GUIDELINES FOR REVIEW OF ENVIRONMENTAL IMPACT STATEMENTS

VOLUME IV

CHANNELIZATION PROJECTS

U.S. ENVIRONMENTAL PROTECTION AGENCY

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FINAL REPORT

GUIDELINES FOR REVIEW OF ENVIRONMENTAL IMPACT STATEMENTS

VOLUME IV

CHANNELIZATION PROJECTS

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U.S. Environmental Protection Agency
Office of Federal Activities
4th and M Streets, S.W.
Washington, D.C. 20460
Attn: Mr. William Dickerson
Project Officer

Submitted by:

Curran Associates, Inc.
Engineers and Planners
182 Main Street
Northampton, Massachusetts 01060

PREFACE

This volume presents detailed guidance for the assessment of the primary impacts of channelization projects.

In its current form, this volume is intended to serve as a supplement to the Environmental Protection Agency's 309 Review Manual and existing assessment techniques related to water resources projects. In toto, these documents provide the detailed framework for the Environmental Protection Agency's review of channelization project environmental impact statements.

As additional or refined review techniques and assessment procedures become available, this document will be reisssued or revised as necessary. Note, however, that only the numbered copies are on the distribution list for revised materials.

Comments and suggestions regarding this document should be directed to the attention of the Director, Office of Federal Activities (A-104), Environmental Protection Agency, Washington, D.C. 20460.

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I. INTRODUCTION

The development of water resources continues at a high level in response to the need for flood control, drainage, irrigation, navigation, and other purposes. Federal and federally assisted channel modification projects to meet these needs have, since the early 1940's, involved the planning for and development of 34,240 miles of waterways.[1] Many of the projects have not yet been constructed and are presently in various stages of planning, design, and implementation. Concurrently, pressures for conservation and preservation have been increasing because of concerns for the ecological, historical, aesthetic, and recreational values of our natural resources. There is also a growing awareness that these resources are rapidly being lost to development of all kinds. Channelization projects often engender conflicts between development and preservation interests, in that the commitments of freely flowing streams, adjacent wetlands, and riparian areas to ecological change may be long-lasting and in some cases irreversible.* From an ecological standpoint, the worst thing that can happen to a stream is impoundment, and the second worst thing is channelization.[2] The range of possible impacts is very broad. Total numbers, weight, and average size of fish in channelized reaches of Missouri's Blackwater River are known to have been drastically reduced in comparison with unchannelized portions of the stream. Seemingly inconsequential shifts in benthic species composition that accompany channel construction may ultimately have major repercussions throughout higher trophic levels. Terrestrial ecosystems can be equally vulnerable to damage, either directly or indirectly, from channelization. Channelization in the Caw Caw Swamp in North Carolina virtually eliminated the watershed's wetlands, and with them the cypress trees, furbearers, waterfowl, and other swamp biota, because of rapid drainage afforded by the pipe and channel network. Although dramatic ecological changes usually receive the greatest attention, similar impacts of varying severity are likely to occur as a result of all channelization projects. A <u>complete</u> assessment of resource commitments in terms of natural stream, land, and alteration of riverine ecology is thus essential for weighing the benefits of channelization against the project's impacts.

Often the basic question of whether a given channelization project should proceed at all sparks the most controversy and cannot be adequately answered using traditional methods of analyzing benefits and costs. Intangible costs, relating to the maintenance of environmental values, take on greater significance as the supply of the affected resources declines. Natural streams are being altered and impacted not only by channelization projects but also

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*The term "channelization projects" in this document includes most stream modifications from the largest to the small watershed work type, but does not focus in depth on creation of completely new canals where no stream existed previously, as in areawide irrigation projects.

by impoundments, highways, bridges, development of flood plains, introduction of wastewater effluents, and a host of other influences. The weighing of impacts that involve long-term resource commitments needs to be examined very carefully in the context of overall environmental goals and objectives, with consideration given to other land and water resource development activities expected to occur during the planning period for a channelization project. Planning must also be conducted relative to the fate of the project after its useful economic or structural life ends. It is clear, for example, that some channels constructed decades ago and since abandoned still exhibit the effects of channelization in significantly reduced populations of fish and other aquatic organisms. The abandonment, dismantling, or continued maintenance of a channel should be consistent with environmental safeguards used during project construction and operation.

EPA's involvement in the channelization development process stems from the mandates of the Federal Water Pollution Control Act (FWPCA), as amended, the National Environmental Policy Act (NEPA) of 1969 and the Clean Air Act Amendments of 1970.*

Under the FWPCA, EPA has authority and responsibility for effecting national water quality goals specified by the law. In particular, channelization projects may affect EPA authority under Sections 208, 303, 313, 402, and 404 of the FWPCA. The relationship of channels to these sections of the FWPCA is addressed in more detail below.

In view of the legal jurisdiction of, and special expertise within EPA, Section 102(2) (C) of the NEPA obligates Federal agencies to obtain comments from EPA wherever an action related to air or water quality, noise abatement, solid waste management, generally applicable environmental radiation criteria and standards, or other provisions of the authority of EPA are involved. Section 309 of the Clean Air Act Amendments of 1970 gives EPA the explicit legal mandate to comment in writing on the environmental impact of any matter relating to EPA's duties and responsibilities. To implement these responsibilities, the EPA manual <u>Review of Federal Actions Impacting the Environment</u>[3] (hereafter referred to as the "309 Review Manual" has established detailed policies, responsibilities, and administrative procedures for the Agency's review of Federal actions impacting the environment. This manual provides that, where an environmental impact statement (EIS)

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*A listing of other relevant legislation, Executive Orders, and Office of Management and Budget circulars and bulletins may be found in <u>Basic Documents Concerning Federal Programs to Control Environmental Pollution From Federal Government Activities</u>, U.S. EPA, Office of Federal Activities, February 1975.

has been sent to EPA for comment, EPA's comments on the EIS shall also constitute its comments for purposes of the Section 309 review. Furthermore, it is EPA policy to use the Section 309 process in conjunction with EPA's other authorities to: (a) provide technical assistance to Federal, State, regional, and local governmental entities; (b) assist the environmentally-related activities of EPA and other Federal, State, regional, and local entities; and (c) assist Federal agencies in meeting the objectives of the National Environmental Policy Act.

Because the 309 Review Manual does not provide guidance for applying the Section 309 review process to specific types of projects, the Office of Federal Activities, in conjunction with the EPA program and regional offices, has prepared a series of detailed review guidelines for several major project categories. As one of the documents in that series, this guideline provides detailed information for applying the EPA EIS review process to channelization projects. Figure I-1 illustrates the 309 review process Chapters II and III of this guideline expand the manual's guidance for implementing the EPA policy described above. Chapter IV supplements the manual by providing a synthesis of the possible hydrological, water quality, aquatic and terrestrial ecology, and other impacts associated with channelization projects. Information on the analysis and assessment of such impacts is also presented. Finally, a detailed bibliography is provided to permit the reviewer to explore specific problem areas in greater depth.

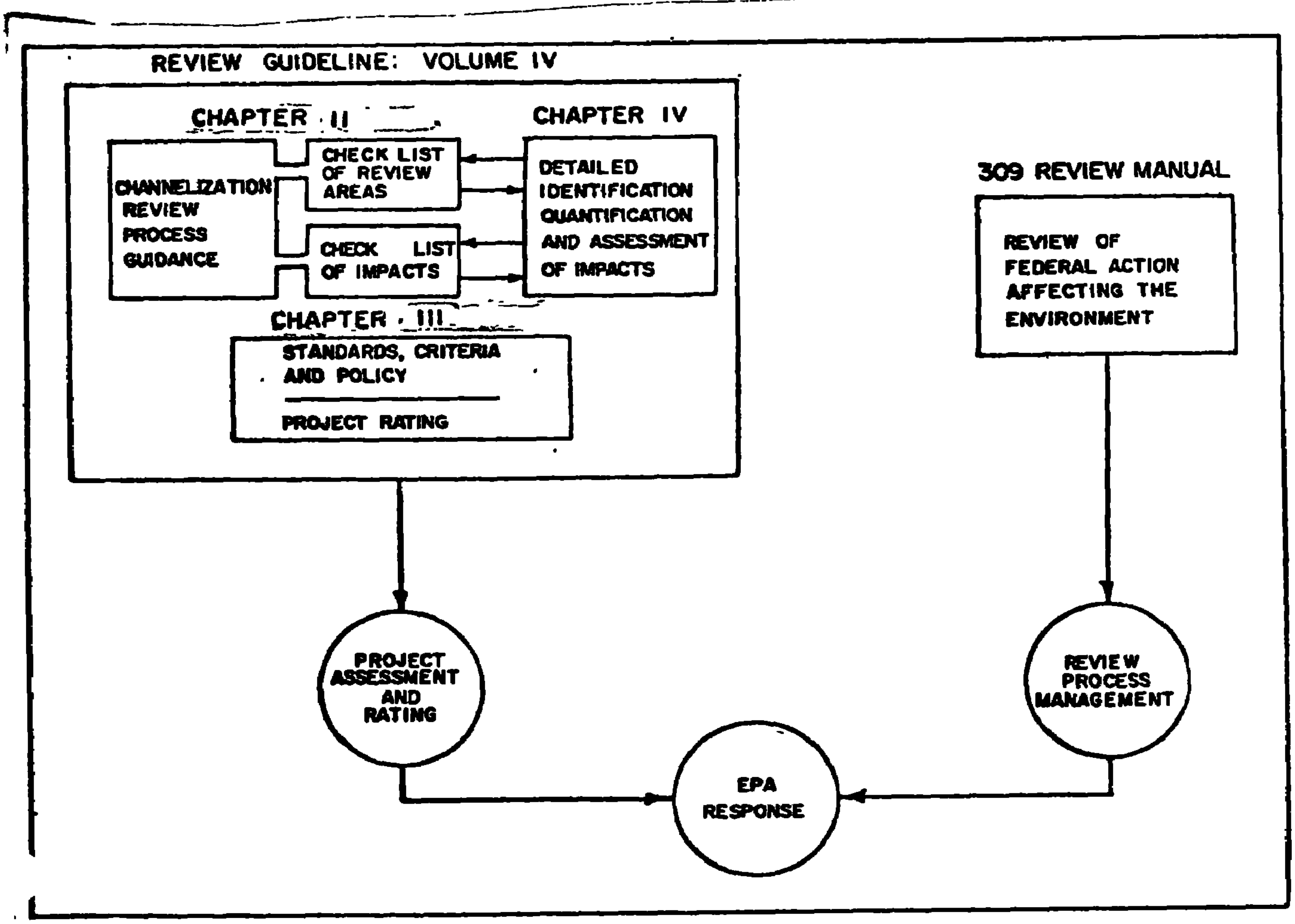


Figure I-1. Channelization Review Process

REFERENCES -- CHAPTER I

1. Arthur D. Little, Inc. and Philadelphia Academy of Natural Sciences, Report on Channel Modifications, Volume I, submitted to the Council on Environmental Quality, U.S. Government Printing Office, March 1973, p. 1.

2. Funk, J. L. and C. E. Ruhr, "Stream Channelization in the Midwest," E. Schneberger and J. L. Funk, eds., Stream Channelization: A Symposium, American Fisheries Society Special Publication No. 2, 1971.

3. U.S. Environmental Protection Agency, Review of Federal Actions Impacting the Environment, Transmittal, March 1, 1975.

II. CHANNELIZATION PROJECT REVIEW

As described in the 309 Review Manual, the EPA EIS review process consists of pre-EIS activities, review of Draft EIS's, pre-final EIS liaison, review of Final EIS's, and post EIS follow-up. Guidance for the review of channelization projects is given in the following subsections in terms of these five review phases. While it is recognized that unique situations within each region may dictate emphasis on one phase over another, all phases of the review process should be conducted to the fullest extent of the region's resources. In any case, it should be kept in mind that the goal of the review process is to maximize the effectiveness of the EPA involvement in channelization projects. Generally, this is accomplished when the EPA involvement: (1) reflects the total environmental responsibilities of EPA, especially in those cases where the basic nature of the EIS indicates a need for a coordinated multi-program response; (2) is part of a continued working relationship with the originating agency to assist in improving their project planning and design processes; (3) focuses sharply on environmentally unsatisfactory actions; (4) lends EPA support to projects having beneficial impacts on the environment; and (5) providing federal agency officials background material for use in developing an EIS; (6) review EIS pre draft program files for previous projects of a similar nature (noting any changes in EPA's positions).

II.A. Pre-EIS Activity

"Pre-EIS activity" is a generic term which includes pre-EIS coordination within EPA as well as coordination and information exchanges with Federal, State, and local agencies responsible for project planning or licensing. Pre-EIS activity within EPA involves the coordination of EIS review with other EPA actions which may affect the impoundment project, such as discharge permits (NPDES), review of 404 permits, non-point source management under Sections 208 and 303, Federal facilities pollution control under Section 313, flow augmentation determinations under Section 102(b)(3), and sole-source aquifer determinations under Section 1424(e) of the Safe Drinking Water Act of 1974. Additionally, EPA positions expressed previously on the project or project site, as might be contained in reviews of earlier EIS's, Congressional correspondence, or other agency statements, must be considered in developing a consistent EPA position.

External pre-EIS activity includes a wide range of activities outlined in the 309 Review Manual: (1) review of an applicant's environmental report or agency pre-draft EIS; (2) review of negative declarations; (3) participation at agency meetings involving the project; (4) substantive discussions with agency officials responsible for a proposed action (with emphasis on alternatives and/or mitigation measures); (5) review of basin plans (Level B studies); (6) site visits. In order to fully realize such opportunities for pre-EIS liaison it is important that EIS Coordinators maintain frequent and regular contact with appropriate field agencies. EIS Coordinators should understand planning processes and associated outputs that might be useful in determining an early environmental assessment of developing projects. Brief descriptions of the planning processes of the Corps of Engineers, the Soil Conservation Service, the Water Resources Council, the River Basin Commissions, and the Fish and Wildlife Service may be found in the Appendix to Volume III, Impoundment Projects, of the EIS Review Guidelines Series.

Pre-EIS liaison with Federal agencies may also be formalized through (1) a memorandum of understanding or (2) through protocols developed by the Federal agency. A memorandum of understanding, such as that developed with the Nuclear Regulatory Commission (NRC) contains provisions for joint preparation of an EIS for projects requiring an NRC license and a new source NPDES permit from EPA. Under such an MOU, EPA bears responsibilities both as an EIS preparer (as issuer of the new source permit) and EIS reviewer (of the EIS on NRC's licensing action). In order to ensure an even-handed and consistent EPA approach in discharging these duties, the MOU establishes procedures requiring close coordination between the agencies at the EIS preparation stage. This specialized form of pre-EIS liaison is necessary in those circumstances in which EPA is involved in granting a permit to a facility that is being licensed by another Federal agency. MOU's analogous to that between EPA and NRC will probably be developed with the a number of other agencies in the near future.

A more general type of arrangement is the pre-EIS protocol established by the Soil Conservation Service. In the early stages of planning, the SCS writes to EPA's regional offices to seek consultation on matters within EPA's area of responsibility and special expertise (see section 650.10(a) (6) of the SCS NEPA regulations). It is the responsibility of the EIS coordinator to ensure that the region is responsive to the SCS request for technical assistance as the planning process is initiated.

