Approaches to Planning Water Resources

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Abstract

This paper attempts to summarize and organize various technical approaches often seen or discussed for water resources planning. The basic approach to rational planning is presented, followed by brief reviews of Requirements-based, Benefit-Cost-based, Multi-objective, Conflict Resolution, Market-based, and Muddling Through approaches to planning. Each approach has particular advantages and disadvantages for specific situations. Each approach also tends to have somewhat different analytical requirements. These approaches are discussed in terms of practical contributions to solving long-term water problems in contemporary contexts.

Introduction

"The plan is nothing. Planning is everything." - Dwight Eisenhower

Water resources planning is an ancient problem, dating back to flood control and water supply activities of the earliest civilizations. The success of most civilizations has rested, in part, on their ability to manage water (China, Indus, Europe, S. and Central America). The demise of several civilizations has been traced directly to failed management of regional water resources (Peru, Mesopotamia) (Artzy and Hillel 1988; Ortloff et al. 1985). In the United States, water resource planning has evolved historically (Shad 1979; White 1969). Quantitative analysis and even economic thinking in water planning date at least to Roman times (Frontinus 97 AD; Leveau 1993) and has been vital to successful water management in modern times (Kelley 1989; Morgan 1951). Lack of planning or poor planning often are blamed for continued controversies, expense, and inefficiencies in water management. The complexity and controversy of water problems should lead water planners and decision makers to seek fundamental principles and approaches for organizing the technical aspects of preparing solutions. This paper attempts to summarize and organize the wide range of planning approaches often seen or advocated for water planning.

The paper begins with a review of rational planning, the fundamental process aspired to by most planning efforts. This is followed by a review of various technical approaches common or commonly discussed for water resources planning. Practical problems for effectively completing planning processes are then reviewed. In light of these practical problems of water management, some realistic and limited objectives are suggested for water resources plans. Finally, analytical aspects for each planning approach are compared and some conclusions are suggested.

Rational Planning

Rational planning is a systematic procedure to resolving problems in the future. Many have written about how rational planning should be done for water resource problems (Orth and Yoe 1997; Yoe and Orth 1996; US Water Resources Council 1983; White 1966). Rational planning ideas also have been employed in some of history's most innovative water projects (Morgan 1951). These thoughts on planning are closely related to work on other urban, regional, landscape, and environmental planning problems (Meyerson and Banfield 1955; Briassoulis

1989) as well as more general rational or “smart” decision-making (Simon 1947; Hammond et al. 1999). While there are substantial differences in the methods and approaches suggested by these authors, there is an essential procedural similarity. This similarity of approach is a largely sequential rational planning thought process.

All forms of rational planning take some variant of the rough series of steps summarized in Table 1. These steps are usually, but not always sequential; often steps are re-visited as a result of technical or stakeholder feedback, new information, or changing events. Nevertheless, the general direction and order of the planning effort remains the same. The special importance of Steps 4, 5, and 7 should be noted. Statement of Objectives, followed by Identification of Solution Alternatives and Evaluation of Alternatives on Stated Objectives are the core of rational planning. This reduced set of steps parallels more formal and mathematical definitions of rationality and mathematical optimization (Von Neumann and Morgenstern 1944; Tribus 1969; Hillier and Lieberman 1995).

Table 1: An Outline of Rational Planning (* = most fundamental steps)

<u>Step 1. Statement of Problem</u>: John Dewey said, "A problem well stated is a problem half solved." Early in rational planning, it is desirable to firmly define the problem, stating people's concerns and what motivates the planning exercise.

<u>Step 2. Inventory/Background</u>: What do we know about the problem and the problem-setting? What has been learned already? How have earlier attempts to solve similar problems fared?

<u>Step 3. Forecasting</u>: The lifetime of most water problems and solutions is very long, far longer than the careers of individual decision-makers, engineers, and planners. Forecasts of demands and related conditions estimate how the problem and problem setting are likely to change over the life of proposed solutions. Uncertainty and inaccuracy in forecasts is unavoidable.

<u>***Step 4. Statement of Performance Objectives**</u>: What makes a proposed solution "good" or desirable? Performance objectives can be economic, financial, environmental, social, or the reliability of achieving technical standards. Both planners and stakeholder representatives typically define performance objectives.

<u>***Step 5. Identification of Alternative Solutions**</u>: What different actions might be taken to solve the problem (including doing nothing)? Alternatives should be mostly reasonable, represent a wide range of approaches to solving the problem, and selected from a variety of sources. Past experience with similar problems is very helpful, as are more academic and creative thinking. Public participation and preliminary modeling often aid planners in identifying alternatives.

<u>Step 6. Development of Alternatives</u>: Time and resources prohibit examining “all possible alternatives.” A limited number of promising alternatives are developed in sufficient detail for evaluation on performance objectives (the next step). Discussions with stakeholders and preliminary modeling often help screen, narrow, and refine alternatives.

<u>***Step 7. Evaluation of Alternatives on Stated Objectives**</u>: Each developed alternative is evaluated in terms of expected performance on each stated objective (e.g., economic, financial, environmental, social, risk, technical standards, etc.). This is typically the most analytical step and may include consideration of reliability and uncertainties. Interpretation and sensitivity analysis are desirable aspects of the evaluation.

<u>Step 8. Selection of a "Best" Alternative(s)</u>. The "best" alternative is selected based on the evaluation in Step 7 and relevant stakeholder and public consultations. "The plan" consists of the write-up of steps 1-8, with particular emphasis on presenting the selected alternative(s). Selection often involves multiple objectives and decision-makers.

