all jurisdictional and non-jurisdictional dams in Arizona; while the Corps of Engineers maintains the national inventory of dams, which lists both the jurisdictional and non-jurisdictional dams. Currently, there are 215 jurisdictional dams and about 100 non-jurisdictional dams in Arizona that are listed in the dam databases. Some dams in the non-jurisdictional database are currently being considered for jurisdictional status pending results of verification and study by the Arizona Department of Water Resources. Dams, whether classified as jurisdictional or non-jurisdictional, are considered to alter the natural flow in the stream and are considered to impact downstream and immediate reaches.

The Arizona Land Resources Information System (ALRIS) maintains a watercourse database that is linked and interfaced with the agency's Geographic Information System (GIS). The database is derived from the original U.S. Environmental Protection Agency's (EPA) Reach Files which comprise of a series of hydrographic databases of surface waters of the continental United States and Hawaii. The structure and content of the EPA Reach File databases were created expressly to establish hydrologic ordering, to perform hydrologic navigation for modeling applications, and to provide a unique identifier for each surface water feature.

The Arizona State Parks or (ASP) database of Arizona rivers was developed in conjunction with the River Assessment Study completed by the agency in 1995. The ASP database was intended to be a planning tool for resource management agencies, organizations, and decision makers for the future of Arizona's river and riparian heritage.

In addition to the databases supplied by the above agencies, the project team also compiled relevant data and information that include:

1. Historical and Modern Boating information obtained from the Greenlee County Historical Society, Coconino Historical Society, Mormon Archives, Apache County Historical Society, Arizona State Parks, Central Arizona Paddlers Club, Arizona Game and Fish Department, and professional river rafting companies.

2. Fish and fishery information obtained mainly from Arizona State Parks and Arizona Game and Fish Department (AGFD).

3. Special Status Data: (a) Instream Flow data were obtained from Arizona Department of Water Resources (ADWR); (b) Unique Waters from Arizona Department of Environmental Quality (ADEQ); (c) Wild and Scenic data from Bureau of Land Management (BLM), American Rivers, and National Forest Service (NFS); (d) Preserved Area from Arizona State Parks, Arizona Game and Fish Department, Nature Conservancy, U.S. Fish and Wildlife Service, and National Park Service; and (e) Riparian data from Arizona State Parks and Arizona Game and Fish Department.

5.3 CUSTOMIZATION OF THE DATABASE

5.3.1 ALRIS Database

The surface water database provided by ALRIS was used as the main source of data for the ANSAC database considering its extensive coverage and identification of watercourse segments. These watercourses in the ALRIS database are identified by their unique identification system of hydrologic unit code and segment number. The fields from the ALRIS database that were considered relevant to the ANSAC database are: (a) hydrologic unit, (b) segment number, (c) mileage, (d) river type, (e) descriptive attribute feature, and (f) reach name.

The hydrologic unit (HU) and segment number (SEGNO) comprise a unique identification system that are assigned to every documented watercourse segment. A river segment or watercourse, however, transcends county boundaries and limits, and thus it is not extraordinary for some watercourses in the database to flow in two or three different counties. Although the original ALRIS database identifies mile markers (called mile index or MI) along river segments, the field was used to identify the length of the watercourse in miles. All river segments that have zero MI's were deleted from the database considering their insignificant reach length.

The only river types that were considered in the ALRIS database are: (a) non-perennial, and (b) perennial river types. This classification system indicates that other river types such as ephemeral, interrupted, and intermittent river are included under the non-perennial category.

The descriptive attribute features for watercourses that were used in the ALRIS database include: (1) natural watercourse, (2) artificial watercourse, (3) shoreline, (4) containment (e.g., dams), and (5) closure lines. Attribute features (1), (2), and (4) are important descriptive attributes for watercourses because they describe the nature of watercourses (whether they are man-made or not), or if water is being contained or not. All watercourses that have feature attributes (2) and (3) are dropped from the database while those with feature attribute (4) are identified to have dams or stock ponds in them. The existence of dams or stock ponds in the watercourse indicates that natural flows are disturbed and impeded. Although this feature attribute (4) will not be used in the query system, the data will be used as a quality check for the dam information provided by ADWR. Records with attribute feature (5) were created artificially in the GIS database to simply link two adjacent watercourses with slightly mismatched ending points. They are not actual watercourse segments and thus were deleted.

The reach names that have been assigned for the watercourses are used as official stream names for the watercourses in the database. Databases that do not employ or use hydrologic units and segment numbers (like the ADWR database) can be linked with ALRIS database using the stream name field which is the common field element for all the databases.

5.3.2 ASP Database

The most relevant information from the Arizona State Park (ASP) database is the river type classification of watercourses. The database has the same unique identification system as the ALRIS database but that the system merges together the hydrologic unit and segment number. Some of the watercourses are provided with alphanumeric extensions that describe additional reach segments. To be able to link the ASP database with the ALRIS database, the identification system used was separated into three fields: hydrologic unit, segment number, and the added reach.

The important fields from the ASP database that would be useful for the ANSAC database include the following: (a) hydrologic unit (HU), (b) segment number (or SEGNO), (c) added reach, (d) river type, and (e) instream flow data.

The hydrologic unit and segment number fields are the linkage to ALRIS database. Despite other added reach fields in the ASP database, only those river segments with "L" or "Lake" extension were considered important as this would indicate whether lakes or reservoirs are formed by the damming of existing streams. For the river type field, ASP provided finer river type classification for watercourses than the river type classification provided by ALRIS. The river types used in the ASP database are more descriptive in scope which include: ephemeral, perennial, intermittent, and interrupted. These river types were defined by ASP according to flow characteristics as follows:

- Ephemeral - streams flow in direct response to precipitation.
- Perennial - streams flow continuously
- Intermittent - streams flow seasonally from springs or surface sources.
- Interrupted - streams have alternating segments of the above river types.

The instream flow field identifies whether a watercourse has an instream flow permit or not. These data compiled by Arizona State Parks will be used as a quality check for the instream flow data that would be compiled by the project team from Arizona Department of Water Resources (ADWR).

5.3.3 ADWR Database

The most relevant data from the ADWR database to be incorporated into the ANSAC database are the dam information. The ADWR database identifies the location of dam in reference to any stream or tributaries. Flow impediment by the existence of dam in the stream identifies the watercourse to be disturbed and thus, merits further investigation. If watercourses are not in their natural state due to the existence of a dam, they advance to Level 2 and are further studied for their possible impact on downstream and immediate reaches. Also, equally important to the evaluation is the time when such disturbance began relative to the date of Arizona's statehood in 1912. Since the ADWR database does not employ the hydrologic unit and segment numbering system that were used in the ALRIS and ASP databases, the reach names identified in the ADWR database with dams are used as the linkage with other databases.

The only field pertinent to the ANSAC database from the ADWR database is the stream name that identifies where dam structures are built and located.

5.3.4 Data Compiled by the Project Team

Other important data that have been compiled by the project team for the ANSAC database include information on the following: (a) Historical Boating, (b) Modern Boating, (c) Fish and fishery, and (d) Special Status information of streams such as Instream Flow, Unique Water Classification, Wild and Scenic information, Preserved areas, and Riparian status.

5.4 DATA FIELD DESCRIPTIONS

The database of watercourses developed for ANSAC is comprised of fields identified to be vital for Level 1 Evaluation. The Level 1 Evaluation is the first stage of a multi-level analysis designed to identify those watercourses that have characteristics of navigability or those that are susceptible to navigation. In addition to the fields described above, there are fields included in the database that are used for information (such as mileage and county data) and quality control (such as instream flow and dam data that were taken from sources other than the primary sources of such data).

The fields defined for the ANSAC database and their descriptions are:

a. HU - Hydrologic unit of the watercourse which is identical to the USGS cataloging unit.

b. SegNo - Segment number of the watercourse which is similar to EPA's river segment.

c. Miles - Length of river segment in miles.

d. StreamName – The name given to the watercourse

e. County - The location of the watercourse by county.

f. PER - The river type of the watercourse. The classifications used are:

   - 1 - Ephemeral
   - 2 - Perennial
   - 3 - Interrupted and Intermittent
   - 4 - Unclassified

g. WithDam - Identifies if watercourse has a dam built in it or not.

h. DamImpact – Identify if river segment is impacted by the existence of dam.

i. WithDam (ALRIS) - Dam information is from ALRIS database associated with a descriptive attribute feature of a containment (e.g. dam). The field is used to check dam information provided in (g).

j. WithDam (ASP) - Dam information is from ASP database associated with "Lake" extension used to indicate the formation of a lake or a reservoir as a consequence of damming a stream. Like WithDam (ALRIS) field, this field is used to check dam information provided in (g).

k. Historical Boating - Identifies whether the watercourse has a documented record of historical boating or not.

l. Modern Boating - identifies whether the watercourse is identified to have a record of modern boating or not.

m. Fish - Field identifying if watercourse has fish or not.

n. InstreamFlow - Identifies if watercourse has (or has applied for) an instream flow permit or not.

o. InstreamFlow (ASP) - The data are taken from ASP Database that identifies the streams that have an instream flow permit. The information provided by this field will be used as a quality check on the data provided by (m).

p. UniqueWaters - Identifies if watercourse has this classification from ADEQ or not.

q. WildScenic - Identifies if the watercourse has been recommended for Wild and Scenic classification or not.

r. Riparian - Identifies if watercourse supports riparian vegetation or not.

s. Preserve - identifies if the watercourse is classified under any one or a combination of the following special status: Nature Conservancy, State Park, and Wildlife Refuge.

t. Source – Sources of the database field information.

u. Notes – Notes or remarks regarding the stream.

v. Ephermeral – This is populated in accordance with the PER field.

The current state of database field population is shown in Table 5.1. Although most of the fields appear 100% populated, confidence on the data is not high because of linkage problems and data issues identified. Queries on Level 1 Evaluation could be performed using the current data and information in the database, however, confidence on the results would be low. The results of the queries built into the database could not be relied upon until data verification is addressed, and steps to improve current data status on some fields are made.

TABLE 5.1
SUMMARY OF DATABASE FIELD POPULATION

Item No.	Database Field Names	Population (%)	REMARKS
(1)	(2)	(3)	(4)
1	HU	100.00	
2	SegNo	100.00	
3	Miles	98.90	
4	StreamName	17.70	
5	County	100.00	Visual check and inspection are necessary to elevate current confidence on the data.
6	PER	100.00	
7	Ephemeral	100.00	
8	With Dam	100.00	Confidence on data is poor due to linkage problems associated with stream names.
9	With Dam (ALRIS)	100.00	
10	With Dam (ASP)	100.00	
11	Dam Impact	0.00	Confidence on data is poor. Population of this must be done in Level 2.
12	Historical Boating	100.00	Confidence on data is poor due to linkage problems associated with stream names.
13	Modern Boating	100.00	Confidence on data is poor due to linkage problems associated with stream names.
14	Fish	100.00	
15	Instream Flow	100.00	
16	Instream Flow (ASP)	100.00	
17	Unique Waters	100.00	
18	WildScenic	100.00	
19	Riparian	100.00	
20	Preserve	100.00	
21	Source	0.00	No data source information are provided.
22	Notes	0.00	No data description are currently provided.

5.5 DATABASE QUERIES AND PROGRAMMING

The following queries of the data fields for the Level 1 Evaluation are defined and described as follows:

5.5.1 River Types Queries (PER)

1. The river types defined in the ANSAC database are classified as ephemeral, perennial, intermittent-interrupted or unclassified. These types were based on the river type classifications used by ALRIS and ASP as follows:

ALRIS	ASP	ANSAC
Perennial	Perennial	*Perennial*
Perennial	Intermittent	*Perennial*
Perennial	Interrupted	*Perennial*
Perennial	Ephemeral	*Perennial*
Perennial	Blank	*Perennial*
Not Perennial	Perennial	*Perennial*
Not Perennial	Intermittent	*Int-Int*
Not Perennial	Interrupted	*Int-Int*
Not Perennial	Ephemeral	*Int-Int*
Not Perennial	Blank	*Int-Int*
Mixed	Perennial	*Perennial*
Mixed	Intermittent	*Int-Int*
Mixed	Interrupted	*Int-Int*
Mixed	Ephemeral	*Int-Int*
Mixed	Blank	*Int-Int*
Blank	Perennial	*Perennial*
Blank	Intermittent	*Int-Int*
Blank	Interrupted	*Int-Int*
Blank	Ephemeral	*Ephemeral*
Blank	Blank	*Insignificant*

1. If a river segment is classified as perennial, it advances to Level 2. It is still queried for the remaining five data tests.

2. If river segments are classified as non-perennial (i.e. ephemeral, intermittent, interrupted, or unclassified), they do not advance to Level 2 evaluation unless they test affirmatively to the other query fields (e.g. WithDam, Historic or Modern Boating, WithFish, and/or Special Status).

5.5.2 Dam Date Queries (WithDam)

1. If a dam is located in a stream segment, that stream segment advances to Level 2. This indicates that natural flow of a stream segment is disturbed.
2. If a blank is encountered in a given record, the river segment is considered to have no dam built in it. This river segment will not be further evaluated for Level 2 Evaluation unless: 1) it is verified that a dam exists upstream of the river segment, or 2) it tests affirmatively to any of the other query fields.
3. A list of dam-impacted segments can only be identified in the Level 2 Evaluation because such river segments can only be verified and checked using more detailed evaluation involving visual analysis and/or inspection. These dam-impacted segments can be resurrected from RL1 dataset for Level 2 Evaluation.