Pre-EIS activity is extremely important in preventing potential environmental problems from being realized. It is at the very early pre-EIS stages of project development that environmental problems are most susceptible to EPA-recommended mitigation measures. Similarly, the consideration of project alternatives is most practical when done before any single alternative becomes entrenched in the minds of project planners. The EIS review function is one of the few Agency programs by which EPA practices prevention, rather than abatement, of environmental problems. To secure the greatest benefit from this program, effective pre-EIS liaison is essential.

II.B. Review of Draft EIS

EPA's purpose in review of EIS's is to ensure that proposed

Federal actions are carried forth in a manner consistent with the attainment of national environmental goals and policies. The Administrator has specific responsibilities under Section 309 of the Clean Air Act to review proposed Federal actions and, if he determines any such action to be unsatisfactory from the standpoint of public health, welfare, or environmental quality, to publish his determination and refer the matter to the Council on Environmental Quality.

In order to carry out these objectives, it is essential that the EPA reviewer assess the impacts related to air, water, noise, solid waste management, and other environmental areas within EPA's jurisdiction. Review of the EIS should indicate whether that document adequately identifies, quantifies, and evaluates the impacts associated with the proposed project and various alternatives to it.

The effective assessment of the environmental impacts of a proposed channelization project must begin with an understanding of the project setting, as described by appropriate physical, chemical, and biological parameters, and the changes in those parameters that would be induced by the project. Beyond that point, the effective assessment must describe the interdependencies and cause-and-effect relationships among these parameter changes which will bring into focus the environmental setting of the channelized stream. The effective assessment allows the reader to compare alternative environmental settings -- "with-and-without" the channelization project, and other intermediate alternatives that will effect project purposes with lesser amounts of environmental damage than channelization.

The first task of EPA's EIS reviewer is to determine if the EIS provides the effective assessment described in the paragraph above. The reviewer should consider both the material presented in the EIS and the material presented in reference documents. According to the Council on Environmental Quality (CEQ) guidelines for preparation of impact statements[1], "Highly technical and specialized analyses and data should be avoided in the body of the draft impact statement. Such materials should be attached as appendices or footnoted with adequate bibliographic references." In what follows, then, the term "EIS" is used in the generic sense of "EIS and referenced technical documents," provided that, first, the EIS contains adequate summaries of the methodologies and results of the various technical analyses, and, second, the detailed reports describing these methodologies and results are available.

The reviewer should note that the foregoing does not preclude the requirement that the EIS itself should contain sufficient "information, summary technical data, and maps and diagrams, where relevant, adequate to permit an assessment of potential environmental impact by commenting agencies and the public."[1]

A systematic review procedure is necessary to insure that all significant primary impacts have been considered and that the assessments of the types of impacts can be combined into a single assessment of the project. The CEQ Guidelines (1500.8) have defined the major analysis categories to be included in an EIS:

(1) Project description;

(2) Relationship to land use plans, policies, and controls for the affected area;

(3) Probable impact of the project;

(4) Alternatives to the project;

(5) Probable adverse impacts which cannot be avoided;

(6) Relationship between local short-term use of man's environment and the maintenance and enhancement of long-term productivity;

(7) Irreversible or irretrievable commitments of resources;

(8) Other interests and consideration of Federal policy affecting the project decision.

The following review guidance is structured along these lines.

II.B.1. Project Description

The reviewer should be able to place the proposed channelization project in its appropriate environmental context. The amount of detail should be, following CEQ guidelines, "commensurate with the extent and expected impact of the action and with the amount of information required at the particular level of decision-making (planning, feasibility, design, etc.)." The reviewer should have an accurate appreciation of the purpose of the project, the socio-economic character of the area in which the project is to be constructed, and the scope of other projects or activities (Federal or non-Federal) which may be affected by the proposed action. CEQ guidelines mandate a comprehensive portrayal of the area to be affected by the project before the proposed action takes place.

Investigations of project background, site characteristics, and discussions with interested parties may support descriptive data included in the EIS and, in turn, may also suggest to the reviewer additional sources of information that will foster a better understanding of the project.

The description of the channelization project's purpose should be detailed enough to provide an explanation of the project's main features, their separate and contributing functions, and the modifications to the environment that these features entail. This descriptive effort should help to define the geographical area of concern for the proposed action. The project's scope may embrace several different kinds of environments (e.g., rural and urban, forested and cultivated, recreational and commercial, etc.) and it should be clear to the reviewer from the EIS how and if the proposed action impinges on these diverse areas. Furthermore, the spatial as well as the temporal nature of environmental consequences of the proposed action should be clear to the reviewer.

As an aid in checking the completeness of the EIS, a review checklist for channelization projects is given in Table II-1. Since no single checklist can be applied to all situations, the reviewer is cautioned to utilize the technical review information in Chapter IV to determine which, and to what extent, each of the checklist items apply to the specific project under review.

II.B.2. Relationships of Project to Land Use Plans, Policies, and Controls for the Affected Area

EPA's particular interest in reviewing a channelization project under this criteria centers on the consistency of the project with the requirements of the Federal Water Pollution Control Act, in particular sections 208 and 303. Under guidelines recently issued as 40 CFR Parts 130 and 131, States are to assume responsibility for development and implementation of water quality management plans to meet the goals of the FWPCA mandated by section 208 and 303: (1) the determination of effluent limitations needed to meet applicable water quality standards, including the requirement to at least meet existing water quality (303); and (2) development of State and areawide management programs to implement abatement measures for all pollutant sources (208).

All States have developed a river basin planning process consistent with Section 303(e) of the Act. The basin planning program has resulted in the development of plans setting out effluent limitations needed by point sources to meet existing State water quality standards (Phase I Water Quality Management Plans). Under 40 CFR Parts 130 and 131, States must consider revisions to water quality standards to meet the "fishable, swimmable" criteria of Section 101 (a) (2) of the Act. The revised plans (Phase II Water Quality Management Plans) should consider all available means to meet water quality standards including effluent limitations for point sources and management of non-point sources.

Section 404 of the Act establishes a permit program for the disposal of dredged or fill material into navigable waters. Guidelines (40 CFR Part 230) pursuant to this section of the Act specify applicability of permit requirements in a like manner to all discharges of dredged or fill material proposed by members of the general public and Federal agencies including the Corps of Engineers. The EPA's role in implementation of the Act includes (a) consultation

Table II-1. Channelization Review Checklist

I. Review the Project Environmental Setting

Issue: What is there now? What are the baseline conditions?

Physical

- Topography
- Soils and geology
  - -- Stability (slides and slump)
- Fluvial geomorphology (e.g. patterns of deposition and erosion, character of the stream and its valley)
- Climate
- Flows, floods (highest and lowest, recurrence intervals)
- Erosion and sediment production, deposition
- Geohydrological
  - -- aquifer location and extent
  - -- recharge characteristics
- Water quality
  - -- existing uses
  - -- existing levels of water quality parameters
- Rainfall-runoff/snow - snow melt characteristics
- Estuaries
- Floodplains and wetlands

Cultural

- Land use
  - -- commercial, industrial, residential
  - -- forestry
  - -- mining
  - -- agricultural

Table II-1 (continued)

-- recreational

-- aesthetic: wilderness, scenic, open space, parks, unique physical features, historical and archaeological sites

Biological (flora and fauna)

- Aquatic

  -- endangered species

  -- unique ecosystems

  -- fish and shellfish, including migration routes and spawning areas

  -- benthic organisms

  -- insects

  -- microfauna, microflora

  -- aquatic plants

- Terrestrial

  -- endangered species

  -- unique ecosystems

  -- range and habitat, migratory patterns, barriers, and corridors

  -- vegetation: trees, grasses, shrubs, crops

- Wetlands

  -- relation to aquatic, terrestrial habitat

  -- type and value

II. Review the Project Characteristics

Issue: What is this project for? What will it do? What does it look like?

Physical

- Construction techniques

Table II-1 (continued)

- Auxiliary systems: access roads, low-level weirs, drop structures

Functions

- Single purpose
  - -- flood control
  - -- drainage
  - -- irrigation
  - -- diversion of water to control erosion and/or sedimentation
  - -- recreation enhancement
  - -- fish and wildlife protection
  - -- water supply
  - -- insect and pest control
- Multi-purpose

Economics

- Demand studies: bases for project need
- Supply studies: ways to meet identified needs
  - -- alternative projects
    - .. structural
    - .. nonstructural
- Project life
- Benefit/cost analysis
- Application of Water Resources Council Principles and Standards

Operating and maintenance characteristics

- Schedule and characteristics of maintenance programs
- Design

-- water level control structures

-- mitigation features (structural and nonstructural)

III. Review Environmental Impacts of Project

Issue: How will completion of this channelization project (described in II above) affect the environment (described in I above)?

- Review the predicted effects of the proposed channel on the environmental characteristics of the river basin: Physical, cultural, biological, (I above).

- In particular, review:

  -- Projected changes in water quality parameters resulting from channelization

    .. in the channelized reach

    .. in downstream reaches

  -- Projected changes in uses (e.g. aquatic biota, water supply, recreation) resulting from changes in water quality parameters or destruction of habitat.

    .. in the channelized reach

    .. in downstream reaches

  -- Projected changes in land use, such as a shift from low intensity (agriculture) to high intensity (industry) uses on the flood plain.

    .. effect on wetlands, aquatic and terrestrial habitat

    .. effect on water quality management planning

    .. effect on air quality maintenance planning

- Review estimation and predictive modeling techniques for:

  -- applicability to the scope of the proposed project

  -- technical validity

  -- predictive reliability

- Review alternatives

-- design

.. channel location and dimensions

.. channel construction methods

.. channel lining, bank protection, gradient variation

.. operating policy

-- structural

.. upstream impoundment

-- nonstructural

.. no project

.. floodplain management

- Review mitigation measures

-- change in maintenance activities

-- design modifications

IV. <u>Review Project Impacts for Consistency with Federal Environmental Policy</u>

<u>Issue</u>: Does the severity of the environmental impacts (described in III above) of the project render it inconsistent with the objectives, standards, or implementing procedures of Federal environmental policy?

- Review EPA legislative authority

-- Is project consistent with legislated environmental objectives and policies?

-- Is project consistent with regulations implementing environmental objectives and policies?

-- Will the project lead to standards violations?

- Review consistency of project with environmental planning efforts

-- Is project consistent with State Water Quality Management Plans?

Table II-1 (continued)

-- Is project consistent with Air Quality Maintenance Plans?

- In particular, review consistency of project with environmental requirements most likely to be affected by channelization projects.

  -- Water quality standards

    .. flow requirements

    .. water quality criteria

    .. designated water quality uses

    .. anti-degradation policy

  -- Section 313 (Federal facilities pollution control)

  -- Section 404 (Dredge and Fill). If disposal of dredged or fill material is involved, review for compliance with 404(b) Guidelines (40 CFR Part 230).

    .. wetlands

    .. municipal water supplies

    .. fisheries and shellfish beds

    .. wildlife

    .. recreational areas

  -- Administrator's Decision Statement on Wetlands

- Review project under related Federal environmental requirements

  -- Conformance with NEPA requirements and CEQ Guidelines

  -- Conformance with Water Resources Council's Principles and Standards (if applicable)

  -- Conformance with:

    .. Coastal Zone Management Act

    .. Endangered Species Act

    .. Fish and Wildlife Coordination Act

.. National Historic Preservation Act

- Review project in terms of mitigation measures (including alternative projects and delayed construction) which could reduce the adverse environmental effects of the project

  -- Mitigation measures available to reduce adverse effects should be fully utilized.

with the District Engineer of the Corps of Engineers on interpretation of the guidelines, (b) review and comment on permit applications, and (c) implementation of Section 404(c) in appropriate cases. Section 404(c) authorizes the EPA to deny or restrict the use of any defined disposal site upon determination that discharge of material to the site would have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreation areas. In cases where channelization projects planned by Federal agencies necessitate the disposal of dredged, excavated, or fill materials in navigable waters or adjacent wetlands, such coordination, review, and comment are necessary in conformance with 40 CFR Part 230.

Another piece of Federal legislation relevant to both land use and water resource planning is Section 701 (Comprehensive Planning Assistance Program) of the Housing Act of 1954 as amended, administered by the Department of Housing and Urban Development (HUD). The land use element of Section 701 establishes policies, standards and studies of "where, when, and what kind" of growth is compatible with urban programs. An Interagency Agreement between the Department of Housing and Urban Development and the Environmental Protection Agency (March 24, 1975) encourages coordination between the land use provisions of Section 701 and those of Section 208 of the FWPCAA. This agreement addresses not only the need for consistency between the two agencies' planning guidelines and procedures but also specific issues as, for example, efficient design of treatment plants and the control of point and nonpoint sources of pollution.

Major factors relating to water quality planning which should be considered during the planning or EIS review of channelization projects are as follows:

Waste Discharges. Stream channelization projects on waterways into which wastewater is being discharged may affect assimilative capacity of those waters, thus requiring the imposition of more stringent effluent limitations or relocation of the wastewater outfalls. Modification of existing outfalls, manholes, and sewers may be required by channel or project construction.

Channels carrying highly saline irrigation return flows from cultivated lands typify special examples of "nonindustrial" waste discharge. The draining of swamps, ponds, and ditches which have long served as receptacles for agricultural runoff and associated sediments, fertilizers, pesticides, herbicides and other pollutants in effect introduces new point sources of pollution into the basin's waterways.

Alteration of Flow Regime. Because the formulation of a basin plan will specify a stated or assumed range of flows for different river reaches, the proposal to channelize a section of stream may induce unanticipated or unscheduled changes in flow. Altered flows may increase or decrease pollutant loadings at impoundments and natural storage areas. Because channels possess the ability to reduce flooding alongside specified stream segments or to drain headwater marshes, they may, perforce, have a profound effect upon patterned intensities of land development in the basin.

EPA policies and procedures,[2] however, specify that states develop basin planning processes which "provide for the preparation of an annual state strategy" as well as "guide decision-making over a five to ten year span of time." Thus the insertion of a proposal to construct a channelized section of stream should be reviewed in the context of strategies adopted by a state's water pollution and land use control plans and regulations.

Alteration of Preproject Water Quality. A channel project may have an influence upon water quality both in the region through which it passes and downstream from that area. Some of the effects are traceable to: increased volumes of pollutants from upstream agricultural or silvicultural activities, increased turbidity resulting from both short-term construction activities and long-term channel-bank instability, reduced aeration potential along channelized reaches of the stream course, reduced oxygen content traceable to warmer water temperatures, reduced in-channel treatment time resulting from substrate removal and more rapid flow-through, reduction of pollutant filtering capacity by removal of riparian and floodplain vegetation, and other factors.

Basin plan formulation, areawide wastewater management strategies, and the discharge-permit system all focus on the identification, evaluation, and control of sources of degraded water quality. The influence of a proposed channel section on established water quality standards, therefore, may be reason for revising plans for the project's dimensions, restricting activities that introduce pollutants to the watercourse, or introducing remedial measures to restore water quality to preproject status. EIS review should include an evaluation of those measures proposed in the channel project's plans to mitigate or correct anticipated sources of degraded water quality.

Alteration of Water and Related Land Use. Stream channel construction or modification may have important implications because of possible direct or indirect effects on water use or related land use. For example: drainage of swamps and marshes may increase the development potential of areas in or adjacent to such lands; such drainage may also diminish aesthetic values and biotic productivity; irrigation channels may result in changed allocation schedules for waters in adjacent areas causing impacts upon existing land or water uses; or creation of channels to constrain flood flows in one area may increase flood hazards in downstream areas. Additional examples may be drawn from those instances where the focus is principally on the proposed benefits to recreation or fish and wildlife propagation programs.