Step 9. Implementation and Pragmatic Revisions of the Selected Alternative(s). Implementation often requires substantial modification of a selected alternative. Practical considerations arise regarding political and institutional support, financial support, construction, operation, and ultimately closure or replacement over an alternative's lifespan.

Step 10. Periodic Re-Examination: For the next problem, did we learn anything from this experience? How could we have improved our work?

Limitations of rational planning are evident (Banfield 1959; Simon 1947; Braybrooke and Lindblom 1970). It is often difficult or impossible for decision-makers and stakeholders to clearly state their objectives in quantifiable ways, particularly for objectives involving reliability and risks. In its idealized form, the identification and comparison of "all possible alternatives" on all relevant objectives is clearly impossible in practice. Only a limited number of alternatives can ever be identified, much less developed into a form that allows comparison of alternatives. In analysis, evaluations contain uncertain assumptions and unavoidable simplifications. Ultimately, any analysis must serve an institutional or political framework that works, however slowly, to make decisions regarding the "best" solution.

The strengths of rational planning are its transparency, logic, and the considerable lack of effective technical alternatives. Many variations for implementing rational planning have arisen, particularly in light of limitations under specific circumstances. Often, planning's greatest contribution to problem-solving is the structure and systematic approach it imposes on information-gathering, deliberation, and decision-making. Both rational planning variations and non-rational alternatives to planning should be compared based on how well they might satisfy the objectives of planning.

Approaches to Water Planning

This section reviews six major approaches for water planning, most of which are variations on rational planning. Each approach addresses technical aspects of water problems within a decision-making context. These six basic approaches are presented in a rough order of their historical formalization for modern applications:

1. Requirements-based Planning,
2. Benefit-Cost-based Planning,
3. Multi-objective Planning,
4. Conflict Resolution Planning,
5. Market-based Planning, and
6. Muddling Through.

For each approach to planning, the following aspects are discussed, a) history, b) methods, analysis, use of models, c) data and computational requirements, d) role of public participation, e) how it helps decision-makers, f) circumstances when it seems to succeed, and g) circumstances when it seems to fail.

Requirements-based Planning

Sometimes referred to as "project and provide," requirements-based planning reflects a traditional approach to formulating engineering problems. First, define the functional specifications the system must satisfy, perhaps with appropriate factors of safety. Then, design (plan), build, and operate the system to meet these requirements (or loads), at the lowest cost or with the greatest reliability for a given budget (Suh 1990). An outstanding characteristic of requirements-based planning is that it typically assumes given and fixed demands, restricting or focusing planning efforts to "supply-side" options. This can be advantageous when demands are outside the control of the planner or of such great importance that the costs of meeting demands are relatively unimportant.

The history, practicality, and method of requirements-based water resources planning are exemplified by the classical Rippl method (1883) for reservoir sizing. Here, future use of water is estimated through a forecasting method and is assumed fixed. The size of the supply is then determined by finding the reservoir size or combination of sources that would allow this demand to be met with a repeat of the historical streamflow record. The sum of supplies must always meet or exceed forecast use. This so-called "firm yield" approach to water planning has dominated water planning until very recently, when the costs of providing such high supply reliability have often exceeded the costs of water scarcity.

Requirements-based planning is very effective and appropriate for many components of water systems (pump stations, distribution lines, local drainage, etc.). For these components performance expectations are relatively fixed and standardized, and more detailed planning analysis might be too expensive relative to potential resulting improvements. But for large components and overall system planning, requirements-based approaches often have been inadequate and resulted in controversial and overly expensive solutions.