5.5.3 Historical Boating Queries (HistoricalBoating)

1. A blank record indicates that no record is available to support evidence of historical boating in the river. Since a blank record is equivalent to no historical boating in the river, this assumption is considered to be true until reliable and verifiable facts are presented to the contrary.
2. All river segments that have historical boating accounts will be forwarded for Level 2 Evaluation.

5.5.4 Modern Boating Information Queries (ModernBoating)

1. A blank record indicates that no record is available to support evidence of modern boating in the river.
2. Since a blank record is equivalent to no modern boating in the river, this assumption is considered to be true until reliable and verifiable facts are presented to the contrary.
3. All river segments that have modern boating accounts will be forwarded for Level 2 Evaluation.

5.5.5 With Fish Queries (Fish)

1. All river segments that are known to have records of fish are forwarded for Level 2 Evaluation.
2. A blank field in the record is interpreted as having no fish.

3. Since a blank record indicates no fish, such assumption is considered to be true and correct until reliable and verifiable facts are presented to the contrary.

5.5.6 Special Status Queries

1. The fields that are used to describe the Special Status designations of river segments in the database include:

   - Instream Flow
   - Unique Waters
   - Wild and Scenic
   - Riparian
   - Preserve Area

2. River segments that are classified under at least one of the fields listed above are forwarded for the Level 2 Evaluation.

5.6 DATABASE TESTING AND RESULTS

Twenty-eight sample watercourses taken from all over the state were used to test the queries for Level 1 Evaluation as described in Section 5.5. The sample test identified those data that are non-diagnostic, and therefore, were dropped from the data tests comprising Level 1 Evaluation. Originally, water rights and groundwater data were included in the data tests to be part of Level 1 Evaluation. From the preliminary analysis that was performed on the initial set of data, virtually every watercourse - perennial or not - have water rights claims filed. Also, the groundwater data were not considered in Level 1 Evaluation due to the complicated approach of processing existing data to come up with information required. Such complications include determination of distance from pumping locations to watercourses or the determination of critical pumping discharges based on evaluated distance to establish if watercourses are impacted by groundwater withdrawal activities or not. These data would require a time-consuming effort in order to populate the fields in the database.

The Level 1 Evaluation for the 28 test cases resulted in two sets of data. The RL1 data set failed every one of the test queries provided in Section 5.5. The NRL1 data set, however, are those that test affirmatively to one or more of the data queries and thus require further analysis at Level 2.

The results of the Level 1 Evaluation are provided in Appendix C-1. The forms provided include the:

- Main - Form shows stream characteristics of each watercourse in the database

- Summary Form - lists the statistics of the records in the database.
- RL1 Data Set Form - lists the watercourses that have tested negatively to every data query.
- NRL1 Data Set Form - shows those watercourses that advance to Level 2.

6.0 Recommended Work Plan

The work products for this project include the technical and historical criteria, the multi-level evaluation system, the database catalog, and the summary report. The application of the evaluation system to each of the small and minor watercourses cataloged in the database is not part of this project scope. It is anticipated that all the cataloged watercourses will subsequently be assessed utilizing the criteria, the evaluation system, and the watercourse catalog developed under this contract. That work will be performed in a priority to be established in the future by ANSAC and under a separate contract.

ANSAC is required to complete its legislatively mandated tasks by July 1, 2002 as described herein. The following work plan is recommended to meet this objective:

PHASE I

- Current Contract No. A7-0109-001

PHASE II

- Verify and Fully Populate Watercourse Database Fields
- Perform Level 1 Screening
- Determine Datasets RL1 and NRL1

PHASE III

- Perform Level 2 Evaluation
- Determine Datasets RL2 and NRL2

PHASE IV

- Perform Level 3 Analysis
- Determine Datasets RL3 and NRL3

DETAILED STUDIES

- Perform Detailed Technical and Historical Evaluations
- Determine Datasets RDS and ADS

Appendix A-1

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Appendix B-1

Bibliography of Works Relating to Historic Boating in Arizona

APPENDIX B-1
BIBLIOGRAPHY OF WORKS
RELATING TO HISTORIC BOATING IN ARIZONA

The most useful works on the history of small boats are: Percy Blandford's Illustrated History of Small Boats; Edgar Bloomster's Sailing and Small Craft Down the Ages; Frank Donovan's Riverboats of America; Paul Johnstone's Seacraft of Prehistory; James Hornell's Water Transport Origins and Early Evolution; James Moriarity's Pre-Spanish Marine Transport and Boat Building Techniques on the Upper and Lower California Coast and The Boat and The Classic Boat by Time-Life Books.

The major general works on boating in Arizona are Lingenfelter's, Steamboats on the Colorado and Lavendar's River Runners of the Grand Canyon. Very useful information about early boating on the Colorado River and its tributaries is found in various documents relating to the "Utah Riverbed Case" USA v. Utah, 1931. A full issue of Utah Historical Quarterly (1969 V 2) was devoted to various articles about boating on the Colorado. The Great Ferry War of 1905 by McCroskey contains information on the use of ferries and other boats on the Gila River and Salt River.

The following list contains general books about the history of boating, books dealing with specific kinds of boating in Arizona or boating in specific locations, articles about boating and boaters, government documents about government surveys where river crossings or other boating were involved, legal documents with emphasis on the "Utah Riverbed Case" in which small boats are discussed at length, newspaper accounts of matters relating to boating, and various manuscripts, collections and other documents relating in some way to boating in Arizona, and previous navigability studies done for the Arizona State Land Department.

There are many guidebooks written for river runners that give information about boatability and boats, of which Whitewater Rafting and Introductory Guide by Cecil Kuhne and Ann Shafer's Canoeing Western Waterways are especially helpful for the purpose of this study.

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Appendix B-2

Pictures of Historic Boating

Appendix B-2

Pictures of Historic Boating

The following is a list of photos and drawings related to historic boating in Arizona. The photos are organized by boat type and within each boat type by river. The location of the photo is given, the year (or often approximate year) of printing, and a brief description of the contents. This listing does not include most of the wealth of photos in Lingenfelter's Steamboats on the Colorado River or Lavendar's River Runners of the Grand Canyon. Complete references for the books cited are in the bibliography.

Drawings, Diagrams and Ads
Many diagrams and drawings for construction of a multitude of small boats, including duck boats, row boats, canoes, etc. From Picard's manual of 1888.

Ads from the Sears and Wards catalogs show canoes, steel rowboats, duckboats, and paddles available in the early 1900s.

A drawing from the Glenbow Museum in Calgary, Alberta shows a typical bullboat.

Rafts
Lower Colorado River
Drawing shows Mohave tule raft in 1854 somewhere near Needles. Original by Baldiun Mollhausen at the Oklahoma Historical Society.

Painting shows the first inflatable boat (pontoon style with wagon bed) crossing the river somewhere near Needles in 1854. Original by Baldiun Mollhausen at the Oklahoma Historical Society.

Photos show an Indian poling a log raft near Yuma in the 1880s. Originals at the Arizona Historical Society and Huntington Library.

Photo of Indian poling a tule raft on the Colorado River near Yuma. Original at Yuma Historical Society.

Sea of Cortez
Drawings in McGee's book on the Seri depict typical Seri rafts.

Canoes
Canals
Photo depicts people riding in a canoe on the Arizona Canal near Phoenix in 1920. Original in the Southwest Collection, Arizona State University Library

Photo depicts people exploring Black Canyon Dam Site with motor boat and canoe in 1924. Original at the Mohave County Historical Society

Lower Colorado River
Photo shows a man in a canoe running the Grapevine Wash rapids between Pierce Ferry and Needles in the mid 1920s, surveying the LaRue Dam site. Original in the Mohave County Historical Society.

Salt River

Photo shows a man in a canoe somewhere on the Salt River in the 1890s. Original in the Southwest Collection, Arizona State University Library.

Rowboats, Canvas Boats, Skiffs, and other Small Boats
Clear Creek
Photo depicts people in a rowboat shown from above in a deep canyon in Clear Creek (near Winslow, Arizona) in the 1890s. Original at the Sharlot Hall Museum

Colorado River, Grand Canyon
Numerous photos and drawings depict the Powell expeditions of the 1870s in Dellenbaugh's Romance of the Colorado River and Powell's report of the expedition.

Photo shows a man rowing a canvas boat near Lee's Ferry in 1923. From Lavendar's book, no photo credit given.

Photos show people rowing and portaging rowboats in the Grand Canyon in 1923. From Westwood's Rough Water Man.

Photos show a man in rowboat in the Grand Canyon in 1896. From Flavell's Log of the Panthon.

Photos in Freeman's Down the Grand Canyon show people boating the Grand Canyon on a USGS survey expedition in 1909.

Photos in Julius Stone's Canyon Country show boating through the Grand Canyon in 1909.

Photos in Birdseye's Boat Voyage Through the Grand Canyon show people traveling in Galloway-Stone type boats in the Grand Canyon in 1911.

Photos show boaters duplicating Powell's voyage through the Grand Canyon. Some show boats damaged after going through rapids. From National Geographic 1914.

Numerous photos in Eddy's Down the World's Most Dangerous River show boating through the Grand Canyon in 1928.

Colorado River, Lower

Photo shows a rowboat in the canal at Andrade (in the Imperial Valley region) sometime in the late 1800s. Original at the Huntington Library.

Photo depicts a small foot-propelled sternwheeler in the 1890s. Original at the Huntington Library.

Photos show the Wheeler expedition at various points along the Colorado River, including Black Canyon - sail-rigged rowboats and plain rowboats. Good copies at Special Collections Library, University of Arizona.

Photo in Desert Magazine depicts a boat transporting men and goods "into the heart of the desertland" in 1898.

Photo depicts a group of men in a rowboat somewhere in the Needles area about 1900. Original at the Mohave County Historical Society.

Photo shows a rowboat with two men in a canyon in the early 1900s. Original at the Water Resources Center Archives, University of California, Berkeley, Lippincott Collection.

Photo depicts a rowboat at Ft. Mohave in 1904. Original at the Arizona Historical Society.

Photo depicts a rowboat on the Colorado River near Giers in 1906. Original at the Huntington Library.

Photo shows a rowboat with four men rowing on Yuma's main street during the 1916 flood. Original at the Yuma Historical Society.

Colorado River, Upper
Photo shows Utah Gov. Dorn with other dignitaries on shore with boats at Lee's Ferry in 1926. Original in the Southwest Collection, Arizona State University.

Gila River
Photo depicts men in a rowboat somewhere on the lower Gila River near Yuma in the 1890s. Original at the Yuma County Historical Society.

Photo shows a rowboat with cables near Maricopa ferrying people during flood time in the early 1900s, probably 1905. Original at the Arizona Historical Society.

Lakes
Photo shows people boating on a manmade lake at St. George Utah about 1890. Original Lynne Clark Photography, St. George.

Photos depict a boat landing on Roosevelt Lake with rowboat in foreground and people fishing for bass from a rowboat in 1916. Originals at Arizona State University, Southwest Collection.

Salt River
Photo shows two men, two women and a dog in a boat on the Salt River in the 1890s. Original at the Arizona Historical Foundation.

Color postcard depicts people in a rowboat somewhere on the Salt River (not in town) in 1918. Original in the Southwest Collection, Arizona State University Library.

San Francisco River
Photo shows a group of men in a rowboat near Clifton crossing the river during flood time in 1884. Original at the Arizona State Research Library.

Unknown Location
Photo depicts the Luhrs family in a rowboat at an unknown location in Arizona in 1910. From the Luhrs family album at Arizona State University, Southwest Collection

Photo shows Mrs. Carl Hayden and other women sitting on a boat dock with several styles of rowboat at an unknown location (abroad) in 1920. Original in the Southwest Collection, Arizona State University Library

Flatboats, Scows, and Barges
Colorado River, Lower
Photo shows a crude homemade flat boat with a sail in the late 1800s. Original at the Arizona Historical Society.

Photo shows the Silas J. Lewis barge at Needles in the 1890s. Original at the Huntington Library.

Photo shows a temporary skiff ferry in use in the late 1890s while the regular ferry is upended to dry out at Ehrenburg. Original at the Huntington Library.

Photo shows a flatboat about to be unloaded from a wagon at Needles in the late 1800s. Original at the Huntington Library.

Photo shows the St. Valier barge loaded with stack wood at Needles in 1899. Original at the Huntington Library.

Photo shows a flatboat loaded with photographer's supplies in the late 1800s. Original at the Huntington Library.

Photo shows a scow holding a diamond drill north of Peach Springs before 1920.
Original at the Mohave County Historical Society.

Photo shows a man on a flatboat on the Colorado River near Needles in 1923. Original at the Mohave County Historical Society

Ferry boats

Colorado River, Lower

Photo shows a sternwheel ferry and rowboat somewhere on the Lower Colorado River in the 1880s. Original at the Huntington Library.

Photo shows a cable crossing on the Alamo River near Brawley, California in the 1880s. Original at the Huntington Library.

Photos of various ferries along the Lower Colorado River from the 1880s-1900s. Originals at the Special Collections Library, University of Arizona.

Photo shows the aerial ferry at Ehrenburg in the 1890s. Original at the Huntington Library.

