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EVALUATION OF THE IMPACT OF SMALL HYDROELECTRIC FACILITIES ON THE VISUAL RESOURCES OF FREE-FLOWING STREAMS IN THE SIERRA NEVADA

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ABSTRACT

Free-flowing streams and scenic quality are non-renewable resources that are being threatened by the development of small hydroelectric facilities on streams in the Sierra Nevada. A majority of the 1,000 permit applications for small hydroelectric projects in California are for streams in the Sierra and quantitative data on visual quality are needed for the permit review process. We have developed a numeric rating to express 17 environmental elements portraying visual qualities of the landscape related to flowing water. Six proposed small hydroelectric power projects in the South Fork American River Basin are evaluated and compared on the basis of these 17 elements.

A scale of 1 to 100 for each element is employed as a measure of visual quality. A composite score is derived through repeated visits to each proposed construction site. Post-construction conditions are depicted by computer generated images of proposed facilities and reduced stream flows. Analysis of these simulated conditions produces scores ranging between 1,214 and 659, 10 to 20 percent lower than pre-project visual quality. This study suggests that the quality of the visual resource at 4 of the 6 sites requires prudent consideration in the permit review process. The rating procedure provides a means of identifying small hydroelectric facilities proposed at sites of unusually high scenic value and a way of evaluating alternative construction options to avoid or reduce undesirable visual impacts on free-flowing streams.

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INTRODUCTION

Resurgent interest in small-scale hydroelectric power facilities illustrates the dominant role socio-economic considerations play in hydroelectric power development in the United States. The basic technology for hydroelectric power production has existed since 1882 (Deudney, 1981), but the present interest in developing small hydroelectric projects can be traced to the oil shortage of 1973 and the Public Utility Regulatory Policies Act (PURPA) of 1978 (Corrigan, 1981; Palmer, 1983). These factors stimulated a wave of permit applications for small-scale hydroelectric projects, and many remain on file awaiting action. The largest number of permit applications involves sites on streams in California, followed by New England and the Pacific Northwest (Palmer, 1983).

Small-scale hydroelectric facilities do not involve large dams or reservoirs and the generation of hydroelectricity is renewable, clean, and efficient. Consequently, these projects appear to present few threats to the environment even though little is known about the cumulative impact on downstream ecosystems of numerous small-scale upstream hydropower installations (Ayers, 1983). In addition, many projects involve damming free-flowing streams and diverting much of their flow a considerable distance downstream which has raised a legal issue concerning whether this is development of a renewable resource (California Office of the Attorney General, 1985). The repercussions of such extensive diversions on visual resources and recreational values are another area of concern.

Although established procedures are used for evaluating most aspects of small hydroelectric projects, a satisfactory basis for quantifying the affects of these projects on visual and recreational resources is not available. Visual and recreational resource issues commonly emerge, however, as the primary conflict involving small hydropower facilities. Regulatory agencies, such as the U. S. Forest Service and the State Water Resources Control Board, recognize the need for including impacts on visual and recreational resources in the license review process and the need for an evaluation scheme that is easily applied to the numerous proposed sites.

The purpose of this study is to quantify the visual resources at 6 small hydroelectric project sites on public lands in the Sierra Nevada. A systematic procedure is presented that emphasizes the role of running water in defining the visual resources and recreational value of the sites. Seventeen environmental elements are assessed to determine pre-construction and post-construction ratings. The ratings permit comparison of the visual resources of the sites, and they provide a quantitative criterion for estimating the impact of development at each site.

The study sites are in the South Fork American River Basin and represent a wide range of local environmental settings common to the Sierra Nevada. Since each project has progressed to a different stage of development, comparable data are not available for all aspects of the planned facility at each site. Analysis is complicated further by the fact that it is common for the specific details for small hydroelectric projects to be revised numerous times. Since FERC licenses and U.S. Forest Service special use permits tend to be granted early in the process and water rights much later (Corrigan, 1981; Pill, 1983), there are numerous reasons why the project design and details may be altered before the final license for the facility is granted. Nevertheless, sufficient data are available for preliminary analysis of the impact of development upon visual elements of the environment pertinent to recreation resources at each of the selected sites.

SCOPE OF THE PROBLEM

Quantification of the visual resource impacted by small hydroelectric projects is linked complexly with hydropower production, recognizing the landscape as a combination of physical resources, and acknowledging the role of water as a highly valued scenic resource. In the Sierra Nevada, resource development decisions often view these factors as a composite rather than as separate considerations.

The California Energy Commission (CEC) (1983) estimates that hydroelectric power supplies about 18 percent of California's electricity demand. While most hydroelectric power generated in California comes from large dams and reservoirs, many watersheds in California offer opportunities for small-scale hydroelectric development at new sites or retrofitting of existing facilities to introduce or expand hydroelectric generation (California Department of Water Resources (CDWR), 1981a, 1981b; Simon, 1985). Over 1,000 permit applications for small hydroelectric projects have been filed with the State Water Resources Control Board and approximately 600 are for previously undeveloped streams (Lacey, 1985). The majority of the proposed sites for small hydroelectric facilities are on free-flowing streams in the Sierra Nevada, but relatively few of these projects have advanced to the construction stage.

One commonly cited attraction of small hydroelectric projects is that they are an alternative means of increasing hydroelectric production while avoiding the costly and environmentally sensitive issues associated with the construction of major dams and reservoirs. However, attempts to assess the energy production capabilities and the environmental impact of small hydroelectric facilities are hindered by the lack of a universally acknowledged definition of a small hydroelectric project. In general, the concept of small-scale hydropower suggests an installation operating with little or no storage capacity and causing minimal changes in river characteristics (Ferguson et al., 1980). While CDWR (1981) uses 30 megawatts (MW) or less to define small hydroelectric projects, the U. S. Department of Energy considers 25 MW as the upper limit (Ferguson et al., 1980) and the U. S. Army Corps of Engineers employs a generating capacity of 5 MW as the upper limit for small hydroelectric facilities. FERC does not recognize an upper limit for small hydroelectric projects (CEC, 1981). The upper limit of 30 MW suggested by CEC (1981) is employed in this study as a convenient designation for small hydroelectric facilities, but none of the 6 projects studied in this report has a capacity greater than 3 MW.

Many of the proposed small hydroelectric projects in the Sierra Nevada are on public lands administered by the Bureau of Land Management (BLM) or the U.S. Forest Service, both of which have visual resource management systems that include rating scenic quality (Bacon, 1979; Grden, 1979; Ross, 1979; Miller, 1984). These agencies are charged with implementing land use strategies that conform to the public trust doctrine which mandates resource use that is beneficial to the greatest good for the public (Sax, 1971). When small hydroelectric facilities are proposed on National Forest or BLM lands, such projects represent another form of resource development competition. Under these circumstances, prudent application of public trust doctrine may increase the complexity of the application review process (U.S. Congress, Public Land Law Review Commission, 1970).

Federal authority is not absolute on small hydro issues, however, because state water rights law often takes precedence (Pill, 1983). Since California recognizes both riparian and appropriative water rights, the range of opportunities for potential conflict is magnified. Furthermore, requests for water rights for small hydroelectric projects are occurring at a time when competition from expanding municipal and agricultural water users is intensifying and when the public is concerned increasingly about the visual quality of the landscape. At the same time, greater safeguards and more rigorous maintenance of visual and recreational resources are being sought.

Concern for visual and recreational resources focuses on perception of the landscape and visual quality. The landscape is the appearance of the land at the interface of the earth's surface and the atmosphere. Landscapes derive distinctive character from the spatial arrangement and relative disposition of individual components (Unwin, 1975). Within any region, some landscapes are considered to be more visually attractive than others based on the aesthetic satisfaction they provide (Dearden 1980a, 1981; Jacques, 1980; Penning-Rowsell, 1981; and Zube, 1984).

Recognition of the visual landscape as a resource has stimulated interest in landscape evaluation and examination of the features of landscapes that contribute to their attractiveness and to their resource value in outdoor recreation (Pigram, 1983). Underlying this sense of value is the realization that the landscape is not a single resource but a combination of physical resources (Duffield and Coppock, 1975). The Wilderness Act of 1964 considers scenery, or the visual landscape, as an important natural resource which enhances the quality of a visitor's experience in a wilderness area (Baumgartner, 1983). In addition, the overall natural impression of the visual landscape appears to be one of the most important attributes influencing the choice of people in deciding where to spend leisure time (Hodgson and Thayer, 1980). The scenic quality of the landscape, therefore, is a major recreational resource in its own right and not just the visual backdrop for other recreation pursuits. This perspective emphasizes that the landscape is a valuable non-renewable resource and decisions concerning landscape use must reflect this value (Dearden, 1980b).

Outdoor recreation in the United States has undergone dramatic growth in recent years (Clawson, 1985) and this growth has increased awareness of the value of scenic or visual resources as a part of the total mix of natural resources (Pigram, 1983). Water has long been a major element in the enjoyment of many forms of outdoor recreation, but now it is acknowledged as making a dual contribution in terms of its role as a natural resource and in terms of its prominence as a highly valued scenic resource (Leopold, 1969; Morisawa, 1971; Zube et al., 1975). One of the most serious management problems is that most water resources are managed primarily for non-recreational purposes (Tanner, 1974).

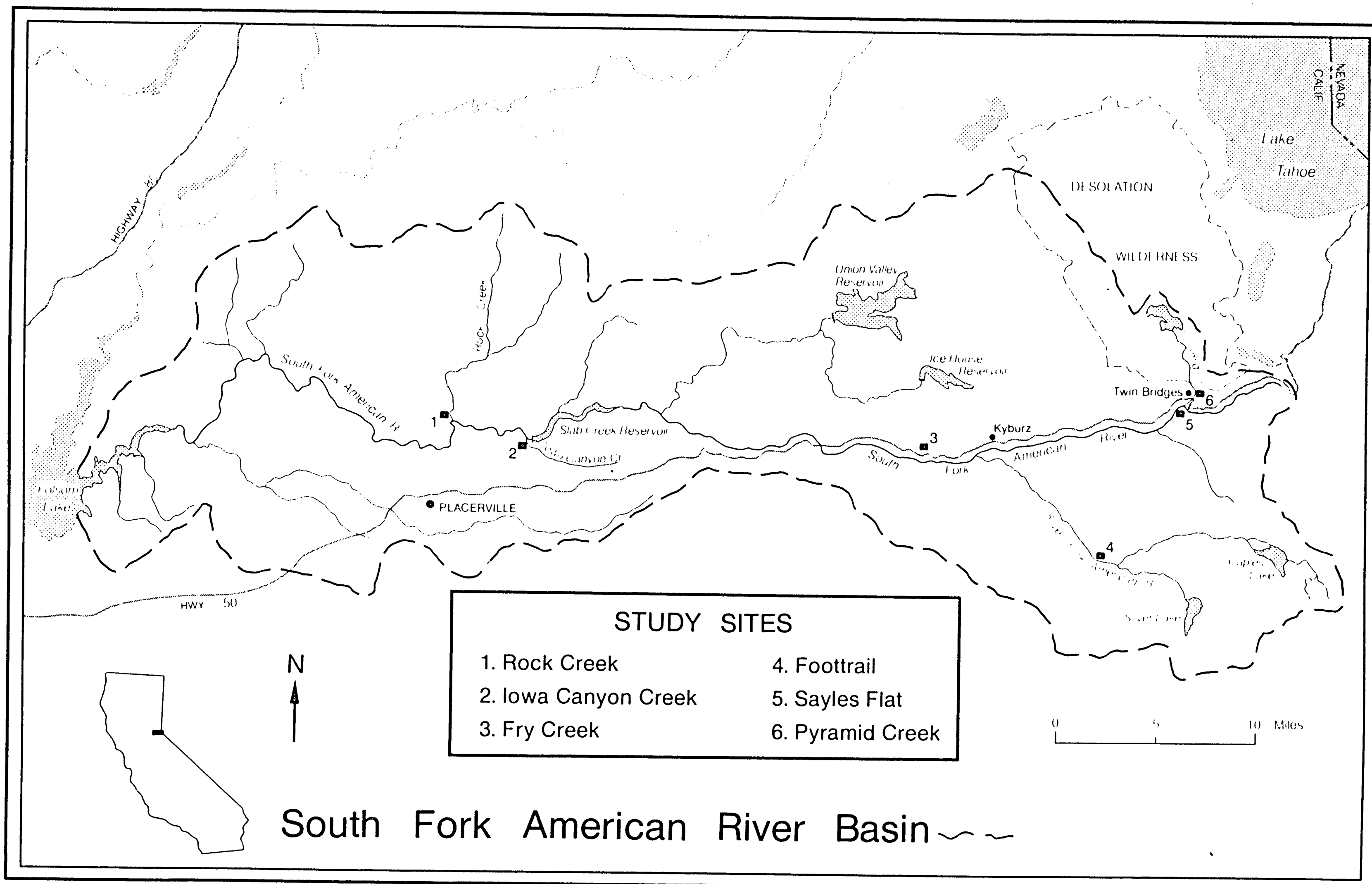

Figure 1. The Study Site.

THE STUDY AREA

The South Fork American River Basin (Figure 1) is an appropriate setting for analysis of the influence of small hydroelectric projects on the visual qualities of recreational land. This watershed is a study in multiple-use land management with timber harvesting and recreation being the major industries. Highway 50, a primary trans-Sierra transportation corridor, provides easy access to more than one-half million acres of National Forest land and a federally designated wilderness area. In addition, an estimated 4 million travelers pass through the area enroute to resorts in Lake Tahoe, the Northern Sierra, and the Nevada desert (California Department of Transportation, 1985).

The entire basin of the South Fork American River rests atop the granitic batholith of the Sierra Nevada. Elevations range from 280 feet at Folsom Reservoir, where the South Fork joins the North Fork American River, to over 10,000 feet along the Sierra crest. Areas above 8,000 feet elevation are characterized by exposed granite with a minimum of vegetative cover. Between 8,000 feet and the foothills at about 2,500 feet, the basin is a heavily timbered plateau that is deeply incised in places by the westward flowing river and its tributaries. Terrain below an elevation of 2,500 feet is open and rolling with scrub vegetation.

Approximately 670 square miles of the north-central Sierra Nevada are drained by the South Fork American River (Figure 1). Although regional climatic systems dictate a pattern of warm, dry summers and cool, humid winters, seasonal temperature and precipitation are strongly influenced by elevation in the basin. Nearly all of the winter precipitation above 5,000 feet elevation falls as snow which accumulates until March or April. At the highest elevations the snow remains until June. Warm temperatures in the spring trigger an annual snow melt flood of variable duration depending on the depth of the snow. Average annual runoff for the South Fork American River is slightly more than 755,000 acre-feet, which is just under one-third of the total discharge for the American River system. Runoff from the watershed is an important resource for recreation and for generating hydroelectric power, and it is utilized by agricultural and urban customers of the Central Valley Project.

An elaborate system of water storage and transfer mechanisms has been constructed in the basin by the Bureau of Reclamation, the Sacramento Municipal Utility District, and Pacific Gas and Electric Company (PGE) to utilize the water resource for production of hydroelectric power. The El Dorado Irrigation District was authorized to develop a series of dams, reservoirs, powerhouses, and related diversion facilities in an area that covers more than 60 linear miles of the basin. This development, known as the South Fork American River (SOFAR) Project, was particularly significant because it was licensed by FERC as a series of small hydroelectric projects even though the plan included diversion of water for consumptive use and it encompassed such a large area (Langley, 1984). The plan was abandoned in early 1987 when efforts to finance the project were unsuccessful.