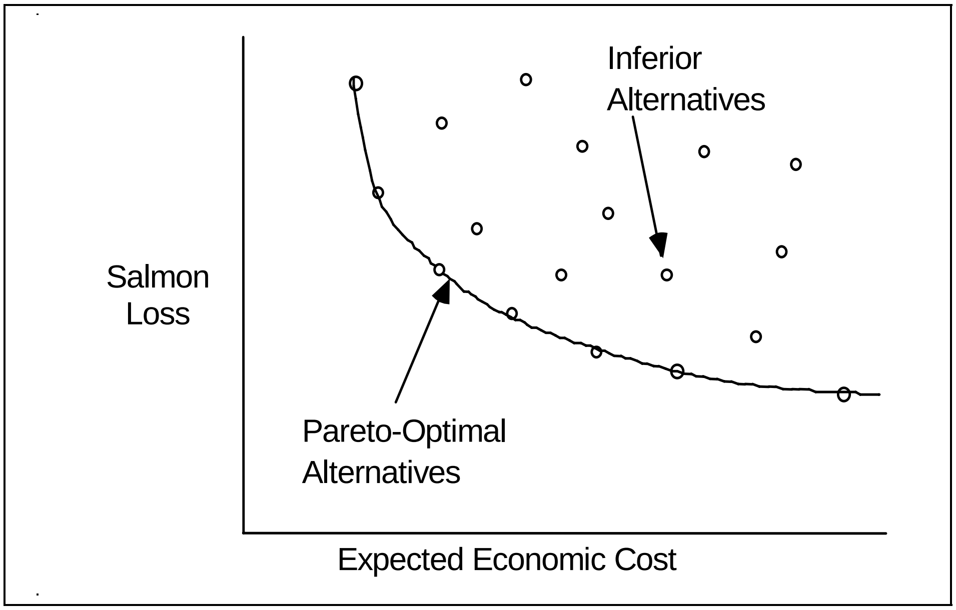
Benefit-Cost-based Planning

Benefit-cost analysis attempts to consolidate the many impacts of each alternative into monetary benefits and costs. The 1936 federal Flood Control Act neatly summarizes the germ of benefit-cost analysis, that a proposed project should have "… benefits to whomsoever they may accrue … in excess of the estimated costs …". Since this time, benefit-cost analysis has expanded steadily beyond flood control to include greater varieties of water uses and impacts (Griffin 1998; Russell et al 1970; Howe 1971; James and Lee 1971; Jenkins and Lund 2000; US Water Resources Council 1983; Boardman et al 1996). Flood control, navigation, water supply, hydropower, recreation, and even some environmental water uses have been incorporated into benefit-cost analyses (Loomis 1987). The limitations of benefit-cost analysis are well known, including monetizing all effects of alternatives, selecting discount rates, incorporating social equity, and representing risk preferences. Nevertheless, its application has helped eliminate unworthy projects, justify worthy ones, and raise the quality of discussion for ambiguous cases. It broadly integrating economic perspective and abilities to incorporate variability, reliability, and uncertainty, either as mean economic values or probability distributions of net economic value, are among the strongest technical features of the benefit-cost analysis approach.

Multi-objective Planning

Partially arising from the perceived one-dimensional economic nature of benefit-cost evaluations, multi-objective approaches to planning attempt to display to decision-makers the trade-offs inherent in selecting alternatives where not all objectives can be measured in the same units (US Water Resources Council 1983; Cohon 1978; Cohon and Marks 1975). Such a trade-off display appears in Figure 1, separating Pareto-optimal alternatives that represent efficient trade-offs from inferior alternatives. Some authors attempt to go beyond the development and display of efficient trade-offs to propose rational bases for making decisions with these trade-offs identifying optimal solutions through multi-dimensional concepts of utility (Keeney and Raiffa 1976; Haimes and Hall 1974).

Figure 1: Multi-objective Trade-off Plot



While the analysis approach of multi-objective planning is technically attractive, it typically lacks a formal institutional mechanism to establish the trade-offs needed to identify a most desirable alternative from a set of "Pareto-optimal" solutions (Figure 1). Thus, in practice for multiple stakeholder problems, multi-objective planning is limited to informing decision-makers or stakeholders on the relevant trade-offs involved in their decisions or to helping identify promising solution alternatives that satisfy a range of likely objective weights (Brill et al 1982). Difficulties visualizing or communicating trade-offs among more than a few objectives often hamper the practical value of multi-objective methods.

Planning to Resolve Conflicts

"Don't walk in front of me, I may not follow. Don't walk behind me, I may not lead. Walk beside me and be my friend." - Albert Camus

Planning to resolve conflicts differs fundamentally from other planning settings. The objective is to reconcile individuals or groups with conflicting objectives for water management to a single plan or plan strategy. In most conflict settings, planning occurs in a political environment where parties have alternatives to participating in a formal planning process. Responding to the common difficulties of planning in many real institutional and political situations, several forms of conflict resolution-based planning have emerged (Viessman and Smerton 1990; Delli Priscoli 1990). These various approaches typically emphasize the need of various parties or stakeholders to communicate, understand, and negotiate as necessary conditions for any solution to be accepted politically. Often considerable emphasis, effort, and time is required to establish broad confidence and communication in both technical and decision-making processes as part of developing and implementing solutions.

Conflict resolution-based planning typically gages its success based on how well a "consensus" solution is achieved, and may not be as concerned with the Pareto-optimal rationality of a solution. Any plan agreed upon by the diverse stakeholders is generally thought to be a good plan. While consensus-based conflict-resolution processes appear to be useful, they have been far from universally successful, perhaps because such problems are tremendously messy and difficult (Walters 1997). Even where formally unsuccessful, such processes can serve an important long-term role in improving communications and other conditions needed to work on solutions in the future. Conflict resolution is often a long process. Two broad categories of these still-emerging planning approaches are summarized below.

Adaptive Management and Shared Vision Modeling

Adaptive environmental management was first proposed in the late 1970s by a group of ecologists (Holling 1978; Walters and Holling 1990; Walters 1997; Walters and Green 1997; *Environmental Management* 1996). The objective was to support ongoing environmental management with consideration of uncertainties and incorporating an ability to change management of the system as more was learned of the system's behavior and response to management. A central tenet of this school of thought is that computer modeling has a central role for synthesizing knowledge of environmental problems, integrating new knowledge of the problem, and developing promising management strategies. In adaptive management, the development of computer models is a collaborative exercise among different disciplines and stakeholders. The intent of modeling is to aid development and negotiation of management alternatives, with both management and model-represented understanding adapting to new information over long periods of time, and to use modeling to design management experiments. The approach has had mixed success (Walters 1997; Lee 1999; Richards and Rago 1999).

A similar approach has taken hold recently among water resources engineers, often called "shared vision modeling" (Palmer, et al. 1999; Keyes and Palmer 1995; Werrick and Whipple 1994; Reitsma et al 1996). This approach also uses a group of stakeholders and technical experts to develop a computer model to represent a common understanding of the problem and develop, quantitatively compare, and negotiate potential solutions.

"Watershed" Planning

“Watershed planning” has been widely advocated by federal, state, and local agencies, though with less formal guidance of how it should be done (Kenney 1999; Gelt 1998). This concept differs fundamentally from long-standing ideas of relatively centralized planning for water at a watershed scale (White 1969; Goodman 1984). The most common tenets of current usage of “watershed planning” are that all stakeholders in the watershed should be involved in discussions regarding its management, all aspects of water quality and quantity in the watershed should be considered, and that the parties should have great flexibility in arriving at a consensus solution. The emphasis is on developing consensus-based water plans, involving all major stakeholders and agencies. As with adaptive management, mutual education among parties and stakeholders is a major aspect of watershed planning, although documentation of understanding is less quantitative. Watershed planning seems to be more successful where there is a balance between expectations and resources/funding, effective leadership and management, interpersonal trust, committed participants, and a flexible and informal structure (Leach and Pelkey 2001). A relatively formalized and comprehensive application of watershed planning principles is the Texas water plan, which was based on watershed plans for 16 regions of Texas (TWDB 2002).