Both the regional context and the scheduling phases of a proposed channel project may embrace ramifying effects extending outside the project area or scope which must be addressed in an EIS. A marsh or a fishery resource, for example, may have values associated with migratory bird flyways or anadromous fisheries, which are especially important during specific seasons. Or the marsh may produce food for upstream or downstream fisheries. These resources have productive utility in and of themselves, and they also have significance as attractors of consumers, both people and wildlife, residing outside of a watershed area. Moreover, channel construction may serve as either a stimulant or depressant to regional development and growth patterns thereby influencing planning factors for wastewater treatment and other service facilities. Such influences are often project schedule-related and need to be considered in an appropriate temporal context by local, state, and regional (e.g. Water Resources Council "level B" studies) water resource planning agencies and by the EPA in both planning and review phases of a project.

In summary, an important part of both the EIS and its subsequent review is the assessment and evaluation of the complex changes in existing and/or proposed programs, plans and policies for land or water use which are directly caused, or induced, by channel-building.

II.B.3. Probable Impact of Proposed Project

Review of the probable impact of the proposed project should include the determinations that all potentially significant impacts have been identified, that they have been adequately quantified (within the limits of state-of-the-art techniques and commensurate with the expected severity of the impact), and that the impacts have been measured against applicable standards, criteria, and regulations.

So that impacts stemming from channelization may be viewed from the differing perspectives of persons reviewing projects with different purposes in a variety of settings, a brief overview of channelization projects and potential environmental impacts is presented in the sections which follow.

Project Purposes. A comprehensive study of stream channelization in the United States was recently (1973) completed by Arthur D. Little, Inc. and the Philadelphia Academy of Natural Sciences for the Council on Environmental Quality. That study reported that nearly 200,000 miles of the more than 3 1/2 million miles -- almost 6 percent -- of the nation's waterways have been modified since the land was first colonized and that nearly 130 million acres (200,000 square miles) of wetlands have been drained. But the study also points out that most of this channel work was completed in response to locally perceived problems and was independent of the regional and national framework planning programs which now precede most channelization projects. The report states that:

It was not until a tardy recognition of federal responsibility and federal capacity to transcend localized problems and consider water on a hydrologically interdependent and unified basis that solutions to the persistent problems of poor drainage and flood damage prevention really began to be solved.[3]

Impacts traceable to stream modification are not solely due to purposeful channelization. Highway relocations, stream and river crossings, upstream impoundments, and even such natural events as floods have all caused modification of streamflows, channel morphometry and alignment not dissimilar from that caused by channelization projects.

Stream channelization projects as herein considered are those involving deliberate modification of existing natural channels, rather than the building of completely new channels where none had before existed -- as, for example, in areawide irrigation projects. And the major navigational improvements on large rivers, though admittedly involving channelization, also fall outside of the scope of the EPA review process here being anticipated. Purposes of those projects most often reviewed by EPA regional offices include: flood control, drainage improvements, the provision of recreational benefits, and the control of insect and other pest populations.

Flood control and drainage projects, the most common undertakings for which channels are proposed, vary considerably in scope and complexity. They may be as simple as removing snags and other obstructions along a stream course or as complex as straightening, enlarging, and lining the channel; they may involve a few hundreds of yards of stream or river course or tens of miles.

Benefits often expected to ensue from these kinds of projects include, in addition to those identified directly by the project's principal purpose (e.g., flood control or improved drainage): increases in land values and agricultural productivity, improvements in the ability of a stream to hold water within its banks, increases in streamflow capacities, stabilization of stream banks, provision of outlets for land treatment measures (e.g., grassed waterways, tile drains, and diversions), decreases in flooding and sediment damages, and enhancement of recreational opportunities.

<u>Characterization of Adverse Impacts</u>. During the course of two congressional hearings[4], held during the spring and summer of 1971 on the subject of environmental impacts of stream channelization, the following summary of "complaints" about channelization were aired:

Artificial channels may cause:

..destruction of game and waterfowl habitat, and also trout (i.e., coldwater) streams;

..increases in upstream erosion and downstream flooding;

..pollution of downstream lakes and reservoirs;

..encouragement of farmers to drain wetlands and bring unused wetland under cultivation;

..drainage of swamps, destroying their ability to act as "giant kidneys" and remove silt, organic wastes and toxic chemicals from the stream;

..acceleration of the release of water which might otherwise percolate into and recharge groundwater reserves;

..encouragement of the development of flood plains, which leads to further demands for flood protection works; and

..destruction of vast areas of wildlife habitat (in the southern U.S.) which nullifies federal investments in wetland areas (in the north of the United States).

Additional undesirable effects of stream channelization were identified at the hearings by the National Audubon Society; they were:

..the lowering of water tables;

..elimination of flood plains which serve as recharge areas for aquifers

..elimination of wildlife cover and soil-holding vegetation along stream banks

..increases in water temperature and turbidity;

..elimination of desirable sport fishing --

"in short, the conversion of beautiful streams that are rich in natural life into sterile and unsightly ditches."[5]

Though the adversarial positions which characterize controversies arising from stream channelization projects are of necessity and purposefully either "black" or "white," such arguments have the positive effect of sharpening the critical viewpoints and appraisals of those concerned with such projects.

Natural streams are very complex systems when viewed in the context of their ecology and interactions with terrestrial and wetland environments. A great abundance of different habitats is formed by a myriad of current, light, and substrate conditions which support a diverse array of flora and fauna. Naturally occurring pools, riffles, and riparian vegetation in small streams provide many niches or microhabitats, each of which has characteristics suitable for specific biota but collectively affording food, shelter, and iving space for numerous kinds of organisms. Meanders, oxbows, and other features of larger or mature streams cause considerable variability in velocity and nature of the streambed which may not be initially apparent to the casual observer. The interdependencies among all forms of life that make up a particular biological community are incompletely understood. However, a basic lesson of ecology that has been learned from all forms of human modifications of natural systems is that introduction of artificial uniformity is likely to invite ecological reactions, whether predictable or unanticipated.

The environmental issues raised by channelization projects ultimately involve the ecology and biota, even though they are often addressed first in terms of physical, hydrological and water quality impacts. The EPA, then, in carrying out its functions to manage and protect the environment, must focus on water quality, pesticides, solid waste, and land use considerations as they relate to biota, whether human, plant, or animal. In order to accomplish the EIS review with this emphasis, the cause and effect relationships among various channel-related activities and impacts should be followed through. For instance, the fundamental alteration of watershed hydrology due to channelization for flood control or drainage will not only affect water quality response and aquatic habitat but also change the development or use potential of adjacent lands. In the eastern half of the country and particularly in the Southeast this change has often been manifest in the drainage and destruction of riparian and even upland marshes and swamps, the decimation of bottomland hardwoods by drainage and groundwater table lowering, large-scale clearing for agriculture, or both. Looking again at the aquatic environment after these changes have occurred, streamflows during dry periods are apt to have been reduced and pollutants (sediments, pesticides, fertilizers, etc.) introduced to the channelized watercourse with agricultural land runoff. Then, both the hydrological and water quality conditions resulting directly and indirectly from channel construction would influence the aquatic biota. Certainly many other impinging factors, including erosion and sedimentation, channel realignment, proposed maintenance programs, and others, also have to be considered in a similar fashion. It is important to maintain a broad ecological perspective in assessing channelization or other water resource projects and realize that damage to natural streams and their biota always have the potential for adversely affecting the human environment and quality of life.

Impact Categories. A format for categorization of probable impacts stemming from channel-building and subsequent stream modification has been adopted in Chapter IV and is shown below in Figure II-1. In that chapter the techniques for impact identification, quantification, and assessment are discussed in sufficient detail to alert the reviewer to the nature and the interrelatedness of potential impacts.

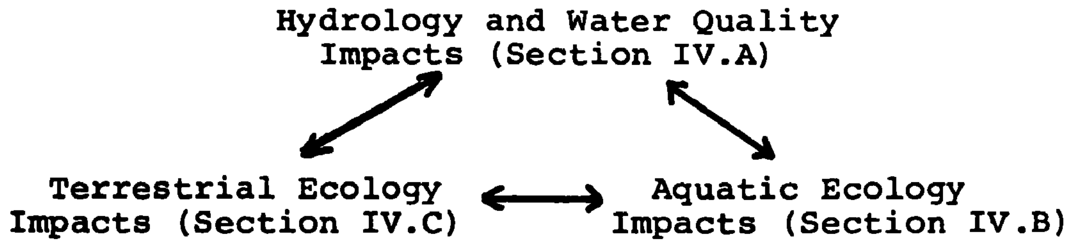


Figure II-1. Separation of Impact Categories

As is true for all EIS's a separation of impact categories should not be construed as anything more than an organizational aid in the approach to impact evaluation and review. Impacts which might be identified as primarily those affecting aquatic ecology (for example, the removal of a stream's substrate and its resident benthic organisms resulting in changes in both the morphometry of the stream and such physical-chemical parameters as dissolved oxygen (DO) content, reaeration potential and stream temperatures) will also have an impact upon the stream's hydrological character and its water quality. Similarly, impacts considered as those principally affecting water quality (e.g., an increase in water temperature and decrease in DO resulting from removal of shade-producing vegetation) will also have related impacts on terrestrial and aquatic ecosystems. Therefore the interrelatedness, iterative nature, and potential for magnification of impacts must be explicitly apparent in the EIS and comprehensively evaluated in the review process.

It follows from the discussion above that an evaluation of not only "primary" but significant "secondary" impacts should be part of an EIS and therefore subject to EPA review. Though channelization projects are, in essence, water resource management projects there may also be related and significant impacts on air quality, noise standards, pesticide dissemination, and solid waste generation -- all areas falling within the scope of EPA's review responsibility.

Identification, Quantification and Assessment of Impacts. Categorization of natural systems or impacts upon them, as earlier implied, is an over-simplification of complex interdependencies for which hierarchical orders, degrees of relatedness, and even cause-and-effect relationships are sometimes only vaguely perceived. The approach taken in Chapter IV aims to assist the reviewer in grasping the more important and identifiable relationships among hydrologic, water quality, and ecological impacts. The cross-references found throughout those sections should be used whenever further and related discussion in another part of the chapter might be helpful.

In a sequential and engineering sense the impacts stemming from channelization may ordinarily be viewed as beginning with purposeful changes in the hydrologic regime of a stream. The altered flow patterns of a stream may, for example, induce such water quality effects as a reduction in reaeration potential or increased erosion and turbidity, or -- in an estuary -- saltwater incursion. Water quality impacts, rather than hydrologic impacts, may appear from some perspectives in the project area to be the initial impact as when, for example, unperceived increases in a stream's velocity shorten in-stream treatment time and result in obviously degraded water quality at specific observation points downstream from a channelized reach of stream. Because of the number of perspectives from which impacts are viewed within a project area, as well as the differing and subjective values of those assessing impacts, the distinction between hydrologic and water quality impacts is not always easy to make. Hydrologic effects, even though they can sometimes be quickly identified and often quantified, nonetheless have little significance in channelization impact assessments unless -- and until -- they have a measurable impact upon the water quality and the ecosystems in, or related to, the modified stream.

Notwithstanding the fact that project purposes usually and implicitly require or involve a change in the hydrologic regime of a stream, the reviewer should recognize the iterative nature of all impacts. A change in stream velocity, for example, may result in stream bank undercutting and destroying bank-side vegetation which, in turn, will result in increased water temperatures, and a degraded fish habitat. These results will, in turn, further influence the flow regime and water quality. But, in the example given, stream impacts traceable to and initiated by the undercutting of bankside vegetation is, for purposes of these guidelines, a separable category of impacts and is assigned to "terrestrial ecology impacts."

Tables II-2, II-3, and II-4 which follow illustrate both the separability and relatedness of impacts which may result from channelization. Each of the impact categories is analyzed individually in the tables.

The reviewer should be aware that the tables do not contain all of the impacts attributable to channelization, nor all of the impacts specified in the tables pertinent to each of the projects which will be reviewed. The tables should be used by the reviewer as a guide to Chapter IV to gain insight into the kinds of activities and resulting impacts which should be evaluated in a representatively comprehensive EIS. In addition, they should aid in locating descriptions of particular impacts and technical references that may be useful in completing the assessment.

Aside from those obvious impacts measurable in such terms as loss of stretches of free-flowing stream and areas of natural streamside vegetation, there are subtly incremental and cumulative impacts which are, in many cases, time dependent. The alteration of downstream water quality, or the accumulation of silt, sand, gravel or boulders in downstream localities, are examples of those

Table II-2. Hydrology and Water Quality Impacts

REVIEW OF HYDROLOGY WATER QUALITY IMPACTS	IMPACTS ATTRIBUTABLE TO: Changes in Hydraulic Parameters	Changes in Watershed Land Use	Construction and Maintenance
Sources of Impacts (Section IV.A.1)	IV-2 to IV-5 -Channel straightening -Levees and channel confinement -Alteration of channel cross-section -Clearing and snagging -Channel lining and protection -Related water resource development	IV-6 -Changes in land cover and effects on hydrology -Runoff- and land use-related pollution -Effects on downstream flood hazards IV-10 to IV-11 -Potential effects on groundwater quality	IV-6 to IV-7 -Equipment types and construction methods -Sediment-generating activities -Other pollutants and sources IV-8 to IV-10 -Alteration of groundwater discharge/ recharge -Conditions favoring minimal effects on groundwater -Influent versus effluent conditions -Effects of land drainage
Review of Quantification (Section IV.A.2)	IV-11 to IV-17 -General data requirements for impact quantification -Approaches to estimation of downstream hydrologic effects -Hydrologic effects on waste assimilation -Evaluation of channel erosion and sedimentation potential -Influence of substrate on purification capacity	IV-19 to IV-21 -Evaluation of runoff/ water quality/land use interactions	IV-18 to IV-19 -Evaluation of thermal regime changes from bank clearing IV-21 to IV-25 -Relevance of project scale, soils, topography, climate, & vegetative cover variables IV-26 to IV-30 -Evaluation of pollution from major construction activities IV-30 to IV-33 -Methods and considerations for groundwater impact quantification
Assessment of Impacts (Section IV.A.3)		IV-34 to IV-37 -Basis for assessment: water quality criteria and standards	
	IV-37 to IV-40 -Assessment of assimilative capacity changes and downstream effects -Measures to mitigate adverse hydraulic and water quality impacts: discussion and table	IV-40 to IV-41 -Assessment of land use impacts related to channelization -Assessment of potential pollution from land use activities	IV-41 to IV-48 -Purposes of assessing construction and maintenance impacts -Reduction of erosion and sedimentation -Nature and schedules for maintenance -Disposal of excavated material -Protection of groundwater