Photos of the Calizona Ferry showing various vehicles aboard. Originals at the University of Arizona Special Collections Library, Huntington Library and Yuma Historical Society.

Photo of a ferry with a loaded barge in tow at Needles from the late 1800s. Original at the Huntington Library.

Photo of the Old Yuma Ferry about 1890. Original at the Huntington Library.

Photo shows Bonelli's ferry crossing the Colorado River at Rioville (mouth of the Virgin River) in the 1890s. Original at the Utah State Historical Society.

Photo shows a car on board the ferry at Ehrenburg about 1900. Original at the Yuma County Historical Society.

Photo shows a horse and buggy on a ferry at Yuma in 1904. Original at the Yuma County Historical Society.

Photo shows a flatboat with a car on board used as a ferry at Sweeny's Landing in 1916. Original at Mohave County Historical Society.

Photos show the Searchlight Ferry in 1919 and in 1930. Originals at the Mohave County Historical Society.

Photo shows a car on a ferry at Parker in 1920. Original at the Yuma County Historical Society.

Photo depicts the "Miss Marjorie of Chloride" at Willow Beach between 1922 and 1926, transporting drillers to the Hoover Dam site. Original at the Mohave County Historical Society.

Two photos show Grigg's Ferry in 1923. Originals at the Mohave County Historical Society. Photos show the Blythe-Ehrenburg Ferry in 1926. Originals at the Mohave County Historical Society.

Photo shows Senator Keller on the ferry at Parker. Original at the Mohave County Historical Society.

Photo shows Murl Emery's Ferry near the Hoover Dam Site in 1930 and again in 1942. Originals at the Mohave County Historical Society.

Photo shows the Arivada Ferry used in building Hoover Dam in the 1930s. It could carry four cars. Original at the Mohave County Historical Society.

Photo depicts the aerial ferry at Needles in 1934. Original at the Mohave County Historical Society.

Colorado River, Upper
Photo shows emigrant wagon being boated across the river at Lee's Ferry in the 1880s. From Desert Magazine.

Numerous photos of Lee's Ferry are shown in Measeles' book Crossing on the Colorado.

Photo depicts the Rust and Wooley Cable Tram in the Grand Canyon in 1913. Original at the Arizona Historical Society.

Photo shows an aerial ferry at Bright Angel Creek in the Grand Canyon. National Geographic 1914.

Gila River
Surveyor's map from 1874 indicates the way to the Redondo Ferry on the Redondo Ranch upstream from Yuma. Original at the Yuma County Historical Society.

Photos show a car on board the ferry at Dome in the early 1900s. Original at the Yuma County Historical Society.

Photos show Gov. Hunt on a ferry going to and from the Florence prison. Originals at Arizona State University, Arizona Collection.

Salt River

Photo depicts the Hayden Ferry in Tempe around 1895. Original in the Southwest Collection, Arizona State University.

Photo shows a barge-ferry used to cross Roosevelt Lake to connect the south side with the road from Young in about 1915.

Little Colorado River
Photo shows an aerial ferry over the Little Colorado River, probably at Sunset Crossing in the 1880s, with three men and two women aboard. Original at the Huntington Library.

Sailboats

Colorado River, Lower
Photo shows people rigging a sail on a boat at Cottonwood Island in 1923. From Rough Water Man

Photo shows a sailboat in open water somewhere on the river in the early 1900s. Original at the Water Resources Center Archives, University of California, Berkeley, Lippincott Collection.

Lakes
Several photos of sailboats on Walnut Grove Reservoir near Wickenburg (Hassayampa River) in the late 1880s before the dam broke. Originals at Sharlott Hall Museum and Arizona Historical Society.

Photo depicts a sailboat on Rogers Lake near Flagstaff in 1911. From an ad for tourism in Arizona the State Magazine.

Photo depicts a sailboat on Lake Mary near Flagstaff in 1914. From Arizona the State Magazine.

Photos depict a sailboats on Roosevelt Lake in 1912-14. Originals in the National Archives and Arizona Historical Society.

Photos show recreational boating at Granite Dells Lake near Prescott about 1907. Original at Sharlott Hall Museum.

Salton Sea
Photos show Godfrey Sykes' sailboat on the Salton Sea and in a nearby canal in 1907. Original at the Arizona Historical Society.

Motorboats, Tunnel-Stern Boats

Colorado River, Lower
Photos show Murl Emery's tunnel-stern boat hauling drilling crews to work on barges anchored in Boulder Canyon. Original at the Mohave County Historical Society.

Photos show Jagerson's tunnel-stern boats transporting Congressmen to Hoover Dam site and launching the boat at Willow Beach in 1922 and by the Chloride garage in 1929.

Photos depict loading a wagon and equipment at Willow Beach and Congressmen on boat visiting

Hoover Dam site in 1923-24. Originals at the Mohave County Historical Society.

Steamboats
Colorado River
Drawing by Balduin Mollhausen of Ives's Explorer on the river in the 1850s. From Ives' Report on the Expedition.

Photo and clipping about Ives' explorer which had been excavated years after its demise. Original at the Huntington Library.

Tourboats
Photo shows people in a tourist boat on Roosevelt Lake in 1925. Original at the Arizona Historical Foundation.

Photos depict a group on a tourboat on Roosevelt Lake with rowboats in the foreground and the boat landing with rowboats in the foreground around 1915. Originals at Arizona Historical Society.

Photo shows a tourist boat landing for a trip on Lake Mead in the 1930s. Original in Special Collections Library, University of Arizona.

Mixture of Boats
Numerous photos show the Yuma waterfront from the 1890s to about 1905 with the prison or railroad bridge in the background and several steamboats, rowboats and rafts. Originals at the Yuma Historical Society, Arizona Historical Society and the Huntington Library.

Photo shows people surveying sites for Laguna Dam in a rowboat and a flatboat in 1907. From Crowe's Early Yuma.

Photo shows the drydock in the Colorado River Delta, with several boats in the late 1800s. Original at Special Collections in the University of Arizona Library.

Photos of various kinds of boats, barges and drilling rigs involved in the survey and construction of Hoover Dam in the 1920s and 1930s. In The Story of Hoover Dam and Building Hoover Dam. Also photos in USGS archives and Bureau of Reclamation archives.

Appendix B-3

Boating Glossary

APPENDIX B-3
BOATING GLOSSARY

The following definitions are those accepted today. Vernacular use of these same terms before 1913 may have been different.

Aerial Ferry - a ferry which is suspended from some type of cable. Ropes are pulled either from shore or by people on the ferry to make the ferry move.

Barge - any of a variety of pleasure, naval and commercial craft, commonly a rectangular flat-bottomed craft with high sides, used to transport heavy nonperishable cargo.

Bateau - Generic term (literally, French for "boat") applied to any of various local or regional craft developed in the U.S. and Canada. The characteristic shape is long, narrow and flat-bottomed.

Beam - the width of a vessel.

Boatability - The capacity of a watercourse to support some type of boating at least part of the year.

Bow - the front (fore) of the boat.

Bullboat - a boat made of hides stretched around a frame of willows or similar materials.

Canoe - a light, open, shallow-draft double-ended boat, ranging from about 12' to 34' (average 15-17') and usually propelled by one or more paddlers. Originally made of hollowed-out trees or birch bark in the eastern U.S., a wooden canoe was invented in 1879. In the 1880s canvas covered canoes appeared. The molded plywood canoe was invented in the early 1900s and the aluminum canoe in the late 1940s. Fiberglass was first used for canoes in the 1950s.

Catamaran - Developed in the Asian Pacific, the catamaran was first built in the U.S. in the 1870s. U.S. interest in catamarans languished until the late 1940s.

Catboat - A sailboat rigged with one mast and one sail set abaft it, usually shallow draft and are often used for working purposes.

Clinker-built - Having the external planks or plates of a boat put in so that the edge of each overlaps the edge of the plank or plate next to it like clapboards on a house.

Cutter - A single-masted sailboat with a mainsail and at least two headsails. Traditionally the cutter was a distinct hull type -narrow, deep, plumb stemmed with the mast stepped about 2/5 of the waterline. This type now practically extinct.

Dinghy - any of various small, open boats designed for propulsion by oars and used for a number of purposes, or adapted to rigging to sail and used in racing or day sailing. Typically a dinghy has a pointed bow, a transom stern and a round bottom, and is made of wood, plywood, or plastic, though aluminum, steel and composite construction are also seen. They range from under 6' to about 14' long with about 8-10' the most popular. The smaller models carry 1-2 adults and are very lightweight.

Dory - a type of rowboat, usually with bow and stern upswept and curved bottom, originally used for fishing, but adapted for whitewater travel.

Draft - the depth of a boat below the waterline, measured vertically to her lowest point. Also the depth of water she requires in order to float freely - a slight fraction more than her own draft.

Draw - To require a specific depth of water in order to float.
Duckboat - Any of various small,open,commonly flat-bottomed boats used by hunters, and designed to carry them as quietly and unobtrusively as possible through marshy shallows and other areas where wild fowl gather. Models range from 8-15' long and are light.

Ferry - a boat used to transport people and goods from one shore to another, either across a river or on the open sea.
Flatboat - A boat with a flat bottom and flat bow and stern, such as a scow, used for transporting freight on inland waterways, a barge.

Folding boat - generic term for any small lightweight boat designed to be partly or wholly folded, collapsed or disassembled after use. The Mayflower carried a pinnace to be assembled after arrival. Canvas folding boats were used in the Civil War. Folding boats for recreational purposes were developed around 1900 by Bavarian sportsmen. Foldboats appeared in the U.S. in the 1930s. They have been used for rafting the Grand Canyon.

Galloway-Stone boat - a type of rowboat suitable for running rapids developed in the 1890s by Galloway and later developed by Galloway and Stone.

Hole - an area in a stream where the current reverses, flowing backward in a circular motion, usually because of a boulder in the stream, considered quite dangerous for boaters. Also called "reversal" or "spinner."

Houseboat - a waterborne,largely self-contained living unit offering most of the basic facilities of a house ashore, mounted atop a hull or combination of hull forms. It was developed early in U.S. history and played an important role in opening up the frontier.

Hydrofoil - Any vessel that makes use of hydrofoils - wing-like parts, commonly of metal, that operate in water and support the vessel above a certain speed. It was first invented in Italy in 1898. In 1911 Alexander Graham Bell built one, but the effort was abandoned and the hydrofoil was not in general use until World War II.

Inboard boat - any vessel smaller than a ship and powered principally by an inboard or inboard-outboard engine. It developed from the steam boat, with its main development as a pleasure craft starting in the 1890s. Usually the boat is at least 15' long.

India Rubber - Natural rubber usually processed by vulcanization.

Inflatable boat - any boat designed to be blown up with air before use and, normally, deflated afterward for convenience in carrying and storage, generally 12' or less and weighing 60 pounds. or less. First developed in the 1850s, the inflatable was not reliable until the invention of artificial rubber in the 1940s.

Kayak - any of various narrow, lightweight boats, originally developed and named by Inuit, decked except for a cockpit, amidships and usually designed for a single occupant. Modern kayaks use the same basic design with modern materials.

Ketch - A fore-and-aft-rigged sailboat with two masts, the taller forward and the shorter mizzenmast stepped a little forward of the after end of the waterline.

Lifeboat - an auxiliary boat used on a larger boat for emergencies. Lifeboats may either be hard-hulled or inflatable.

Lugger - a vessel rigged with lugsails (quadrilateral sail with specific shape, bent to a yard that hangs from the mast obliquely and is raised and lowered with the sail). The lugger is traditionally a small boat used for fishing or coastal trade.

Mackinaw boat - a flat-bottomed boat used especially on the upper Great Lakes and their tributaries.

Motorboat - any boat propelled by an engine, usually some kind of gas.

Neoprene - a form of artificial rubber used for inflatable rafts.
Oakum - Loose hemp or jute fiber, sometimes treated with tar, creosote, or asphalt used for caulking seams in wooden ships.

Oar - an implement for propelling or steering a boat, particularly a dinghy or other rowing boat. It consists of a long shaft (usually of wood, sometime aluminum or plastic) with a handle at one end and a flat or somewhat concave blade at the other. It is fastened to boat with an oarlock, rather than held free.

Outboard boat - any vessel powered principally by an outboard motor (internal combustion engine with propeller attached, designed to be secured to the stern of a boat and usually burning gasoline or diesel fuel). Originally the motors had low power and were used on small rowboats or skiffs. Motors were improved in the 1920s and 1930s and can now be used on craft up to about 25' long.

Paddle - an implement with a relatively long shaft and a broad, flat (or somewhat concave) blade, used to propel and steer small craft, most commonly canoes. The paddler holds the paddle free with both hands.

Paddle wheel - a form of propeller on the end of a rotating horizontal shaft that lies across a vessel's centerline, so that the wheel revolves longitudinally to propel the boat. They are relatively inefficient and are best suited to shallow water and recreational boats.

Personal watercraft - a one-person powered boat used for recreation on lakes.

Pirogue - a canoe, usually hollowed from a single log up to about 18' long, used for fishing in sheltered waters of the Gulf Coast. Typically it has a flat bottom, round sides, and a sharp bow and is propelled by oars or paddles.

Portage - the transport of boats and gear overland between two navigable bodies of water, also the land so traversed.

Powerboat - a boat propelled by a motor which, in most cases, burns either gasoline or diesel fuel. Also called motorboat.