A common problem with consensus-based planning conflict-resolution planning, especially its adaptive management forms, is the need for extended studies, funding, and attention from parties involved. While the exchange of ideas in these processes can produce valuable results, the long time frame often causes many good efforts to lapse due to budgetary variability, management and personnel transitions, and short attention spans at funding, managerial, and political levels. However, for controversial systems, conflict resolution approaches sometimes are the only approaches that political authorities can support.

Market-Based Planning

Markets are a decentralized form of planning, which in some circumstances can accomplish planning objectives very effectively (von Hayek 1945). Markets, negotiated contracts, and exchanges have long been important components of water planning, providing flexibility at local scales to adapt to short-term hydrologic, economic, and water demand variability. In recent years, the use of markets and other negotiated transfers in water planning and management has received increased interest and application to provide short and long-term flexibility in water allocation and operations (Lund and Israel 1995). Market-based planning often includes water contracts, markets for spot, dry-year, or permanent water transfers, transferable discharge permits, or privatization of facilities or operations. Often water markets are exclusively among public agencies or districts. In addition to providing a means for efficient and flexible operations, markets also provide financial incentives to adapt management policies to hydrologic and economic conditions.

There are obvious limits and disadvantages of market-based solutions to public resource problems. The assignment and accounting of rights and real water, third-party and externality effects, and other classical market imperfections all pose problems. Nevertheless, markets are often effective and efficient components of water and environmental management (Anon. 1995; Howe, et al. 1986; Eheart and Lyon 1983; Lund et al. 1992).

Practical "Muddling Through"

Political and economic circumstances often do not support long-term planning, particularly plans that recommend major changes to the current situation. Under these conditions, it is often more effective for planning efforts to take a short-term view of making small improvements in a direction which is desirable for the long term. This approach is sometimes called disjoint incrementalism or "muddling through" (Lindblom 1959, 1979; Braybrooke and Lindblom 1970). Often, plans developed with the intent of following other planning approaches end up merely contributing to "muddling through." Numerous advantages have been ascribed to incremental alternative evaluations and actions in a pluralistic political environment (Braybrooke and Lindblom 1970), including improved responsiveness to perceived problems, ability to identify important consequences, and diffusion of decision and evaluation responsibilities. In this way incremental decisions in a political context are seen as superior in some ways to more formal planning decisions based on formal decision-making calculations (such as benefit-cost analysis).

While exposition requires making distinctions between major approaches to planning, actual planning often reflects several of the approaches described above. Real planning situations often require an artful mix of approaches tailored to achieve practical political and technical objectives through practical political and technical means. Table 2 is a summary comparison of the water planning approaches discussed above in terms of the three most fundamental steps of Rational Planning.

Table 2: Rational Aspects of Common Water Planning Approaches

Planning Approach	Performance Objectives	Alternative Identification	Performance Evaluation
1. Requirements-based	Cost and simple technical performance standards (e.g., meet forecast water demands in 95% of years)	Alternatives suggested by experts, stakeholders, and sometimes model results	Cost-effectiveness

2. Benefit-Cost-based	Maximize net economic or financial benefits for owner, region, or nation	Alternatives suggested by experts, stakeholders, or model results	Benefit-cost analysis, perhaps including uncertainty & variability
3. Multi-objective	Quantifiable objectives specified by decision-makers or stakeholders	Alternatives suggested by experts, stakeholders, and model results	Reduce alternatives to the Pareto-optimal set
4a. Conflict Resolution: Adaptive Management (Holling 1978)	Quantifiable objectives specified by decision-makers or stakeholders	Alternatives suggested by experts, stakeholders, and model results	Reduce alternatives to the Pareto-optimal set, including long-term efforts to adapt, monitor, and narrow uncertainties
4b. Conflict Resolution: "Watershed Planning"	Objectives stated by decision-makers or stakeholders	Alternatives suggested by stakeholders and sometimes by experts	Little or no formal evaluation
5. Market-based	Each party has its own objective(s), not necessarily revealed	Alternatives identified by parties to the market individually	Each party evaluates alternatives individually and privately; unsuitable alternatives rejected in market
6. Muddling Through	Only limited objectives and expectations	Only easily implemented alternatives considered	Only simple and expedient evaluation of alternatives

Practical Problems

"Planning is an unnatural process; it is much more fun to do something. The nicest thing about not planning is that failure comes as a complete surprise, rather than being preceded by a period of worry and depression." - Sir John Harvey-Jones

The many practical limitations of planning often govern which approaches to planning can or should be taken for a particular situation. Some major practical problems are discussed below.

Conflicting Water Uses and Objectives

Conflict among uses and users of water is the dominant characteristic of contemporary water planning. Agricultural water supply, environmental water uses, urban water supply, flood control, hydropower, recreation and other uses all compete in economic, legal, and political forums over the management of water, at local, regional, state, and federal levels. Even within each common water use, individual users or user groups often disagree on allocation of water, financial costs, and environmental impacts. Table 3 compares how each planning approach addresses conflicts over water use objectives.