Table II-3. Aquatic Ecology Impacts

REVIEW OF UATIC COLOGY IMPACTS	IMPACTS ATTRIBUTABLE TO: Habitat Alteration by Riparian Vegetation Removal	 Habitat Alteration by Channel Excavation and Maintenance	 Habitat Alteration by Changes in Land Use & Water Quality
Sources of Impacts (Section IV.B.1)	←	IV-49 -Basic ecological principles underlying impact identification	→
	IV-50 to IV-51 -Effects of instream debris removal -Effects of riparian vegetation removal on temperature, erosion potential, and habitat diversity	IV-51 to IV-54 -Turbidity and sedimentation impacts -Reduction of available aquatic habitat -Relationship of velocity to habitat diversity -Effects of groundwater changes and drainage on aquatic ecology -Ecological effects of channel maintenance	IV-54 to IV-55 -Land use changes due to flood protection or drainage functions -Changes in nutrient, sediment, pesticide, and other pollutant loads; ecological implications
Review of Impact Quantification (Section IV.B.2)	IV-56 to IV-57 -Basic data requirements for characterizing aquatic habitat -Ecological effects of altered temperature patterns (see also Section IV.A.2)	IV-57 to IV-62 -Quantification of habitat gains and losses -Relevance and need for fisheries, benthic invertebrate, and aquatic plant data -Approaches to evaluation of suspended solids and sedimentation impacts -Tolerance of benthic organisms to pollution (Table IV-9) -Consideration of impacts on fish spawning and anadromous species migration IV-62 to IV-64 -Approaches to evaluation of ecological impacts of hydrologic modifications and creation of backwaters (due to channel realignment)	IV-64 to IV-65 -Baseline data requirements for impact prediction (water quality, land use, etc.) -Uncertainties in impact quantification -Possible shifts of species abundance
Assessment of Impacts (Section IV.B.3)	IV-65 to IV-68 -Applicability of criteria to ecological impact assessment -Judgment of adequacy of EIS with respect to ecological impact evaluation -Assessment of thermal regime changes -Assessment of suspended solids and sedimentation impacts -Assessment of habitat changes for which no explicit criteria exist -Applicability of mitigation measures		

Table II-4. Terrestrial Ecology Impacts

<table>
<tr><th rowspan="2">REVIEW OF TERRESTRIAL ECOLOGY IMPACTS</th><th colspan="4"><u>IMPACTS ON:</u></th></tr>
<tr><th colspan="2">Riparian Habitat and Land Use</th><th>Wetland Habitat and Land Use</th><th>Upland Habitat and Land Use</th></tr>
<tr><td>Sources of Impacts (Section IV.C.1)</td><td colspan="2"><u>IV-70 to IV-72</u>
-Streambank clearing; terrestrial and aquatic ecology considerations
-Effects of groundwater changes
-Effects of major construction activity on terrestrial ecosystem
-Possible indirect effects on riparian habitat and land use</td><td><u>IV-72 to IV-75</u>
-Wetland drainage and alteration of inundation patterns
-Impacts on bottomland hardwoods
-Impacts of spoil disposal
-Impacts of drainage facilities tributary to main channel</td><td><u>IV-75 to IV-77</u>
-Impacts of ancillary structures and land treatment (upstream impoundments, cropping practices, etc.)
-Regional considerations beyond project area</td></tr>
<tr><td rowspan="3">Review of Impact Quantification (Section IV.C.2)</td><td colspan="4"><u>IMPACTS DEPENDENT ON:</u></td></tr>
<tr><td colspan="2">Project Dimensions</td><td colspan="2">Land Use and Ecological Value</td></tr>
<tr><td colspan="2"><u>IV-77 to IV-80</u>
-Basic data requirements for impact estimation (project dimensions, environmental settings, land use inventory etc.)
-Approaches to classifying wetlands
-Approaches to evaluating importance of wetlands
-Evaluation of impacts on urban and recreational lands; aesthetic considerations</td><td colspan="2"><u>IV-80 to IV-83</u>
-Adequacy of time frame for evaluating land use changes and impacts
-Categorization of land uses
-Economic, social and ecological criteria relevant to land use and terrestrial habitat</td></tr>
<tr><td>Assessment of Impacts (Section IV.C.3)</td><td colspan="4"><u>IV-83 to IV-86</u>
-General approach for terrestrial impact assessment
-Assessment of wetland and riparian impacts and interrelationship with aquatic ecological effects
-Regenerative potential of impacted areas; rare and endangered species
-Assessment of land use impacts
-Applicability and assessment of mitigative measures and alternatives</td></tr>
</table>

impacts which are often cumulative in nature. On the other hand, impacts stemming from such temporary activities as construction or periodic maintenance, are only episodic and may therefore be of lesser significance.

But the reviewer should take note that though an identified impact (e.g., diminished trout population due to reduction in gravel riffles which are prime reproductive habitats) may be small, in combination with other minor impacts (e.g. incorporation of additional agricultural runoff and aesthetic degradation) the combined effect may be of major significance.

Traditionally the modification of fish and wildlife resources, vegetation, and other elements of an ecosystem has been equated with losses, or gains, in hunting, fishing, and other recreational activities. However, this sort of trade-off analysis in an EIS should also include an accounting of those intangible values associated with rivers and streams in their natural states. And among these values there may be included areas of unique or special ecological or geological value.

It should be recognized that adequate assessment techniques do not exist for all impacts, even those which can be accurately identified and quantified. For example, subtle changes in water quality (e.g. in temperature, salinity, or other parameters) may occur as the result of a channel project and thus violate the Statewide antidegradation policy established in conformance with 40 CFR 130.10(a)(5) and 131.11 (e), even when numerical water quality criteria are not violated. Such changes may have environmental significance when viewed along with the many other influences on basin water quality.

II.B.4. Alternatives to the Proposed Project

Where adverse environmental impacts will occur if the proposed action is taken, it is important to review if and how the initiating and responsible agency has explored and objectively evaluated the environmental impacts of all reasonable alternative actions, "particularly those that might enhance environmental quality or avoid some or all of the adverse environmental effects" of a project. Alternatives to the proposed action can be presumed to exist in those situations where disagreements and conflicts over the use of available resources remain unresolved.

The reviewer should review the alternatives included in the EIS to assure that they are reasonably comprehensive and that the evaluations of their environmental benefits, costs, and risks are comparable with the conclusions on the proposed action. Alternatives may be thought of either as project-related modifications or project replacements.

One purpose of both the EIS and the EIS-review process is to avoid premature rejection of any and all alternatives or options which might result in an environmental impact significantly reduced from that of the proposed action.

Alternatives to be reviewed should include:

..no action (i.e., foregoing the project), and

..rescheduling of proposed channel construction.

In addition the reviewer should consider the applicability of the following types of alternatives to channelization:

..change in scope, design, or magnitude of the proposed project;

..change in location of portions or all of the project;

..alternative nonstructural methods of accomplishing the project's functions (Example: consideration of nonstructural techniques for providing flood protection, e.g., flood plain zoning, relocation of buildings, floodproofing, etc.);

..alternative structural methods of (or project components for) achieving the purposes (Example: consideration of such techniques as: digging relief drains or wells instead of constructing channels to solve drainage problems; or building a separate flood flow channel instead of channelizing a natural channel to contain floodwaters);

..compensatory or mitigating measures (Examples: consideration of limiting construction activities to one side (i.e., not both sides) of a natural channel; or construction of bank covers or wings to restore fish habitat.

All reasonable and feasible alternatives should be included in the EIS and should be reviewed in sufficient detail to identify:

..the degree of increase or decrease of impacts as contrasted with those anticipated for the proposed actions;

..the adequacy of impact assessments for proposed actions;

..the adequacy of impact assessments for each alternative; and

..the effective mitigation of impacts by each alternative over the proposed project's lifetime.

The reviewer's task will be to determine which of the alternatives could be recommended as less environmentally damaging than the proposed action but which substantially meet project purposes and objectives. In some cases the alternative proposed by the originating agency may have been judged the most acceptable for economic or other reasons even if other courses of action offer a lesser threat to the environment. However, EPA's assessment and recommendations should be based primarily on the environmental merits and drawbacks of each option.

II.B.5. Probable Adverse Impacts that Cannot be Avoided

Where all mitigating measures have been taken, the probable adverse impacts that cannot be avoided will be the basis for the overall assessment and rating of the project. Probable adverse environmental impacts to be considered include: water and air pollution, undesirable land use patterns, damage to fish and wildlife habitat, threats to health, and all other consequences specified in section 101(b) of the National Environmental Policy Act.

The reviewer should appraise this section of the EIS as a summary of those adverse impacts which are unavoidable results of the proposed action (as earlier identified for review in Section II.B.3 of these guidelines). The reviewer should also find in this section, as contrasting data, identification of the mitigating or compensating measures proposed for reduction of the adverse impacts specified.

In essence the review process should insure that "the kinds of adverse impacts which cannot be reduced in severity or which can be reduced to an acceptable level, but not eliminated" are identified in the EIS.

II.B.6. Relationship of Short-Term Uses to Long-Term Productivity

Reviewers should note the stipulation in CEQ guidelines which states that "this section should contain a brief discussion of the extent to which the proposed action involves tradeoffs between the short-term environmental gains at the expense of long-term losses, or vice versa, and a discussion of the extent to which the proposed action forecloses future options." Of particular importance are those projects which "narrow the range of future uses of land and water resources or pose long-term risks to health or safety".

Channelization impact assessments should be reviewed to determine relationships between such project resources (both natural and cultural) and project elements as:

..intrinsic values of natural and free-flowing streams in the project area, and those benefits estimated from enhancement of agricultural productivity and/or flood protection of developed areas, etc.;

..anticipated duration of short-term and long-term impacts-both beneficial (e.g. to flood-prone and water-saturated areas) and adverse (e.g. to water quality, noise standards, air quality, etc.), and estimate of time for regeneration of the watershed's renewable resources to preproject status:

..anticipated demand schedules for benefits from proposed and induced actions compared with the anticipated life of the project;

..justification for project implementation, as proposed, rather than deferral of action in order to preserve future options;

..consistency with federally funded projects in flood hazard areas (i.e. review of Executive Order 11296).

II.B.7 Irreversible and Irretrievable Commitments of Resources to Proposed Project

The intent of this section of the EIS is to identify those unavoidable impacts induced by the projects and the "extent to which they curtail" the potential uses of the environment. And the term "resources" refers not only to the labor, funds, and materials committed to a project but also to the natural and cultural resources affected by the proposed action.

The reviewer should note the adequacy and comprehensiveness with which the EIS addresses such elements of the proposed channelization as:

..induced growth which forecloses alternative uses of land in the watershed;

..losses of irreplaceable historical and archeological resources or populations of rare biological species;

..ecological, social, and aesthetic values associated with those sections of a stream or its riparian environment which will be lost as a result of channel modification; and

..the impacts of conversion of those areas required for project facilities (basins, outlets, levees, etc.) and easements (flowage, right-of-way, etc.) from prior open and/or productive uses.

REFERENCES -- CHAPTER II

1. 40 CFR Part 1500 - Preparation of Environmental Impact Statements - Guidelines.

2. 40 CFR Part 130.1.

3. Arthur D. Little, Inc. and Philadelphia Academy of Natural Sciences, Report on Channel Modifications, Volume I, submitted to the Council on Environmental Quality, U.S. Government Printing Office, March 1973, p. 60-61.

4. U.S. Congress - (1) House of Representatives, Subcommittees on Conservation and Natural Resources - Committee on Government Operations - Hearings on Stream Channelization, 92nd Congress, 1st session (4 pts.); (2) U.S. Senate Subcommittee on Flood Control - Rivers & Harbors, Committee on Public Works - Hearings on the Effect of Channelization on the Environment, 92nd Congress, 1st Session.

5. Senate Hearings, p. 214.

III. PROJECT RATING

The basis for the EPA comments on the environmental impact of channelization projects is quite broad. As stated in the Clean Air Act, Section 309(a), EPA comments on "...any matter relating to duties and responsibilities granted pursuant to this Act or other provisions of the authority of the Administrator..." The NEPA, section 102(2) (C) states "...the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to the environmental impact involved."

The above mandates have been interpreted to mean that the EPA comments should be related to the impact of projects on water quality, air quality, solid waste management, noise, radiation control, and pesticide and other toxic substances use and control. Water quality concerns include protection of beneficial water uses, wetlands, aquatic life and habitat, and water-related wildlife. Comments related to land use, terrestrial wildlife, aesthetics, recreation, and other areas must be related to areas of expertise. It is proper to discuss agricultural or other land development a channelization project may induce if it will aggravate an already serious air or water pollution problem. It is also proper to evaluate the potential for downstream development in floodprone areas as a result of flood control functions of a channel as well as the extent to which projects benefits assigned to flood control include such projected development.

If an EPA reviewer has special insight on a project, such as that resulting from an on-site inspection or discussion with community leaders, it is appropriate to make comments on matters falling outside of EPA's specific areas of jurisdiction. The EPA policy is that such comments are for information only and are not used to justify the assigned EPA rating. Furthermore, such comments must include a statement to the effect that final determination on the matter is deferred to the Federal agency with the appropriate jurisdiction.

The specific basis for the EPA assessment of environmental impacts consists of the standards, criteria, EPA policy decisions, and consistency requirements with other EPA program responsibilities as shown in Table III-1.

As detailed in the 309 Review Manual, the EPA rating scheme is different for draft EIS's, final EIS's, and pre-Clean Air Act Amendments EIS's. At the draft stage comments shall be designated by an environmental impact rating of LO (Lack of Objections), ER (Environmental Reservations), or EU (Environmentally Unsatisfactory), Category 2 (Insufficient Information), or Category 3 (Inadequate). If a draft EIS is assigned a Category 3, normally

Table III-1. Standards, Criteria and Regulations Related to Channelization Projects

Standards

- ..Latest version of primary drinking water standards prepared by EPA pursuant to the Safe Drinking Water Act (PL 93-523)
- ..Water Quality: State adopted water quality standards consisting of water quality criteria and plans for the enforcement and implementation as referenced in 40 CFR Part 120.
- ..Air Quality: National primary and secondary ambient air quality standards as specified in 40 CFR Part 50

Criteria, Regulations and Policy

- ..Criteria for Water Quality, Volume I (Proposed) U.S.EPA, October 1973
- ..Water Quality Information, Volume II (Proposed), U.S. EPA, October 1973
- ..Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, U.S. EPA, March 1974
- ..Regulation for the Disposal and Storage of Pesticides and Pesticide Containers, 40 CFR Part 165
- ..EPA Policy to Protect the Nation's Wetlands, Administrator's Decision No.4
- ..Navigable Water, Procedures and Guidelines for Disposal of Dredged or Fill Material, 40 CFR Part 230
- ..Latest regulations prepared by EPA pursuant to Section 1424 (e) of the Safe Drinking Water Act regarding Federal projects in a recharge area of an aquifer designated as a sole source aquifer
- ..Amended FIFRA Act. The Federal Environment Pesticide Control Act of 1972 (FEPCA)
- ..Thermal Processing and Land Disposal of Solid Waste Guidelines, 40 CFR, Parts 240, 241

Consistency with Other EPA Programs

- ..Areawide Waste Treatment Management Planning Areas ("208" Plans), 40 CFR Part 126
- ..Water Quality Management Basin Plans ("303(e)" plans), 40 CFR Part 131
- ..National Pollutant Discharge Elimination System, 40 CFR Part 125
- ..State Air Implementation Plans, 40 CFR, Parts 50 and 51

no rating will be made on the environmental impact of the proposed project or action since a basis does not generally exist on which to make such a determination. When there is a basis for assessing the environmental impact of a proposed action, such as independent documents or on-site surveys, such a rating may be established at the discretion of the principal reviewer after consultation with OFA.

At the final stage, no alpha-numeric designations are made since only the project impact is considered and not the completeness of the EIS. The project impact rating assignments for the final EIS consist of: Lack of Objection, Environmental Reservations and Environmentally Unsatisfactory. A rating assignment of Unresponsive Final Impact Statement can be made if the final EIS has not responded adequately to comments made by EPA on the draft EIS. Such comments may also be offered if new environmental concerns have been brought to the EPA's attention since the review of the draft EIS and the originating agency does not adequately evaluate these factors in the final EIS. In the case of projects which were authorized prior to passage of the Clean Air Act Amendments (December 31, 1970), the determination of Environmentally Unsatisfactory shall not be used. Instead, the final EIS comment should present EPA's substantive comments on the project, omitting both reference to Section 309 and use of the term "Environmentally Unsatisfactory."