The 6 sites selected for study are all private projects that span a variety of physical characteristics (Table 1). Four of the study sites are at elevations above 3,000 feet. Five of the sites are on public lands in the National Forest. The Rock Creek facility occupies approximately equal parts of private land and land administered by BLM. In general, development of the 6 projects in the South Fork American River Basin represents visual resource and recreation issues that are representative of concerns involving small hydroelectric facilities on public lands throughout California.

Table 1. Selected Features of Six Proposed Small Hydroelectric Power Projects in the South Fork American River Basin.[a]

Feature	Pyramid Creek	Rock Creek	Foottrail	Sayles Flat	Fry Creek	Iowa Canyon Creek
FERC Project No.	3188	3189	3194	3195	7930	8122
Dam Height (feet)	15	6	6	8	2	0
Dam Width (feet)	168	80	148	130	15	0
Impoundment (Acre-feet)	4.2	5.2	2.5	6.2	0.0006	0.0
Elevation of Intake (feet)	6,290	1,315	5,845	6,410	4,400	2,000
Elevation of Powerhouse (feet)	6,120	1,115	5,567	5,900	3,640	1,680
Drainage Area (sq. miles)	9	68	90	16	2	10
Maximum Legal Diversion (cfs)	100	240	160	90	1.5	25
Affected Stream Reach (feet)	1,200	4,750	4,060	4,225	2,500	2,400
Pipeline and Penstock (feet)	1,200	4,100[b]	4,495[c]	4,000	2,500	2,400[d]
Maximum Diameter of Penstock (inches)	42	36	54	42	6	24
Capacity (megawatts)	.99	3.00	2.20	2.95	.03	.45
Transmission line (feet)	1,200	75	42,240	1,200	200	1,000

[a]Source: Permit applications as of May 1984.
[b]Includes 3,200 feet of tunnel.
[c]Includes 3,330 feet of tunnel.
[d]Includes 1,500 feet of 42-inch diameter corrugated culvert pipe.

RESEARCH METHODOLOGY

Landscape assessment techniques strive to measure the visual quality of natural environments and weigh them with respect to the public's judgement of their worth. Individual landscape evaluation procedures are most commonly generated in response to a particular problem context in resource planning (Wilson-Hodges, 1978) and are intended to provide information to improve the quality of decision-making with reference to environmental management . No one methodology, however, has emerged as the favored format for the evaluation of natural landscapes (Saarinen and Sell, 1981; Priestley, 1983; Saarinen et al., 1984; Zube, 1984), and several methodologies have been developed to treat rivers and water resources (e.g. Craighead and Craighead, 1962; Leopold and Marchand, 1968; Leopold, 1969; Dearinger and Woolwine, 1971; Morisawa, 1971, 1972; Litton et al., 1974; Chubb and Bauman, 1977).

The conceptual structure of the landscape assessment methodology employed in this study is a 3-part system of classification, inventory, and evaluation which has been widely used in landscape studies (Litton, 1974; Litton et al., 1974; Unwin, 1975; Anderson 1979). This structure provides a systematic framework for analyzing the role of water in the visual quality of the landscape. The classification and inventory phases are an adaptation of concepts introduced by Litton et al. (1974). Evaluation is achieved using a numerical rating of visual aspects of the environment related to moving water. This approach provides a basis for comparing pre-construction and post-construction conditions of the interrelationship among water, landforms, and vegetation and the extent of human impacts on the landscape.

CLASSIFICATION OF THE LANDSCAPE

There are no precise categories in the endless variety of water-oriented landscapes. Rather there is a continuum of individual environmental settings that take on special significance only in relation to their immediate surroundings (Tetlow and Sheppard, 1979). Consequently, there is value in imposing a spatial constraint when evaluating visual resources.

The classification component is founded upon the delineation of 3 spatial scales that, in general, occupy a nested hierarchy but which contain variables that must be evaluated individually. At each scale, a visually conspicuous landscape can be identified. The largest landscape entity may contain more than one of the next largest landscape units (Litton et al., 1974), but this is not a requirement. The field of vision may limit visual perspectives to only one unit at each scale or more than one of the smaller units may be apparent. The classification system for water-oriented landscapes must be flexible enough to incorporate variations in the landscape that would not necessarily fit a rigidly structured scheme.

Landform Landscape

The regional variation of landform characteristics defines the geographic setting or the physical province of a stream. This perspective provides for the differentiation of landscapes at the largest scale and employs the basic form of the land surface as a delimiting criterion (Crofts, 1975). Linton (1968) suggests that the geomorphologic appearance of the land surface is a basic element in scenic resources. In recognition of its link to geomorphic processes that shape the earth's surface, this large-scale unit is identified as the landform landscape (Figure 2).

The landform landscape is best viewed from the air where distance and relation to other landscape units are apparent and provide a perspective on the spatial setting (Duffield and Coppock, 1975). Generalized impressions rather than images of detail characterize the concept of the landform landscape which is likely to contain a series of characteristic streams or water bodies. While small streams may be contained entirely within a single landform landscape like the Sierra Nevada, large rivers may traverse several landform landscapes. The 6 small hydroelectric projects examined in this study are all on streams within the Sierra Nevada landform landscape province.

Viewable Watershed

The viewable watershed is the intermediate-scale unit used in the classification (Figure 2). The spatial extent of this entity is a visual corridor or panorama that is established by a sense of enclosure. In the field, enclosure is defined by the horizon line which is a function of surrounding landforms or vegetation bounding the observer's field of view. The viewable watershed defined in this manner is very similar to the visual unit recommended

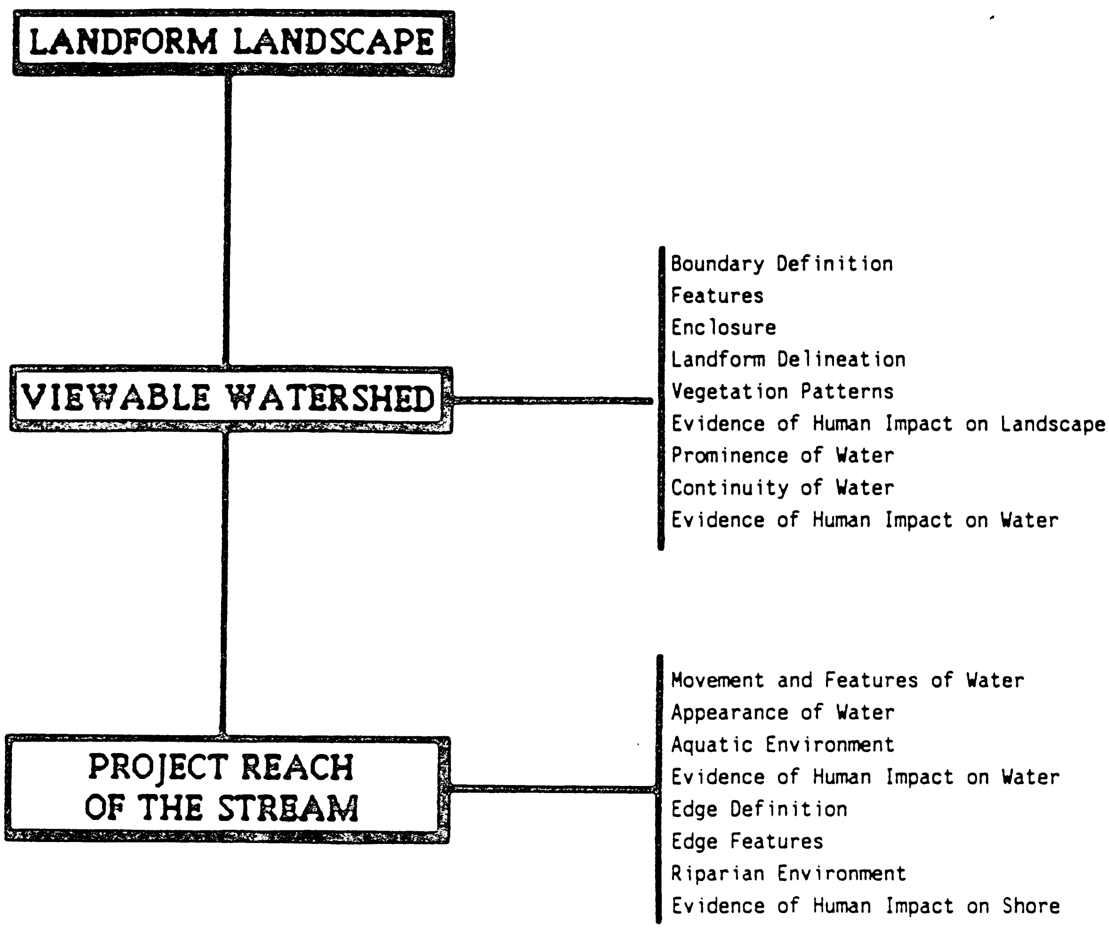

Figure 2. Classification and Inventory Framework for Assessing the Visual Quality of Small Streams. (Modified from Litton et al., 1974.)

by Tetlow and Sheppard (1979) as the spatially defined area that enables the viewer to accumulate and form a unified impression of the surrounding landscape.

Delineation of the viewable watershed requires the presence of the observer on the ground in the spatial unit. As suggested by Leopold and Marchand (1968), the observer stands near the stream and looks up and down the stream course. The boundary of the viewable watershed is determined by executing a series of 360 degree views commencing at the point of diversion and continuing along the stream to the location of the powerhouse. The viewable watershed is a composite image representing the maximum 360 degree view achieved by integrating the visual limits defined by the overlapping views (Unwin, 1975) between the diversion and powerhouse. The number of individual observations required to complete the composite view for a given site is determined by the visual complexity of the location. Although the entire unit is generally visible from a limited number of points along the stream, occasionally a single 360 degree view will encompass the viewable watershed. The purpose of this approach is to develop a spatial unit for analysis that captures the general change in view that occurs as an observer moves from one part of the stream to another. The observer's movement through the viewable watershed provides a dynamic perspective of the landscape and may profoundly alter the sense of scenic quality (Litton, 1979).

The focus of the viewable watershed is a single stream. For very small streams, the boundary may be nearly coincident with the topographic watershed. For all but the smallest streams, however, the viewable watershed represents an area that is something less than the topographically defined boundary of the basin. The balance between water and land becomes apparent at this scale. For this reason, analysis of the viewable watershed addresses environmental elements that represent expressions of both the land and water components of the landscape.

Project Reach of the Stream

The smallest spatial unit employed in this scheme of landscape classification is the project reach of the stream (Figure 2). Water is the focus at this scale, but the limits of the project reach of the stream are defined by the proposed small hydroelectric facility rather than by visual characteristics of the landscape. Typically, the project reach of the stream extends from the diversion facility to the powerhouse.

Analysis of this spatial component requires the presence of the observer on the ground within the target reach of the stream. The stream and the immediate shoreline are the primary focal points. In this context, the scope of concern is limited not only to the linear distance between diversion and powerhouse but also to the immediate stream environment. The environmental elements important to analysis at this scale are either strongly water oriented or shoreline and vegetation features functionally linked to the stream.

INVENTORY OF LANDSCAPE ELEMENTS

The process of assessing the impact of small hydroelectric facilities on the landscape is facilitated by developing an inventory of environmental elements to be evaluated at each site and at each areal subdivision (Unwin, 1975; Litton, 1979). This inventory represents a systematic framework that promotes comprehensive analysis regardless of site specific variables, and it serves as a reminder of the more general visual qualities which may be present in the landscape (Laurie, 1975). Although it is not evaluative itself, the inventory functions as an information base which is subject to evaluation. In addition, the standardized format allows quick site-to-site comparison which is a key issue in the evaluation of riverscapes and small hydroelectric projects. Development of an appropriate list of environmental elements applicable to steep gradient streams is aided by selecting elements from those recommended by other studies (Leopold and Marchand, 1968; Leopold, 1969; Dearinger and Woolwine, 1971; Morisawa, 1971, 1972; Litton et al., 1974). While the optimum approach would be to assess every landscape element, it is necessary to select those thought to be most influential on visual quality (Dearden, 1980a).

Landform Landscape

Specification of environmental elements at the scale of the landform landscape is not necessary since the present concern is with small streams in the Sierra Nevada which represents a single landform landscape. However, environmental elements can be included at this scale for comparing streams in different landform landscapes (Lacey, 1985).

Viewable Watershed

At the scale of the viewable watershed, 9 environmental elements are used to depict scenic resources (Figure 2). Four of the elements are related to the general terrain pattern of the landscape, 2 involve water, 2 relate to human activities, and 1 reflects the character of vegetation.

The 4 elements that express the terrain component of the landscape represent a broad statement of biotic, geologic, geomorphic, and hydrologic relationships. Boundary definition refers to the edges created between dissimilar parts of the landscape which are most likely to take the form of ridges and skylines or vegetation changes for small streams.

Features are landform elements or water elements that are recognized by their size or through their collective structure (Litton et al., 1974). Enclosure is a product of visual relationships at various scales and with diverse vertical-horizontal proportions among parts (Tetlow and Sheppard, 1979). Landform delineation is an expression of the consistency of the dominant visual form of the landscape.

Vegetation patterns are a useful surrogate measure for the total visual affect of the landscape conveyed by vegetation (Morisawa and Murie, 1969; Shafer et al., 1969; Dearinger and Woolwine, 1971; Litton et al., 1974; Tetlow and Shepard, 1979). Human impact on the land in the viewable watershed involves modifiers which may be either in opposition to or in sympathy with the natural conditions and visual composition of the landscape (Lea, 1968; Morisawa, 1971; Litton et al., 1974). While the presence of development may not necessarily impair landscape quality, various studies have indicated that natural scenes are considered to be of higher visual quality (Hodgson and Thayer, 1980; Vining et al., 1984).

In the viewable watershed, the contribution made by water to the total scenic resource is assessed by the prominence and continuity of water. Prominence of water is an expression of the relative dominance or subordinance of water within the landscape unit. The volume of water in small streams and its surface turbulence are an index to its relative visual importance (Dearinger and Woolwine, 1971; Morisawa, 1971; Litton et al., 1974).

Continuity of water is an expression of the relationship between land and water. This relationship is assessed on the basis of serenity or the extent to which the land and water appear to be in harmony both within the viewable watershed and with adjacent stream reaches. The most visually stimulating streams are those that display a strongly defined internal unity while possessing a distant continuity with reaches above and below the point of observation (Dearinger and Woolwine, 1971; Litton et al., 1974).

Evidence of human impact on the water takes the form of direct modification in the flow, alterations of the channel configuration, or the visual presence of pollution (Litton et al., 1974). These characteristics are distinct from those involving human influence on the landscape in that these impacts affect the water directly.

Project Reach of the Stream

At the scale of the project reach of the stream, water is the dominant feature and the observer must be in or near the stream. Four of the 8 environmental elements employed as inventory variables to characterize the visual quality of the landscape at this scale (Figure 2) are water related characteristics and 4 are expressions of the immediate shoreline.

Movement and features of water are an expression of the relationship among disturbed surfaces consisting of falling and turbulent flow, surfaces apparently undisturbed by flow, and the marked contrast between disturbed and undisturbed water surfaces which causes them to emerge as prominent isolated elements (Leopold, 1968; Litton et al., 1974). Movement and features are highly valued components of a visually stimulating water landscape (Dearinger and Woolwine, 1971).