Table 3: Planning approaches and conflict, authority, and integration

Planning Approach	Conflicting Uses, Users and Objectives	Limited Authority to Implement Plans	Integrating Local, Regional, & State Plans

1. Requirements-based	Requirements must be established first	Rests on consensus over defined "requirements"	Difficult
2. Benefit-Cost-based	Economic valuation mediates conflicts	Requires consensus on economic basis for evaluation	Explicit
3. Multi-objective	Conflicts presented as trade-offs	Authority to complete planning is lacking	Difficult
4. Conflict Resolution	Negotiating conflicts is central to the planning process	Recognized as part of planning process	Difficult
5. Market-based	Market mediates conflicts	Market forces overcome limited authorities	Implicit, relatively easy
6. Muddling Through	Conflicts avoided whenever possible	Only limited plans attempted	Usually not attempted

Limited Authority to Implement Options

Regional water planners have very limited ability to directly affect the vast majority of water management decisions because most water management decisions are made locally. The effectiveness of regional water plans would be greater if they could be integrated with local water management efforts and activities. In the past, State and Federal governments often intervened in water problems to facilitate regional solutions. In recent times, this has become difficult due to reduced State and Federal ability and willingness to fund regional options, particularly in the face of controversy. Each approach's treatment of limited planning authority is summarized in Table 3.

The need for centralized authority in water management has long been debated, and is central to political theories of water management. The classical work by Wittfogel (1957) argued that the origin of central governments and indeed dictators arose from the need for a central authority to develop and manage irrigation and flood control in early Mesopotamian civilizations (so-called “hydraulic civilizations”). More recently, centralized planning authority has been seen as essential to regional flood and water management (Kelley 1989; Worster 1985). However, others point to the effectiveness and efficiency of many highly decentralized water management systems, such as Bish’s (1982) work on the Puget Sound region and Blomquist’s (1992) work on Southern California groundwater management. Some theorists hold that decentralized management better utilizes local knowledge, maintains local accountability and performance objectives, widens the range of options considered, and ensures widespread review and comment on intermediate and final policy and planning products. Effective decentralized management requires coordinating mechanisms that can be informal or formal, such as coordinating committees, agreements and contracts, a regional agency of local agency members, regulations, markets, or the courts. A water plan for a region with decentralized water management is likely to be more educational and define a framework or direction for common activity, and less likely to define a direct plan of action.

Integrating Local, Regional, State, and National Plans and Policies

Most water management decisions are local. For every State or Federal water planner, there are dozens of local water utility planners. And for each local water planner, there are thousands of agricultural, residential, commercial, and industrial water users, each making long and short-term water management decisions. Integrating these local and user decisions with regional and state water management decisions is both difficult and essential for effective regional water management plans. Some summary thoughts on how each approach pursues this function appear in Table 3.

Water planning can rarely be undertaken with the precision and comprehensiveness of an industrial or military enterprise. More commonly, regional water planning must consider policies and plans already existing at local, regional, state, and federal scales. Thus, plans sometimes resemble to the “exquisite corpse” of early 20th century surrealist art circles, as illustrated by the quote below from an early housing study.

> “The process by which a housing program for Chicago was formulated resembled somewhat the parlor game in which each player adds a word to a sentence which is passed around the circle of players: the player acts as if the words that are handed to him express some intention (i.e., as if the sentence that comes to him were planned) and he does his part to sustain the illusion. In playing this game the staff of the Authority was bound by the previous moves. The sentence was already largely formed when it was handed to it; Congress had written the first words, the Public Housing Administration had written the next several, and then the Illinois Legislature, the State Housing Board, the Mayor and City Council, and the CHA Board of Commissioners had each in turn written a few. It was up to the staff to finish the sentence in a way that would seem to be rational, but this may have been an impossibility.” Meyerson and Banfield (1955), p. 269.

Data, Time, and Resources for Analysis

Technically, most planning analysis is limited by the quantity and quality of data available. Moreover, some types of data, such as future water demands, exist reliably only after their quantities are irrelevant to planning. Large amounts of data do not necessarily contain useful information. Poorly or unsystematically collected or estimated data often contain less useful planning information than simple more transparent estimations. Data often must be digested and reconciled to be useful analytically or conceptually, with understood limitations.

Data problems are compounded if there is fundamental scientific controversy over how empirical data should be assembled or interpreted. This is often the case with biological problems, where there is both significant variability in empirical data and fundamental questions of how particular biological and ecological systems work. The lack of data, or useful data, tends to encourage some forms of planning relative to others. These are summarized in Table 4. The cost and time required for collection, digestion, and use of data will always place technical limits on how planning can be done.

Few planners complain of having too much time, funding, or expertise. The lack of time is often imposed by statutory limitations or the attention period of governing political bodies. Such limits inevitably reduce the level of analysis undertaken, with implications for the approach taken to planning. In some cases, the time and resources allocated for plan or study completion extends beyond the likely time of political attention or importance for a subject.

Variability and Uncertainty

Many aspects of real water problems are highly uncertain or variable, particularly over planning time frames. Many fundamental uncertainties exist regarding how water management affects specific environmental resources. Hydrologic uncertainty, from "usual" variations between drought and flood to prospects for climate change; water demand uncertainty, from changes in population and wealth, changes in water use efficiency, and changes in weather; and changes in water quality and demands for water quality all are central to regional water planning and must be treated carefully in planning analysis (Lund 1991). Unavoidable uncertainties exist for long-term prediction in most of these areas.

The formal understanding and analysis of uncertainties involves the use of probabilities. Probabilities are a very powerful, rigorous, and essentially unavoidable analysis tool for such problems. However, the use and results of studies using probabilities are difficult to explain to many decision-makers, the public, and even most technical people. The treatment of variability and uncertainty for the six planning approaches are compared in Table 4.