Pram, Pram Dinghy - a small open boat characterized by a square bow and stern, gently curved sides, and a flat or vee bottom with a slight rocker. Most models are about 8' long, with a beam of about 4'.

Rapids - an area in a stream where the slope increases and the water flows faster, usually over a rocky bottom. Rapids are classified according to the difficulty of running them.

Raft - a simple structure of buoyant elements - logs, empty barrels, supporting planks, etc. - fastened together and used as a water vehicle or float. Normally propelled by a pole, paddle, or sail. Some prehistoric rafts along the Colorado River and all along the western coast of the Americas were made of reed bundles lashed together.

Rowboat - any of various small, open craft designed primarily for propulsion by oars., though more recently also powered by sail or motor, ranging in size from about 10-16' and made of wood, plywood, plastic, or aluminum. Rowboats originated thousands of years B.C. and have been used in many parts of the world.

Rubber duckie - slang term for a one-person inflatable boat.

Sail - A piece of fabric or other material of such size and shape that, when spread to the wind, it will drive or help drive a vessel through the water. Sails come in many sizes and shapes.

Sailboat - a boat smaller than a ship designed to utilize the force of the wind for propulsion. If it also carries a motor for use when the wind falls, or for maneuvering in small quarters, it is called an auxiliary sailboat.
Schooner - Any fore-and-aft-rigged sailboat, with two or more masts, the foremast being no taller than the mainmast. The schooner originated in New England in the early 1700s.

Scull - a single long oar sometimes used to propel a small boat. Also, a small, light open boat of narrow beam and very small draft, designed to be propelled by sculls, usually in racing.

Scow - a large flat bottomed boat with square ends, used primarily for transporting goods.

Sidewheeler - a type of steamboat, with a paddlewheel at the side of the boat.

Skiff - any of various pleasure and work boats. Originally it defined a small open craft with a flat bottom and shallow draft, pointed bowsquare stern. Typically it was used by fishermen and rowed or sailed.

Sloop - a single-masted sailboat with at least two sails. The traditional U.S. sloop was a beamy, shoal draft centerboard hull.

Steamboat - a large boat or ship powered by a steam engine, typically fueled by wood in the 19th century.

Stern - the back (aft) of the boat.

Sternwheeler -a type of steamboat, with a paddlewheel at the stern of the boat.

Tender - a dinghy or other small boat used for transporting persons or supplies to or from a larger one.

Tourboat - an open slow-moving boat, usually gas powered, used to show people the scenery.

Tubing - use of inner tubes to float down a river.

Tugboat - a boat used to maneuver a ship into and out of harbor.

Tunnel-stern boat - a motor boat designed with a tunnel affixed underneath to filter out sand so the motor doesn't get clogged up.

Whitewater - Fast flowing water with rapids.

Yacht - a pleasure boat, ordinarily powered by sails, with auxiliary motors, legally classified as a ship.

Yawl- a fore-and-aft-rigged sailboat with two masts, usually more than 28' long.

Appendix B-4

Selected Historic Quotes about Boating in Arizona

APPENDIX B-4
SELECTED HISTORIC QUOTES ABOUT BOATING IN ARIZONA

The following are quotes chosen from a much larger group that illustrate various historic modes of travel. They are organized by type of boat and chronologically (date of event) within each boat type. For numerous quotes on steamboats on the Colorado, see Lingenfelter's Steamboats on the Colorado. For numerous quotes and descriptions of Grand Canyon boats, see Lavendar's River Runners of the Grand Canyon. Complete references can be found in the Bibliography.

Rafts

Basket Boats on the Lower Colorado River

"Diaz was determined to cross the [Colorado] river, hoping that the country might become more attractive. The passage was accomplished, with considerable danger, by means of certain large wicker baskets, which the natives coated with a sort of bitumen, so that the water could not leak through. Five or six Indians caught hold of each of these and swam across, guiding it and transporting the Spaniards with their baggage, and being supported in turn by the raft."
(Winship, George Parker, 1896, page 407, describing events of about 1540)

Reed Rafts on the Lower Colorado River

"Jedediah [Smith] loaded a part of his goods on rafts of cane grass and moved out on the broad river."
(Morgan, Dale 1953, page 240, describing the Lower Colorado in the 1820s)

Indian Rafts on the Lower Colorado River

"... almost all North and South travel and most light freighting, both by Indians and river-side white folk, was carried on by water. ... Indian family parties were what pleased my wife most. They were often drifting downstream on balsa rafts; men, women, children, dogs, and sometimes chickens. A balsa raft is made of long bundles of tules lashed together into the form of a raft and sometimes stiffened transversely with a few willow poles. One squats with other passengers as nearly over the center of flotation as may be unless one happens to be the steersman with the long pole who endeavors to keep the craft clear of bars and shallows. Getting aground in the muddy Colorado water generally involves unloading, dismantling the entire structure, carrying the tules ashore, spreading them out in the sunshine to dry, shaking the sand out of them and then laying the several keels afresh. A somewhat similar craft was used by the Ceri [Seris] round and about Tiburon Island, in the Gulf of California, but these did not require such frequent dry-docking and dismantling in the clear gulf water.

"Other features of the Indian river navigation above Yuma as we observed it, were the rafts of peeled and dried willow poles, cut to standard lengths, which were floated down, usually under the control of a single navigator equipped with a long steering and fending pole. Yuma was still largely built of willow poles chinked with mud, and the contents of these rafts were sold and used for constructive purposes. They were delivered and piled at the top of the river bank by the draftsman. Then, too there were the floaters of watermelons. This industry was followed in the Summer and Autumn ... The equipment was a triangle of three willow poles, tied together at the angles, a bent pole tied across near to one angle, and the freightage of melons, perhaps a score or more. The triangle was placed in the river with the bent cross-member sagging into the water and the melons were carefully lifted in until the triangular space was about filled. The pilot then tied his clothes, matches and tobacco, and other effects into a compact little bundle which he fastened securely upon the top of his head, took his seat in the water upon the submerged boat pole, said good bye to relatives and friends, kicked off from shallow water into the current and the voyage began. ..."

(Sykes, Godfrey 1945, pages 247-248, describing events of the early 1900s)

Indian Rafts on the Upper Colorado River near Lee's Ferry

"Brother Pierce found an old raft made of two poles lashed together with bulrushes thought to have been used by the Utes. The idea of repairing the raft to ferry their luggage over was abandoned until, as Jacob suggested, a try was made at attempting to ford the river on horseback. Before Thales and Brother Shelton had their mules saddled up and the packs removed in preparation to start across, the Indians had left. He and Brother Shelton stripped off everything but their garments, shirt and hats, plunged their horses into the cold water expecting a long swim. To their surprise they were able to cross without swimming.
Corbett, P.H., 1952, pages 154-155, 173-174 and 200, describing events of the 1850s)

Wooden Rafts on the Gila River

"... proceeded with the construction of our Rafts. Our new Associate, the Husband of the Missouri Woman, was most zealous and active, and proved the most skillful man among us in fashioning the Boats. The Dutchmen's Wagon and the side-boards of a number of other Wagons were utilized for the double purpose of constructing the Boats and lightening the loads. We stripped our own Wagon of one board from the bottom and two from the sides, shortening the coupling, and discarding about three hundred pounds of Provisions (including what we put on the Rafts) and several articles of convenience that had theretofore appeared to be indispensable, which made us about nine hundred pounds lighter than at the commencement of our Journey.

"In five days the Rafts were ready, provided with oars, ropes and stone anchors. ... The Crew told us afterwards that they found the [Gila] River shallow and full of Bars, and the Current very rapid; they frequently found themselves aground and had much difficulty in getting off. No event happened except that on the third day out the Woman was taken with Labor Pains. ... In the evening they helped the Husband carry his Wife and Baby on the Boat; the next morning they went on ... They arrived in Yuma six days before us." [describing events of 1849]
(Hannum, Anna ed. 1930, pages 250-251)

Wooden Rafts on the Lower Colorado River

"West Bank of the Rio Colorado, Tuesday 28th Nov. [1849]. Crossed the river yesterday 27th. After all the ingenuity of some five hundred souls, together with the pretended labor thereof had been in full play since 22nd and without an accident, that is, a serious one. Master workmen, shipmakers, carpenters, coopers, blacksmiths, majors and quartermasters, wagon masters, forage masters and boatmen, and generally artificers and mechanics of all and every description (saying nothing of soldier folks and teamsters) all, all had a finger in the pie, or Raft. Everyone found a small place in the monster, of "Felix Grundy #2" to slip in an idea of his own. She was launched on night of 25th and the welkin made to ring with the shouts of the multitude (?) assembled to witness the exhibition or baptism, and as she glided into the turbid waters of El Colorado was christened "Felix Grundy No. 2" after Evan's horse that departed this life at the Pima Village on 31st ult. ...

"But the F.G.#2 she was not more than christened, before six or eight men jumped aboard of her and under she went. ... The wood is too heavy, dead cottonwood, although 20 kegs are under her, and she sinks with about ten men. Another was constructed on 26th of same wood, but kegs left out, much larger than the "#2" called the "Pawnee Dash" ... The Dash drew as much water as she well could without sinking; but with stretched ropes, pulleys, &c, or, on the whole by the assistance of all trades and professions, ... We could send over nearly one wagon at a time.. So near it that in a couple of days we had all over, making about six trips per hour, a wagon with a very light load could go but otherwise her freight had to be landed for another trip. ... In crossing yesterday on the Raft, with Givens; baggage wagon and some ten men, the Raft sunk as soon as it hit the channel, one corner of it going down and the one diagonally opposite tilting up. ..."
(Couts, Cave J., 1961, pages 79-80, describing events in 1849)

Wooden Raft on the Gila River

"Killed four [cattle] and made a raft of cottonwood poles and started down the river." [Gila River near Gila Bend.]
(Hattie Anderson, 1858, page 76)

Wooden Raft on the Lower Colorado River

"After traveling about 10 miles we struck the Colorado river, at a large sand bar, and here there was nothing for our animals but some cottonwood bark; we had to feed some corn as we were about to start across a great desert of eighty miles and we had to get across the river in quick time which we did. We got 4 cotton wood logs, dried and cut them about 8 feet long, put a wagon bed on them, caulked as well as we could, lashed all together tightly, making a very serviceable ferry boat. We were very fortunate in securing the services of 4 Indians who pushed the ferry boat over, one swimming at each corner."
(Etter, Patricia, ed. 1986, quoting from Robert Brownlee's journal of the 1849).

Wooden Rafts on the Colorado River near the Mouth of the Virgin River

"They constructed a raft from the dry driftwood which had been washed up on the bank during flood time. They remembered the boat and supplies they had cached about four months before on their first journey. They found the boat in good condition, but the supplies were ruined. ... This crossing was later named 'Pierce's Ferry.'"
(Corbett, P.H., 1952, pages 154-155, 173-174 and 200, describing events of the 1850s)

Bullboats and Canoes

Bullboats on the Colorado River Near Present Day Lake Mead

"We slept here at night and started at dawn for the Colorado. It was entirely barren of wood, save for a few scant osiers of green willow. But there was the river and to cross it there was not a bit of standing or drift timber wherewith to build a raft. By a long search we found willow enough to make an osier frame for our skin canoe sufficiently strong for our purpose. We killed two horses, made a canoe of their hides and landed safely over. ...

[On the return trip] "Again we killed two of our few horses to make a canoe and we crossed well."
(Adams, Winona, ed.. 1930, pages 11 and 16, journal of woman describing events of 1841, trappers crossing the Colorado River twice somewhere near the mouth of the Virgin River.)

Canoes on the Rio Grande River

"Here we had to cross the [Rio Grande] river [Joyeta, NM]. We sounded and found that the Channel was over six feet deep. The nearest timber was three miles away over an almost impossible road; so we decided to raise the bodies of our Wagons to the top of the standards and pull them over with ropes. We purchased a lot of brushwood which the People had gathered for fuel, and nailed it across the standards to support the Wagon bodies. This was no small labor, as it involved the unloading and reloading of the Wagons as well as that of raising the bodies upon the cross pieces. This done, we dug down the banks to make a road, then carried the line over in a Canoe, and hitching a few yoke to the rope, pulled the Wagons over separately, wetting nothing but the running gear. ...

"Two ladies with white veils and painted faces arrived on the opposite side of the River, riding in an Ox Cart. They were recognized by two Young Mexicans on our side, who instantly stripped themselves naked, swam across the River, and embraced the Ladies, both Parties appearing to be rejoiced at the meeting. After a short chat they returned, procured a Boat, and ferried the ladies over.

"On Saturday night we passed over the River in Canoes and spent Sunday on the other side."

(Hannum, Anna, 1930 pages 223-225, describing events of 1849)

Canoe on the Lower Colorado River

"We notice also an Indian pirogue [dug-out canoe] which is moored to the California shore. ... Large trees must be very scarce, for since Yuma we have seen only two pirogues. ... We are again taking wood on the Arizona side. We see many Indians, men and women, some ponies and some pirogues. ..."
(Berton, Thomas, 1953 pages 68-73, describing a voyage up the lower Colorado in 1878).