Appearance of water in the project reach of the stream is a composite of the water's clarity, color, and capacity to reflect images (Litton et al., 1974). Relative clarity is a simple and positive mark of visual quality of water and the visual attractiveness of water is enhanced as clarity increases (Dearinger and Woolwine, 1971; Pigram, 1983).

The aquatic environment of the project reach of the stream is composed of the plants and animals that exist within the water. This perspective is employed since the focus of the evaluation is the free-flowing stream. For example, a beaver living in the stream would be part of the aquatic environment as used here but a hawk would not be included. Aquatic vegetation must be visibly surrounded by water and will appear attractive only so long as it is clearly related to water and does not confuse the land-water contrast (Litton et al., 1974; Erman et al., 1982).

Evidence of human impact at the scale of the project reach of the stream consists of the same types of modifications as those described for the viewable watershed. At this more focused perspective, only modifications to streamflow or channel disturbances that occur within the project reach are considered.

Four environmental elements are utilized to characterize the visual quality of the shoreline which is the platform from which water may be best appreciated. Edge definition characterizes particular kinds of transition forms between water and land in the narrow band paralleling the channel. Edge features are vivid focal points displayed against the more static background of the shoreline. The riparian environment visually delineates the stream and is a source of visual diversity that enriches scenic quality (Litton, et al., 1974). Human impact on the shore in the project reach of the stream includes the same types of modifications as those described for the viewable watershed.

EVALUATION OF ENVIRONMENTAL ELEMENTS

Most attempts at landscape evaluation have recognized the fact that some landscapes are generally appreciated as being more attractive than others (Leopold, 1969; Dearden, 1981). In the absence of a universal method for evaluating scenic quality that applies to all locations (Penning-Rowsell, 1975; Dearden, 1981), the common practice is to design a method that is appropriate for the problem being studied.

The purpose of evaluation in this study is to assess the sensitivity of scenic resources along small Sierra Nevada streams to the development of small hydroelectric power facilities. The small hydropower projects are recognized as intrusive elements in the landscape. A practical approach is required so that evaluation can be compared with assessment of other resource impacts which are more readily quantified. In addition, to enhance the utility of the evaluation procedure for license applicants and regulatory agencies, it must be a scheme that can be applied reliably within a realistic span of time while avoiding high costs (Duffey-Armstrong, 1979; Dearden, 1981).

Rationale for the Single Observer

Considerable disagreement exists regarding the optimum procedure for landscape evaluation, but Briggs and France (1980) suggest that the choice depends ultimately upon the specific requirements of the individual project. When the visual qualities of the landscape are stated objectively for use in decision-making, the common approaches are based on expert judgements (Palmer, 1981; Zube et al., 1982). Numerous descriptions of the relative merits of the single evaluator as opposed to evaluation by a selected sub-group of the population are available (e.g., Lewis, 1973; Laurie, 1975; Litton, 1979; Dearden, 1981; Palmer, 1981; Sadler and Carlson, 1982; Shuttleworth, 1984). In addition, research has shown that there is a high degree of consensus among different individual observers judging the scenic quality of landscapes (Dearinger and Woolwine, 1971; Schroeder and Brown, 1983). Consequently, most visual quality and impact assessments use standardized procedures and are conducted by experts using established criteria (Palmer, 1981; Zube et al., 1982; Miller, 1984).

The use of an expert for visual resource evaluation is based on the assumption that trained professionals are capable of objectively analyzing landscape qualities (Zube et al., 1982). Fines (1968) suggests that the training and experience of professionals enhance their appreciation of landscape and their awareness of the subtleties of landscape. Others have observed that professionals have the knowledge necessary for assessing the aesthetic quality of the environment (Carlson, 1977), they are experienced in ways of comprehensively assessing and interpreting the visual qualities of the landscape, and they have a better understanding of what is rare within the regional landscape (Miller, 1984). Zube et al. (1982) found that evaluation of landscape quality by skilled and trained observers was the dominant theme in articles appearing in professional journals during the 16-year period they surveyed. Journals within the forestry and landscape professions placed especially heavy emphasis on expert judgement.

The expert evaluator is not an elitist approach; rather it recognizes the skill of the trained evaluator in discerning landscape qualities (Laurie, 1975). The standards of the experts are more likely to be realistic than the opinions of untrained observers who lack specialized knowledge and developed sensibility about the environment (Carlson, 1977). The untrained observer may be less discerning on some criteria (Arthur et al., 1977). In fact, Carlson (1977) refers to trained and experienced experts as environmental critics, and he presents a convincing case demonstrating that environmental critics provide a subtle appreciation for the environment that is missed by public preference methods. Such expert evaluation of the landscape by the environmental critic is often compared to the role of the art critic or the tax assessor. The training, knowledge, experience, and sensibility of the art critic and the tax assessor are recognized prerequisites which prepare these experts to render individual judgements for society in a manner similar to the environmental critic's evaluation of nature (Carlson, 1977).

Judgements by groups of non-experts are most commonly employed to determine how people perceive the environment (Palmer, 1981; Zube et al., 1982). This approach stems from research in experimental psychology and addresses public preferences for the landscape and the meaning of landscape (Laurie, 1975; Carlson, 1977; Zube et al., 1982). Both quantitative and non-quantitative methods have been employed to systematically survey public opinion of various landscapes (Arthur et al., 1977), but doubt exists about the size of the sample necessary to obtain a valid representation of public opinion (Briggs and France, 1980). Furthermore, it is suggested (e.g., Fines, 1968; Laurie, 1975; Arthur et al., 1977) that such studies represent a more modest range of values than those based on expert opinion because non-expert judgements reflect landscape utility preferences rather than assessments of visual quality. Consequently, evaluations by non-experts tend to be favored in behaviorally-oriented studies rather than in decision-making situations by public agencies (Zube et al., 1982).

The single observer is employed for assessing the visual resources of small hydropower sites because the procedure is intended for use in a decision-making framework, and the evaluation of small hydroelectric projects requires the evaluator to make an on-site inspection to assess the visual qualities of the pre-construction location. The objective is not to choose the preferred scene from among a number of alternatives, but to rank the visual qualities of a specific location in the context of similar streams in the region. The use of a trained observer in this analysis is recommended by the work of Leopold (1969) whose method for quantifying the aesthetics of riverscapes is probably the most widely known method for analysis of scenery (Hamill, 1986). Additional support for using the trained professional in this study is provided by research reported by Dearinger and Woolwine (1971), Morisawa (1971), Appleton (1975), Carlson (1977), and Gray et al. (1979). From a pragmatic standpoint, the single observer is preferred over a group of non-experts because public agencies are unlikely to have sufficient staff to allocate a group of expert evaluators to assess a site from multiple perspectives unless the project is a major resource development (Feimer et al., 1979). An alternative would be to use a group of non-experts, but Litton (1979) observes that it is nearly impossible for public agencies to conduct social response studies on public land. At the same time, it would be difficult to determine efficiently whether each individual in a group of non-experts had adequate knowledge of the regional landscape (Miller, 1984) for assessing the visual quality of small hydroelectric sites.

The reliability of the single observer cannot be expected to be as high as the composite score derived from evaluations performed by numerous raters (Feimer et al., 1979). However, Carlson (1977) suggests that the objectivity of assessments by trained and knowledgeable individuals is vastly underrated. Litton (1979) points out that objectivity is the professional responsibility of those individuals selected to perform landscape evaluations, and their ability to maintain objectivity is linked to recognition of the integrity between typical and atypical landscapes in maintaining scenic quality. Even if the judgements of a single observer vary slightly from the mean for a large group of evaluators, Carlson (1977) and Briggs and France (1980) argue that it is preferable to sacrifice some small degree of objectivity by an expert when a simple, quick, and inexpensive method of evaluation is required. It can also be argued that the concern for bias by a single observer is offset by the advantage derived from the knowledge of the region's resources which the expert observer is able to use in performing the resource evaluation (Hammitt, 1979). Furthermore, the use of a systematic evaluation format, such as the scheme employed in this study, reduces opportunities for bias (Litton, 1979). The contribution of the structured format is to remind the observer of the general visual qualities to be evaluated, and it facilitates tabulation of the observer's landscape assessment (Laurie, 1975). Multiple site visits by an evaluator are recommended by Feimer et al. (1979) to establish intra-observer reliability, and this strategy was employed for all site evaluations by the single observer in this study.

All of the evaluations in the present study were performed by one individual with extensive training in landscape analysis and fully familiar with the region. To provide a measure of the reliability of this observer, four other individuals with training in landscape analysis and familiar with the Sierra Nevada were recruited to serve as a control group. Unfortunately, time and monetary constraints prevented acquisition of a data set suitable for comprehensive statistical testing. Each member of the control group was asked to evaluate two or more small hydroelectric sites depending upon their availability to visit selected sites. Comparison of the scores assigned by the individual observer and the control group revealed that the control group's scores ranged above and below the individual's scores by magnitudes of 5 to 30 points. The small size of the control group and the different number of site visits by each individual in the control group precluded a more detailed statistical comparison. Nevertheless, these data establish that the individual observer's scores are within the range of scores assigned by the control group under a variety of environmental conditions. Overall, the variability of the ratings provides no basis for concern regarding the reliability of the individual observer's scores.

The Rating System

Components or elements of the landscape, forming the skeleton of scenery, are recognized as being fundamental and permanent determinants of scenic quality as suggested by Crofts (1975). The first step in evaluating the environmental elements is accomplished by assessing the scenic qualities of each site in terms of unity, vividness, and variety. These criteria are recognized as important components of visual composition (Litton, 1974; Gray et al., 1979; Kaplan, 1979; McCarthy, 1979). Human landscape modification is judged primarily on its tendency to complement or detract from the aesthetics of the natural environment; thus emphasizing the functional consequences of human modification as they affect visual quality.

Assessment of scenic qualities as represented by the environmental elements shown in Figure 2 is accomplished using a rating system to depict the visual quality of scenic resources. In this context, quantification is dependent upon acceptance of the concept of breaking down a landscape scene into its component parts and assessing each separately to determine its contribution to the overall visual quality of the landscape (Iverson, 1975). The rating system takes the form of an evaluative appraisal (Craik, 1975) designed to judge the relative visual quality of the site against an explicit standard of comparison provided by the Sierra Nevada regional landscape. In this context, scenic quality constitutes a continuum represented by a cardinal scale of 1 to 100 to rate each element in a comparable and consistent way. While ordinal scales are widely used in studies of public preferences for landscapes (Arthur et al., 1977; Palmer, 1981), the assessment of the visual quality of small hydroelectric sites involves a comparative evaluation better served by a cardinal scale. The cardinal scores are easier to interpret in a comparative sense than the ordinal scores derived from semantic scales commonly used in environmental perception studies. In addition, the cardinal scale permits the full advantage of the single observer to be realized by providing for expression of subtle differences in visual quality which could be masked by an ordinal scale.

A score of 1 represents the lowest scenic quality and 100 represents the highest scenic quality for the environmental element in the region. This concept of absolutely worst and absolutely best scores must be related to the landform landscape of the classification scheme, which in this case is the Sierra Nevada. In this way, the limits of the scoring scale are defined by a specific frame of reference. For example, the worst scenic quality for a small stream in the Sierra Nevada is illustrated by conditions where dredge tailings have largely obliterated the natural character of the stream. The best scenic quality is provided by a pristine stream at a moderately high elevation which has sustained seasonal flow, a clearly defined watershed, and easily identified vegetation and water boundaries.

This approach to rating visual quality has been used successfully where benchmark landscapes are used as reference points along the scale (Gray et al., 1979). The trained observer's familiarity with the regional landscape is essential in identifying characteristics of each environmental element to serve as reference features. Ratings derived in this way can be thought of as percentile values with the frame of reference, or the landform landscape, being the Sierra Nevada. For example, an environmental element that receives a rating of 90 is considered to be of higher aesthetic quality than 90 percent of its counterparts in other landscape units of similar spatial scale in the Sierra Nevada. The rating methodology is based upon intra-regional comparisons of visual resources; consequently, all values from 1 to 100 would be present in a comprehensive survey of all landscape units at a specified scale. The trained observer's familiarity with the region and with the reference environmental elements are used for determining the placement of a specific site on the rating scale.

The numerical rating of environmental elements is aided by descriptive accounts of higher and lower value scenic qualities provided by Litton et al. (1974). Descriptive accounts developed explicitly for the 17 environmental elements employed in the analysis of small free-flowing streams are presented by Lacey (1985). Using these descriptions has the advantage of providing a concise standard that can be easily applied by different evaluators.

Rating the environmental elements for the viewable watershed and the project reach of the stream (Figure 2) requires extensive field work. The observer makes repeated visits to each study site. Repeat visits, which serve to synthesize seasonal changes, are recommended by Litton (1979) as a way of assessing the temporal dynamics of the watershed. In addition, repeat visits are important in establishing intra-observer reliability (Laurie, 1975; Feimer et al., 1979) and in developing a comprehensive data set. The rating for each element is a composite score derived from consideration of all views. After a rating is derived for each environmental element, the ratings are summed for the viewable watershed and for the project reach of the stream. This step provides a scenic quality score for each of the two landscape units. The summation approach is similar to that used in the BLM scenic quality rating procedure (Miller, 1984). The sum of the ratings for the environmental elements is used for determining the general visual quality of the study site by computing the ratio of the sum to the maximum possible score. At the scale of the viewable watershed, 9 environmental elements are evaluated and the maximum score is 900. Eight environmental elements are evaluated at the scale of the project reach of the stream; consequently, the maximum score at this scale is 800. The rating system assigns equal weight to all environmental elements since it is considered that a change in any one element is sufficiently important to alter the scenic quality of the spatial unit (Tetlow and Sheppard, 1979), and there is no compelling basis for weighting a particular element (Arthur et al., 1977). However, the system does, by the choice of environmental elements, emphasize dominant components in a water oriented landscape.

The overall rating of the visual quality of the study site is derived by summing the total scores for the viewable watershed and for the project reach of the stream. Although the theoretical maximum for the overall rating of visual quality is 1,700, such a rating would be expected infrequently. In practice, the maximum rating for the viewable watershed and the project reach of the stream may be 50 to 75 points below the theoretical maximum of 900 and 800, respectively, because it is unlikely that all environmental elements would be rated at 100. The nature of some of the elements means that a high score on one will necessitate a lower score on another due to the prominence of the highly rated element.

Post-Construction Evaluation

Computer generated images which permit visual simulation of landscape changes (Angelo, 1979; Duffey-Armstrong, 1979; Elsner, 1979; Stevenson et al., 1979; Treiman et al., 1979; Iverson, 1985) play an important role in developing post-construction ratings for each environmental element in the inventory. Computer images are derived from photographs taken at the same locations as the views used to develop the pre-construction evaluations at each site. An advantage of this procedure is that photographs are the only required input data. The number of photographs used for developing video images varies with the site and depends upon the nature of the small hydroelectric facilities and the physical characteristics of the landscape. Figure 3 is an example of a digitized image for the powerhouse location at one site. Figure 4 is the same location with the pipeline, penstock, and powerhouse added to the computer enhanced image.