The general criteria for assigning the Environmental Reservations, Environmentally Unsatisfactory, or Category 3 ratings are given in Table III-2. The reviewer should note that these criteria are intended to be used as guidelines rather than strict rules. The decision regarding the impact of each project must incorporate all the mitigating factors for that particular project. The sensitivity of the environment to the changes imposed by the channelization project, as well as the effectiveness of mitigating measures, must be taken into account.

Table III-2. Rating Channelization Projects

Category EU: Environmentally Unsatisfactory	
General Criteria (from 309 Review Manual)	**Specific Criteria for Channelization**
a. Where it is highly probable that a violation of standards will occur. 1. Federal, State, and local standards are included; includes EPA regulations and and guidelines.	.Violations of water quality standards, including noncompliance by Federal facilities with requirements for pollution abatement and control (section 313); ..violations of water quality criteria for the uses designated in standards; ..violations of flow requirements required by water quality standards; ..violation of State anti-degradation provision or EPA's anti-degradation policy; ..violation of State mixing zone policy. .violation of informational guidelines, such as those for non-point source control (304 (e)). .Unacceptability under FWPCA Section 404, i.e. channelization projects for which EPA has denied a permit under 404(c) for reasons relating to water supply, shellfish beds and fishery areas, wildlife, or recreational areas.
2. Projects which as "an initial step do not violate standards but inherently create significant pollution problems in related areas."	.Projects which, with high probability, will lead to undesirable growth rates adversely affecting the attainment of air quality goals in critical Air Quality maintenance areas or water quality goals established through State Water Quality Management Plans (Section 208,303).

Table III-2. (continued)

	.Projects which will not "stand alone," i.e. those for which full realization of benefits strongly implies further system development which, taken as a whole, would lead to standards violation or "undesirable growth rates" described above.
b. Where a Federal agency violates its own substantive environmental requirements.	.As applicable
c. Where there is a violation of an EPA policy declaration	.Violation of EPA's Statement of Policy on Protection of Nation's Wetlands (38 FR 10834).
d. Where there are no applicable standards or where applicable standards will not be violated but there is potential for significant and severe environmental degradation: 1. which could be mitigated by other feasible alternatives; <u>or</u> 2. which related to EPS's area of jurisdiction or expertise.	.Where adverse environmental effects are beyond EPA's jurisdiction and expertise (e.g. historic site, wild and scenic rivers), but there exists a feasible alternative (i.e. one that would substantially accomplish project purposes) which would significantly reduce adverse environmental effects. .Where severe adverse environmental effects are within EPA's jurisdiction and expertise but no standards violations are expected, e.g. either no standard exists for a particular water quality parameter, or considerable uncertainty regarding project environmental effects exists. .Where aquatic biota, water supply, or recreational areas are threatened, but no 404 permit is involved.

Table III-2. (continued)

Category 3: Inadequate	
General Criteria (from 309 Review Manual)	Specific Criteria for channelization
a. Insufficient information to permit a reasonable review of project features, thus precluding evaluation of project effects on EPA standards regulations or policies.	.Inadequate description of water quality parameters and their effects on uses (e.g. aquatic biota, water supply), either for the channelized area or downstream reaches. .Inadequate description of project operation, purposes, benefits and costs, construction techniques, resulting growth patterns, and other features necessary to allow comparison of project effects with area Water Quality Management Plans (and, perhaps, Air Quality Maintenance Plans).
b. The EIS fails to adequately consider important project features which EPA believes have a significant impact on the environment. (e.g. (if certain project components are not covered in a broad based EIS and the Agency's intent is not to prepare subsequent EIS's on these components).	Projects which may provide comparisons with Water Quality Management Plans, but are inadequate for determining local effects on water quality, aquatic biota, or other areas of EPA jurisdiction and expertise.

Table III-2. (continued)

Category ER: Environmental Reservations	
General Criteria (from 309 Review Manual)	Specific Criteria for channelization
a. Reservations exist concerning the environmental effects of certain aspects of the proposed project.	.Rare natural resources are directly or indirectly destroyed by operation or construction of the project and these resources are unprotected by Federal or state regulations. .Long-term effects of proposed actions are estimated by EPA to be serious but have not been adequately considered.

IV. IDENTIFICATION AND ASSESSMENT OF PROJECT IMPACTS

The purpose of this chapter is to furnish more detailed information and sources of information on the impacts of channelization projects. Impacts are discussed in three broad categories (hydrology/water quality, aquatic ecology, and terrestrial ecology), but the reviewer should recognize that substantial interdependence exists among these groups. Under "Sources of Impacts," impact-producing activities and situations in which particular effects are likely to occur are described. "Review of Impact Quantification," focuses on the methods that may be used to estimate the magnitude of various impacts. The "Assessment of Impacts," sections address the relationship of impacts to pertinent environmental standards, criteria, and regulations, and describe opportunities for mitigating project impacts. Tables II-2, II-3 and II-4 provide a detailed reference to discussions of impacts and should be used freely in locating specific material in this chapter.

IV.A. Review of Hydrology and Water Quality Impacts

Alteration of watershed hydrology is inherent in channelization activity. The changes that take place may affect not only water quality, but also aquatic and terrestrial ecosystems. Because of the strong interrelationships among impacts in these various categories, the review guidance on hydrologic impact sources and quantification provided in this section is also relevant to discussion of aquatic and terrestrial ecology impacts (IV.B. and IV.C.).

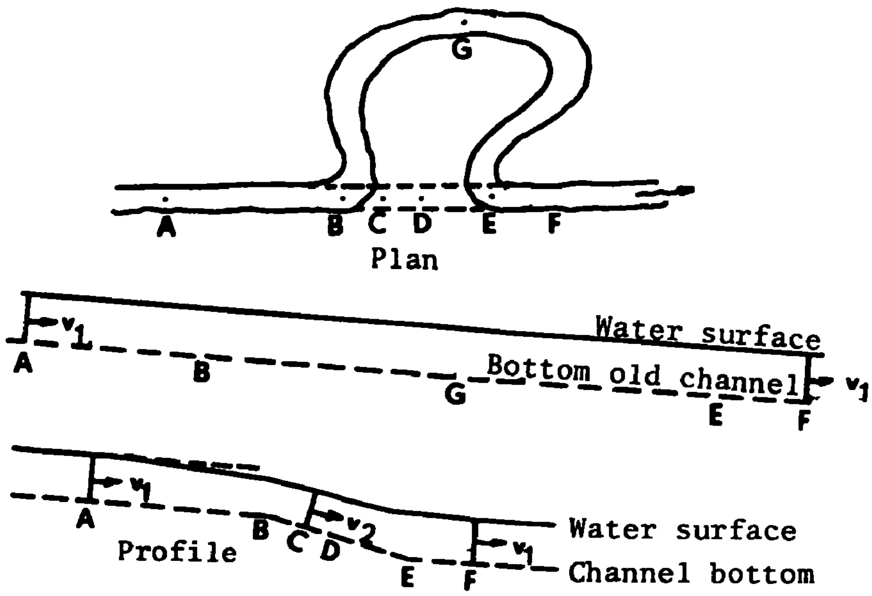
The construction phases of a channelization project give rise to increased pollutant loadings, primarily from work directly in the stream and from erosion of disturbed areas. Changes in water quality response of the stream result from the modified hydraulic characteristics of the channel following construction as well as from alteration of land uses in the watershed, both upstream and in the vicinity of the channelized segment. An understanding of the intimate relationships between hydrology and water quality characteristics in streams is essential to identification and prediction of impacts. The following descriptions of these relationships should enable the reviewer to ascertain, for a given channelization project, whether water quality impacts have been properly treated, and to comment on deficiencies in the EIS concerning evaluation of probable impacts not considered. The guidance presented herein may be supplemented by reference to the cited technical publications or through appropriate program offices within EPA.

IV.A.1. Sources of Impacts

Although direct construction phase impacts associated with channelization projects may persist for a relatively short time, on the order of months or years, the basic changes in stream hydrology brought about by channelization will endure for far longer periods. The water quality implications of channelization stem directly from the resulting hydrologic modifications and perhaps indirectly as well from overall changes in watershed land use and development. Therefore, adequate review and assessment of environmental impacts demand that the two perspectives, of time and geographical area that influences or is influenced by the project, be carefully considered. The description of hydrologic and water quality impact sources which follows is divided into several general categories, all of which must be examined spatially and temporally.

Changes in Hydraulic Parameters. The basic purposes of channelization necessitate that hydraulic characteristics be altered to increase the efficiency of water passage. This objective may be met in several ways. Channel straightening, accomplished by realignment or cutting off meanders, results in shortening the channel length and an increase in the slope of the stream bed in the channelized reach. Consequently, water velocities through the segment can be expected to be greater, with a corresponding decrease in depth or stage for a given flow. For some distance upstream and a lesser distance downstream from a shortened channel, the surface profile would also be lowered below that which would have occurred without channelization. In this situation, depicted in Figure IV-1, the stream gradient is unstable, and there exists a tendency for erosion of material from the channel bed and banks and increased deposition in downstream reaches. Downstream flood stages may increase as a result of this type of channelization project because of not only the increased hydraulic capacity but also the loss of flood storage capacity previously afforded by the longer natural channel and adjoining flood plain. Changes in water depth and turbulence in the channelized reach will have an effect on reaeration, and the decrease in travel time may result in more rapid transport of pollutant loads to downstream sections of the watercourse. For this reason, it is important that existing waste sources and water quality in the project area be adequately identified and described in the EIS. If an areawide waste treatment management (Section 208) plan has been prepared for the area, it may contain information on nonpoint sources of pollution.

Also, levees may be incorporated in a channelization project in order to confine river flow to a definite width and protect adjacent flood plain areas from inundation. Spoil material from channel excavation may be used as fill material for levee construction. Hydraulically, levees act to (a) increase velocity and river stages through the section during floods, (b) increase the maximum discharge at all points downstream, (c) decrease the time of travel of the flood wave, (d) decrease surface slope of the stream for a distance upstream, and (e) reduce valley storage. By preventing flooding of low-lying areas, groundwater recharge associated with overbank flooding and ponding of water will be decreased. During times of flooding, water flowing over the flood plain is slowed by friction from contact with the soil surface, trees, shrubs and other vegetation, and all except the very fine solids settle out. The contact with vegetation allows the absorption of minerals, nutrients, and other pollutants that may be present in the water.



General Hydraulic Effects	Potential Environmental Considerations
Shortened channel length and reduced channel storage	Change in reaeration, section AF (may or may not be greater than total reaeration formerly provided in longer channel)
Increased velocity in affected portion due to increased gradient (B-E)	Change in total amount and type of aquatic habitat, section BGE, resulting from loss of riparian vegetation and pool-riffle sequence of unchannelized stream
Decreased depth of flow from A to F	Tendency for increased channel and bank erosion (downcutting) for some distance above and below cutoff
	Increased flood stages in downstream sections
	Increased sediment deposition in downstream sections
	Reduction of groundwater recharge

Figure IV-1. Hydraulic Effects of Channel Straightening (Cutoff) and Related Environmental Considerations

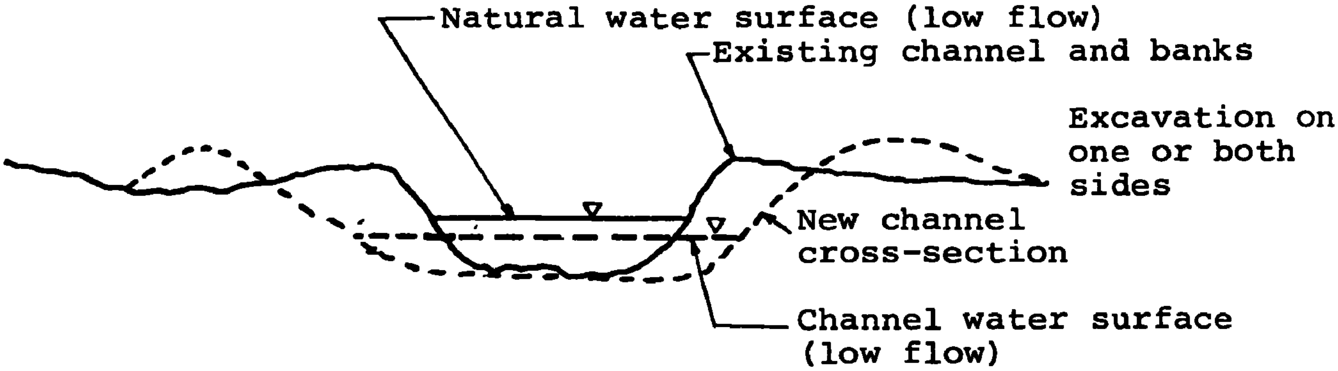
Source: Adapted from Schwab, G.O., R.K. Freuert, T.W. Edminster, and K.K. Barnes, Soil and Water Conservation Engineering, Second Edition (New York: John Wiley and Sons, Inc.), 1966, p. 344.

The capability of flood plains to remove suspended material will be reduced in a leveed or channelized reach, resulting in greater sediment transport to downstream sections. Dissolved and absorbed constituents would similarly pass through such a channel instead of being deposited on the flood plain.

Modification of an existing channel may be undertaken to increase channel capacity. Alterations may entail (a) increasing the channel cross section (width and/or depth) and (b) decreasing resistance to flow. Generally, for the same increase in cross-sectional area, deepening will be more effective than widening in terms of hydraulic efficiency. Figure IV-2 illustrates some of the general effects of channel deepening and widening. Resistance to flow, or the "roughness" of a channel section, may be decreased most simply by removing trees, stumps, vegetation, debris and other obstructions that have accumulated. This method will probably have a greater hydraulic effect on a small stream than on a large stream. Low-flow regimes can also be affected by channelization, particularly if land drainage is improved and groundwater contributions to discharge are thereby reduced. If the channelization project necessitates removal of trees along the banks which formerly shaded the stream, the thermal regime may also be altered. With a substantial increase in exposure of the water surface, it is probable that diurnal temperature fluctuations will increase, due to greater warming during the day but also faster radiational cooling at night.

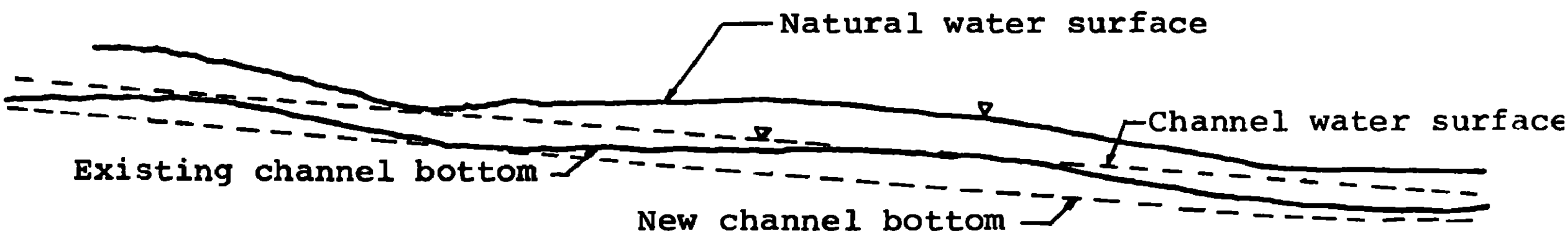
In special circumstances, channel lining with rock rip-rap, concrete, vegetation, or other materials may be utilized to provide channel bottom and bank stabilization, and at the same time enhance the hydraulic efficiency of the channel. Water quality considerations in this context are basically the same as for channel straightening: changes in travel time and factors affecting reaeration. Installation of a smooth, uniform channel in which water is deeper and less turbulent than in the natural stream is likely to adversely affect assimilative capacity in the altered segment. In unlined channels, the potential for bank erosion and increased turbidity also exists. Noncohesive soils may be more susceptible to erosion than fine-grained, cohesive materials.