Canoe on the Salt River and Grand Canal

"Mr. North Wilcox and Dr. Anderson inform us that they came in from Fort McDowell, day before yesterday by canoe, coming down Salt River to the head of the Grand canal and down the canal to town. They camped one night on the way down and traveled about a day and a half."
Phoenix Herald 2-15-1883

Common Rowboats and Skiffs

Rowboat covered made of India Rubber on the Lower Colorado River

"Our company are making two boats to cross their goods in. Their frames are made of willow poles, in shape of a ship's boat, and covered with India rubber blankets. ... The company having completed a boat, made two trips with her this afternoon. She is 18 feet long and shaped like a whaleboat. The others are about the same size. In crossing, the current carries the boat downstream, and in returning a little more distance is added in spite of the most active rowing."
(Clarke, A. B. 1988 page 84, describing crossing the lower Colorado in June 1849)

Rowboats and Rafts in the Grand Canyon

" ... with four boats constructed upon the ground, the largest of which was twenty-two feet in length. The limited time I had to construct these, the quality of the lumber, the capacity of the mill for sawing, and the rapid falling of the water in the river, prevented me building the boats in every respect as I could have desired. In consequence of the reduction of our force, and sickness, I was compelled to take charge of my boat alone; this was swamped twice by running under a fallen tree, and by being dashed against the rocks below the upper end of Cave Canyon ... The river here was fifty feet in breadth; the depth twenty-two feet. ... My boat was so much injured by the late accidents that I was compelled to abandon it one mile from the mouth. ... Such was the rocky character of the river, that the lower edges of the sides of my boat were so much worn that I was compelled to cut these down twice since starting. The water falling rapidly, made it more difficult to run over the rocks. ... Our first boat was lost at the mouth of Rocky Canyon; the second one mile from the moth of Cave Canyon; the third one mile from the head of Grand Canyon; and the fourth one mile below this. ... Built a cedar raft, five by sixteen feet, and upon this we took passage ran down the river thirty miles, ... In this our raft again struck, where we lost all our salt, all our cooking utensils, except one frying pan, and most of our flour and bacon. There was less elasticity to this than the Tulie rafts upon which I passed through the canyons of the Lower Colorado, and in striking with much force against the rocks the material of the cedar raft would part.... Built another raft, and descended forty miles further, when again, in turning an angle in the river, she struck a rock, and all our provisions, except five days rations of flour and bacon were lost. [8]
(Adams, Samuel, 1869, pages 6-8)

Skiff on the Salt and Gila Rivers

"Messrs. Cotton and Bingham will leave tomorrow for Yuma by way of the Salt and Gila Rivers. They have constructed for the trip an 18-foot skiff, flat bottom, which will draw very little water, while at the same time it has the appearance of being very strong and durable, and able to stand pretty severe buffeting."

(Phoenix Gazette 2-17-1881)

Rowboat on the Salt and Gila Rivers

"The Yuma or Bust party which left Phoenix recently for the purpose of exploring the Salt and Gila rivers were seen yesterday, only twelve miles from here, all wading in mud and water up to their knees, pulling the boat, and apparently as happy(?) as mud turtles."
(Phoenix Gazette 11-30-1881)

Rowboat on the Gila River

"Two men arrived here last week who had accomplished the dangerous feat of navigating the Gila River from source to mouth. ... About six months ago they sold their horses and wagon and started down the Gila in a boat of their own making. Their starting point was in the Black Range New Mexico, where the Gila has its source. ... They met with no special incident until the high water of the February floods began to come down. Their boat was upset and lost, but they built another and started on. ... The men hunted and trapped on the way but met with only moderate success. They claim to be the first who ever made the whole length of the river.
(St. Johns Herald, 7-7-1891, quoting the Yuma Times)

Rowboats on the San Juan River

"I am a carpenter and between 1893 and 1895 lived in Bluff and made 5 or 6 boats for miners who took the boats down the San Juan River with their supplies. There were other men in Bluff who made boats for miners during that 2-year period and some of the miners made their own boats. They were a crude sort of row boat, 22' long, 3 ½ or 4' wide and with a draft of about 1' loaded."
(William J. Nix, describing events of 1893 to 1895, witness in the Utah Riverbed Case)

Canvas Covered Rowboat on the Salt and Gila Rivers

"... We would build a boat and just drift down! [Salt-Gila rivers from Phoenix to Yuma] We set about building a boat in a corral ... It was a good boat, with a light wooden frame, canvas covered. We gave the canvas a good coat of white lead and oil, sold our burros and were ready to start. ... fortunately the boat was of light construction, which we found later was what saved the situation. For after eating our breakfast, loading the duffel into what might well have been christened "The Pride of the Salt River: and shoving off, the river went dry on us. ... There wasn't enough water to float the boat with us in it, but by walking along each side and helping the craft over the shallower places, we managed to make some progress. ... This kind of thing kept up for some days, until at last we reached the Gila, and from then on we had a little better going. There was not what could be called too much water, ever here, but most of the time one of us could stay in the boat. ... After this we had as much desert but more water in the river bed, so we made pretty good time to Yuma. I don't recall just how long it took us to make the trip. Three weeks or maybe a month would be my guess now."
(Coconino Sun, Sept. 5, 1945 and Arizona Wildlife and Sportsman, Aug. 1945. Stanley Sykes recalling a trip he made "about 52 years ago" in the winter at low-water time.)

Rowboats and a small steamboat on the Lower Colorado River

"It was past midday, the 21st of Dec. 1901, when our party of nine, in 3 rowboats (a black canvas boat, a red boat and a green boat) pushed off from the muddy bank of the Colorado at the town of Needles, and began our journey of 300 miles to the southward. The smoky little railroad town was soon left behind ... The current was swift with many shoals and sandbars, but with a little practice we soon learned to keep the channel. ...

"At Friant's ranch, on the AZ side, 3 miles above Williams Fork, was the first attempt at agriculture we

had seen. Here Mr. Friant has a few acres of alluvial soil, above high water, to which he pumps water with an engine and windmill ... He owns a little steamboat and carries most of his produce to Needles, a distance of 55 miles. ..."
(Three Hundred Miles on the Colorado, 1901)

Rowboats on Granite Dells Lake

"Grand Opening of Granite Dells Resort. ... Dancing, boating, bathing, log riding, swings for young and old, a shooting gallery, and a ball game between the Diamond Jos and a team from Jerome will be among the attractions to be found at this summer resort, so popular with Prescott people. ..."
(Prescott Journal-Miner, 5-5-1907)

Rowboat on the Salt River and Canals

"WATER ROUTE TO ROOSEVELT - Accomplishment of Two Mesa Voyagers
VIA CANALS IN ROWBOAT
Another Story of Two Men Not Including the Dog.
The Route is Not Yet Recommended for General Travel.

"The first trip ever made from Roosevelt to Mesa by way of boat was that of yesterday when Roy Thorpe and James Crawford arrived in Mesa by way of the Mesa canal, having made the entire journey from the dam site by means of an ordinary row boat.

"The original idea of the voyagers in making the trip was to enjoy the sensations of going over a route that is seldom frequented and also attempting a feat which has never yet been accomplished. It is understood that at least two parties have made the trip by boat from Roosevelt to Granite Reef, but the making of the entire trip by water from Roosevelt to Mesa is a record.

"The row boat that was used was in a very dilapidated condition at the end of the trip. Before the start was made three bottoms had been placed in the craft and one of these had been worn through by the constant friction with the boulders and sands found in shallow waters. Many times the men were compelled to lift their craft from the water and carry it over obstacles and at other times had to haul it along the stands. ....

"One incident of the trip was that just prior to leaving Roosevelt one of the men exchanged a faithful dog to which he had become attached for a puppy. The idea being that the older dog would be entirely too heavy for the craft. The dog, which was left at Roosevelt, in some manner chewed the rope in two with which he was tied, and followed the master the entire distance, arriving at Granite Reef but a few hours after the boatmen had left. Those who understand the Salt river will recognize that the feat performed by the dog is even greater than that by the men. Coming through the Box Canyon necessitated the animal swimming for a considerable distance while the falls this side of Mormon Flat would offer many obstacles. The men are well pleased with their adventure, but have no serious intention of attempting to go into competition with the stage company, nor did they attempt to break any speed regulations."
(The Arizona Republican. 6-28-1910).

Rowboat on the San Juan River

"Armed with the boat design from Billy's Alaska forays, Norman began construction of his first boat in January, 1934. An old horse trough and a privy provided the lumber. Huge knot-holes were patched with tin, and old undershirts stuffed into the cracks made it watertight. The boat had a six inch "kick" or upsweep from the bottom to the top of the bow, and stood sixteen feet long by five feet wide. To keep out waves, a six inch splashboard was tacked onto the twenty inch sides. Two feet wide at each end, the boat looked "something like a cracker box." This description was a distinct improvement over the recent honeymoon expedition in the Grand Canyon, that of Glen and Bessie Hyde. The Hydes disappeared in 1928, leaving behind few clues and a boat described as resembling a coffin. Pumprods from a well served for Nevills' oar shafts, and "borrowed" Utah State Highway signs made serviceable oar blades.

On a test run in February, a rock tore open the bottom of the boat. The next day Norman cut some sheet iron into three inch strips and covered the bottom and sides of the boat. On future boats, oak stripping replaced the sheet iron."
(Nelson, N., 1991, page 3, describing travel on the San Juan River) .

Rowboats on the Upper Colorado River to Lee's Ferry
"The party descended the canyon by using two 16-foot flat-bottomed rowboats, which were built in Los Angeles, Calif., shipped to Green River, Utah and hauled 170 miles with a quad truck to a point on the river 4 miles below Bluff, Utah. The boats were launched and the canyon voyage began ...
"Numerous oil and gold prospectors have descended in rowboats and on rafts parts of the San Juan between Bluff and Zahn's Camp. ... Some of the prospectors ascended the canyon with their boats, but they had to tow the boats upstream, because the current is too swift for upstream rowing.
"In 1894 Water E Mendenhall, a gold prospector, of Lake City, Colo., made the trip alone in a crude hand-made boat from Mendenhall Cabin to Lees Ferry."
(Miser, H. D., 1924, pages 2-3)

Rowboat on the Upper Colorado River
"My brother and I went in a 16-foot rowboat with a 5-foot beam, drawing only 4 inches of water loaded."

(John Galloway describing a trip in 1926, witness in the Utah Riverbed Case)

Scows, Flatboats, and Miscellaneous

Wagons Used as Boats on the Gila River
"Thurs. Dec. 31st. ... Here the Colonel ordered two wagons to be unloaded, their boxes put into the Gila River [downstream of Gila Bend, 9 days march from the Colorado River] and loaded with corn, bacon, and flour, and set down the river with men to man them, with instructions to haul in every afternoon and camp with the command. This move of the Colonel's we did not like and we had forebodings it would not be a success.
"Sun. Jan. 3rd ... Our boat have not come up since they left on the first and the Colonel has sent up the river to know what is the matter and this evening a report came in that the boats had run aground and it was doubtful about their coming any further. ...
"Wed. 6th This evening the boats arrived minus the provisions. Part of it had been put ashore and part left on a sandbar in the middle of the river. ..."
(Bigler 1932 p. 52, speaking of events in 1847.)

Scow on the Lower Colorado River
"Major Lawrence P. Graham, in 1848, commanding a troop of US soldiers destined for California, had abandoned here about twenty wagons. Selecting the most seaworthy body to be found among those wagons, with nails extracted and lumber supplied from others, we constructed a scow, caulked it with strips of torn-up shirts, for want of pitch using tallow supplied from the bladders bought from the Mexicans for use as lard. This tallow answered astonishingly well, the cool water keeping it hard and unmelted even under a blazing heat. Oarlocks were attached and, lo!, she floated the water - thing of life - though mayhap not of beauty."
(Harris, B. B., 1960, p. 85, quoting travelers crossing the Colorado in 1848)

Flatboats on the Gila River
"The Gila Copper Mines. These mines were discovered in the early part of 1856 by Richard Halstead, well known in the Gadsden purchase ... They are situated about twenty-four miles from the junction of the

Gila, with the Colorado, on the left bank, southern side of the Gila, and two miles from the river.

"... The great advantage in the location of this mine must make it immensely valuable - the ore or smelted copper can be transported on flatboats down the Gila to the junction of the Colorado and Gila, whence it can be carried by steamboats now running on the river, and delivered on board vessels at the head of the gulf at eighty dollars a ton, a rate which would defy competition from any distant part of the Gadsden purchase. ..."

(Mining Magazine, May 1857, page 483. There is no record of such transport actually occurring.)

Flatboat on the Salt River and Canals

"Salt River is navigable for small craft, as last week L. Vandermoerk and Wm. Kilgore brought five tons of wheat in a flat boat from Hayden Ferry, down the river to the mouth of Swilling canal and thence down the canal to Hellings & Co.'s mill."

(Weekly Arizona Miner Prescott, 5-3-1873)

Hand-Propelled Boat on the Gila River

"A new model of Gila craft was launched at the Florence pier Thursday, but did not meet the expectations of the inventor, Alex Gay. The new craft was provided with hand driven side propellers, but when the trial trip was undertaken it was discovered that the Gila current was mightier than human muscle and the boat drifted with the stream for a mile or more before a return to the launching shore could be effected. Nothing short of a ten horse power engine could drive a paddle wheel successfully in the Gila."

(Florence Blade-Tribune, 3-18-1905)

Houseboat (?) on the Salt and Gila Rivers

"The Phoenix Shipyard. Its First Boat, a Suspicious Looking Vessel, Launched Yesterday.