Some image resolution is lost in printing the video displays, but the scene portrayed on the computer monitor provides a close approximation of a high quality photograph. Although experience with the visual display is a valuable asset in performing the analysis, the techniques are relatively easy to apply. The video image produced by the computer simulation provides a realistic portrayal of the facilities. The 360 degree view is simulated by employing numerous images displaying various perspectives of the project site with the facilities included in the images. In this way, assessment of the visual quality of the post-construction environment is as similar as possible to the procedure

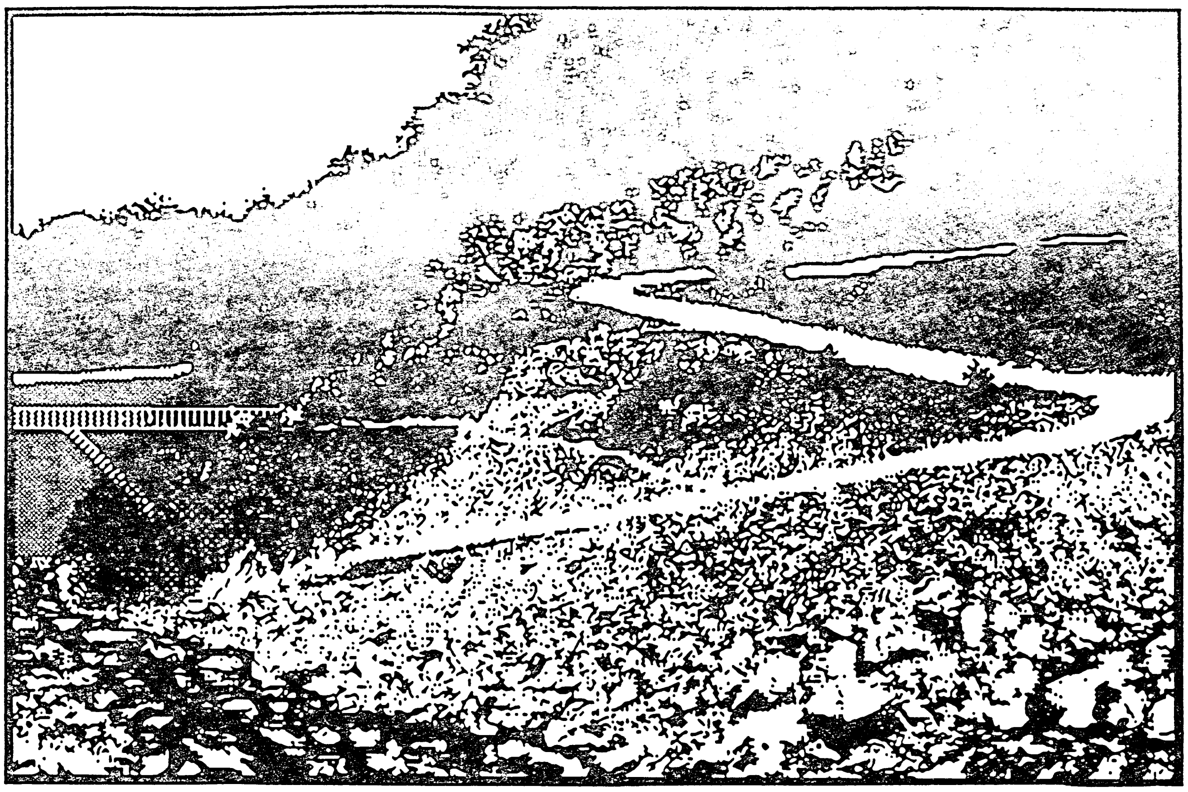

Figure 3, Optically Digitized Image of the Proposed Powerhouse Location for the Iowa Canyon Creek Small Hydroelectric Project.

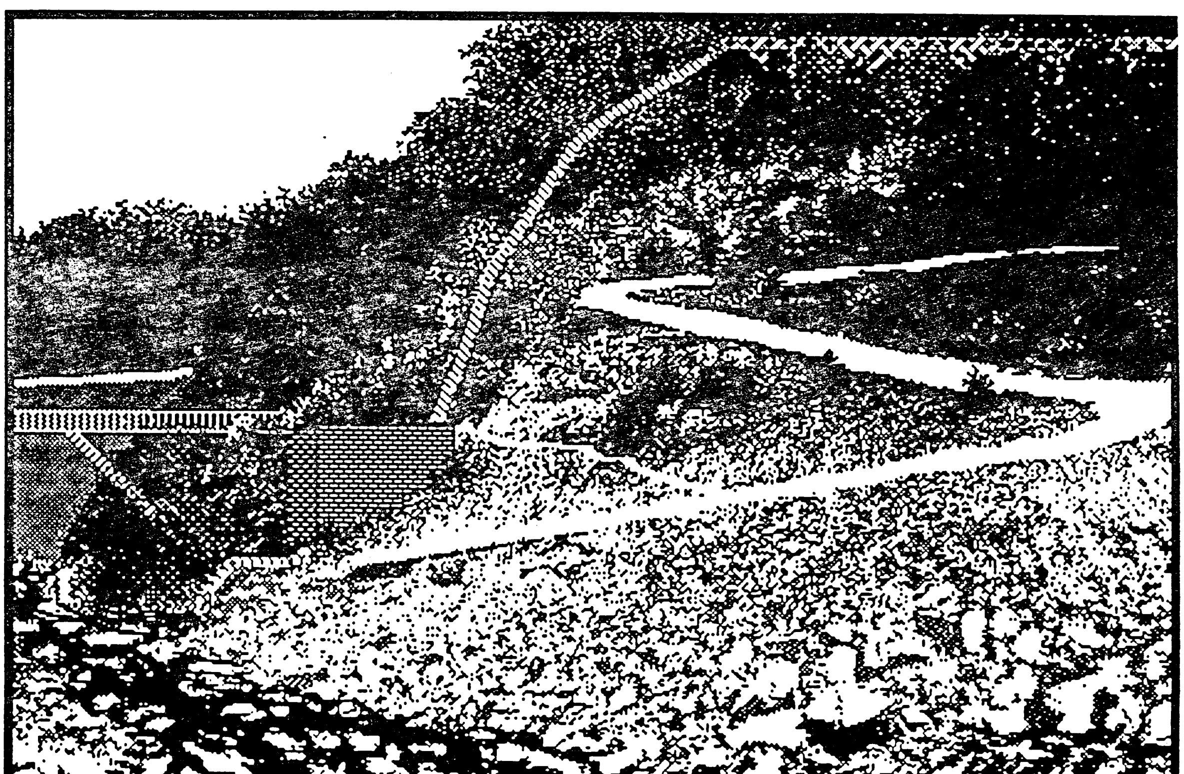

Figure 4. Computer Enhanced Image Including the Proposed Pipeline, Penstock, and Powerhouse for the Iowa Canyon Creek Small Hydroelectric Project.

used for evaluating the pre-construction environment. The same criteria employed in the pre-construction evaluation are used for the post-construction evaluation.

Any technique of environmental simulation has inherent advantages and disadvantages (Zube et al., 1975), and computer graphics share some of the disadvantages of photographs as a means of conveying landscape qualities (Duffey-Armstrong, 1979). Perhaps the greatest deficiency in using photographs and computer graphics is that they are unable to capture the dynamic qualities of the landscape. In addition, depth of field of vision is restricted in photographs and many computer simulations (Bernaldez et al., 1988). Chief among the advantages of using computer graphics is that large numbers of views can be prepared rapidly at low cost (Palmer, 1981). Also, it is significant that computer images provide a level of realism and objectivity that is often lacking in retouched photographs (Stevenson et al., 1979). These characteristics contribute to computer simulations being ideally suited for the generation and comparison of alternative design features (Palmer, 1981).

Comparison of the pre-construction and post-construction ratings provides a quantitative assessment of the expected changes that may occur in scenic resources at the site if the small hydroelectric facility is constructed. Following the recommendation of Gray et al. (1979), a change in landscape visual quality can be expressed as a ratio which compares visual quality scores for the pre-construction and post-construction condition. The ratio computed in this way provides an easily derived basis for conveying the relative magnitude of change in scenic quality for post-construction conditions. In addition, it is possible to determine whether the greatest change occurs at the scale of the viewable watershed or at the scale of the project reach of the stream. A composite ratio based on both scales provides an expression of the overall change occurring with construction of the small hydroelectric facility.

SITE EVALUATIONS

The 6 small hydroelectric sites selected for study (Figure 1) represent diverse environmental settings for evaluating the effects of development on the visual qualities of the sites. The variable nature of small hydroelectric facilities is illustrated by the physical characteristics summarized in Table 1. These data show that dam height and the size of the impoundment are insignificant compared to the large dams and reservoirs commonly associated with hydroelectric facilities in the Sierra Nevada. While the affected stream reach may be relatively short it can represent a significant percentage of the total stream course. In the same manner, the diversion is negligible in volume compared to the discharge of major rivers, but it may constitute 90 percent or more of the total flow at any one time for the affected small stream. These uncommonly large impacts due to small hydropower projects occur because the sites are on snowmelt streams for which the greatest historic flows probably are less than 10,000 cfs for the largest streams while the lowest summer flows are less than 100 cfs for all six streams. Analysis of these sites reveals significant individual diversity, but the research methodology is designed to address these individual traits within the context of the general environmental setting.

The following analysis of the study sites presents the numerical ratings for the environmental elements and brief descriptive accounts of each site. The narrative material is particularly important in this study as a means of documenting the ratings and illustrating the basis for ratings of different magnitudes. A detailed discussion of the value of description in landscape analysis cannot be undertaken here, but summaries of this topic are provided by Arthur et al. (1977) and Litton (1979).

PYRAMID CREEK PROJECT

The small hydroelectric facility proposed for the lower reaches of Pyramid Creek near Twin Bridges replaces a smaller, abandoned penstock and powerhouse (Figure 1). The modern facility requires increasing the height of the existing dam by 2 and one-half times while the length, including the construction of two lateral dikes, will be increased from 11 feet to 168 feet (Table 1). The 1,200 feet of 42-inch welded steel penstock running from the dam to the powerhouse will be entirely above ground and will rest on concrete piers attached to the sloping granite which dominates the landscape.

The dam is proposed at a site where Pyramid Creek crosses a granite lip and continues down the granite slope in three primary channels or cascades. Day-use recreationists use the area near the cascades for hiking and picnicking and it serves as a corridor for hikers entering and returning from the Desolation Wilderness Area. Horsetail Falls, a cascade flowing over approximately 850 feet of the precipitous granite wall to the northwest, provides a picturesque setting that attracts the attention of most motorists using Highway 50.

Evaluation of the Pyramid Creek small hydroelectric site produces especially high ratings for environmental elements in both the viewable watershed and the project reach of the stream (Table 2). These high ratings are a statement of the region's unusual scenic beauty and recreation resource value.

Table 2. Assessment of the Pyramid Creek Site.

Environmental Element	Rating of Pre-Construction Environment	Rating of Simulated Post-Construction Environment
Viewable Watershed		
Boundary Definition	96	96
Features	98	90
Enclosure	90	90
Landform Delineation	97	97
Vegetation Patterns	67	67
Evidence of Human Impact on the Landscape	98	80
Prominence of Water	93	72
Continuity of Water	71	58
Evidence of Human Impact on Water	84	61
Subtotal	794	711
Ratio of Post- to Pre-Construction		0.895
Project Reach of the Stream		
Movement and Features of Water	99	37
Appearance of Water	93	89
Aquatic Environment	93	65
Evidence of Human Impact on Water	70	44
Edge Definition	88	81
Edge Features	78	66
Riparian Environment	69	50
Evidence of Human Impact on Shore	77	71
Subtotal	667	503
Ratio of Post- to Pre-Construction		0.754
Total	1461	1214
Composite Ratio		0.831

The viewable watershed for the proposed Pyramid Creek project is an open canyon extending south from the lip of Horsetail Falls to beyond the confluence of Pyramid Creek and the South Fork American River at Twin Bridges. Unobstructed views from virtually any point within the canyon are available due to minimal vegetation cover and steep slopes. Lover's Leap and the north-facing slopes of the South Fork American River canyon form the southern boundary. Angles of view created by topography conceal most of the evidence of human use of the area even though Highway 50 crosses Pyramid Creek just below the proposed powerhouse. These qualities and the barren canyon walls silhouetted against the sky establish a dramatic sense of place.

The 3 environmental elements that measure the aesthetics of large scale topographic variables, landform delineation, boundary definition, and enclosure, receive high ratings of 97, 96, and 90, respectively, for the pre-construction environment (Table 2). The highest ratings for the viewable watershed, however, are assigned to features and evidence of human impact. The nearly vertical granite cliffs that surround the small hydropower site and the ubiquitous vistas of Horsetail Falls at the head of the canyon form a regionally distinctive landscape of interrelated components with exceptional richness. These characteristics are judged to be of especially high quality and merit a rating of 98 for features.

A similarly high rating of 98 is assigned to evidence of human impact, but for this environmental element the rating is assigned for what is absent in the landscape. Only the southernmost portion of the viewable watershed contains any permanent landscape modification and even here the development is located in a forested area and is largely concealed from view. There is no evidence of historic logging or mining in the Pyramid Creek viewable watershed, and the upper two-thirds of the valley in the Desolation Wilderness Area is rated at a maximum value of 100 when judged against other Sierra Nevada landscapes for evidence of human impact.

In contrast, the evidence of human impact on water is much greater and produces a significantly lower rating of 84. Campfire rings and occasional litter along the creek are evidence of recreational use, and the abandoned powerhouse and penstock are additional evidence of human impact along the stream.

Vegetation patterns are assigned the lowest rating among the environmental elements of the viewable watershed for the Pyramid Creek site. The moderate rating of 67 reflects a vegetation community that is complex and vigorous but not visually stimulating or of singular quality. The most notable characteristic of vegetation near the Pyramid Creek site is its relative scarcity.

The project reach of the stream for Pyramid Creek extends from the dam and diversion at the top of the expanse of stair-step cataracts to the proposed powerhouse immediately upstream from the Highway 50 bridge over Pyramid Creek. Although the Sierra Nevada is a water-rich region, only a small number of sites surpass the scenic beauty of Pyramid Creek's spectacular cascades. The prominence of water in the otherwise harsh granitic landscape and the complexity of the forms it assumes in rushing over the granite impart unique visual qualities to the water. On the basis of these qualities, movement and features of water for the Pyramid Creek site are rated at 99 (Table 2) which is the single highest value given an environmental element at any of the study sites.

As a group, the environmental elements for the project reach of the stream are rated slightly lower than the elements in the viewable watershed. The mean score for the 8 elements in the project reach of the stream is 83 while the mean score for the 9 viewable watershed elements is 88. The ratings for the evidence of human impact help explain the difference. At the scale of the stream reach affected by the proposed project, the heavy recreational use and the presence of the abandoned hydroelectric facility are prominent. These features are more concealed at the scale of the viewable watershed. At this scale the ratings for human impact are significantly higher to reflect their diminished intrusion on the scenic quality of the site.

The rating for the riparian environment in the project reach of the stream may contribute to improved understanding of the sensitivity of the rating procedure. Virtually the entire length of Pyramid Creek supports a healthy and diverse riparian community. However, the vegetation is not significantly different when compared to the riparian vegetation along most small streams in the Sierra Nevada. The rating of 69 for riparian environment indicates that it is judged to be healthy, attractive, and reasonably diverse, but somewhat limited in scale.

Evaluation of the Pyramid Creek site with the proposed hydroelectric facility included in the landscape assessment reveals several distinct changes in the ratings. The magnitude of the change in the ratings for environmental elements increases as the scale decreases; therefore, the ratings for elements in the project reach of the stream display the greatest differences (Table 2).