In some cases, channelization will comprise only a part of a more comprehensive land and water resources program in a watershed. Impoundments, retarding basins, sediment pools, and other structures will modify flow regimes and water quality to some degree. Retention of sediment behind dams or low weirs will result in the discharge of clearer water which will tend to erode the stream bed and banks and pick up a new suspended sediment load. Possible reduction of flood peaks or augmentation of low flows would also affect flow conditions in a downstream channelized reach. Natural water temperatures below impoundments may be reduced in the warm months due to deep, cold water releases or possibly increased if surface waters exposed to solar radiation are discharged. The reviewer should consult EPA's guidelines for review of EIS's on impoundment projects[1] for further description of these impacts.



<u>Widening of Existing Channel</u>

<u>General Hydraulic Effects</u>	<u>Potential Environmental Considerations</u>
Increased cross-sectional area through which flow occurs.	Greater exposure of water surface to atmosphere.
Decreased water depth at normal and low flows.	Increased solar radiation and warming.
Reduced frequency of overbank flooding.	Loss of aquatic habitat, including loss of cover for fish and loss of stream bank vegetation.
Greater uniformity of velocity.	Alteration of erosion-deposition patterns.



<u>Deepening of Existing Channel (Profile)</u>

<u>General Hydraulic Effects</u>	<u>Potential Environmental Considerations</u>
Reduced water surface elevations.	Change in sediment transport capacity.
More uniform gradient, due to elimination of pool-riffle sequence.	Alteration of substrate.
Lowering of water table.	Alteration of riparian wetlands and vegetation.
	Loss of aquatic habitat for some species

Figure IV-2. Hydraulic Effects of Channel Widening and Deepening, and Related Environmental Considerations

Changes in Land Use. Land use patterns can have a marked influence on watershed hydrology and water quality. Channel modifications may contribute to changes in land use over the life of the project, as when land drainage or flood protection is provided. However, projected conditions of land use both in the immediate area of channel improvement and in a broader region of possible influence may have relevance to the identification and assessment of environmental impacts. In the first place, land uses in the upstream watershed affect hydrology and stream flow. Reductions of forest cover due to silvicultural or agricultural activities, urbanization, or other development tend to increase the volume and decrease the time of concentration of surface runoff, causing increased flood peaks downstream. This effect depends on the extent of such land use changes relative to total watershed area, and may be highly significant on small watersheds. Channel modifications, which generally increase flood stages in downstream reaches, would have the effect of augmenting flood levels even further if upstream watershed practices and activities increased runoff. Therefore, consideration must also be given to flood plain land uses below a channelization project, where flood hazards may increase.

Inputs of pollutants, including sediment, agricultural chemicals, and possibly municipal or industrial wastes, may change as land use patterns in a watershed are altered. Within the area afforded flood protection or drainage benefits by channelization, potential pollution will be related to the expected changes in land use. It is likely that conversions of additional land to agricultural use will cause some increase in sediment, nutrients, and dissolved solids loads to the channel. However, this may not occur if the project simply improves productivity of existing agricultural lands without stimulating new agriculture. Secondary effects on water quality may be experienced if channelization leads to development of adjacent flood plain areas. Land conservation measures that are integral components of federally assisted small watershed projects may counteract possible water quality degradation from land use changes.

Construction and Maintenance Activities. Channelization can involve a variety of construction activities and maintenance practices having the potential to directly or indirectly affect water quality. Because project construction necessitates work directly in the stream and in low-lying adjacent riparian areas, sediment will usually be the principal pollutant. The types of construction equipment utilized in channelization vary depending on the size of the project, nature of construction specifications, and design features. On small projects actual excavation would normally be accomplished by dragline or power shovel situated on the stream bank. For larger projects, self-loading scrapers, and bulldozers may be utilized. Often work areas will be dewatered by construction of coffer dams or diversion of streamflow. Shaping of channel banks and placement of excavated material for berms or levees will involve grading machinery as well as soil compaction equipment such as vibrators, sheep's-foot rollers, and other devices. Although not addressed in detail in these guidelines, channel deepening and widening projects in estuaries and harbors for the purpose of boating or shipping access are undertaken with barge-mounted mechanical or hydraulic dredging equipment. Generally, equipment working in the streambed rather than from the banks poses a greater threat to water quality.

Excavation and earthmoving, removal of snags and other debris, clearing of access and haul roads, and other activities can accelerate soil erosion and result in the introduction of significant quantities of sediment to a watercourse. Suspended solids and turbidity are important in that they are very noticeable forms of pollution; however, conditions favorable to the production of sediment may also cause the introduction or the release of other pollutants that are absorbed on solid particles or present in the runoff water. These may include organic, oxygen-demanding matter, chemical pollutants such as petroleum products, pesticides, fertilizers, metals, and construction chemicals, and biological pollutants (bacteria, fungi, and viruses) from the soil or due to improper sanitation on the construction site. Generation of sediments and runoff-related pollutants should decline rapidly following completion of construction and installation of erosion protection and site restoration measures. Over the longer term, periodic maintenance of the channel involving removal of in-stream debris, aquatic vegetation, and terrestrial vegetation that is encroaching on the channel banks, repair of bank protection, or redredging may be required.

As a basis for insuring that potential construction and maintenance impacts on water quality have been identified, the reviewer should determine whether all major activities logically required for installation of the project are discussed in the EIS project description or other sections. In addition, a concise description of construction timing, phasing, and extent of operations should be presented.

Groundwater. Groundwater effects from channelization result from changes to the streambed and through modifications of floodplain and wetland recharge areas.

Changes to the streambed may affect its potential as a recharge area, by modifying any or all of several variables related to recharge potential. These variables include:

..time of water residence in the channel,

..depth of channel (e.g. above or below the water table),

..slopes and elevations of the groundwater (piezometric) surface and stream gradient,

..and the transmissivity of sediments (in the channel bed and adjacent banks) to groundwater flow.

Transmissivity is a measure of infiltration and groundwater-movement potential and is itself dependent upon variables such as:

..permeability and porosity characteristics of the banks and channel bed,

..accumulated silt and clay in the channel bed, for example, which will impair infiltration or recharge by the channel; colloidal material in the water may reduce aquifer transmissibility.

A channelized reach of stream, as contrasted with a natural stream segment, will often result in a shorter length of time during which a given volume of water is in contact with the land surface thereby decreasing infiltration and the channel's potential to act as an influent stream. (Influent conditions occur when stream beds serve as groundwater recharge areas; "effluent" conditions occur when groundwater discharges to streams, as in most perennial streams where groundwater contributions to streamflow are equivalent to "base flow".) Both infiltration from the channel to groundwater reserves, or transfer of volumes in the opposite direction may be simultaneous effects observed at different places along a channel or stream, or they may occur at the same place at different times, for example, during drought conditions or after storms.

Although the effects of channelization on groundwater have been extensively reported in monographs and journals, it is difficult to draw generalizations about predicting those effects. The ADL report, in its assessment of "watertable changes and stream recharge" across the U.S., makes the following observations:[2]

> A proper factual assessment of the effects of channel modification on groundwater levels and the capacity of drainage areas to recharge streams is seriously hampered by lack of data. While effects are generally assumed or predictable, specific situations are extremely difficult to document with accuracy . . . Each localized situation presents such high variability and measurement has been so scattered, that no conclusive groundwater and surface flow data are found that can be directly related to drained lands and adjacent downstream flows.

The report goes on to state that, of the 42 channel projects studied, only 13 appear to have had "an uncertain and mixed cause-and-effect relationship" on adverse lowering of groundwater levels or on the capacity of drainage areas to recharge streamflow. Another 20 projects were "unimportant" in modifying groundwater levels. The conditions characterizing channelization projects which had minimum effects on groundwater included:

- a short channelized segment relative to the impacted groundwater basin;

- a small adjacent zone-of-influence in channels relative to natural inflow to such zones;

- a floodplain which is narrowly confined and/or has relatively steep gradient;

- a high average rate or precipitation, distributed over all seasons;

- the channel traverses bedrock outcrops or has a bed of rock/gravel;

- an absence of opportunity for post-project and off-channel drainage extensions;

- the presence of upstream storage which acts to minimize low flow conditions and to recharge watershed aquifers;

- channel flow which is ephemeral under natural conditions;

- control structures exist in the channel to regulate drainage and flow;

- construction/maintenance activities are predominantly clearing and snagging (instead of excavation).

For example, the use of in-channel control structures, such as low-level weirs and dams may serve to transform channels into channelized reservoirs. If the channels are unlined, the effect of water retention in the channel may serve to replenish groundwater reserves, to raise groundwater levels, and to irrigate plant root zones in adjacent bank areas. Channels are then similar to what are termed "influent" streams. Without such control structures, an unlined channel, if dredged in the water table, will act as a drain and lower the water table. Lining the channel with impermeable material may also negate the drainage effect, but some drainage may be necessary to prevent uplift, or "floating", of the channel lining.

Vegetational changes will also affect the amount of water available for groundwater recharge. For example, differing species of vegetation, especially such phreatophytes (water-seeking plants) as saltcedar, greasewood, mesquite, and alfalfa exert a seasonal influence on groundwater recharge rates. Losses from evapotranspiration resulting from changes from forest land to crop land will also result in decrease in water for recharge.

Floodplains and Wetlands. Channelized segments may diminish that potential recharge to aquifers which otherwise occurs in floodplains by denying access to these over-bank areas by normal flood volumes. This has been a critical issue in some areas such as the Kissimmee River Control Project of Central Florida.[3] Similarly, drainage of wetlands associated with channelization projects directly lowers the water table and also greatly reduces the wetlands' recharge potential. The physical changes in surface/groundwater conditions that may be caused by channelization can also have an effect on plant cover; the riparian and wetland vegetation that exists along a stream or channel will respond to changes in groundwater levels. Bottom land and wetland fauna may be gradually eliminated in favor of upland vegetation associations by lowering groundwater levels alone, or the process may be accelerated by conversion of the lands to other than natural open space uses. In most cases the drainage functions of channels will have a much greater impact on groundwater levels and groundwater quality than will the physical modification of the streambed itself, particularly where tributary drains and other facilities will be installed in conjunction with the main channel for drainage of upland as well as riparian areas. Any changes in vegetative cover initially induced by land drainage and reduction of groundwater recharge may in turn affect groundwater by retarding or enhancing runoff or because of differing consumption and evapotranspiration rates. The cause-effect relationships among channelization, groundwater, and vegetation can be complex and underscore the difficulties of determining the nature of effects on groundwater hydrology.

Effects on Groundwater Quality. Water quality impacts on groundwater resulting from channelization activities may result from the channelization work itself, including wetlands drainage, and from the shifts in land uses or intensities brought on by channelization. During both the construction and maintenance phases there may be appreciable disturbances to the groundwater regime in the project vicinity. Interception, augmentation, or diminution of groundwater flows by: (1) excavation of the channel itself -- or by collecting drains, (2) the placement of spoil on top of recharge areas, and (3) the ponding of waters in temporary or permanent sediment basins are typical of those impacts which should be assessed. The existence of such impacts may be explicitly stated in the EIS or may have to be deduced by the reviewer.

The effects of shifts in land use or intensities different from pre-channelization conditions, will also affect groundwater quality. For example, the drainage of the wetlands in a Florida watershed resulted in increasing available pasturage, occasioning an increased density of cattle and subsequent pollution problems with animal wastes in the waterways of the project. Changes in agricultural practices, the quantity and character of domestic or industrial wastewater discharges are the principal sources of impacts on groundwater quality. The pathways of pollutants which enter the groundwater because of the presence of channels depend upon whether the channel is receiving or discharging groundwater at specified times or places. Measured concentrations of pollutants and nutrients in groundwater are obtainable from water quality analyses. But the chemical modification of these pollutants (e.g. denitrification of nitrates) while in aquifers, and their interaction in channels (or other water bodies) with waters from other sources are not well understood.

The depletion of groundwater reserves subsequently may cause a reduction of instream flows which is of special concern during periods of low flow. This can have the following effects upon water quality:

..prevention of in-channel oxidation and dilution of organic chemicals,

..raising water temperatures (especially in the summer) thereby reducing the dissolved oxygen content of the waters,

..degrading water quality aesthetics (e.g. sight and odor),

..increasing the rate of accumulation of sediment, litter and debris in the channel thereby diminishing hydraulic efficiency.

IV.A.2. Review of Impact Quantification

A wide range of techniques may be used to quantify hydrologic and water quality impacts of channelization. Since careful investigation of flows and hydraulic response is usually required for the proper design and functioning of a channel, these factors are likely to be covered in some detail, if not in the EIS then in corresponding technical engineering and planning reports for the project. Methods presently used by Federal agencies can provide reliable characterizations of existing and postproject hydraulics. In many cases too, probable effects on water quality and waste assimilation can be interpreted from knowledge of a channel's hydraulic behavior under various flow conditions. However, the water quality analysis is apt to be complicated by many factors outside of actual channel modification, including changes in land use and other water resources development projects in the watershed or basin. Impact prediction becomes more speculative as uncertainties in future land use and wastewater sources are introduced. Nevertheless, the consequences of possible development and land use can often be described, at least qualitatively, in terms of their pollution potential or effect on watershed hydrology. It is important that the interactions between the direct effects of channelization and the indirect influences of land use be addressed in impact estimation. The major subdivisions of this section therefore complement each other in some ways, illustrating the interrelatedness of different sources of impacts and the need for a sufficiently broad view of a channel project.

Changes in Hydraulic Parameters. Because the hydraulic regime of a channel has relevance to many of the impacts that are likely to occur, adequate quantification of flow conditions is basic to impact evaluation. Of primary interest are the changes in stream geometry, flow, depth, substrate and other characteristics due to channel modification, relative to the existing situation. The starting point for impact quantification is, therefore, a thorough description of hydrology and water quality in the area to be affected by channelization.

Basic Hydrologic and Water Quality Characteristics. Existing flow characteristics in the project area must be described sufficiently to indicate the nature and extent of flooding, drainage or other problems to be rectified by channelization. For purposes of design, high flows are usually most important, but normal and low flow regimes are also of interest for water quality management. Flood discharges in and downstream from the reaches where channel improvements are proposed should be related to frequency of occurrence, stream stage, and the flood plain areas subjected to inundation. The low-flow characteristics should be similarly quantified, as, for example, the average minimum consecutive 7-day flow to be expected once in 10 years, which is normally used for interpretation of state water quality standards and the design of wastewater treatment facilities. In the absence of fairly long historical records of discharge (such as those provided by USGS stream gauging stations), high water marks from previous flood events and field measurements of velocity, depth, and cross-sectional characteristics may be used to construct stage-discharge relationships, water surface profiles, and other hydrographic information.