"The People that live along the lower Gila are pretty well accustomed by this time to seeing all manner of strange things drifting down on the breast of that ever surprising stream. Such odd collections as railroad bridges, ferry boats, farm houses, chicken coops, lumber yards, etc., no longer create surprise. But there was launched here yesterday something that may make their eyes bug out for it was ostensibly a houseboat, though it may be a torpedo boat in disguise or some new manner of war vessel that has been constructed here on the quiet for the Russians with a plan of attacking Tojo's nest in the rear while he is busy heading off Rodejvehsky's battle squadron as it enters Chinese waters. It will the same time be a matter of news to Phoenix people to know that this city has a real shipyard that the product of it is already in evidence.

"The master mind of this shipbuilding enterprise is Mr. Jacob Shively that came here not long ago from Ashland, Oregon. While Phoenix was standing around in open mouthed wonder, not imagining before that there was so much water in the world, Mr Shively was engaged in plans to make some use of it. He came from a country where they had had water before and a little surplus does not bewilder them. Mr. Shively says he's 76 years old and therefore of sufficient mature experience to conduct his own business without taking the whole world into his confidence or asking the advice of the whole town as the average man does before he starts something.

"He secured space for a drydock at the Chamberlain Lumber Co. and proceeded with the construction of the keel and first deck. A second deck was contemplated at first and the fact that the plans were changed leads to the suspicion that Mr. Shively had a warship in mind and received a change of orders from his prospective purchaser or employer. In the event the plans had been previously perfected. Anyhow it is surmised that a one decker could creep about more stealthily than a formidable appearing boat. In lieu of a second deck or a cabin therefore he equipped the vessel with bows for a wagon against which will turn Arizona hailstones, the only thing one needs armor for in these waters. When stripped for motion or action the wagon wheel may be removed.

"The boat was finished yesterday morning and the dry dock being some distance from the harbor a two horse wagon was pressed into service to assist in the launching which was accomplished without the slightest trouble. The launching went on in the presence of a vast crowd of two or three men and there was no champagne wasted or ceremony of a public character. The builder announced his intention of accompanying the crew as far at least as Yuma, but he was silent concerning the later plans. There are fears in some quarters that the boat may prove to be a submarine before it leaves American waters."

An article two weeks later reported that the boat had nearly reached Gila Bend with many trials and tribulations before capsizing. Capt. Shiveley opined that "no one has any business on that river with a boat les than 6 feet wide 14 feet long 3 feet hie an 2 good men." [sic]
(Arizona Republican, 3-24-1905 and 4-3-1905)

Flat-bottom Boat on the Verde River

"Word has been received at Clarkdale that Fred Fogal and Earl Gireaux who left Clarkdale about three weeks ago on a small flat-bottom boat, to brave the dangers of navigating the Verde river as far as Granite Reef dam, have successfully traveled approximately seventy miles.

"The two adventurers are at present trapping in the Bloody Basin country and report bagging coyote, civet cat and many other fur-bearing varmints. They also state that the river becomes easier to navigate the farther south they go and that they are thoroughly enjoying the trip."
(Jerome Copper News, 2-6-1931)

Sailboats

Sailboat on the Colorado River Delta and Lower Colorado River

"I had purposely designed and was building my craft of ample size and equipping it for both river and sea use in order to carry my reconnaissance down into the Gulf. She was turning out to be a clinker-built Mackinaw-type boat, about twenty-two feet in length by six feet beam, rather heavily framed and fitted with a large iron center-board. She was schooner-rigged, and intended to balance under either her full spread of canvas (two pound boat sails and a jib), her mainsail and jib, or her foresail alone
... a small load of lumber in accordance with my specifications, were dumped on the river-bank and I set to work on the boat."
(Sykes, Godfrey, 1945, pages 210 and 227, describing the early 1900s).

Sailboat on the Salton Sea

"I shortly thereafter found myself camped alone on the shore of the still filling "Salton Sea," building a large and commodious sailing boat for botanical and eremographic investigation. ... I had designed and was building the craft sufficiently commodious to provide ample space not only for an unknown number of co-explorers, but also for the usual load of specimens, botanical and otherwise, which I had already learned would be collected upon a trip of the kind we were to make. I rigged her with a single large sail, a sprit-sail, and equipped her with a lee-board in order that she might be worked to windward if the occasion arose. She was of coarse flat-bottomed for making mud landings ..."
(Sykes, Godfrey, 1945, pages 269-270, describing the early 1900s).

Ocean-going yacht on the Sea of Cortez

"Went to Tiburon Island
Arizona Charley Meadows ... and party returned Saturday [to Florence] from their trip to the gulf. On account of the floods and high tides the hunting grounds about the mouth of the Colorado river, usually so prolific of exciting sport for the hunter, were mostly submerged and the party had little enjoyment in this direction, but in another way their expedition was interesting. Two or three days were spent in trimming up and preparing Charley Meadow's yacht for a voyage and the party then set sail for Tiburon Island about 500

miles distant. The wind and weather were favorable and they had a fine trip. Reaching the island they sailed all around it, landing in at least twenty different places. ..."
(Florence Blade Tribune 5-6-1905)

Ferries

Wooden Ferry on the Colorado River at Yuma

"July 1850 Foster wrote in the SF Herald that 2 other ferry companies were being organized to take over the lucrative job of transporting emigrants from the east to the west banks of the river. Rumors had it that one of these was got up under the auspices of Col. Jack Hayes Whilom of Texas, and now sheriff of San Francisco. Both of these parties numbering 20 men each had arrived at San Diego one of them it was said, with $20,000 worth of goods to trade with the Indians. In addition, an application for a license to keep a ferry at this point had been made by a brother of Major Fitzgerald.

"To make up the complement a couple of Yankees were actually on their way with goods to this point and would be up in a few days. This being the state of affairs, it was at once concluded to be indispensable that we should proceed forthwith from our then camping ground, and take possession at this point, as this has been heretofore the place where the ferries have been established, and it is also unquestionably the point where the military was to be stationed when it arrives. Accordingly the next night we yoked up our teams, and pushed ahead, and without meeting any obstacle worth relating, found ourselves at the point which my letter is dated. This you must know is on a high bluff at the angle formed by the Colorado, immediately before and after its junction with the Gila .. The spot we occupy has always been called Concepcion on the Mexican maps. Etc. ...

"Dug a well, then went into the slough, cut down cottonwood trees that gave us butts two and half to three feet through and 10 to 15 feet long. Sawed them into sized lumber necessary for flat boats. Between doing guard duty daytime, and picket nights, sawing out lumber, building boats and cattle guard duty we were busy."
(Sweeny, Lt. Thomas W. , Woodward, E. ed. 1956, in a journal from 1848)

Wooden Ferry on the Colorado River south of Yuma

"Paddock's Old Ferry which was about 23 miles below Ft. Yuma, where there were ruins of an adobe house. 3 miles lower down was Gonzales Ferry which was a place where the Mexicans crossed the river (this was an old and established place of crossing). Cooke's Old Ferry was about 6 miles below Algodones which at that time belonged to L.J.F. Jaeger. He also operated the ferry about 1 mile below the fort. In 1848 Couts built a raft, allegedly the first ferry to cross the Colorado. Many were simply made by covering wagon boxes with waterproof sheets or tarpaulins, some of willow boughs covered with rubberized cloth, but these were in the main cranky, unstable and decidedly unsatisfactory craft. ... In 1849 Couts was once again at the ferry and helped immigrants across."
(Couts, 1960)

Ferry on the Gila River East of Gila Bend

"Boating in Arizona

"It does one so much good to read of boating in Arizona that we produce the following account of a wreck on the Gila from the Arizonian:

"On the 9th inst, the large ferry boat which had been used for years on the Salt River at the Maricopa crossing was floated down the river with the purpose of taking her to the Gila Bend crossing. Five men were manning her and everything was going on smooth until they reached a point about forty miles below Phoenix, when the boat came into contact with a willow snag just in the middle of the river. The current of the river being about at the rate of fifteen miles per hour the five men lost control of her and she struck the snag. She

was cut in two parts as if she had come across a buzz saw. She is a total loss. Her owners, Messrs. Vol Gentry and W. Cox, valued her at about $1,000."
(Tombstone Prospector, 1-24-1885)

Ferry Boat on the Salt River at Phoenix
"The new ferry boat for the Gila is delayed for want of oakum for caulking purposes."
(The Phoenix Herald 4-8-1894)

Aerial Ferry at Kelvin
"The Gila river is still up and dangerous to ford. At Kelvin a wire rope is stretched across the river on which runs a cage for carrying passengers and freight. On Thursday a cart was carried over and an attempt was made to lead a horse across. The man in the cage foolishly tied the halter rope around his body, the other end attached to the horse. As the cage started towards the middle of the river the horse bogged down in the quicksand, the rope became taut and jerked the man out of the cage and it was by the skin of the teeth that he was rescued alive. That historical animal, Thompson's colt, has many prototypes."
(The Florence Blade-Tribune, 2-16-1901

Ferries on the Gila River at Florence and Kelvin at Flood Time
"Eight hundred feet of the Maricopa railroad bridge across the Gila went out Saturday and the break has not been repaired, hence the S.P. passengers booked for Phoenix are now coming from Casa Grande to Florence by stage. They ferry the raging Gila here and go on to the capital by the P. & E."
(Florence Blade Tribune 02-18-1905)

"The Gila Queen, a finely constructed boat recently purchased by the Florence Commercial company, was busy all day Sunday transferring freight for that company. Over 8,000 pounds, together with several passengers and trunks were hauled during the day. ...
"The Kelvin Navigation company launched their new flat boat Sunday afternoon. The boat is attached to a wire cable, extending across the Gila from a point opposite the Ray mill, by means of two travelers and ropes. The trial trip was an exciting one. When it struck the swift water it began to buck and plunge like a true Arizona bronco. ... Jack was on the other side of the river watching the antics of that awful monster. ... "
(Florence Blade-Tribune 02-25-1905)

"The Mayflower and the Rey del Gila have gone into active competition at the Florence port and both now issue tickets to passengers. The competition was particularly keen Thursday and the cost of a voyage across the raging Gila fell to 20 cents."
(Florence Blade Tribune 03-18-1905)

Aerial Ferry on the Gila River at Kelvin
"The Florence Commercial Co. and Troy-Manhattan are at present putting a cable at Kelvin which, when completed, will solve the problem of safely crossing the Gila."
(Florence Blade-Tribune 3-25-1905)

Aerial Ferry on the Gila River at Kelvin
"E. O. Devine, the Kelvin merchant, was a visitor at Florence Monday and Tuesday. He says there are now two cables in operation at Kelvin, across the raging Gila. The car on one of the lines is operated by gravity and will carry 2,000 pounds of freight. These cable ferries are putting the marine fleet out of business."
(Florence Blade Tribune 04-08 -1905)

Ferryboat on the Gila River at Maricopa

"Building Boat to Cross the Gila. Maricopa and Phoenix Expects to Transfer Passengers Tomorrow.

"Carpenters are busy today building a boat that will be used to cross the Gila River until such time as the Maricopa and Phoenix road can make repairs to the bridge, 400 feet of which has been swept away by the high water of the past few days.

"H.W. Riley, who has the contract for building the boat, is working extra men on it this afternoon in order to have it completed in time to be take to the Gila river some time tomorrow and given its first trial.

"... The boat will be eighteen feet long, five feet wide and three and a half deep. It will be fixed for several pairs of oars. ...

"Transfers have been made in the past at the Gila River when the bridge was out, but never before has the boat used been as large as the Maricopa & Phoenix is now having made. It will carry about three times the amount of the ordinary row boat. ..."

(Arizona Enterprise, 1-6-1905. The location described must have been near the town of Maricopa, between Gila Bend and Phoenix.)

Ferryboat on the Gila River at Maricopa

"At the Gila Bridge. M & P. Railroad Cooperates with Gila River Navigation Co."

"Passengers who find it imperative to travel can get across now, though the transfer is a disagreeable and provoking one, and it will be several days probably before the mails will begin coming regularly from that direction.

"The ferry is across the south channel of the river, and the train from this side cannot get within a quarter mile of it. That is because the bridge over the north channel is too badly washed out to run an engine over. Passengers have to walk down this paralyzed structure to the south channel and then descend to the muddy bank and embark in boats. ...

"Another incident was the overturning of one of the ferryboats or canoes. Beside the boatman there were two men in it, members of a party of eastern visitors who were enroute here on for a mining enterprise. ... Both of them testify that the water was very wet, notwithstanding it was chocolate-like in both color and consistency."

(Arizona Republican, 1-16-1905)

Ferries on the Gila River at Florence

"Jack Hanson had a good thing and did not know it. He thought the cage on the cable was too slow so, he got the Gila Blunder back up the river attached her to the cable and loaded down with whiskey and beer he started across the river. In mid stream the cable parted and down the river they both went. Jack jumped overboard followed by Dave, making for shore. The Dutchman who was with them was sighted bobbing up in the water amidst the floating barrels, The Gila Queen crew started out and was able to rescue the crew of blunderers. They then started down stream for the barrels of beer, which they were after to rescue at the peril of their lives.

"The old Gila is doing business in the good old way this week. It has been impossible to cross it without the use of boats and at present the water is higher than at any time this season."