At the scale of the viewable watershed, most of the environmental elements that are expressions of topographic features are not typically influenced by local landscape modification associated with the small hydroelectric project. For the Pyramid Creek facility, features drop from a 98 to 90 primarily because of the prominence of the proposed penstock which becomes a feature and slightly reduces the relative prominence of the natural elements. Evidence of human impact is reduced from 98 to 80 due to the adverse visual impact of the powerhouse and penstock which is amplified by the open landscape.

The rating for the Pyramid Creek project reach of the stream elements is reduced by about 25 percent for post-construction conditions (Table 2). Ratings for all of the environmental elements in the project reach of the stream category are reduced because this is the scale at which the proposed construction has the greatest influence. The most significant changes, however, are for the stream-related elements which experience reductions as great as 60 percent due to the reduced flows resulting from the proposed diversion of water.

Diversions will significantly reduce, or in some instances eliminate, the parallel stair-step cascades largely responsible for the rating of 99 for movement and features of water for the pre-construction environment. It must be remembered, however, that the proposed facility will operate for only a few weeks each year during the period of highest runoff. Consequently, the effect of the diversion is to reduce streamflow on a segment of the cascade rather than to eliminate streamflow completely. Instream flow requirements regulating the amount of water required by law to remain in the natural channel between the point of diversion and point of re-entry make no provision for maintenance of the cascade aesthetics on Pyramid Creek. However, recent research has contributed to general understanding of the flows necessary to maintain visual quality when streams are influenced by diversions (Taylor, 1982). Since low flow cataracts are a common sight in the Sierra Nevada, the 3 parallel cascades on Pyramid Creek sustained by the reduced flow will lack a distinctive quality. Therefore, the rating for this element is reduced to 37. This change is the largest reduction in rating sustained by an environmental element at any scale for the 6 study sites.

ROCK CREEK PROJECT

The small hydroelectric facility on Rock Creek approximately five miles north of Placerville (Figure 1) is the only project in the study that has progressed through the entire construction phase. Construction of this facility was completed in April 1986 at a cost of more than $5,000,000. Operation of the project is pending, however, until a decision is reached by the California Water Resources Control Board concerning the issuance of water rights and until other litigation is settled.

The Rock Creek facility is at the lowest elevation of the 6 study sites (Table 1). It is situated in a region that is typical of Sierra foothill terrain. Broad, rolling plateaus form the higher elevations and streams cut deep, steep sided canyons into the plateaus. In recent years, the middle and upper portions of the watershed above the project site have undergone development for retirement and vacation homes. The present powerhouse is constructed at least partially on the foundation of an abandoned hydroelectric powerhouse, and the modern project uses buried penstocks originally installed for the abandoned facility. These abandoned features were part of a project using water diverted from the South Fork American River and not from Rock Creek.

The viewable watershed for the Rock Creek project represents a clearly defined example of the difference between the viewable watershed and the physical or topographical watershed. When viewed from the stream level, the horizon is defined by prominent ridge lines produced by the dense vegetation. Views are limited to 500 to 600 yards upstream from the dam and diversion facility and extend to a maximum of about one mile on the east and west slopes. At the powerhouse, views extend along the broader South Fork American River canyon about one-half mile upstream and three-fourths mile downstream. The north-facing slope of the South Fork canyon constitutes the southern boundary of the viewable watershed.

The project reach of the stream involves approximately the last mile of Rock Creek. The dam and diversion facility are immediately downstream from the Rock Creek Road bridge across Rock Creek, and the powerhouse is on the north bank of the South Fork American River at the point where Rock Creek joins the South Fork. In this reach, Rock Creek is characterized by expanses of smooth, weathered rock and a series of stair-step pools joined by highly attractive cascades of one to three feet. The exposed rock of the stream channel keeps vegetation at a distance at many points and heightens the visual aspects of the stream.

The modern project on Rock Creek utilizes a dam 6 feet high and 80 feet long (Table 1). The intake structure on the east end of the dam diverts water into a 500 foot long, 72-inch diameter buried concrete pipe. The pipe discharges into a 3,200 foot long horseshoe tunnel which carries the water to the buried penstocks. Diverted water will be discharged into the South Fork American River adjacent to the river's natural confluence with Rock Creek. This project will reduce streamflow in the entire reach of Rock Creek below the diversion dam.

The rating of the pre-construction environment for the Rock Creek site is achieved by reversing the procedure used for the other 5 sites. Computer enhanced images of the project area are developed to remove the constructed facilities from photographs. The images are evaluated as for the other sites, but for Rock Creek the images depict the pre-construction environment.

The valley excavated by Rock Creek focuses attention on the stream and its surrounding environment. The basin boundary is clearly defined and the stream course contrasts markedly with the surrounding landscape. These qualities are the basis for the highest rating of 90 for boundary definition among the environmental elements in the viewable watershed (Table 3). However, the densely vegetated slopes and the rocky stream channel appear to be a random assemblage typical of this area and one that lacks the presence of a regionally prominent landform. The lack of distinctive landscape or waterscape components is the basis for a rating of 46 for features. Other environmental elements in the viewable watershed fall between these two ratings, but most tend to be above 70. The rating of 67 for evidence of human impact on the landscape results from the presence of the road and bridge just upstream from the dam and the abandoned hydropower facilities and traces of a bridge foundation at the powerhouse. In addition, powerlines extending up the ridge just south of the South Fork American River are visually prominent.

The environmental elements of the project reach of the stream display a narrower range of ratings than for the viewable watershed (Table 3). The highest rating of 85 is given to evidence of human impact on water. The bridge across Rock Creek and evidence of recreation use just below the bridge and along the stream are the major factors responsible for reducing this rating from a maximum of 100. The lowest rating of 66 is given to riparian vegetation which appears as random clusters of growth with little continuity.

Construction of the small hydroelectric facility has a modest affect on the environmental elements at the scale of the viewable watershed (Table 3). Continuity of water and evidence of human impact on water display the greatest reductions due largely to the interrupted flow produced by the impoundment. These conditions contrast markedly with adjacent areas and the prominence of the impoundment degrades the visual attractiveness of the stream.

Ratings for elements in the project reach of the stream are reduced from 2 to 35 points in response to the impoundment and the diversion of water (Table 3). Construction has little impact on riparian vegetation along the stream reach influenced by the project and the rating for this element is reduced minimally. However, evidence of human impact on water and on the shore display the influence of significant changes occurring to these elements and they account for the greatest changes. The dam and intake structure are focal points on the stream and the flow in the regulated reach contrasts markedly with the free-flowing stream above the dam. The legal diversion for this project is the largest of the 6 study projects and is 1.5 times larger than the next largest diversion (Table 1). These changes in the nature of the stream are judged to be sufficient to reduce the rating for evidence of human impact on water by 35 points. The evidence of human impact on the shore is reduced by 28 points due to the disturbance associated with burying the pipeline, construction of the tunnel and powerhouse, and reconstruction of an access road to the powerhouse that parallels the creek and is prominent for the entire project length. Overall, construction of the project reduces the rating for the project reach of the stream by about 26 percent. The magnitude of the change would have been greater, but evidence of existing human influences reduced the rating of the pre-construction site.

Table 3. Assessment of the Rock Creek Site.

Environmental Element	Rating of Pre-Construction Environment	Rating of Simulated Post-Construction Environment
Viewable Watershed		
Boundary Definition	90	90
Features	46	43
Enclosure	88	88
Landform Delineation	88	88
Vegetation Patterns	74	74
Evidence of Human Impact on the Landscape	67	53
Prominence of Water	71	53
Continuity of Water	80	46
Evidence of Human Impact on Water	72	49
Subtotal	676	584
Ratio of Post- to Pre-Construction		0.864
Project Reach of the Stream		
Movement and Features of Water	79	54
Appearance of Water	79	61
Aquatic Environment	80	53
Evidence of Human Impact on Water	85	50
Edge Definition	82	71
Edge Features	70	56
Riparian Environment	66	64
Evidence of Human Impact on Shore	67	39
Subtotal	608	448
Ratio of Post- to Pre-Construction		0.737
Total	1284	1032
Composite Ratio		0.804

FOOTTRAIL PROJECT

The proposed Foottrail small hydroelectric facility is on the Silver Fork of the South Fork American River approximately eight miles southwest of Kyburz (Figure 1). This project has the largest drainage area of the six study sites (Table 1). Above the proposed diversion, the watershed contains two distinct geologic realms. At elevations above 6,500 feet, the exposed granite of the Sierra crest dominates the landscape. Below 6,500 feet, the watershed is a rolling to moderately steep landscape of deep soils and dense vegetation. The smooth rock shelves and broken boulders that are characteristic of the river channel stand in sharp contrast to the surrounding slopes.

Forest cover provides the primary control for defining the viewable watershed for the Foottrail site. The expanse of heavily forested rolling terrain and the absence of singular landforms prevent distant lines of view. Horizons are defined by repetitive and forested ridge lines associated with intermittent tributaries and, in general, are limited to 360 degree views of about two-thirds of a mile or less. The viewable watershed is somewhat elongated along the course of the Silver Fork, but there are no unobstructed distant views either upstream or downstream.

The project reach of the stream involves approximately one-half mile of the Silver Fork immediately upstream from the Fitch Ranch Bridge. Up to 160 cfs will be diverted from a pool behind a 6-foot high dam of cement and native rock. The diverted water is to be transported first through a horseshoe tunnel and then a 54-inch diameter pipeline that connects the tunnel and the powerhouse (Table 1).

The powerhouse is on the north bank of the Silver Fork just upstream from the bridge and immediately above the unconstructed Sherman Canyon Reservoir which is a component of the SOFAR project proposed by the El Dorado Irrigation District.

Table 4. Assessment of the Foottrail Site.

Environmental Element	Rating of Pre-Construction Environment	Rating of Simulated Post-Construction Environment
Viewable Watershed		
Boundary Definition	46	46
Features	40	38
Enclosure	79	79
Landform Delineation	63	63
Vegetation Patterns	85	85
Evidence of Human Impact on the Landscape	60	57
Prominence of Water	54	50
Continuity of Water	86	66
Evidence of Human Impact on Water	78	61
Subtotal	591	545
Ratio of Post- to Pre-Construction		0.922
Project Reach of the Stream		
Movement and Features of Water	71	63
Appearance of Water	92	88
Aquatic Environment	92	70
Evidence of Human Impact on Water	91	78
Edge Definition	64	57
Edge Features	81	77
Riparian Environment	80	74
Evidence of Human Impact on Shore	68	52
Subtotal	639	559
Ratio of Post- to Pre-Construction		0.875
Total	1230	1104
Composite Ratio		0.898

At the broad scale of the viewable watershed, the rating of 86 for continuity of water is the highest rating for a pre-construction environmental element (Table 4). The river is uninterrupted by reservoirs or topographic variation, its course creates a visual line even where the water is hidden from view, and it fits harmoniously into its surrounding environment. Vegetation pattern is rated 85 due to the dominance of the conifer canopy which establishes a sense of internal consistency that imparts a cohesiveness to the region. Both of these characteristics are expressions of highly valued visual resources.

The dominant expression of vegetation in the landscape reduces the prominence of landforms in the watershed and the plateau-like terrain lacks focal topographic elements. Such conditions reduce the ratings for environmental elements reflecting these characteristics. The absence of regionally distinct and interrelated landforms is the basis for a rating of 40 for features. The continuous vegetation masks the boundary of the Watershed and there is little contrast among adjacent drainage areas. Consequently, the rating for boundary definition is only 46.

Within the project reach of the river, the water elements are distinctly dominant in the ratings. The aquatic environment, appearance of water, and evidence of human impact on water are all rated in the 90s (Table 4). These ratings are a reflection of an unusually high water quality level which results from the pristine nature of the Silver Fork watershed upstream from the project site. In addition, summer flows often are higher than flows in other streams because the upstream basin contains volcanic material that retains some spring runoff in groundwater storage which is released during the dry summer months. Summer flows sustained by natural processes are augmented by releases from Caples Lake and Silver Lake near the Sierra summit. Discharges from these lakes are regulated by Pacific Gas and Electric Company to augment flows in their hydroelectric facility on the South Fork American River west of Kyburz. The effect of these discharges is to provide a sustained summer flow at the Foottrail site that appears to be due to natural causes; consequently, the rating for evidence of human impact on water is a high value of 91.

The lowest ratings at the scale of the project reach of the stream are a 64 for edge definition and a 68 for evidence of human impact on the shore (Table 4). The rating for edge definition is a product of the dense vegetation which often obscures the river or produces a weak river-to-shore transition. The visual quality of the shore in the project reach of the river is reduced by the presence of a campground near the powerhouse site, an unimproved road serving the campground, and numerous trails along the river.

Analysis of post-construction conditions at the Foottrail site indicates little evidence of substantial change in the ratings of the environmental elements (Table 4). This is due largely to the dense vegetation and the tunneled penstock which conceal much of the project and mitigate differences between the pre- and post-construction visual quality of the site. The ratings are reduced by 46 points only for the elements in the viewable watershed and by 80 points for elements at the smaller scale of the project reach of the stream.

At the broad scale of the viewable watershed, notable reductions are limited to continuity of water and evidence of human impact on water (Table 4). These changes reflect the reduced flows caused by the stream diversion which produce a reach of the river that is misfit when compared to the river above and below the project. The segmented appearance of the stream and the clashing contrast between the natural flow reach and the project reach are the basis for reducing continuity of water 20 points to a post-construction rating of 66. The project intake and powerhouse facilities increase the evidence of human impact on water and contribute to a 17 point reduction in the rating for this element.

Changes related to the decreased streamflow due to the diversion of water account for the largest reductions in ratings at the scale of the project reach. While most of the environmental elements in this spatial unit are reduced by 4 to 8 points, aquatic environment is reduced 22 points (Table 4). The stream channel at the Foottrail site is relatively broad and shallow and is composed of large cobbles. Diverting a portion of the streamflow is likely to change the character of the stream to a slower and more sinuous flow around the rocks in the channel. Such reduced flows will permit greater sedimentation in the channel and encroachment of riparian vegetation. The reduction in streamflow is largely responsible for a decrease of 13 points for evidence of human impact on water. At the scale of the project reach of the stream, the project's physical components become more prominent and account for a reduction of 16 points for evidence of human impact on the shore.

SAYLES FLAT PROJECT

The proposed Sayles Flat small hydroelectric facility is on the South Fork American River between Twin Bridges and Camp Sacramento (Figure 1). The City of

Sacramento operates Camp Sacramento which offers numerous recreational activities for about 200 guests per day from May to October The Sayles Flat diversion site is about one mile from the proposed Pyramid Creek diversion site and it involves the reconstruction and enlargement of an abandoned dam, penstock, and powerhouse like the Pyramid Creek project. However, the general environmental setting of the Sayles Flat site is distinctly different.

The watershed above the proposed project is heavily forested and contains little evidence of glaciation compared to the Pyramid Creek watershed. The river occupies a steep, v-shaped canyon that widens into a subalpine meadow of approximately 10 acres at Camp Sacramento. The meadow is a product of deposition behind a large lateral moraine that dammed the river at this point (Schaffer, 1975). After breaching the moraine, the river enters an area of exposed and highly glaciated granitic shelves similar to those in the lower reach of Pyramid Creek and the river gradient is unusually steep. Vegetation in this area is scattered, but it contains a variety of species.