Table 4: Planning Approaches and Data, Variability, and Assessment

Planning Approach	Data Requirements	Variability and Uncertainty	Assessing Performance on Each Use Objective
1. Requirements-based	Limited	Reliability indices or targets	Usually simple. Are "requirements" met?
2. Benefit-Cost-based	Great	Can be explicit	Performance estimated in economic terms. Often controversial or difficult.
3. Multi-objective	Moderate to Great	Difficult to present	Often difficult.
4. Conflict Resolution	Minimal to Great	Difficult	Done by relevant stakeholders; may conflict.
5. Market-based	Minimal	Implicit, relatively easy	Implicit. Performed by parties in market.
6. Muddling Through	Modest	Usually not attempted	Only attempted in limited ways.

Limited Range of Alternatives
It is possible to develop, refine, and evaluate only a limited number of alternatives. Each new alternative, particularly creative or novel ones, requires a great deal of development and education of stakeholders. It is often difficult to develop promising alternatives in an atmosphere of controversy. Stakeholders sometimes perceive an interest in limiting the range of alternatives to be considered.

Assessing Performance For Each Objective
In planning, we would like to quantitatively evaluate proposed alternatives on each performance objective. Several common difficulties commonly arise in doing this: 1) Stakeholders often find it difficult to specify their performance objectives, sometimes for political reasons, but also because it is a difficult intellectual and technical problem. 2) Given reasonable verbal statements of performance objectives, it is often difficult to derive quantitative mathematical analogs. 3) Fundamental uncertainties often exist in knowing how a particular performance objective (such as salmon populations) will be affected by specific water management decisions.

The assessment of performance is made more difficult by the variability in hydrologic conditions and operations. How well can a particular water use tolerate or benefit from variability in flows? How should various probability distributions of water availability for specific uses be compared? Table 4 summarizes performance assessment problems for each planning approach.

Transparency: Can We Understand and Communicate It All?

Even among the most experienced water planners and managers, few individuals have both broad and detailed knowledge of a particular large regional water system. One career usually cannot encompass complete and up-to-date detailed knowledge of a system and deep thinking about how to improve the system over the long term. No one can understand it all. This problem is compounded by the employment transience at technical, managerial, and political levels; in any planning meeting, there are usually several who must be "brought up to speed."

With the diverse audiences and objectives of regional water planning, can we ever make our thinking and analysis understood? Given the real limitations and realistic expectations of planning, a simplified analysis that more clearly communicates water management guidance might more effectively improve a region's water management than presentation of sophisticated methods. However, more sophisticated and detailed analyses are likely to be essential for developing and detailing much of a regional plan. A plan or analysis that cannot be understood is unlikely to attract the kind of confidence or readership needed for implementation.

Some Realistic Objectives for Regional Water Planning

We all have ideas of what a water plan should accomplish. Popularly, many think a water plan always leads to the solution of a region's water problems. Alas, the world is complex and this is often not the case. In reality, water plans serve a variety of related and important functions, only some of which lead directly to resolution of water problems.

1. Education. Local, regional and statewide water plans are important for educating the public, political leadership, and water policy professional staff and leadership about water problems and options. Water plans provide a regularly updated practical and authoritative overview of a region's water problems, with some directions for improvement. Each individual party concerned with a region's water problems will have a much narrower view of the subject, and so cannot provide the integrated perspective of a regional plan. The public education role of the plan is not always direct; a tiny proportion of the population reads plans. But an authoritative water plan document can provide a reasoned and readable perspective on regional water problems read by the media and "opinion leaders" to improve the quality of public decisions and the accuracy of public perceptions.

The political leadership of general and water-related governments is tremendously distracted by many issues and their own political dynamics. Even the best political leaders can devote little time to technical aspects of the decisions they make. Thus, political leaders must rely on advice from others and authoritative accounts of the problem. Water plans provide specific and contextual information on water problems and options. A plan can inform decision-makers and their advisers on relevant aspects of water problems and provide some assurance to statewide, regional, and local stakeholders and water managers that their problems and alternative solutions have been fairly presented for consideration.

New water professionals often use local, regional, and statewide water plans to orient themselves in the practice and context of their work. For these people, regional and local plans provide an authoritative view of the context of their activities as well as perspectives on the overall direction of water management activities and examples of accepted planning methods and options.

2. A reference document. Regional water plans are central reference documents for many statewide, regional, and local water management and planning activities and decisions. In one location, a regional plan provides authoritative estimates of water demands and forecasts (dissaggregated by use type), information on storage, conveyance, and water supply availability, an inventory of water distribution systems and their organization, an authoritative inventory of water problems, and a wealth of other information, including where additional information can be found. Plan estimates, data, and discussions have every-day uses for local, regional, statewide, and private water management and user activities. An authoritative source of such information provides a common benefit.

3. Leadership in water management. Although most regional water plans are conducted by entities with only limited financial and jurisdictional powers for water management, such plans are significant in terms of "leadership". The options and objectives considered and the methods used in a plan constitute leadership by example for other local and regional planning efforts. At regional and statewide scales, and for federal agencies, planning practices set precedence and expectations for lower levels of government that are more active and have more resources and jurisdiction to implement water management options. This leadership in content and method has great potential to help integrate and improve the planning efforts of lower units of government, increasing the number of promising alternatives examined and solidifying their evaluations of alternatives. Such leadership must be responsible. It's leadership rests on neither lagging too far behind the advanced state of practice, nor being so far ahead of advanced practice as to risk being misunderstood or ignored.

4. Planning process fosters discussion and negotiations. While plans might or might not lead directly to the solution of water problems, any planning process provides long-term opportunities to discuss and negotiate water problems as well as opportunities for public input, feedback, and support. These opportunities can be valuable in long-term development of solutions and understandings of stakeholder concerns, even when plan recommendations are ignored.