(Florence Blade-Tribune, 8-1-1908)

Motorboats

Gas-Powered Boat on the Salt River and Canals

"Round Trip Voyage of the River Fleet

"La Primera" with two small boats in tow sails to Consolidated Heading and returns.

La Primera, with Capt. Le Baron in charge, C.C. Jacobs at the helm, loaded with passengers and having in tow two smaller boats carrying passengers left the dock at the division gates Tuesday evening for a trip to Consolidated Heading and return. ...

"To all of those on board the experience was a novel one. Here were 18 people, none of whom, with two or three exceptions, had ever made a voyage on a gasoline power boat in Arizona. Few had ever ridden on any boat and a large part of the passengers had resided in Arizona when the water supply for the Consolidated Canal would hardly have damped a 6' X 9' dooryard. Only a few years ago and the idea of a boat ride in what was then called a desert would have been ridiculed. ... A beaver at work, unmindful of the reward offered by the government for its scalp, paused in its labors to gaze on the unexpected sight and an occasional coon, night hawk and owl sought to make themselves invisible. ...

"On the return trip the two small boats were cut loose and came down with the current assisted by oars in the hands of Messrs. Pomeroy and Lewis. ... Messrs. Le Baron and Jacobs were the hosts at the first voyage but they have purchased the boats as a business proposition and will, it is understood, place them at the disposal of the public for picnic and business trips - for a consideration. Their plans have not yet been fully given out."

Arizona Republic 8-22-1912

Outboard Motorboats on the Lower Colorado River

"My boat turned out to be a rectangular box, four feet wide and about eighteen feet long. One end, supposed to be the bow, was sloped up in order to offer less resistance to the water. The oarlocks were holes between pieces of boards nailed to the sides. The oars were lengths of inch board nailed to willow saplings. The was a foot of difference in their lengths, and the shorter of them had been broken and repaired with a couple of rusty nails and a shoestring. The craft was not exactly an Argosy (or at least it does not appear to me such at this day), but still it had a capacity for considerable freight in the way of Golden Hopes; also, which was of more practical importance, for several score of heads and hides. Boat room was not going to be a matter of serious worry.

"The boats we were to take had been constructed by the Southern California Edison Company for the use of their engineers who had made surveys in Glen Canyon the previous summer. Very solidly built in the first place, the rough bangings against rocks had left the heavy planks of their bottoms considerably shattered. Water poured through in streams on launching and the worst of them required brisk bailing to be kept afloat in pulling upstream to our camp. Twenty-four hours of soaking stopped the worst of the leaks and careful caulking most of the rest. A certain amount of seepage through some of the crushed planks persisted, however, and it was evident that it was going to take a deal of nursing to keep the aspiring flood of the Colorado on the under side of those boulder-battered bottoms until the end of the trip.

"The outboard motors were assembled and tried out during the afternoon of the sixteenth. True to form, my little Elto, clamped to the rail of the Ferry-boat started and ran like a top at the first turn. No less satisfactory was its trial run on the stern of my still leaking boat. Tiny as it looked in comparison with the other motors, there was still power and to spare in its diminutive cylinders to drive the big skiff at good speed against the four-mile current. I had used an Elto down three thousand miles of the Missouri and Mississippi the previous summer, unclamping it finally in New Orleans in practically as good shape as when I shipped it at Bismarck. But this was running with the current on a light boat, and in rivers with bottoms of sand and mud and offering nothing to bump against harder than snags. Pushing a thousand-pound load in a six-hundred pound boat against the current of a river flowing in a continuously rock-walled canyon was quite another matter. Also to be reckoned with was the fact that the abrasive action of the grit-charged waters of the Colorado was incomparably more severe than even that of the muddy Missouri. ... Tome, who had made some use of outboard motors in freighting for another government party in upper Glen Canyon the summer before, was determined to take full advantage of the experienced gained on that occasion in preparing our own motors for the stiff grind ahead. Against the inevitable and continuous bumping of rocks to be expected, he hinged the section of the stern to which the motor clamped, so that the effect of striking an obstruction would be to tilt rather to break it. Having found that no plunger pump would stand the scouring of the Colorado water for more than a few hours, he dispensed with pumps entirely, replacing them with five gallon gasoline cans, set on boxes in the stern, from which water to cool the cylinders cold be circulated through rubber tubes. To minimize the scouring of the submerged gears, these were to be opened and greased twice a day...

"We went on a USGS survey in a 16' Evinrude motor boat, in which we had two rolls of bedding, supplies for a week, at least 25 gallons of gasoline and our camera and surveying instruments."
(Carroll Dobbin, a witness in the Utah Riverbed Case, describing events of 1926 on the Lower Colorado River and Hardy River)

Motorboat on the Upper Colorado River to Glen Canyon

"The boat was 27 feet long, 5 feet wide, and drew 10" of water with ordinary load; it had a 6-cylinder automobile engine. Another boat was 20' long, 4' wide, with a draft of 6-8" of water and was powered with a Ford motor. Another boat was 18' long, 3 1/3' wide, and drew 10" of water."
(Virgin Baldwin describing events of 1925-30, witness in the Utah Riverbed Case)

Tunnel-stern motorboat

Tunnel-stern Motorboat on the Colorado River near the Hoover Dam Site

"I was running the ferry at about 14 years old. So I developed the ability of navigating on the Colorado River. No rapids, just muddy water. It was awfully hard to find clear water to run the boat in. I became the expert at it as time went along. I had to know what I was doing, because I could get the ferry to Arizona and back to Nevada.

"Another highlight of my life was when the beaver trappers came down the river. What they would do - about Christmas time each year they would wind up in St. Thomas Nevada. They would come in there, make a deal with somebody to load up their gear, and go by wagon down the Virgin River to Rioville. Part of their load, outside of the necessary bacon and beans, their lard and whatnot - the load consisted of two-by-fours, one-by-twelves, a bucket of tar, and a handful of nails. They'd just built themselves a little flat-bottom boat and make a pair of oars. And that's what they used coming down the river.

"So we built this little boat - 30 feet long, 6 feet wide. The only thing we had to go by was the old rule of thumb that a boat on the Colorado River must be six times as long as it is wide. That was the most ridiculous thing that ever come up. But that was it. That was how you'd do it. It was made out of one-by-twelves and two-by-fours, just like the trappers'. Thirty feet long, 5 feet wide, tunnel stern. Up to the building of the dam, all our boats were tunnel stern. That was a tunnel-like arrangement at the stern of the boat, usually a third as long as the boat. A propeller was run into this opening so you could navigate. We hauled it down to Cottonwood, down below the ferry line.

"I left there and went on up and got up to Boulder Canyon. I got over the roaring rapids, pushed my way over that. We got over Rainbow Rapids. I got over the reverse rapids. I had to get out and pull a little, push and pull a little to get over it. So we got up there. The boats were operated were homemade, flat-bottomed boats with a tunnel built in the bottom contoured to curve the water [as it went through], which would keep the propellers and the rudder above the bottom of the boat so they didn't hit rocks and things to damage them. These boats were powered by automobile engines. The one I operated had two Studebaker engines in it. In navigating the river you only navigated by what you could see on the surface, because you could not see through the water at all. And you operated only by the currents to guide your boat back and forth. [quoting Murl Emergy and Ray Cutright]
(Dunar, Andrew J and McBride, Dennis, 1993, pages 7 and 18, describing events in the 1920s and 1930s)

Rowboats Adapted for Whitewater

Rowboats on the Colorado River from northern Utah through the Grand Canyon

"The boats for this trip were modeled on those used on the former descent, with such changes and improvements as experience had suggested. They were honestly and thoroughly constructed by a builder named Bagley, who had a yard where he turned out small craft at the north end of the old Clark Street bridge [Chicago], and we often felt a sense of gratitude to him for doing his work so well. They were three in number, of well-seasoned, clear-gained, half-inch oak, smooth built, double-ribbed fore and aft, square-sterned, and all practically the same, the former trip having shown the needlessness of taking any smaller or frailer boat for piloting purposes. These were each 22 feet long over all, and about 20 on the keel. They were rather narrow for their length, but quite deep for boats of their size, drawing, if I remember correctly, when fully laden, some 14 or 16 inches of water. This depth made it possible to carry a heavy load, which was necessary, and at the same time which acted as a ballast to keep them right side up amidst the counter-currents and tumbling waters. A rudder being entirely out of place in the kind of navigation found in the canyons, a heavy rowlock was placed at the stern to hold a strong, 18 foot steering oar. The boats were entirely decked over on a level with the gunwales, excepting two open spaces left for the rowers. These open spaces, or standing rooms, were separated from the decked portions by bulkheads, thus forming under the decks three water-tight compartments or cabins, that would not only protect the cargoes and prevent loss in event of capsize, but would also serve to keep the boats afloat then loaded and full of water in the open parts. The rowlocks were of iron, of the pattern that comes close together at the top, so that an oar must either be slipped through from the handle end or drawn up toward the thin part above the blade to get out. By attaching near the handle a rim of hard leather, there was no way for the oar to come out accidentally, and so well did this arrangement work that in a capsize the oars remained in the rowlock. To anyone wishing to try the descent of the Colorado, I commend these boats as being perhaps as well adapted to the work as any that can be devised; though perhaps a pointed stern would be an improvement. Iron construction is not advisable, as it is difficult to repair.

"An arm chair obtained from the field was arranged so that it could be strapped on the deck of the middle cabin of our boat, as a seat for Powell, to enable him to be comfortable and at the same time see well ahead. This had a tendency to make the Dean slightly top-heavy, but only once did serious consequences apparently result from it, and I am not sure that the absence of the high load would have made any difference. (Dellenbaugh, Frederick, 1926, pages 236-240, 349, 359, describing Powell's second voyage. In 1871)

Cedar Rowboats on the Colorado River through the Grand Canyon

"After purchasing a boat, an ordinary flat-bottomed dory, fifteen feet in length, made of pine and ribbed with oak, ... I went to the railroad yard and opened the box car to see our boats. As soon as I looked upon them my heart sank within me, not on account of their size, their build or manner of fitting, but on account of the material - thin, light, red cedar - with which they were planked. The handling they had received in transportation had split two of them almost from end to end. ... They were five in number, fifteen feet long, forty inches wide, and about eighteen inches deep, sharp at both ends, clinker built, and planked with thin red cedar. ... had had them strengthened with extra ribs and braces, decked over at both ends and long the sides, thus giving them extra stiffness, and perfect strength for the material of which they were built, and they were provided with large air-tight compartments in both ends. Their one defect was the material - thin, red cedar - with which they were planked and the way it was put on, clinker built," which made them more difficult to repair. These boats were well fitted in form for the water, even the rough waters of the Colorado, but the delicate cedar of their sides and bottoms could not stand the bumping on the rocks of the River, and not be split at every contact.

"Profiting by the experience of the summer before, our new outfit was vastly different from the first. I had built, at Waukegan, Illinois., three boats, twenty-two feet long, four and a half feet beam, and twenty-two

inches deep. These were made of oak, from plans of my own, with ribs of one and a half by three-quarters of an inch, placed four inches apart, and planked with one-half-inch oak, all riveted together with copper rivets. Each boat had ten separate air-tight compartments, two large ones in the ends and four along each side. (Two water-tight lockers were built in the ends, for meats and other things, which, if possible, we did not wish to unpack when making a portage.) Two cross seats were built into the sides, which with the bulkhead division in the center (without deck) completely braced and stiffened the sides. A fifty-foot line in the bow, and two hundred and fifty feet of three-quarter-inch line at the stern, a life line rigged all around the whole boat, and a plentiful supply of selected eight-foot oars for rowing, and twelve-foot oars for steering, constituted the equipment of the boats.
The best cork life preservers, made expressly for us from my own pattern, were provided for all the men, and during the expedition, everyone was compelled to wear them, whenever on the water."
(Stanton, Robert, 1987, pages 36-37 and 95, describing events of 1889)

Rowboats on the Upper Colorado

"We started with 6 boats, (15' boats with a 3' beam and a depth of 2' and keel bottom) which were so heavily loaded that the water came within 3-4" of the gunnel. Thereafter we pulled ashore and made a raft, which the 6th boat towed with part of our cargo on it. We lost 2 boats in Cataract Canyon and broke up a 3rd boat in order to get nails to make repairs on the other 3 boats. Below Cataract Canyon we encountered the Tickaboo Rapid, where one boat was damaged and repaired and we had more trouble at Trachyte Rapid, where we stopped and repaired leaks."

On another 1889 trip - "We shipped 3 22' boats, with a 3 ½ ' beam and a depth of 22",having a draft of from 15-18" loaded."
(Frederick A Nims describing the 1889 Stanton expedition, witness in the Utah Riverbed Case)

Galloway Style Rowboat on the Colorado River Through the Grand Canyon

"In 1896 Nathan Galloway, a Utah trapper, with one companion, made the complete voyage through the canyons from Wyoming to Needles. Galloway designed the type of boat which has since been used almost exclusively in the canyons of the Colorado, and later parties have profited much by his careful study of the features and conditions of the river. Our little navy consisted of four wooden boats of the Galloway type, 18 feet long by 4 feet beam, decked over fore and aft and fitted with water-tight hatches and airtight compartments. The oarsmen sat in an open cockpit in the center, running the rapids stern first, so as to have as much chance as possible to avoid the rocks and rough waves. A strong, light canvas boat was provided to aid in the work of the rodman.
(Birdseye, C. H., 1911, page 179-181)

Galloway Style Rowboat on the Colorado River Through the Grand Canyon

"A simpler, less pretentious boat than Mr. Galloway's could not be conceived, yet experience has demonstrated that it is the safest yet constructed for running the rapids of the Colorado River and going over its dangerous places. Mr. Galloway is his own architect and builder. A few three-quarter inch planks; a little heavier timber for braces; oars with holes in them, through which iron rods, fastened to the sides of the boat, serve always to keep the oars in the same place and are more secure than ordinary oarlocks; with canvas outriggers and cover to keep her form being filled with water and swamped when running the rapids; a bow at both ends, and a flat bottom with the merest pretense of a keel, and the boat is ready. For our trip the outriggers were taken off, as we had no dangerous rapids to encounter."
{James, G.W., 1903, page 231)

Galloway-Stone Type Boats on the Colorado River Through the Grand Canyon

"Three boats had been built for this expedition and paid for by the Southern California Edison.