While the viewable watershed for the Sayles Flat site is defined rather distinctly by topographic features, the composition of the area is highly variable and presents a challenging test of the observer's ability to synthesize and weigh all facets of the landscape. The viewable watershed extends eastward about one-third of a mile above the diversion point at Camp Sacramento. The northern boundary is the south-facing slope of the South Fork American River and the lower one-half of the Pyramid Creek drainage. The western view truncates with the ridge line in the South Fork canyon near Strawberry Lodge. The northeast flank of Lover's Leap and the forested ridge line extending to the meadow at Camp Sacramento form the southern horizon. Although not visible from all locations, the presence of Highway 50, powerlines, summer homes, and recreation facilities conveys the sense of a strong human influence in this landscape.

The proposed Sayles Flat dam, located just upstream from the footings of the abandoned dam, will be 8 feet high and 130 feet wide. Of the 6 sites studied, this project is at the highest elevation and it impounds the largest volume of water (Table 1). A 42-inch diameter penstock will cross the river at one point and will parallel the river for 4,000 feet. Approximately 2,400 feet of the pipeline will be above ground on concrete piers.

The project reach of the stream extends from the dam and diversion at Camp Sacramento nearly one mile downstream to the powerhouse. The powerhouse is to be located on the south bank of the South Fork American River approximately 600 feet downstream from the confluence of the South Fork and Pyramid Creek. Within this reach, the South Fork contains a subalpine meadow, cascades, broad granite shelves, a boulder and scrub choked canyon, dense aspen groves, and a red fir forest. At the six sites studied, this is the most visually complex landscape encountered at the scale of the project reach of the stream.

The ratings for the pre-construction environment at the scale of the viewable watershed are moderate to good ratings with few exceptionally high values (Table 5). The physical environment is a dominant factor and this is evident in the rating of 89 assigned to landform delineation and 83 for features. The low ratings are due in large part to the presence of Highway 50 running the length of the area and the concealed nature of many stream segments which limits opportunities for water to serve as major focal points in the region. This does not imply that the area is not visually attractive. Rather it suggests that human modifications have diminished the pristine beauty of the natural landscape.

The unusually low rating of 39 for evidence of human impact on the landscape results from several anthropogenic influences. Highway 50 is concealed from view at few points in the viewable watershed. In addition, numerous summer homes are visible along the river, Camp Sacramento and its associated recreational facilities are prominent, and the presence of an electrical transmission line is evident. These human land uses are slightly removed from the water and their influence is greater on the landscape than on the river.

Table 5. Assessment of the Sayles Flat Site.

Environmental Element	Rating of Pre-Construction Environment	Rating of Simulated Post-Construction Environment
Viewable Watershed		
Boundary Definition	71	71
Features	83	80
Enclosure	82	82
Landform Delineation	89	89
Vegetation Patterns	70	70
Evidence of Human Impact on the Landscape	39	31
Prominence of Water	62	40
Continuity of Water	75	48
Evidence of Human Impact on Water	51	43
Subtotal	622	554
Ratio of Post- to Pre-Construction		0.891
Project Reach of the Stream		
Movement and Features of Water	82	55
Appearance of Water	87	79
Aquatic Environment	88	68
Evidence of Human Impact on Water	60	30
Edge Definition	68	59
Edge Features	70	52
Riparian Environment	69	63
Evidence of Human Impact on Shore	48	41
Subtotal	572	447
Ratio of Post- to Pre-Construction		0.781
Total	1194	1001
Composite Ratio		0.838

Ratings for environmental elements at the scale of the stream reach affected by the project are lower than might be expected also. The aquatic environment and appearance of water have the highest ratings due largely to the high elevation of the Sayles Flat site (Table 5). Most high elevation streams in the Sierra Nevada have small suspended and solution loads which result in high water clarity. In addition, the shore to water transition tends to be well defined patterns that are visually pleasing. Such characteristics account for the rating of 88 and 87 for aquatic environment and appearance of water, respectively, which are modestly strong ratings for a site in this environment.

The lowest ratings at the scale of the project reach of the stream are dominated by evidence of human impact (Table 5). The rating of 60 for the water element is largely due to the heavy water-oriented recreation at Camp Sacramento and the numerous artifacts of the abandoned hydroelectric project that appear randomly in and along the stream. However, the influence of human activity affects the appearance of the shore even more and results in a rating of 48. In addition to the Camp Sacramento facilities and the abandoned hydroelectric powerhouse and penstock remnants, numerous summer homes are present, hiking trails are abundant, and an unfinished granite block ski lodge constructed during the 1930s as part of a Civilian Conservation Corps project is located near the proposed powerhouse site. These features produce a shore environment that is distinctly altered by human use.

Analysis of the images depicting post-construction conditions at the Sayles Flat site results in few changes for the environmental elements in the viewable watershed. The macro-scale topographic elements remain unchanged in quality and retain their comparatively high ratings (Table 5). The most severe reductions occur for those elements affected by low instream flows resulting from the stream diversion. Both prominence of water and continuity of water are rated more than 20 points lower. The reduced streamflow nearly disappears in the boulder clogged channel or appears as a thin film of water as it runs across the granite slabs in the reach known as Slippery Ford. In both cases, the reduced volume of water significantly degrades the visual quality of the stream. The effect would be more pronounced except for the relatively short duration of the diversion.

The flow reduction has an even greater affect on elements at the scale of the project reach of the stream. The rating for these elements is reduced 125 points which is 22 percent of the pre-construction rating (Table 5). Evidence of human impact on water is given a rating of 30 because the diversion creates a stream reach that is a continuous and readily apparent anomaly compared to reaches above and below the diversion. The pre-construction human impacts on water are more evident with the project reach as a focal point. The rating for movement and features of water is reduced from 82 to 55 because the amount of water in the channel is clearly out of proportion to the channel size. However, the effect is not as great as the flow reduction in the Pyramid Creek project. With the exception of two small segments, the American River remains in a single channel throughout the reach influenced by the Sayles Flat project regardless of the volume of flow. This has the effect of reducing the visual quality of movement and features but not to the severe extent produced by the nearly complete flow loss in some of the parallel-channels of Pyramid Creek. Ratings for other environmental elements at the scale of the project reach of the stream are reduced by smaller magnitudes, but these changes are all related primarily to the reduced surface area of the river and subsequent alterations in the relationship between the oversized stream channel and the shore environment.

FRY CREEK PROJECT

The facility proposed for Fry Creek is on a minor tributary of the South Fork American River approximately four miles west of Kyburz (Figure 1). This facility is the smallest of the 6 study sites in almost every aspect (Table 1).

The Fry Creek watershed consists of less than 2 square miles of the steep north wall of the South Fork American River canyon. The creek drains a segment of the deeply incised valley cut by the South Fork and stream gradients reflect the slopes of 30 to 50 percent that dominate the terrain. Thin soils cover decomposed granite and metamorphic rocks, but the surface is concealed by a canopy composed of yellow pine and a mixture of other trees and a thick layer of understory vegetation. Evidence of human land use in the watershed includes an unimproved road across the higher elevations, a summer home, and Highway 50 crossing the lower portion of the basin.

For the Fry Creek site, the viewable watershed is a small portion of the South Fork American River canyon and not a separate drainage area in the traditional sense. This characteristic, the small size of the stream, and the small area affected by the proposed project are a contrast to the physical characteristics of the other study sites. From most locations along Fry Creek, views are limited to a few yards by the dense vegetation. Near the proposed powerhouse site, the south wall of the South Fork canyon can be seen and views up and down the canyon for less than a mile in either direction are possible.

The project reach of the stream involves the lower reach of Fry Creek before it passes under Highway 50. The powerhouse is to be about 300 feet above the highway and the diversion facilities will be approximately one-half mile up the slope. After the diverted water passes through the powerhouse, a discharge pipe 30 feet long will return the water to the natural channel of Fry Creek about 250 feet above Highway 50.

The proposed small hydroelectric project requires construction of a dam 2 feet high and 15 feet wide that will impound about 200 gallons of water (Table 1). An exposed 6-inch diameter penstock will carry water 2,500 feet from the intake to the powerhouse.

All of the ratings for the pre-construction environment at the scale of the viewable watershed are relatively low (Table 6). This is due to the absence of outstanding topographic features and the continuous vegetation cover which obscures the surface and prevents precise definition of the watershed boundary. In addition, the small size of the stream makes it impossible to identify the stream channel at this scale and especially low ratings result for prominence and continuity of water. The rating of 11 for prominence of water is the lowest rating given to any environmental element at the six study sites.

A positive quality accruing from the steep terrain is that the impact of human activity in the watershed is limited primarily to the lower portion of the basin near Highway 50. However, the small size of the watershed means that this area of human use is prominent. The rating of 77 for evidence of human impact on the landscape and 73 for evidence of human impact on water are only moderately strong, but they are the highest ratings for environmental elements at this scale.

The stream reach affected by the proposed project is largely coincident with the viewable watershed except for the slopes on the south side of the South Fork canyon. The ratings of the environmental elements at this scale are somewhat similar to those in the viewable watershed category (Table 6). Evidence of human impact on the shore and on the water receive the highest ratings although they are slightly lower than for the viewable watershed. The difference in ratings is a product of the stream reach being the focus at this scale and the effects of human land use are slightly amplified by this perspective. At this scale, movement and features of water are rated at 12 because the stream is concealed from view by the vegetation. The water offers few visual rewards when compared to other streams throughout the Sierra Nevada.

Analysis of post-construction conditions for the Fry Creek site is hindered by the vegetation canopy and steep terrain which make it difficult to acquire adequate photography for producing computer enhanced images. Photographs for this site depict narrow and shallow fields of view. Such limited views, however, are typical of the Fry Creek setting.

Evaluation of the post-construction images produces ratings that are changed only slightly from the ratings for the pre-construction environment (Table 6). At the broad scale of the viewable watershed, the ratings for evidence of human impact are reduced slightly by the presence of the dam, penstock, and powerhouse and by the diverted flow. The flow diversion reduces the rating for prominence of water to 5 which is the lowest rating given a post-construction environmental element at any of the six study sites. Continuity of water is reduced from an already low rating of 20 to 12 as the reduced flow disappears from view under the vegetation that screens the channel.

Table 6. Assessment of the Fry Creek Site.

Environmental Element	Rating of Pre-Construction Environment	Rating of Simulated Post-Construction Environment
Viewable Watershed		
Boundary Definition	39	39
Features	36	35
Enclosure	41	41
Landform Delineation	60	60
Vegetation Patterns	51	51
Evidence of Human Impact on the Landscape	77	68
Prominence of Water	11	5
Continuity of Water	20	12
Evidence of Human Impact on Water	73	62
Subtotal	408	373
Ratio of Post- to Pre-Construction		0.914
Project Reach of the Stream		
Movement and Features of Water	12	9
Appearance of Water	28	25
Aquatic Environment	50	47
Evidence of Human Impact on Water	68	57
Edge Definition	18	11
Edge Features	18	16
Riparian Environment	66	59
Evidence of Human Impact on Shore	71	62
Subtotal	331	286
Ratio of Post- to Pre-Construction		0.864
Total	739	659
Composite Ratio		0.892

With the project facilities simulated on computer enhanced images, ratings for environmental elements in the project reach of the stream display small changes which are in part a reflection of their already small magnitudes (Table 6). The ratings for this spatial unit are reduced by about 14 percent or 45 points.

The highest ratings for this site continue to be for evidence of human impact and riparian vegetation (Table 6). These elements suffer limited degradation from the addition of the proposed project structures due to the presence of dense vegetation along the stream channel. At the other end of the rating scale, movement and features of water drops from an already low value of 12 to 9 in response to flow reduction in the reach. The largest relative change, however, occurs for edge definition which is reduced 39 percent to a rating of 11. For this environmental element, the diminished flow increases the chaotic arrangement of shore features and promotes an impression that the stream edges are unrelated to one another.

IOWA CANYON CREEK PROJECT

The Iowa Canyon Creek small hydroelectric project is proposed for construction near the confluence of Iowa Canyon Creek and the South Fork American River approximately six miles northeast of Placerville (Figure 1). Slab Creek Dam, operated by the Sacramento Municipal Utility District, is approximately one-quarter mile upstream on the South Fork American River. The watershed of approximately 10 square miles contains low density residential structures and limited agricultural acreage, but access roads and power transmission lines are prominent.

The project area is a typical Sierra foothill environment with rolling hills dissected by deep, v-shaped stream canyons with steep slopes. The landscape is covered by dense vegetation composed of white alder, hazelnut, and creek dogwood which becomes especially thick near streams. Soils are moderately thin fine sandy loam, but there are few rock outcroppings that expose the underlying metamorphic marine deposits and granodiorite.

The viewable watershed for the Iowa Canyon Creek site is remarkably small for the size of the stream. Near the proposed diversion facilities, the 360 degree view is of a tightly constricted and narrow stream valley. Dense vegetation and steep slopes limit views to 100 to 200 feet at many points along the stream. Views are more distant near the access road to Slab Creek Dam, but even here the horizon is limited to about one-quarter mile. At the powerhouse, views are limited to no more than one-half mile by the narrow South Fork American River canyon, Slab Creek Dam, and the twisting course of the river.

The project reach of the stream extends from the diversion facility about 100 feet upstream from where the Slab Creek Dam access road crosses the stream to the confluence of Iowa Canyon Creek and the South Fork American River approximately one-half mile downstream. The powerhouse is to be located on the south bank of the South Fork American River about 30 feet above the river and about one-fourth mile downstream from Slab Creek Dam. Water passing through the powerhouse will be discharged into the South Fork and this will result in reduced flow in the lowest one-half mile of Iowa Canyon Creek.

Of the 6 projects studied, the Iowa Canyon Creek site is the only one that does not involve construction of a dam (Table 1). Diversion of a maximum of 25 cfs is to be accomplished by a network of walls and movable baffles that will not change substantially the existing channel configuration. Diverted streamflow will enter a 42-inch diameter corrugated culvert pipe which will follow the natural contour of the canyon slope for 1,500 feet. A 24-inch diameter penstock will transport the water through a descent of over 300 feet to the powerhouse about 30 feet above the channel of the South Fork American River. After passing through the powerhouse the water will be discharged into the South Fork American River.

Assessment of the pre-construction environment for the Iowa Canyon Creek project at the broad scale of the viewable watershed reveals ratings that are modest to low for each environmental element (Table 7). The highest rating is 64 for vegetation patterns. This rating is a reflection of the mixture of vegetation types present in the Sierra foothill transition zone and their tendency to occur without a strongly defined pattern. The 22 for evidence of human impact on the landscape is the lowest rating for an environmental element at this site, and it is the lowest rating for this element at any of the sites included in the study. The access road to Slab Creek Dam, power transmission lines from the dam, residential property, access roads and power transmission lines to residential property, and a variety of litter in the stream channel attest to a high level of human use for this area.

When focusing on the project reach of the stream, assessment of the environmental elements produces ratings that are slightly higher than those at the scale of the viewable watershed. The highest rating in this category is 72 for appearance of water (Table 7). Although this rating is appreciably lower than the rating assigned to this element for projects at higher elevations, it indicates that the water at this site is reasonably clear and inviting. The lowest rating of 31 for edge definition reflects the influence of dense vegetation along the stream channel in foothill locations and a tendency for Iowa Canyon Creek to have a weakly defined channel corridor with poorly developed visual continuity.