5. Specific recommended actions and their implementation. We normally think of water plans as recommending particular thought-through actions for improving a region's water management. However, practically, this is often not the functional case. The specifics of a water plan usually are most relevant at the local level, where agencies tend to have greater financial resources and more independent implementation authority. As one moves higher in regional authority, including to state authority, the actual financial, jurisdictional, and political wherewithal to implement plan specifics is often much less. Historically, State and Federal agencies have dominated water development only for short periods. In California, for example, Federal water projects dominated regional water development from the 1940s until1982 and State projects from 1967-1982. This occurred despite Federal and State planning studies dating from 1873 (Pisani 1984). Before and since these periods, almost all major water supply projects in California have been instigated, financed, owned, and operated locally or sometimes regionally. Now and for the foreseeable future, regional water plans are likely to be effective only where they can integrate the activities and options of water management across jurisdictions and users. This is likely to be a difficult and prolonged process.

6. Following the Law. Planning processes often exist and are tailored to meet relevant state or federal legislation, such as the federal National Environmental Policy Act (NEPA) or state acts, such as the California Environmental Quality Act (CEQA). Such legislation requires various procedures for involving different units of government and the public, specification of objectives and identification and evaluation of alternatives. These forms of legislation provide some standardization of planning across many types of planning problems. For example, NEPA requires that federal agencies develop and consider alternative courses of action and evaluate them in terms of environmental impacts. Implementing regulations for NEPA further specify how these and other planning activities are to be accomplished. In addition, there is also often more specific legislation for particular water problems, such as the federal Clean Water Act or Endangered Species Act and their state variants. Any water management or development proposal or project will be expected to comply with relevant legal requirements. These legal requirements often explicitly or implicitly require a planning process.

Given the increasingly public nature of planning and the decentralized nature of water management, the educational, leadership, and procedural roles of plans and planning processes can have great long-term significance, even where their short-term effects are limited. In terms of rational decision-making, the purpose of a plan is to convince a broad audience of decision-makers and publics that:
1) the problem is relatively well considered, including the implications of uncertainties,
2) a wide range of potentially promising alternatives has been identified with reasonable thoroughness,
3) unreasonable alternatives have been reasonably eliminated,
4) remaining alternatives have been developed to provide desirable performance, and
5) that the final plan was judged the "best" of these well-performing alternatives.
For long term water problems, contributions to any of these aspects of addressing water problems can be a valuable accomplishment of a plan.

Technical Analysis in Planning

Water planning is a complex business, and almost all regional water planning and management activities have a heavily technical component. (We are, after all, talking about moving and storing millions of tons of liquid every day with substantial economic impacts and financial costs.) Lund and Palmer (1997) present a more detailed overview of the roles of computer modeling in planning and conflict resolution in water resources. Table 5 summarizes common forms of analysis for each planning approach.

The role of technical planning expertise can vary greatly between planning approaches. Under requirements and benefit-cost based approaches, engineers and planners are largely isolated technicians, toiling in response to a problem defined by others and offering definitive recommendations or "preferred alternatives" as products. Multi-objective planning requires engineers to interact more with stakeholders or their representatives to define and clarify plan objectives and communicate performance estimates to decision-makers. Conflict resolution and muddling through forms of planning place engineers and planners in a far more demanding (and interesting) situation near the center of active political decision-making. Here, technical study management must interact directly and interactively with opposing stakeholders, often for prolonged periods of time. In this interactive role as a technical mediator and facilitator, engineers and planners are often aided by professional facilitators overseeing the conflict resolution discourse, and must become familiar with the details of stakeholder objectives so as to better represent them, as well as to identify promising consensus solutions. In market-based planning, the engineer often retires somewhat from the public fray, but still must understand market actors and conditions so as to advise in the negotiation of purchases, sales, and exchanges, as well as related legal and regulatory activities.

The purpose of analysis is usually not numbers, but insight (Geoffrion, 1976). Under practical conditions and political limitations, it is often difficult to perform such analysis. In many cases, strategic analytical insight can be better achieved through the more independent analysis of internal agency "skunk works", universities, or similar settings with diminished political accountability.

Table 5: Planning Approaches with Common Forms of Analysis

Planning Approach	Common Forms of Analysis

1. Requirements-based	Supply modeling constrained by satisfaction of projected demand quantities. Reliability and cost of satisfying demand projection often is estimated.
2. Benefit-Cost-based	Explicit economic valuation and summing of benefits and costs, often with explicit integration of some major uncertainties.
3. Multi-objective	Identification of trade-offs in major objectives across major alternatives. Optimization can suggest promising alternatives for a range of objective weights.
4. Conflict Resolution	Models are used to consolidate scientific understanding of the system; the resulting models are used to develop promising alternatives and estimate tradeoffs; bring decision-makers into modeling early and use models as part of stakeholder negotiations. But, many forms of conflict resolution avoid modeling entirely.
5. Market-based	Buyers and sellers largely do their own market calculations in private.
6. Muddling Through	Modest analysis. Since only small decisions are taken, less extensive analysis is needed.

When to Plan How

Considerable public and professional controversy exists regarding how water planning should be done. Each planning approach presented has been successfully applied in some situations, and has failed in others. No single planning approach will succeed in all circumstances. In developing regional and statewide plans, often it will be necessary to integrate plans developed under different planning philosophies.

For discussion, three broad sets of planning circumstances are used to illustrate the likely suitability of different planning approaches. The first circumstance is where only rapid and inexpensive studies are possible. There may be few resources for conducting the study, the pace of political events may limit the time available for planning, or the problem might not merit much attention. The second set of circumstances is where planning resources are far less limited and a single formal decision-making process exists to adopt and implement a plan. The planning details of most engineered water facilities traditionally fall into these first two categories and represent the bulk of day-to-day engineering planning work. In the third set of circumstances, multi-party decision-making occurs in the midst of considerable controversy and conflict. Table 6 presents some hypothetical ideas on the suitability of each approach for each set of circumstances.