Two of them were of the Galloway type and were on the same lines as the Edith, but larger, because ten men in all had to be transported down the [Colorado] river, and no supplies were available after leaving the town of Green River until the Cataract Canyon survey was completed. These two boats were named the L.A. and the Edison. The third boat had different lines from the others, being short and broad with deep sloping sides and a flat deck, and was equipped with an outboard motor.

"Later it was christened the "Static." All boats were of wood, flat bottomed, with a ten-inch rocker both bow and stern. Emery Kolb's Edith was the fourth boat. We had two sixteen-foot skiffs, about sixteen inches deep, with probably a four foot beam. The boats would be used mainly for transportation of supplies and equipment, but occasionally both men and equipment had to be transported. On these occasions the boats sat very low in the water.

That spring H.E. built a twenty-foot boat equipped with a fourteen-horsepower engine, naming it the Ida B. for his wife. He made several trips on the river with the Ida B. before deciding to build another boat, one with less draft. The second boat was longer and narrower and used the engine from the Ida B. He called it the Utah. ... On the trip to Moab the Utah carried 2,000 pounds of freight besides the passengers. ...

Three boats for the expedition had been built in Wilmington, California and shipped by rail to Green River, Wyoming. Two of them were of the Galloway type, eighteen feet long and about four and a half feet of beam. The other one was sixteen feet long with a hull like a common flat-bottomed rowboat. The boats were similar to those used by the Kolb brothers in 1911 and the Chenoweth party in Cataract Canyon the year before. ...

These boats were far different from those used the year before on the San Juan. They were decked over at each end with an open cockpit in the center for the oarsman. The end compartments were equipped with hatch covers fastened with wing nuts, and these covers had been made watertight by lining the contact edges with rubber. The frames of the boats were oak, and the two larger ones had shiplap sides. The bottoms were flat and protected by oak strips running lengthwise.

"When the boatmen looked over the two longer boats before unloading them, they seemed too large for one man to handle. For a while they considered having them cut down. But the plan was soon abandoned because when the boats were in the water they did not seem nearly as large and unwieldy.

"The new boat was eighteen feet long, made of oak, and weighed 800 pounds. It had a four-inch rake (the amount of overhang or incline from perpendicular at the bow) its bottom was protected with two-and-a-half-inch slats spaced two inches apart, and it had thin sheet copper at the chines (the intersection of bottom and sides).

"Each of these boats was equipped with a three-quarter inch lifeline that led all around the gunwale (the upper edge of the boat's side) through iron eyes. The rope was stopped by turksheads (turban-shaped knots worked on the rope with a piece of small line) at both sides of each ring. The oars were copper-covered at the tips. A metal handle or portage bar was fitted at the sterns, and all the boats had air tanks for safety and buoyancy. All were without keels.

"The fifth boat was a fourteen-footer made of canvas. It had tire inner tubes on each gunwale for bumpers and oil cans fitted inside for buoyancy. Life preservers for everyone were of cork with a kapok collar. Of the four wooden boats, the new one handled the most easily."
(Westwood, Dick, 1992, pages 6, 10, 51-53, 74-75, and 130-131, describing events of the early 1900s)

Galloway-Stone Type Boats on the Colorado River Through the Grand Canyon

"The four boats to be used on the expedition, while differing slightly in size and details, were all of the flat-bottomed, decked-over, one-man type that is appropriately called the Galloway-Stone. The somewhat crude original was designed and built by Nathan Galloway, a Mormon hunter, for use on his lonehand trapping expeditions to stretches of the upper Colorado canyons not reachable except by boats. One the very sound theory that it is better to avoid a rock in a light boat than to hit it with a heavy one, Galloway sacrificed strength for handiness, but built a boat which he repeatedly ran single-handed through rapids in which the large, heavy boats of Powell and Stanton had encountered much trouble.

"When Julius F. Stone, an Ohio manufacturer, scientist and sportsman, decided to make a voyage to photograph and study the geology of the Colorado River canyons in 1909, he had Galloway come to his home in Columbus, where the two men put their heads together to build an ideal boat along the lines of that already used with such success by the Utah trapper. The present type of the Grand Canyon boat was the result. It was entirely decked over except for a cockpit for a single oarsman, and weighed less than 250 pounds. Its length was sixteen feet, four inches, it beam forty-six inches and its depth sixteen inches. The material was Michigan white pine, five-eighths of an inch thick. The four boats of this type built to Mr. Stone's order were used with signal success on his voyage through the canyons. The run from Green River, Wyoming, to Needles, California, was made in one week over two months. Both Stone and Galloway brought their boats through all the ways without an upset and with but a single light collision each while under control of the oars. These are by long odds the best records ever made in the Colorado Canyons, both for time and for skillful boatsmanship. [describing a voyage in 1909]
(Freeman, Lewis R., 1924, page 311)

Steel Rowboats on the Colorado Rive Through the Grand Canyon

"In 1907 three miners, Charles Russell, E.R. Monett, and Albert Loper, with three steel boats, each 16 feet long, left Green River, Utah, September 20 to make the descent. Lopez and one damaged boat were left at Hite, near the mouth of Fremont River, while Russell and Monett proceeded. In the beginning of the Grand Canyon they lost a boat, but with the remaining one, after various disasters, finally made their exit from the Grand Canyon January 31, 1908. Their boats of steel were unsuited to the river work".
(LaRue, E.C., 1916)

Galloway-Stone Type Boats on the Colorado River Through the Grand Canyon

"They were beauties - - these boats of ours - - graceful, yet strong in line, floating easily, well up in the water, in spite of their five hundred pounds' weight. They were flat-bottomed, with a ten-inch rake or raise at either end; built of white cedar, with unusually high sides; with arched decks in bow and stern, for the safe storing of supplies. Sealed air chambers were placed in each end, large enough to keep the boats afloat even if filled with water. The compartment at the bow was lined with tin, carefully soldered, so that even a leak in the bottom would not admit water to our precious cargoes. We had placed no limit on their cost, only insisting that they should be strictly in accordance with our specifications. In every respect but one they pleased us. Imagine our consternation when we discovered that the hatch covers were anything but water-tight, though we had insisted more upon this, perhaps, than upon any other detail. Loose boards with cross-pieces, fastened with little thumbscrews - - there they were, ready to admit the water the very first upset. ... Certainly the boats acted so beautifully in the water that we could almost overlook the defective hatches.

"Directly underneath and beyond the roots of the tree were large rounded boulders, covered with slippery mud. Past this barrier the full force of the water raced, to hurl itself and divide its current against another rock. If was useless to try to take a boat around the end of the rock. The boat's sides, three-eighths of an inch thick would be crushed like a cardboard box. If lifted into the V-shaped groove, the weight of the boats would wedge them and crush their sides. Fortunately, an upright log was found tightly wedged between these boulders. A strong limb, with one end resting on a rock opposite, was nailed to this log; a triangle of stout sticks, with the point down, was placed opposite this first limb, on the same level, and was fastened to the upright log with still another piece; and another difficulty was overcome. With a short rope fastened to the iron bar or handhold on the stern, this end was lifted on to the cross-piece, the bow sticking into the water at a sharp angle. The short rope was tied to the stump, so we would not lose what we had gained. The longer rope from the bow was thrown over the roots of the tree above, then we both pulled on the rope, until finally the bow was on a level with the stern. She was pulled forward, the ropes were loosened and the boat rested on the cross-pieces. I foolishly insisted on making another trial at it with the Edith, for I felt sure I could make it if I only had another chance, and the fact the Emery had the empty boat at the end of the rapid and could rescue me if an upset occurred greatly lessened the danger. The idea of making a portage, with the loss of nearly a day, did not appeal to me.

"It is difficult to describe the rapids with the foot-rule standard, and give an idea of their power. One unfamiliar with "white water"usually associates a twelve-foot descent or a ten-foot wave with a similar wave on the ocean. There is no comparison. The waters of the ocean rise and fall, the waves travel, the water itself, except in breakers, is comparatively still. In bad rapids the water is whirled through at the rate of ten or twelve miles an hour, in some cases much swifter; the surface is broken steams shooting up from every submerged rock; the weight of the river is behind it, and the waves instead of tumbling forward, quite as often break upstream. Such waves less than six feet high, are often dangers to be shunned. After being overturned in them we learned their tremendous power, a power we would never have associated with any water, before such an experience, short of a waterfall.

(E.L. Kolb., 1989. pages 7-8, 186-188 and 240-241, describing events of 1909)

Galloway-Stone Type Boats on the Colorado River Through the Grand Canyon

"The current is swift and the water, loaded with sand and silt, has tremendous power. Except where the rocks actually extend above the surface of the muddy water, it is impossible to know precisely where they are and falls cannot be avoided when the men wade out into the stream to work the boats along. If the boats are kept too near the shore they must be lifted over the rocks and if they are run too far out there is constant danger of their being capsized in the river or jammed against rocks and held there by the force of their current."

(Eddy, Clyde, 1919.)

Galloway-Stone Type Boats on the Colorado River Through the Grand Canyon

"We obtained 3 boats of the Galloway type and used them down the Green River and through Cataract Canyon. When we brought the boats down the Green and made our survey through Cataract Canyon we had an Evinrude motor in one boat. It was 16' long, 4' beam, and drew about 10" when loaded with about 1000 pounds. The other boats were 16' boats with rounded sides. ... just above the confluence we hit a sand bar and broke the propeller shaft of our motor. ... I don't think we could have brought the same loads they had up the river with that motor."

(Leigh Hunt, describing a trip in 1921, witness in the Utah Riverbed Case)

Galloway-Stone Type Boats on the Colorado River Through the Grand Canyon

"Nathan T. Galloway and S.S. Dubendorf come in from Vernal, Utah. All set about unloading the boats, which are apparently in good condition, except that the canvas decking over the front and rear cockpits is not water proof, as it should have been, and the method provided for fastening it down is not as arranged for. The iron standards at each corner of the cockpit which should have been provided to hold the canvas sides and ends have been omitted entirely. Neither are the small bow and stern compartments provided with airtight covers according to contract.

"Here we find signs of a party consisting of two men and a half-grown boy just ahead of us. ... They have but one flat-bottomed -and that not a very large one. The bottom is not protected with sheet metal and already carries some patches. ... [4 days later] Just below the head of this rapid we find a wrecked boat, evidently belonging to the party just ahead, and on a rock nearby a blue serge coat spread out as though to be dried in the sun. Near the coat is a crude oar and a push pole. ... The boat is irrevocably lost. ... We find no further trace of them.

"We are up at daybreak and begin patching my boat by nailing a strip of tin with a double strip of cotton cloth covered with white lead, underneath it, all the way around the lower seam, then clinching the nails on the inside of the boat. ..."

(Stone, Julius, 1932, pages 45, 71, and 73, describing events of 1909)

Rowboats on the Colorado River Through the Grand Canyon

"The boats were designed after those used by Powell and Stanton. His 2 large boats were 22' long, 5' beam, built of ½" Mexican mahogany, on very heavy oak ribs and keels, having 3 water-tight compartments, forward, amidships, and aft, and intended to be unsinkable. The small boat was 16' long, built of 5/8" cedar, on same heavy oak ribs and keels, decked over for 4' at each end, and had a splash board, but no water-tight compartment. The draft was 14-18" loaded."

(Parley Galloway describing a trip made in 1927, witness in the Utah Riverbed Case)

Canoe Construction

Our canoes, or boats, as they were usually called, were made of one-half inch marine plywood. They were shaped like sadirons and were 16 feet long, 6 feet wide and about 18 inches deep. They had been "cockpitted" for the baling bucket, an extra oar and ropes for both bow and stern. Behind the boatmen was the bow deck, which had a small hatch and a place for storing some of the lighter material. ...

The stern deck was wide -- extending on out to the squared-off end of the boat. And here was where the passengers mostly rode. If there were too many, the smallest would be put behind the oarsman n the bow, usually on the bow deck with his feet hanging over into the cockpit. It was customary to keep the minimum weight on the bow to allow for quick maneuvering.

The boats were flat-bottomed, but rocker shaped from bow to stern. And with oars remaining almost in the same spot, it was possible to spin the boat rapidly enough to give the passengers a bad time. If the oarsman reversed quickly, they needed to be aware, or they might be dumped into the water. They were a little sluggish at the beginning of a roll, but they could spin rapidly, which was essential in the rapids.

Wayne McConkie 1940

Appendix C-1

Watercourse Database Catalog