Evaluation of post-construction conditions at the viewable watershed scale for the Iowa Canyon Creek project indicates few changes in ratings (Table 7). The largest relative changes in ratings occur for the evidence of human impact elements which are among the lowest rated in the pre-construction environment. Although human effects are prominent for both the landscape and water elements, the proposed construction adds new components which have high visibility even at the broad scale of the viewable watershed (Figure 4) and the low ratings for pre-construction conditions are reduced further. The largest absolute change in a rating occurs for prominence of water which looses 16 points. The magnitude of the change in the rating for this element is a reflection of the diversion of water which reduces the size of the stream and reduces the visibility of water.

Table 7. Assessment of the Iowa Canyon Creek Site.

Environmental Element	Rating of Pre-Construction Environment	Rating of Simulated Post-Construction Environment
Viewable Watershed		
Boundary Definition	37	37
Features	30	28
Enclosure	61	61
Landform Delineation	52	52
Vegetation Patterns	64	61
Evidence of Human Impact on the Landscape	22	11
Prominence of Water	44	28
Continuity of Water	41	31
Evidence of Human Impact on Water	32	19
Subtotal	383	328
Ratio of Post- to Pre-Construction		0.856
Project Reach of the Stream		
Movement and Features of Water	57	50
Appearance of Water	72	64
Aquatic Environment	55	51
Evidence of Human Impact on Water	68	44
Edge Definition	31	30
Edge Features	32	26
Riparian Environment	66	60
Evidence of Human Impact on Shore	49	36
Subtotal	430	361
Ratio of Post- to Pre-Construction		0.840
Total	813	689
Composite Ratio		0.847

At the scale of the project reach of the stream, analysis of the post-construction images reveals a relatively consistent lowering of ratings by 4 to 8 points for most environmental elements (Table 7). The change in the rating for the 8 elements of 69 points represents a reduction of about 16 percent which is slightly greater than the change of 14 percent in the rating for elements at the broader scale of the viewable watershed.

The rather small changes in ratings are due largely to the low ratings for the pre-construction condition of the stream reach. The only changes outside this range are evidence of human impact on the water and the shore which incur reductions of 24 and 13 points, respectively. Flow reductions in the project reach exacerbates existing human influences and amplifies their visual affect so that the post-construction rating for this element drops from the second highest to the fourth lowest among the elements at this scale. On the shore, the diversion facilities and the pipeline add new features of human influence to the road, culvert, and fill that are strong indications of human modification in the pre-construction environment. This element is rated a relatively low 36 in the post-construction analysis.

COMPARISON OF SITE EVALUATIONS

The methodology employed in this study is designed to analyze site specific visual qualities before and after construction of small hydroelectric facilities. Ratings for the 17 selected environmental elements identify which elements make the greatest contribution and which make the least contribution to the total visual resource of the project site. Comparing pre-construction and post-construction scenic values and visual resources among the different sites is aided by summation of the ratings data (Table 8).

Under pre-construction conditions, the viewable watershed for Pyramid Creek has a visual quality that is distinctly greater than the other sites (Table 8). Its rating of 794 represents 88 percent of the possible 900 score. Rock Creek has the next highest rating of 75 percent of the maximum, but none of the other sites exceed 70 percent of the maximum rating for the viewable watershed. The visual quality of the viewable watershed for Iowa Canyon Creek is the lowest of the 6 study sites. The rating of 383 for Iowa Canyon Creek represents only 43 percent of the maximum rating and is explained largely by the prominence of intrusive human modifications and limited views at the site.

At the scale of the project reach of the stream, the same general pattern of ratings is apparent (Table 8). The numeric values at this scale are somewhat lower because the maximum score is 800 which reflects the rating of 8 environmental elements rather than the 9 evaluated in the viewable watershed. Pyramid Creek retains the distinction of having the highest rating for visual quality, but the percentage of the maximum rating at this scale is 5 percent lower than the rating for the viewable watershed. The rating for the Foottrail site is 28 points less than for Pyramid Creek, but this difference of about 3 percent is substantially smaller than the difference in visual quality for these sites at the scale of the viewable watershed. The smallest rating at this scale is 331 for Fry Creek. Such a low rating, equivalent to 41 percent of the maximum, indicates limited visual quality at this site.

Summing the ratings for scenic quality at the two scales provides the best single measure of the visual resource at each site. This index of visual quality combines ratings for expansive views with those focused on the impacted stream reach. On this basis, the scenic quality of the Pyramid Creek site is distinguished by its rating of 1,461 which represents 86 percent of the possible score (Table 8). Rock Creek, Foottrail, and Sayles Flat are grouped between 70 and 76 percent. These sites have substantial scenic value, but they lack the qualities associated with spectacular visual stimuli in the Sierra. The two lowest ranking sites, Fry Creek and Iowa Canyon Creek, have ratings that are less than 50 percent of the maximum which indicates that these locations have modest scenic quality for locations in the Sierra Nevada.

Post-construction ratings of scenic quality display only one variation in the ordering of the 6 study sites on the basis of visual resources. Pyramid Creek receives the highest rating of 1,214 and Fry Creek has the lowest rating of 659 or 39 percent of the maximum of 1,700 (Table 8). The difference in ratings occurs with the reversal of Foottrail and Rock Creek in the second and third positions. For post-construction conditions, the scenic quality of Foottrail is rated 1,104 while Rock Creek is 1,032. The greater change in visual quality at Rock Creek is due largely to a reduction of 160 points in the rating for the project reach of the stream while the rating for Foottrail at this scale is reduced by 80 points. Only the change at Pyramid Creek of 164 points for the project reach of the stream is greater than the reduction in scenic value at Rock Creek at the same scale.

Table 8. Comparative Ratings of the Study Sites.

Project Name	Pre-Construction	Ratio to Maximum	Post Construction	Ratio to Maximum
Pyramid Creek				
Viewable Watershed	794	0.882	711	0.790
Project Reach of the Stream	667	0.834	503	0.629
Total	1461	0.859	1214	0.714
Rock Creek				
Viewable Watershed	676	0.751	584	0.649
Project Reach of the Stream	608	0.750	448	0.560
Total	1284	0.755	1032	0.607
Foottrail Creek				
Viewable Watershed	591	0.657	545	0.606
Project Reach of the Stream	639	0.799	559	0.699
Total	1230	0.724	1104	0.649
Sayles Creek				
Viewable Watershed	622	0.691	554	0.616
Project Reach of the Stream	572	0.715	447	0.559
Total	1194	0.702	1001	0.589
Fry Creek				
Viewable Watershed	408	0.453	373	0.414
Project Reach of the Stream	331	0.414	286	0.358
Total	739	0.435	659	0.388
Iowa Canyon Creek				
Viewable Watershed	383	0.426	328	0.364
Project Reach of the Stream	430	0.538	361	0.451
Total	813	0.478	689	0.405

Greater insight concerning the change in scenic quality resulting from the construction of small hydroelectric facilities is provided by examination of the change in the total rating score for each site. The data in Table 8 reveal that the largest numeric change related to visual quality occurs at the Rock Creek site. The scenic quality of the post-construction environment is rated 252 points lower than the pre-construction environment at this site. This is equivalent to a reduction of nearly 20 percent based on the pre-construction rating of 1,284 (Table 8). The magnitude of the numeric change is nearly as large for the Pyramid Creek project, but the higher rating for the pre-construction environment at this site means that the 247 points represent a 17 percent reduction in visual quality (Table 8).

A number of factors account for the large reduction in visual quality at the Rock Creek site. This project involves the largest diversion of water among the six study sites and this has a significant impact on all the water elements contributing to scenic quality. All of the human modifications have high visibility due to the inability of the native vegetation to provide concealment. There is a general lack of prominent landscape features in the area and the eye is drawn to Rock Creek and then to the intrusive features related to the small hydroelectric project. Also, access to this site provides an elevated view upstream from the project while access to all of the other study sites is from below the proposed facilities. At Rock Creek, this has the effect of providing a full view of the project from many locations rather than the limited views common to the other sites. This array of influences, rather than the fact that this is the one site where construction is completed, is a sufficient basis for the magnitude of the change in visual quality inferred for this site.

At the other end of the scale, Foottrail and Fry Creek have small reductions in visual quality. The change at Foottrail is 126 points or about 10 percent of its pre-construction rating (Table 8). The small change at this project is attributed to the use of a tunnel rather than a penstock for transporting the diverted water, the presence of a dense vegetation canopy that screens access roads and other modifications, and the absence of elevated views for observing the site. For Fry Creek, the change is 80 points or about 11 percent of the pre-construction rating of scenic quality (Table 8). The small size of the pipeline, impoundment, and powerhouse for this project make it relatively easy for the dense vegetation to conceal their presence. Topography limits overviews of this site and access is from below the proposed facilities. The low pre-construction rating of scenic quality for this site may be an additional influence on the small magnitude of the reduction in visual resources expected to accompany construction of the proposed small hydropower facility.

DISCUSSION

Evaluation of the influence of small hydroelectric facilities on the visual resources of public lands in the Sierra Nevada requires a flexible approach. While some projects may not singly constitute major land use intrusions, others may significantly impair visual quality of the area. Therefore, a technique for evaluating the influence of small hydroelectric projects on scenic resources must be able to assess the impact of the project regardless of the scale, location, or type of construction. An additional constraint is that the technique must be simple and brief so that it can be applied by existing state and/or federal agency staff.

Small hydroelectric projects span a large range of site characteristics that are even broader than those illustrated by the 6 sites summarized in Table 1. However, one feature shared by these 6 sites is that none would operate for more than a few months each year. While some larger projects are designed to operate all year, probably the majority of projects in the Sierra Nevada are intended to be operational for 30 to 90 days during the spring or early summer (Lacey, 1985). This means that the influence of the physical facilities on the landscape will be present all year, but the influence of the small hydroelectric project on streamflow will be concentrated during one period. In addition, none of the facilities studied are designed to divert all of the streamflow while they are in operation. These factors demonstrate that a technique designed to evaluate the impact of small hydroelectric projects on visual resources must be robust enough to span a large range of conditions without sacrificing sensitivity to landscape differences.

NUMBER OF ENVIRONMENTAL ELEMENTS EVALUATED

There is little or no consensus concerning the number or nature of environmental elements necessary for adequately assessing visual quality (Arthur et al., 1977). The environmental elements selected for this study were drawn from a general list recommended by Litton et al. (1974). Selection was based on the pertinence of the element to moving water in the environment and scale constraints imposed by small hydroelectric projects. In particular, consideration was given to the relevance of an element to scenic quality associated with steep gradient streams on which small hydroelectric facilities are commonly located. Redundant or irrelevant items likely to cause misleading scenic evaluations at this scale were avoided. At the same time, care was taken to include items that would be sensitive to environmental differences at small hydropower sites.

Approximately 30 elements were field-tested at two locations to determine whether differences in visual quality were apparent at small hydropower sites. Seventeen elements were judged to be suitable as indicators of differences in the scenic quality of land and water for these settings on the basis of their inter-site score variations. These 17 environmental elements (Figure 2) were retained as the basis for the evaluation procedure. Subsequent use of the 17 elements in evaluating the 6 study sites supports their selection. Although too little data are available for comprehensive statistical testing, examination of the scores in Tables 2 to 7 demonstrates that these elements perform well in conveying diversity in the visual quality of the landscape.

For the pre-construction assessment, 10 of the 17 elements display a range of scores that exceeds 50 points. The greatest difference of 87 points is for movement and features of water at the scale of the project reach of the stream. This element is rated as 99 for Pyramid Creek (Table 2) on the basis of the extreme visibility of water in the landscape and the extraordinary beauty of water cascading down the granitic slopes. In contrast, this element is given a score of 12 at Fry Creek (Table 6) where the stream channel and water are nearly invisible components of the landscape.

The three smallest score ranges are for elements in the project reach of the stream as well. Two of these elements are human impact indicators which have score ranges of about 30 points each. Riparian environment displays a difference of only 14 points. This small variation among the 6 sites suggests that additional study of this element's contribution to the evaluation procedure may be necessary. Intuitively, the riparian environment is a significant landscape element, but its contribution to the visual resource may be incorporated in such elements as edge definition and edge features. Elimination of riparian environment as a separate element would not alter materially the assessment of the pre-construction environment at the 6 sites. However, the contribution of the riparian environment as an element in assessing the post-construction environment is a more complex matter. For post-construction conditions, scores for riparian environment range from 74 at Foottrail to 50 at Pyramid Creek, and these scores make a more substantial contribution to the assessment of the 6 sites.

These results support retention of the riparian environment in the evaluation procedure, but additional specification of the criteria for this element might improve its capacity to identify variations in this element. Of course, it must be recognized that the small range of values in the pre-construction assessment may reflect an unusually small variation in riparian environments among the 6 sites. Assessments of more sites are needed to provide a definitive answer to this question, but careful reexamination of the site evaluations in this study suggests that the small range of values reflects the true nature of the riparian environment at these locations.

THE SINGLE OBSERVER

The single evaluator approach employed in this study is consistent with the staffing capabilities of most public agencies involved with small hydroelectric projects. Evaluation of small hydropower sites is a frequently occurring task due to the number of license applications on file. Public agencies typically assign such high frequency tasks to one or two individuals rather than to a team of five or six evaluators (Feimer et al., 1979). Thus, the most practical approach is a technique employing a single evaluator. Such an evaluation tool has the further advantage that it is available to the license applicant who can use it in developing the design characteristics of the project.

The reliability of judgements rendered by a single evaluator are an obvious concern. Feimer et al. (1979) suggest that intra-observer reliability can be achieved by the observer visiting a site more than once. In this study, the evaluator visited each site more than 10 times in order to achieve reliability and to observe seasonal changes at the sites.

To provide an additional test of the reliability of the single observer's evaluations, assessments by three individuals not used in the control group testing during the early stages of the study were conducted for the Pyramid Creek site. Each evaluator was experienced in landscape evaluation and was familiar with the Sierra Nevada and Pyramid Creek. The on-site visit occurred in the fall when streamflow was a minimum. Table 9 contains the mean and standard deviation for each environmental element as rated by the three evaluators, and the scores assigned by the individual evaluator.

The ratings by the individual evaluator are very close to the mean of the ratings assigned by the group for each of the environmental elements. Scores for 6 of the 17 environmental elements are different by a value of 2 only. Nine of the 17 elements are different by a score of 5 or less points, and 13 are different by 8 or less points. Therefore, the majority of the environmental elements are rated by the single evaluator within a range of plus or minus 10 percent.

Two of the larger differences are 12 points for prominence of water at the scale of the viewable watershed and 14 points for movement and features of water at the scale of the project reach of the stream. These differences, of 13 and 14 percent respectively, are very likely related to the low streamflow at the time of the site visit by the three evaluators. Even though they were familiar with the appearance of Pyramid Creek during times of higher flow, the lower scores assigned for these two water related features suggest a strong influence from the low flow they observed during the evaluation visit. In fact, these differences in scores support the original research design which includes repeat visits to a site to avoid exactly this occurrence of a rating being overly influenced by a specific seasonal condition.

Evidence of human impact on water in the project reach of the stream was rated 11 points higher by the three evaluators than by the single observer. The difference of about 13 percent appears to be due largely to the low flow at the time of the evaluation by the three and the fact that during this time of the year human use of the area is a minimum. This latter point is illustrated by the fact that on the day when the three evaluators were at the Pyramid Creek site they were the only people present in the vicinity of the stream. Under these circumstances, there are more limited indications of human alteration to streamflow and less evidence of human influences on water quality which would lower the rating for this environmental element.

Table 9. Comparison of Ratings for the Pyramid Creek Site.