In an era when federal and state governments lack the funding and will to impose or persuade formal planning procedures on stakeholders, conflict resolution, marketing, and muddling through approaches to planning are all that remain for stakeholders wishing to solve regional water problems. However, even within this less formalized and more pluralistic setting, requirements-based, benefit-cost-based, and multi-objective planning and techniques can be informative and useful.

Figure 2 attempts to place the theories discussed along two commonly relevant dimensions, degree of planning formality and degree of stakeholder inclusion. Other dimensions could have been used, and the placements are inexact, but the figure serves to illustrate how muddling through, doubtless the most common approach to planning in practice, can often result from a collapse of formality in planning method and tends not to be very inclusive in its application, unless multi-stakeholder venues exist for discussion and coordination. Even in the worst cases, attempts at more formal or inclusive planning can generate insights, alternatives, coalitions, and information useful for muddling through more effectively.

The rational selection of a planning approach should be based on the likely success of alternative approaches in achieving practical objectives for a planning effort. This selection process itself illustrates many of the practical problems in water resources planning.

Conclusions

Water problems are often complex and controversial. Complexity, controversy, expense, and delay can be magnified if the technical approach to planning for these problems is unclear or otherwise ineffective. Thus, a clearly structured approach to planning for water resources problems is often necessary, or at least valuable.

A variety of planning approaches are available for different types and contexts of planning problems. While the general concepts of rational planning reflect fundamentals of rational decision-making and are of broad utility, no specific planning approach is suitable for every planning problem and context. Planning problems vary greatly, with each one being arguably unique. The specifics of planning for a particular problem should attempt to reflect problem peculiarities.

Local and intra-agency water plans are most likely to apply traditional planning notions. In most cases, larger-scale regional water plans will not lead directly to the complete solution of a region's water problems. Instead, regional water plans typically serve wider and more foundational functions for regional water management. For planning to fulfill most educational, leadership, policy, and project development roles, it must be transparent and comprehensible, "rational", and not require unavailable amounts of time and financial resources.

The selection of an appropriate planning approach or mixture of approaches should reflect the objectives and context of addressing the particular planning problem.

Table 6: Hypothetically Good Conditions for Different Planning Approaches

Planning Approach	Only Rapid and Inexpensive Studies Possible	Single Formal Decision-making Process	Controversial Multi-Party Decision-making
1. Requirements-based	Reasonable; especially effective for small, well understood, and non-controversial problems	May overly limit alternatives and evaluation	Usually unsuccessful
2. Benefit-Cost-based	Only limited analysis possible	Good, but usually requires interpretation	Informative, but politically insufficient
3. Multi-objective	Only limited analysis possible	Good, but requires interpretation and final judgment	Informative, but politically insufficient
4. Conflict Resolution	Usually inadequate time or resources	Not needed	Promising, but often politically futile
5. Market-based	Potentially good, if properly arranged	Sometimes good	Promising, if properly arranged

6. Muddling Through	Often the best possible approach for large problems	Probably not good	Often the only possible approach; success limited and incremental

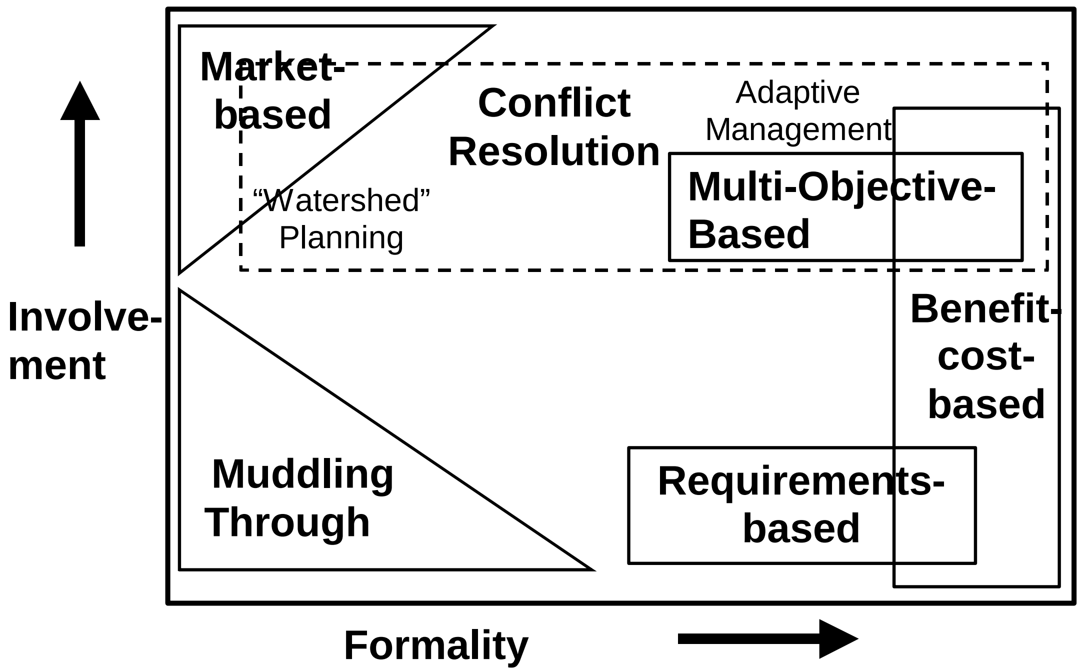


Figure 2: Approaches to Planning

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