Other attributes of the existing stream environment are fundamental to the evaluation of impacts of channelization and must be described, quantitatively where possible, in the EIS. Pertinent elements include:

- Length and normal width of stream(s) in the proposed project area

- Velocity and depth at representative cross-sections and travel times through the reach, particularly for the low-flow condition

- Location, type, height, and density of woody vegetation along both stream banks

- River bottom composition including location and linear extent of various substrate types (silty, sandy, gravelly, etc.)

- Sediment yields from upstream drainage area

- Present water quality and classification

- Point and nonpoint sources of wastewater discharges

The physical stream characteristics are important because of their relationship to water quality and assimilative capacity. The extent to which assimilative capacity must be considered is primarily a function of present and projected water uses and wastewater discharges in the watershed. For example, some of the Soil Conservation Service small watershed projects implemented under Public Law 566 are located in areas receiving no municipal or industrial discharges. In more developed watersheds, however, water quality implications of channel modifications may be important.

Detailed descriptive and quantitative information on surface water qualty, present and probable future waste loads, and assimilative capacities may be contained in state or other water quality surveys, the 303(e) basin plan, and the 208 areawide waste treatment management plan if one has been prepared for the area. Results of any site-specific investigations that have been conducted, either during project planning or as part of State or Federal water quality management programs, may have relevance to estimation of channelization impacts.

Quantification of impacts due to channelization is rarely a simple, straightforward procedure. The direct implications of altered hydrographic behavior on downstream flood stages can be identified and quantified fairly accurately using tested methods of hydraulic and hydrologic analysis. The validity of estimates of water quality impacts, on the other hand, hinges on the proper interpretation of the altered stream flow and channel conditions. In evaluating the treatment of hydrology-related water quality impacts in an EIS, the reviewer should keep in mind the potential significance of various physical features of the existing stream and proposed channel project. For instance, oxygen transfer or reaeration in a stream or channel generally increases with velocity and is inversely related to depth. Irregularities in the channel bottom, such as gravel, rocks and other obstructions create turbulence and increase reaeration. The nature of the benthic community, whose productivity depends heavily on the type of substrate, is also a very important factor in the self-purification ability of the stream.

Downstream Hydrologic Effects. A quantitative analysis of the post-project hydrographic regime should be presented with detail sufficient for comparison with preproject conditions. Such an analysis must take into account other identifiable influences on streamflow in the watershed, particularly upstream reservoirs which may reduce peak flows and possibly augment low flows through the channelized section. In considering potential downstream effects due to an increase in hydraulic efficiency in a channelized reach, estimates of downstream flood stages corresponding to design peak discharges are required. The Soil Conservation Service guide, Planning and Design of Open Channels,[4] recommends that where downstream effects of channel improvement are significant, the analysis should be carried downstream to the point where effects on flood stages have been dissipated. These predictions are critical because of the possibility that channel modification may ultimately contribute to the need for further protective measures downstream. Problems may arise particularly if downstream flood plain areas are being, or are expected to be, converted to more intensive uses susceptible to flood damages.

Methods appropriate for quantifying effects on downstream flood flows vary with complexity of the stream network, extent of reservoir and other influences on flow, and the location and scope of the proposed project. Basic operational techniques normally used by Federal agencies involved in planning and design of channel improvements range from computation of surface water profiles to hydrologic flow or storage routing methods. Various Federal agency and other publications[5-9] delineate the predictive techniques most frequently used in practical planning and design application. Data on: channel cross-sections, roughness, slope for the stream or channel sections of interest, and, for the routing methods, inflow hydrographs are required. Most of this data will have been collected during project planning as it is essential to the design of channel improvements. The reviewer needs to ensure, nevertheless, that potential effects on downstream flood patterns have been quantified. If this information is lacking from the EIS, a request for more quantitative data is reasonable and should be made in the reviewer's comments. Description of the extent and characteristics of floodplain areas that would be affected should accompany the analysis of changes in downstream flood stages. As a general guide, impacts on flood stages will probably be most significant in reaches immediately downstream from a channel project, decreasing as flow contributions from larger drainage areas are added.

Hydrologic Effects on Waste Assimilation. Although much more difficult to quantify, water quality and other benefits may be associated with overbank flooding, primarily the removal of a portion of a stream's suspended solids load, nutrients, and other dissolved materials. By confining a stream to an artificial channel, sediments and other pollutants that normally settle out on adjacent floodplains would be conveyed downstream adding to the sediment load. Obviously a trade-off between sediment/flooding damages and the natural purification ability of a stream is involved. It is important that the potential impacts of channelization on the natural role of floodplains in removing sediment and other impurities be recognized, even if the magnitude of effects on water quality cannot be easily estimated.

Normal and low-flow regimes also need to be evaluated for a channel modification project. Discharge estimates should reflect any existing and anticipated influences on flow through the channel, such as flow regulation by upstream impoundments, diversions for water supply or irrigation, alteration of groundwater/stream interactions, or other water management projects. Channelization may have beneficial or adverse impacts on natural degradation and assimilation of pollutants, depending on the resulting flow characteristics. Techniques for quantifying these impacts may range from judgmental estimates based on channel dimensions, slope and other factors for short channel modifications on small streams to more detailed analyses involving estimation of reaction coefficients and modelling for larger projects where water quality is an important issue. For either approach, a clear description of channel geometry and its effects on discharge should be provided, at least for a representative low flow. In essence, the EIS must present data sufficient to determine how the length, width, slope, bottom composition, and water velocity and depth in a channelized section will differ from preproject conditions.

In the case of channel straightening, passage of water through the section will be more rapid, thereby reducing residence time. Although the effects of a channel on travel time cannot be directly measured in the planning phase, estimates of average velocity and channel dimensions will permit accurate determinations. Because of the need to design channels so that excessive deposition of suspended material will not occur during low flows or scour at high flows, the planning agency should have developed estimates of postproject velocity patterns for the reach to be channelized. The magnitude of the change in travel time is related to the change in channel length and slope, bottom roughness, and cross-sectional area. Oxygen-demanding wastes as well as bacteria and other pollutants will be borne through such a channel more rapidly with less time for purification, thus increasing oxygen demand and water quality degradation downstream.

When channelization follows an existing stream alignment, changes in cross-sectional area and bottom characteristics are the major factors that may affect the water quality response of the stream. Anticipated low-flow conditions in the channel, including average water depths and widths should be quantified in the EIS and contrasted with existing flow parameters. In addition, expected alterations of the stream bed must be described. Generally, for example, destruction of rocky riffle areas will have a more significant adverse effect on natural purification than will the excavation of alluvial silt and mud. Clearing, snagging, and removal of other obstructions should be described in terms of the areas affected. Elimination of debris that enhances turbulence may contribute to lowered reaeration. On the other hand, increasing the bottom width of a channel will cause a reduction of water depth and exposure of a greater water surface area to atmospheric reaeration. If detailed field studies of oxidation and reaeration constants have been performed in connection with basin planning or other studies, this information would facilitate prediction of the impacts of channel improvements. Otherwise, careful comparison of qualitative data on channel characteristics for pre- and postproject conditions should be made. Detailed water quality modelling would not, in most cases, improve materially the estimation of water quality impacts that can be performed by descriptive and semiquantitative methods. Exceptions might be the projects on larger streams where channel geometry is to be modified significantly over long stretches and where numerous waste discharges enter the project area or upstream watercourses.

<u>Hydraulic Influences on Channel Stability and Erosion</u>. The hydraulic changes accompanying channelization necessarily lead to differences in erosion and sedimentation patterns within, upstream, and downstream from a project area. The soils and geology of the lands through which a channel may be constructed, the characteristics of the suspended and bed load, and velocity regime are the primary determinants of bottom composition, unless some kind of channel lining (rock, rip-rap, concrete, vegetation, or others) is used. Table IV-1, based on field investigations of 42 channelization projects, provides initial guidance on conditions under which significant erosion and sedimentation problems are not likely <u>within</u> a proposed channel. Conversely, conditions deviating from those described suggest the possibility of difficulties over the life of a project, the need for special attention in the EIS and perhaps modification of project design.

Table IV-1. Conditions Favoring Low Potential Contributions to Erosion and Sedimentation Problems Within a Channel Modification Area

-- Short channelized reach relative to land-water system

-- Slight design gradient

-- Moderate design velocities

-- Moderate channel-bank design slope

-- Limited excavation

-- Limited realignment

-- Riprapping or concrete lining of critical areas

-- Seemingly stable channel beds

-- Banks stabilized by vegetation

-- Mitigation measures such as drop structures or sediment traps in upstream storage reservoirs to reduce sediment transport

SOURCE: A.D. Little, Inc., Report on Channel Modifications, Volume I, for the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., March 1973, p. 163.

Quantification of the expected performance of a channel with respect to aggradation and degradation is approached through stability analysis, which takes into account the factors of geology, flow, and sediment transport. With respect to judging the differing potential for erosion in channels with different cross-sectional dimensions, Chow[10] offers the following general rule:

> When other conditions are the same, a deeper channel will convey water at a higher mean velocity without erosion than a shallower one . . . probably because the scouring is caused primarily by the bottom velocities and, for the same mean velocity, the bottom velocities are greater in the shallower channel.

A qualitative assessment of bed stability and deposition of suspended sediments and moving bed loads in alluvial channels can be obtained by the method of permissible velocities.[11] This technique has been expanded and is currently being used by the Soil Conservation Service[12] for certain design situations. Basic data requirements are the hydraulics and transport characteristics of the channel and the character of the earth materials through which the channel will pass (grain-size distribution, cohesiveness, plasticity, etc.).

More detailed investigations of channel stability with respect to sediment transport may be necessary when significant amounts of sediment, either suspended or bedload, are introduced from upstream sources that will affect erosion and deposition in the channelized reach. Perhaps the most widely used empirical method for total load computation was developed by Einstein.[13] This prediction method computes the equilibrium rate of scour and deposition based on channel cross-section, sediment characteristics, and properties of flow regimes. The method can be used in hand calculations for simple channel cross-sections or short reaches to predict sediment discharge rate. Since the rate of bedload sediment transport has been shown to be strongly related to mean velocity, at least for materials in the size range of medium to fine sand, the SCS makes use of this relationship in channel stability design when applicable. Where velocity characteristics may change considerably, as in the case of straightening and shortening a stream channel, potential for sediment erosion, transport, and deposition should be analyzed for a distance upstream and downstream as well as in the project area itself.

In special cases involving large projects or multiple influences on sediment transport (such as impoundments), computer models may be used for studying the short- and long-term effects of reservoirs, levees, and channel modifications. The effect of altering the frequency and duration of flow can be investigated in terms of the response of the bed and water surface profiles. Such a model developed for the Corps' Hydrologic Engineering Center[14] includes predictions of: total bed material, volume and gradation of material deposited, armoring of the bed surface, suspended sediment load and aggradation, and resulting bed geometry. In addition, sediment outflow at the end of the modelled channel is calculated. It should be noted that the use of computer models is comparatively expensive and would be appropriate only for assessment of large or complex projects or a series of projects in a basin.

The reliability of results obtained by any of the methods mentioned above depends on the type and amount of baseline data on which sediment-related predictions are based. Data requirements for channel planning purposes should, in general, be linked to the scope of the project and the value of the resources that may be affected. For many upper watershed projects, little or no quantitative information on hydrology and sediment yields may exist. Representative hydrological estimates are usually constructed, as discussed earlier, without undertaking extensive field investigations. Measuring the sedimentation characteristics of a stream, however, is one of the most difficult tasks in an environmental monitoring program. In many cases, estimation of the availability of movable bed material within and upstream from a proposed channel improvement, rather than actual field measurements of sediment discharge rate, will be made for purposes of stability design. Data descriptive of the geomorphology of deposits in the project area should be included in the EIS. Knowledge of watershed land uses and related sediment yields is also relevant to estimation of potential erosion and sedimentation problems. Conditions differing greatly from those described in Table IV-1 may warrant field measurements of sediment discharge. A good synopsis of the methods for measuring suspended, bedload, and total sediment discharges is the report "Determination of Fluvial Sediment Discharges." [15]

The reviewer should know that the techniques for predicting sediment transport processes are for noncohesive sediments (those which are not prone to flocculation or aggregation but behave more like sand grains). The state-of-the-art for quantitatively estimating erodibility of fine-grained cohesive materials is not as well developed; experience and judgment must therefore be relied on more heavily in these situations.

Techniques in use for estimating channel stability are generally applicable to analysis of bank stability as well, except that additional forces must be considered. Methods from soil mechanics for evaluating the effects of alternate wetting and drying, seepage, slope, and other factors are normally used. As a general rule, the vulnerability to erosion of unlined channel banks and bottoms constructed in noncohesive sediments increases with decreasing grain size, into the sand range. Mixtures of silts and clays cannot be categorized as easily, except that fine-grained soils with high percentages of clay and high plasticity are often more erosion-resistant than sandy material.

Changes in Channel Substrate. One other aspect that should be addressed in the EIS is the probable change in substrate composition over time. In channels that follow an existing stream course with no major changes in gradient, the bed may be very much like that of the existing stream. However, if velocities are increased such that some channel scouring will occur, the fine-grained fraction of well-sorted sediments may be eroded, leaving coarser gravel or cobbles as an "armor" against further erosion of the channel. This possibility is sometimes anticipated and planned for in channel design. Although difficult to quantify, the nature of the bottom plays an important role in the self-purification of a stream or channel. Besides physical influences of the substrate on turbulence and reaeration, the character of the bottom is a significant factor in determining the diversity and abundance of benthic organisms that will inhabit a channel. The benthic organisms in turn consume organic detritus and otherwise aid in removal of impurities from the overlying water. Generally, clean stony bottoms will exhibit a richer diversity of benthic fauna, both in numbers of species and total biomass, than will silty reaches and pools.[16] Section IV.B., Aquatic Ecology Impacts, presents further information on these relationships.

Changes in Temperature Regime. The issue of thermal regime changes will not be important for all channel projects. Generally, construction activities that necessitate removal of shade-producing trees and vegetation from the banks of small streams are likely to cause potentially significant changes in temperature patterns.

Cooper et al.[17] describe several techniques for estimating surface water temperatures which can provide temperature profiles based on stream geometry, inflows, outflows, inflow termperatures, and meteorologic data. Brown,[18] however, has developed a prediction method that focuses more directly on the probable effect of channelization, that is, the maximum change in water temperature as a result of clearcutting of streamside forests. Basic data requirements for applying the method are: the boundaries of the proposed clearcutting, minimum summer discharge and corresponding stream surface area and travel time, and readily obtainable solar data. The reviewer should note that shaded zones below cleared stream segments will probably not cause any cooling of the stream once its temperature has risen due to greater exposure to the sun.

The report, Temperature and Aquatic Life,[19] provides a documented summary of important effects of water temperature and changes on chemical reactions, bacteria, fish, aquatic plants, and benthos which should aid in reviewing the EIS treatment of the impacts of thermal regime changes. From a water quality perspective, chemical reaction rates geneally increase as temperature is increased and oxygen solubility decreases, meaning that the decay of organic substances will have a greater adverse effect on DO levels at elevated temperatures. Section IV.B. further addresses the ecological consequences of temperature alterations that should be considered in the EIS.

Changes in Watershed Land Use. Basically, any changes in land use can affect the quantity and quality of runoff, and thus the hydrologic regime and surface water quality as well. However, neither the prediction of future land use nor the estimation of hydrology/water quality effects of a particular land use is an easy task. For areas directly affected by flood control, drainage, or other channel functions, the EIS must contain descriptions adequate to quantitatively compare present and forecast (postproject) land uses in terms of location, intensity, and the acreages involved. Fertilizer and pesticide application rates and total loadings without and with the project should be estimated for affected agricultural lands, as should the ameliorating influences of any land treatment and soil conservation practices to be undertaken adjunct to structural measures. The EIS should also discuss conversions of open or lightly developed flood plain lands to more intensive residential or other urban uses that may take place over the life of the project.