Environmental Element	Rating by Single Observer	Mean Rating by Three Rating Observers	Std. Dev. of by Three Observers
Viewable Watershed			
Boundary Definition	96	94	4.51
Features	98	90	8.66
Enclosure	90	87	2.89
Landform Delineation	97	80	9.07
Vegetation Patterns	67	75	4.99
Evidence of Human Impact on the Landscape	98	91	5.13
Prominence of Water	93	81	9.64
Continuity of Water	71	69	10.02
Evidence of Human Impact on Water	84	82	7.64
Subtotal	794	749	
Project Reach of the Stream			
Movement and Features of Water	99	85	12.71
Appearance of Water	93	88	2.89
Aquatic Environment	93	91	6.56
Evidence of Human Impact on Water	70	81	7.94
Edge Definition	88	86	3.21
Edge Features	78	80	10.01
Riparian Environment	69	72	10.58
Evidence of Human Impact on Shore	77	85	4.62
Subtotal	667	667	
Total	1461	1416	

The 17 point difference for landform delineation was the largest variation between the single observer and the group rating. All 3 of the evaluators in the test group rated this element lower than the single observer. A post-test critique of the evaluation technique with the group participants suggested that the difference in scores for this environmental element may be attributable to the individual weighting given to the summation of the 360 degree views of the watershed. The last observations by the group evaluators were made along the lowest reach of Pyramid Creek where landform delineation is the least specific. On the basis of a single evaluation visit, the image of the lower watershed may have been excessively influential in the scores assigned by each of the group evaluators. The rating assigned to this element by the single observer was the composite of numerous visits and the summation of repeated 360 degree views from all parts of the watershed. The result of the repeated evaluation visits by the individual observer may have been to diminish the visual influence of the lower stream reach.

The group evaluation of the Pyramid Creek site and the earlier tests of individual evaluations at other sites both indicate that the single observer's ratings are reliable within a range of plus or minus 10 percent. Additional tests at other small hydroelectric sites are desirable to enlarge the data base and to provide a stronger statistical basis for evaluation. However, such testing is expected to support the results reported here. There is no evidence in the two test situations already conducted to suggest that a larger range of reliability is likely to be revealed by additional testing.

IDENTIFYING SCENIC DIFFERENCES

Numeric values for individual environmental elements and for the sum of the elements at the designated scales are a straightforward expression of visual quality that is easily understood and inherently correlative. For example, an environmental element that receives a score of 95 in pre-construction evaluation indicates extreme visual quality that is judged to be higher than 95 percent of its regional counterparts. Summations for the viewable watershed, the project reach of the stream, or the combination of the these two landscape units representing 85 percent or more of the maximum score signify a generalized sense of high visual quality that extends beyond a single environmental element. Conversely, a rating of 20 for an environmental element indicates that the visual quality being assessed is judged superior to about 20 percent of its regional counterparts. In the summation of ratings for individual environmental elements, totals representing less than 50 percent of the maximum score indicate that low visual quality is not confined to an individual environmental element but is a general characteristic of the setting.

Evaluation of numerous proposed small hydroelectric sites is needed to provide a suitable data base for statistical inference. For the present, the evaluation of the 6 sites in this study provides a first approximation of the range of values that might be encountered. In this context, the methodology indicates that ratings of the visual quality of small streams can distinguish various levels of scenic value, and settings with high visual quality and low scenic value can be identified. This is accomplished at several steps in the analysis, but the simplest illustration is provided by the ratio of the sum of the ratings of the environmental elements to the maximum possible rating. From these data it is apparent that the visual quality of the Pyramid Creek site is judged superior to all but a small percentage of comparable stream settings in the Sierra Nevada. This is especially true at the scale of the viewable watershed where 6 of the 9 environmental elements are rated at 90 or higher (Table 2).

On the other end of the continuum, Iowa Canyon Creek and Fry Creek are judged to have visual resources that are exceeded by a substantial number of stream settings in the Sierra Nevada. The visual quality at both sites is rated below 50 percent of the maximum rating of 1,700 (Table 8). The mean rating of the 17 environmental elements for Iowa Canyon Creek is 48, while Fry Creek has 5 environmental elements with a visual quality rating of 20 or less (Table 6). The implication is that the visual quality of these sites is modest.

Examination of both the composite scores and the scores for individual environmental elements indicates the need for considering the influence of small hydroelectric facilities on visual quality from two different perspectives. The pre-construction scenic value of a site, such as Pyramid Creek, may be so high that it has singular value as a visual resource and a low tolerance for any reduction. Even minor alterations of such sites are an issue. On the other hand, proposed development may produce a large reduction in scenic quality which is unacceptable even when the stream's original visual resource is more common place. The evaluation procedure employed in this study offers a procedure for identifying both conditions.

A stream reach with visual quality ratings of 90 or above on most of the water related environmental elements is a stream with particularly high scenic quality. Streams with these qualities can be expected to have a total score exceeding 80 percent of the maximum or above which clearly identifies an important scenic resource. Such sites are in the top 20 percent of the small stream environments in the Sierra Nevada. A case can be made for protecting these sites from development because the streams may experience especially high reductions in scenic value due to water diversions. At the very least, a scenic value score of 80 percent or above identifies a site where particular care is recommended in considering the influence of a small hydroelectric facility.

Even streams with less spectacular visual resources should not be subjected to large reductions in scenic quantity due to the construction of a small hydroelectric facility. This represents a second perspective addressed by the assessment procedure. For example, the visual quality of Rock Creek (Table 8) decreased nearly 20 percent as a result of the construction of the small hydropower facility. This is an excessively high reduction in visual quality largely due to the prominence of human impact on the land and water. By detailing the magnitude of changes in visual quality, the assessment procedure is able to identify locations where construction is likely to result in a large reduction in the scenic resource.

PORTRAYING POST-CONSTRUCTION CONDITIONS

Computer simulation of the small hydroelectric facilities permits evaluation of the project impact by providing a visual representation of the human modifications. In this way, the visual quality of the simulated post-construction environment can be assessed in the same quantitative terms as the scenic quality of the pre-construction environment. The computer simulation provides the additional benefit of affording the opportunity to assess the visual consequences of a variety of facility design options prior to construction. This accomplishment is possible due to the use of computer simulation of the project facilities and landscape changes and the numeric evaluation of the post-construction condition. In this way, different ideas can be tested to identify the design most likely to minimize the decline in visual quality.

The magnitude of the change in visual quality associated with construction of the small hydroelectric project is conveyed clearly by comparing the pre-construction and post-construction ratings for the 6 sites studied (Table 8). The visual quality for the Pyramid Creek, Rock Creek, Foottrail, and Sayles Flat sites is rated at 70 percent or more of the maximum for the pre-construction environment. For the post-construction environment, only the Pyramid Creek site is given a visual quality rating above 70 percent. At Pyramid Creek and Sayles Flat, penstocks on or above the surface become prominent landscape features and replace the project reach of the stream as the primary focal attraction. The access road to the powerhouse at the Rock Creek site is a major intrusive feature that competes with the affected stream reach for viewer attention. The diminished role of water in the landscape accounts for much of the loss in visual quality at Foottrail.

At the 6 sites considered in this study, 3 environmental elements sustain average losses in visual quality of 17 points or more with the simulated post-construction features in place. The visual quality of these 3 elements, human impact on water, movement and features of water, and aquatic environment, is reduced in response to the low flows in the project reach of the stream. For most small hydroelectric projects, the access roads, powerhouses, and other physical components constructed on the land, except for pipelines and penstocks which are sometimes buried, can be concealed satisfactorily with vegetation or through environmentally sensitive construction designs. The stream channel, however, remains highly visible. There are no mitigation options for restoring scenic quality to a stream reach with unseasonably reduced flows.

If regulatory agencies determine that the identified changes in visual quality are unacceptable, design changes or other mitigating strategies could be undertaken. The computer simulation provides a convenient method of testing alternative project designs. In the case of Rock Creek, where construction of the facility is completed, an innovative approach may be required to screen the access road and powerhouse to lessen their visual impact. A smaller diversion at the Foottrail site could improve significantly the extent to which the scenic quality of water related elements at this site is altered by the proposed project. Mitigating strategies for Pyramid Creek and Sayles Flat may be more difficult to define due to the nature of the environmental setting of these proposed projects. Consequently, these sites represent projects where consideration of the desirability of retaining the scenic resource should receive high priority.

INTERPRETATION OF CHANGES IN SCENIC QUALITY

An important part of assessing the impact of small hydroelectric facilities on the scenic resource is recognizing when the magnitude of change in visual quality is significant. The technique employed in the present study offers two perspectives for judging significant change. The composite scores in Table 8 provide an indication of the overall extent of the change in visual quality, but these scores mask potentially important impacts on individual elements. The composite scores are useful as a general index of the significance of the change in visual quality. A reduction of 15 percent or more in the composite score is an indication that a significant change in individual elements is likely. Composite score changes of less than 15 percent represent an array of conditions which may or may not signal a significant change in the visual resource.

Change in the visual quality of each environmental element must be considered to evaluate the importance of modifications in the scenic resource. In this evaluation, the original rating of the environmental element is important, but the magnitude of change due to construction of the small hydroelectric facility is equally important. The need for this dual perspective is illustrated clearly by the evaluations for the Pyramid Creek, Fry Creek, and Foottrail sites.

The visual resource of the Pyramid Creek site places it in the top 15 percent of small streams in the Sierra Nevada. The proposed small hydroelectric facility will reduce the scenic value of the watershed by about 17 percent (Table

8). This is an large loss of scenic quality for such a highly rated resource. In addition, examination of the change in individual environmental elements (Table 2) reveals that much of the loss in visual quality is occurring at the expense of a few elements which are clearly outstanding scenic resources. For example, movement and features of water is rated as being in the top 1 percent of comparable streams, but it is reduced 63 percent by the proposed construction. It could be argued, however, that even a reduction of 10 percent in this element for Pyramid Creek would be undesirable due to the high visual quality it represents. Similar cases could be made for the changes in prominence of water and aquatic environment for Pyramid Creek (Table 2). For each of these elements, the change in visual quality represents too great a loss in the quality of a valued resource. The conclusion is that the changes at Pyramid Creek represent a significant loss of scenic quality.

The visual quality of the pre-construction environment at the Fry Creek site is in the lowest 45 percent of streams in the Sierra Nevada (Table 8). Construction at this site is expected to reduce visual quality by about 11 percent. While this is somewhat less than the 17 percent reduction at Pyramid Creek, the actual changes in the environmental elements are significantly different due to the overall higher scenic quality of the Pyramid Creek site. The highest rated element for Fry Creek is a 77 for evidence of human impact on the landscape, but this element is reduced by 12 percent only. The largest change is a 55 percent reduction in prominence of water. However, the pre-construction rating for this element is 11 which means that its visual quality is exceeded by nearly 90 percent of the small streams in the Sierra Nevada. The large percentage reduction in a low rated element does not represent a loss of comparable significance to the case where the environmental element is rated among the highest visual qualities in the region. Although environmental elements that would benefit from additional design considerations are identified by the assessment, the post-construction environment at Fry Creek would not represent a significant reduction in visual quality.

The Foottrail site illustrates visual quality characteristics that may be common for many streams. The pre-construction scenic resource has an overall rating of 72 percent and the post-construction environment a rating of about 10 percent less (Table 8). Visual quality is exceeded by about 30 percent of the small streams in the Sierra Nevada and the loss of scenic value due to the small hydroelectric facility is modest. However, examination of the ratings for the individual environmental elements (Table 4) reveals that the majority of the change is concentrated in a small number of the elements. At the scale of the viewable watershed, continuity of water has a pre-construction rating of 86 and its post-construction rating is 23 percent lower. In the project reach of the stream, the pre-construction rating for aquatic environment is 92 and the post-construction value is 24 percent lower. Both of these conditions represent unacceptably high reductions in visual quality. Therefore, even though the overall change in visual quality of 10 percent at the Foottrail site appears to be relatively minor, alterations in the visual quality of individual elements is significant. The Foottrail data clearly illustrate that the summation process may mask important changes in individual elements. Consequently, the final decision on the significance of the post-construction change in visual quality must focus on the initial rating of each environmental element and the magnitude of the change in the element.

CONCLUSIONS

Although high scenic quality is often cited as a central motive in preserving stream environments, the ambiguous nature of beauty has made it difficult to incorporate visual resources into the decision-making framework. Visual analysis techniques provide a rational means of indicating aesthetic value, but most resource management decisions are complex and require understanding of the implications of various management activities on scenic resources. The evaluation system presented in this study employs a format wherein visual resources are assessed and summarized numerically. In this way, small hydroelectric sites can be analyzed systematically and their scenic quality compared to other sites.

Evaluation by a single observer is responsive to the needs of agencies reviewing small hydropower license and permit applications. This approach emphasizes knowledge of landscape issues and familiarity with regional resources which are important components in the decision process. Reliability of single observer evaluations has been shown by comparison with ratings by other evaluators and a team of 3 evaluators. Multiple visits to small hydropower sites have been used to achieve intra-observer reliability.

Computer enhanced images of post-construction conditions are an especially attractive feature of the assessment procedure used in this study. Such images cannot capture all of the qualities of the real landscape, but they provide a useful visual representation of the landscape after construction of small hydropower facilities. The value of this approach is that the evaluation can be accomplished prior to construction of the project. The quantification procedure and the computer simulation make it possible to assess the post-construction landscape in the same way as the pre-construction setting. Because of differences in the visual stimuli of a real landscape and a computer image, the post-construction ratings in this study may undervalue the actual differences between pre- and post-construction conditions. This possibility will be examined in the future by conducting on-site evaluations of projects as they are constructed and comparing the results of these new surveys with the evaluations based on computer images. Such research will have the further advantage of providing insights which may contribute to the formulation of specific guidelines for analysis of the computer images. Construction of the Sayles Flat project is completed, and resurvey of this site will be undertaken first.

Additional refinements to the evaluation procedure will support expansion of its application. None of the sites in the present study are operated all year or divert the entire flow of the stream. The assessment technique can accommodate both of these circumstances, but sites with these characteristics should be studied to verify the procedural integrity of the technique. Especially in those instances when the facility is operated all year, incorporation of long-term changes in some environmental elements, such as riparian environment (Taylor, 1982), will be necessary. Of course, evaluation of additional small hydroelectric sites by the single observer and by a control group will provide an improved data base for testing the reliability of the single observer used in this study and other individuals selected to perform assessments of small hydroelectric facilities.

Comparative evaluations of the visual resource at proposed small hydroelectric sites can play an important role in the decision process concerning the development of these projects. Small hydropower projects at sites offering unusually high visual stimuli can be identified as well as projects that will not intrude on a singular scenic resource. Such information can help guide regulatory agencies in decisions to grant or deny a license application. In addition, the evaluation procedure can be useful for revealing the features of a project responsible for an undesirable visual impact before construction of the project is begun. Both the assessment scores and graphic presentation of the computer simulations can be submitted to regulatory bodies to assist them in the decision process. Alteration of the project design to avoid visual conflict can be demonstrated with the computer simulations or different mitigation strategies can be tested to determine the best method for minimizing the reduction in visual quality.

Development of small hydroelectric projects in the Sierra Nevada has increased concern for the relative scarcity of free-flowing streams which may be so few in number that their diversion for hydroelectric generation can no longer be considered development of a renewable resource (California Office of the Attorney General, 1985). Indeed, the value of free-flowing streams as scenic and recreation resources is amplified and the need for assessing the scenic quality of these streams increases as their number diminishes.

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