The projected course of land use and development in a watershed, whether or not influenced by channel modifications, is relevant to the estimation of impacts. The greatest potential for significant changes in hydrology and water quality exists when substantial conversions and alterations of land use and vegetative cover are expected. From a hydrologic perspective, runoff rates and volumes are closely related to land use. A general ranking of runoff potential, from low to high, for different land uses on a given land area (and soil type) might be: forest, meadow, close-seeded legumes, small grains, row crops, residential with storm drainage system, and commercial and business areas. Trends in watershed land use toward removal of forests or urbanization can thus be expected to increase flood discharges. Installation of drainage facilities on agricultural land in conjuction with channelization would have the same effect.

It is important, therefore, that hydrologic analyses reflect probable changes in runoff rates and peak flows for future land use patterns. The Soil Conservation Service[20] has developed methods for estimating the relationship of runoff to characteristics of soil, land use, and land treatment practices such as contour plowing or terracing. The methods have been designed for use in watersheds where historical streamflow records do not exist, since most SCS projects are located in ungauged watersheds. Input requirements are rainfall, soils, vegetative cover, and topographic data, all of which are ordinarily available or readily obtainable in enough detail to make preliminary estimates of runoff for purposes of watershed planning.

On small watersheds that are undergoing or expected to undergo significant changes in land use, hydrologic impacts can be substantial, with peak flood discharges increasing in magnitude by several times. Intensive silvicultural activity, conversion of forest lands to agricultural use, and urbanization are the major shifts that must be considered. The publication, Rainfall-Runoff Relations on Urban and Rural Areas,[21] illustrates the impacts that various degrees of urbanization, as measured by population density, can have on flood peaks. The reviewer should ensure that the effects of land use changes over the life of the project have been considered in hydrologic estimates.

The water quality aspects of land use present greater difficulties for quantification. It does not necessarily follow, for example, that more intensive agriculture on lands drained or protected from flooding by a channel project will lead to introduction of greater amounts of pollutants to the watercourse. For agricultural lands directly affected by channelization, the EIS should present quantitative estimates of both existing and projected applications (per unit area and total loading) of agricultural chemicals including pesticides and fertilizers. Such values will only indicate the potential for agricultural pollution; resulting effects on water quality will be influenced by land treatment, agricultural chemical application practices, and other factors. The reviewer should note also that agricultural lands are one of the largest contributors of sediments to surface waters.

Uttormark et al.[22] present a thorough search and compilation of data from literature on nutrient loadings of agricultural, forest and urban runoff. Generally, nutrient content of urban runoff was found to be highest, and from forests, the lowest. Tables 9, 11, and 13 from this publication should be consulted for information on the variability of nutrient export with land use, crop type, and other factors. Statistical analyses of National Eutrophication Survey data[23] also give some insight on probable effects of urban and agricultural land uses on stream nutrient levels, for the region east of the Mississippi River.

The basis for conclusions reached about changes in pollutant inputs from affected lands should be apparent to the reviewer. Unless important shifts in the kinds of crops grown, the acreages under cultivation, or land management are foreseen, agricultural pollutant levels are not likely to change considerably as a result of project construction and operation. Conversion of flood-protected areas to urban uses may be expected to cause an increase in pollutants transported by stormwater runoff. In most cases, detailed site-specific modelling or predictive methods will not be feasible (or even reliable) for predicting these impacts; therefore, descriptions of present and projected land uses become particularly important and must be presented in enough detail to permit judgments of the magnitude of probable impacts.

Construction and Maintenance Activities. The quantification of hydrological and water quality impacts traceable to construction and maintenance activities is fundamentally related to the scale of the project. Lengths and widths of channel projects may vary by several orders of magnitude, for the scale of a project is determined not only by its purpose but by constraints imposed by channel design standards and competing uses for land resources. It is important, therefore, that the EIS initially quantify the areal impact of the proposed action. The significance of this impact is measurable in acres of land allocated to the project and its appurtenances and contrasted with resource values which will be altered or destroyed by the channel, as, for example, miles of a free-flowing natural stream or acres of timberland. In those cases where the quality of the proposed channel is already seriously degraded, as they may be in an urban flood improvement project or previously modified stream, the reviewer should be sensitive to potential benefits (e.g. aesthetics, warm water fishery, etc.) that the project may provide.

In addition to overall project scale, impact variables are introduced by the characteristics and constraints of environmental conditions at the site. The significance of these characteristics is related principally to their influence on sediment generation and water quality impacts traceable to increased turbidity. These environmental characteristics may be categorized as follows:

- Topography - which may include sites which are nearly flat and dry, flat and wet, or steeply inclined;
- Climatic conditions - which include variations in temperature, rainfall, and prevailing wind intensities and direction;
- Vegetative cover - including such diverse types as intensively urbanized areas, forests and grasslands, and sparsely vegetated steppes.

Soil types are classified by a number of systems on the basis of grain size (texture), sorting and grading (structure) as well as various engineering indices. (One commonly used system is the

"Unified Classification System").[24] Of principal concern in channel construction and maintenance is the susceptibility of soils to erosion - both by channel flow (in unlined channels) and by rainfall, wind, and/or gravity on exposed soils. Characteristics of high resistance to erosion are not necessarily coincident with those of compressibility (measuring resistance to the influence of gravity). For this reason channel beds and channel banks of the same material may generate sediment volumes differently -- because forces acting on them are different. Table IV-2 below shows the relative desirability of several soil types to erosion-resistance and compaction, ranked from #1 (best) to #9 (worst):

Table IV-2. General Ranking of Soil Types
With Respect to Erosion Resistance and Compaction

Rank	Erosion Resistance	Compaction
1	gravels & gravelly sands	clayey gravels & gravel-sand-clay mixtures
2	clayey gravels & gravel-sand-clay mixtures	clayey sands & sand-clay mixtures
3	silty gravels & gravel-sand-clay mixtures	inorganic clays of low plasticity
4	clayey sands & sand-clay mixtures	silty gravels w/sand admixture
5	well to poorly graded sands with gravel	silty sands
6	silty sands with gravel	inorganic silts with clay and low plasticity
7	inorganic clays of low plasticity	organic silts & clays of low plasticity
8	inorganic clays of high plasticity	inorganic silts & clays of high plasticity
9	----------------Peat and other organic soils----------------	

Source: U.S.D.A., SCS, Engineering Field Manual for Conservation Practices, 1973, p. 4-18.

Correlations of soil types with water velocities, on the basis of erosion resistance, appear in several handbooks.[25,26] In general, the following table represents a consensus of these correlations.

Table IV-3. Suggested Water Velocities Not to be Exceeded in Various Soil Types

Soil Texture	Mean Water Velocity (ft/sec)
Light, loose sand	1.25
Coarse clean sand or light sandy soil	1.75
Sandy loam	2.50
Silt loam, alluvial soil, average loam	3.00
Clay loam	3.75
Stiff clay, fine gravel, gravelly soil	4.50
Graded silt to cobbles	5.50
Shale, coarse gravel	6.00

Topography has an effect on the sediment generated by channel projects because adjacent slopes and channel gradients influence runoff volumes and stream or channel velocities. Channel projects designed for drainage of wetlands are less frequently found in regions of appreciable topographic relief than are flood flow channels. Another generalization is that areas at higher elevation often have less soil cover susceptible to erosion than do low-lying areas. An aid to estimation of the influence of topography on a channel project is the comparison of parameters of the proposed channel project with that of a nearby natural stream. To the extent that the channel nearly conforms to natural grade and alignment the comparison -- after the stabilization of construction-induced impacts has been reached -- is a valid one. Hydraulic systems, however, whether natural or man-made, are dynamic systems in varying, or relative, degrees of stability.

Topographic influences may also have a bearing on the areal extent of a watershed or the variability of climatic conditions in the watershed. These variables will influence flood hydrographs and river stages, thus imposing constraints on construction and maintenance schedules which, ideally, should coincide with low flow periods.

Groundwater impacts are more easily anticipated and evaluated in lowlands than in areas of relief, but in both areas the measurable effects upon water quality and ecosystems induced by construction activities will be delayed.

During construction and maintenance activities topographic (e.g. gradient) influences at the site are relevant most especially to soil stability in the channel and spoil disposal areas. The cohesiveness of soils and rock strata and their resistance to erosion are more critical, in terms of volumes of sediment entering the channel, than any other measurable environmental parameter.

Climatic conditions are project variables to be identified and quantified for construction-induced impacts. Rainfall is perhaps the most significant of these variables -- both its seasonal pattern and its intensity. Hydrographs of flows in comparable streams within the project area are of assistance in anticipating the frequencies and volumes of high flows which occur in response to rainfall (and/or snow melt), as well as intervening periods of low flow. Insofar as impacts of construction and maintenance are concerned rainfall data has specific relevance to:

..the timing of construction and maintenance activities so as to avoid periods of protracted rainfall or those of high intensity,

..the scheduling of mitigating and/or preventive measures taken to prevent soil erosion during rainy periods; or, if cofferdams or other construction aids are used, to augment or divert low flows to maintain downstream water quality standards.

Table IV-4 illustrates and compares the yield of sediment from a denuded and thereafter sodded road cut slope (i.e. similar to a channel cut) in Oregon.

Except in areas of high aridity construction-induced impacts on water quality resulting from wind erosion are insignificant. In areas of high aridity loess and other fine soils in the region which are disturbed or scarified may accumulate in the project's channels and impair both hydraulic efficiency and water quality standards. Or these same soils, disturbed at the project site, may cause objectionable impacts on lands adjacent to the project. Predictive methods for estimating soil and sediment loss by wind erosion may be referred to if needed. 27,28

The influence of high temperatures during periods of construction and maintenance, especially to the extent that they coincide with periods of low flow, may cause violation of water quality standards, especially those of dissolved oxygen. Mucking and the removal of accumulated debris during these periods -- especially the removal of organic materials -- may cause not only the release of pollutants to stream flow and the lowering of dissolved oxygen content of the waters, but the generation of noxious odors in the vicinity.

Vegetative cover, or the absence of it, at channel construction sites will influence sediment generation. The reviewer will find it helpful to estimate, in the area to be disturbed by construction, acreages of different vegetative cover types which will be disturbed or removed (e.g. forested land, grassland, sparsely vegetated areas, and urbanized areas). Techniques for estimating sediment generation, under varying conditions and at sites with differing types of soil cover have been developed.[29,30] Table IV-5 is illustrative of the influence of forest cover on erosion in fifteen (15) sub-basins of the Potomac River.

Table IV-4. Comparative Sediment Yield From Bare and Seeded Road Cut on the H. J. Andrews Experimental Forest in Western Oregon

Condition of Plot	Period of Measurement	Sediment Yield Kilograms/Hectare (Tons/Acre)
Bare	9/58 to 9/59	23,370 (12.7)
Seeded to Grass (1st year)	9/59 to 9/60	7,728 (4.2)
Seeded to Grass (2nd year)	9/60 to 9/61	4.232 (2.3)

Source: Wollum, A.G., "Grass Seeding as a Control for Roadbank Erosion," USDA Forest Service Research Note 218, 5 pages (1962).

Table IV-5. Influence of Forest Cover On Control of Sediment Yield by Erosion

Percent of Land Area With Forest Cover	Sediment Yield Metric Tons/Sq.Km/Yr	(Tons/Sq.Mi/Yr)
20	140.00	(400)
40	70.00	(200)
60	31.50	(90)
80	15.75	(45)
100	7.70	(22)

Source: Luss, Howard W. and Kenneth G. Rewbard, "Forest & Floods in the Eastern U.S.," USDA Forest Service Research Paper, NE-226, 1972, pp. 72-73.

Distinctions Between Construction and Maintenance Activities. Because of separable impacts the distinction between the construction phase and the operation/maintenance phase of a project is an important one. Differentiation between the responsibilities of the executing Federal agency (responsible for the EIS) and the local sponsoring agency is statutorially -- though differently -- defined by Federal agencies; even within the same Federal agency the contractual obligations of that agency for separate projects may vary. The EIS reviewer, however, need only be concerned with these distinctions to the extent that the EIS specifies: 1) the local sponsoring agency which will be a party to the operation/maintenance agreement, and 2) defines the project-monitoring program and operation/maintenance schedules. But -- and this should be emphasized -- project operations and maintenance procedures should be described in the EIS in the same detail as are installation (construction) procedures.

Initial considerations of impacts related to construction and maintenance activities stem from the values placed on the pre-project status of a proposed channelization -- i.e., whether the channel (and its appurtenances) are to be installed in: 1) an undisturbed and natural watercourse (or portions thereof), 2) in a previously modified watercourse, and/or 3) in areas where no defined waterway had before existed. These impacts upon water quality and hydrology, in a generalized but qualitatively significant sense, are directly proportional to the lengths and widths of channel to be re-aligned, modified, and/or newly built, for such dimensions reflect the scale of land-disturbing activities.

The major impact problem -- or major pollutant -- from land-disturbing activities is sediment generation and the subsequent increase of turbidity in downstream waters. The reviewer's prime focus, therefore, should be on those kinds of construction and maintenance activities required by the project's definition and purpose. These impacts are related to:

..the amount of land acreage to be cleared for the project's construction;

..the area, volume, and other dimensions of all excavations or fillings (i.e. berms, levees, and spoil disposal areas);

..the location of borrow pits, or quarries for rip-rap materials;

..the location of access roads, batch plants, stockpile yards, etc.;

..the specifications and details of road and bridge relocations or requirements; and

..project schedule requirements for maintenance facilities or procedures.

Aesthetic impacts, too, are related to these same scalable values. But these impacts are more subjectively evaluated and therefore dependent upon such variables as the environmental setting of the project (e.g. urbanized land, agricultural land, or wild land), the aesthetic values of neighboring residents and others frequenting the area, and upon such mitigative project elements as: landscape plantings, artificial riffles, and the limitation of construction activity to only one side of the channel.

The reviewer should find, in the EIS, sufficient details on both the environmental setting of the project and the anticipated construction and maintenance activities to be able, at least qualitatively, to appraise the environmental impacts of the various stages of the proposed action.

Channel construction and/or maintenance usually begins with such preliminary activities as clearing, grubbing and pest control. Unwanted vegetation -- trees, shrubs, and grasses -- will be removed, as will any existing structures found within the channel right-of-way. Certainly the removal of rooted vegetation will bare soil surfaces to accelerated erosion by wind and water, though the volumes of surplus sediment thus generated will be less than during later construction phases when excavation and levee-building may take place.

The early stages of construction may also result in the generation and accumulation of miscellaneous pollutants, litter and debris which could, if not removed, be transferred downstream when water enters the channel. Impacts of this sort may be traceable to:

..wastes and spills of fuel and lubricants (from vehicles, chainsaws, and stockpiles)

..applications of chemicals to reduce dust and stabilize roadways,

..disposable containers and parts,

..scaffolding, discarded masonry forms, cleaning solvents, etc.,

..wastes from temporary sanitary facilities which are improperly located or maintained.

Quantification of impacts due to the introduction of such pollutants to both surface water and groundwater resources cannot be precise, and the reviewer must be judgmental in determining whether the EIS takes cognizance of their persistence, magnitude, and significance (e.g., potential bioaccumulation).

The application of herbicides, insecticides and other target-specific toxic chemicals (e.g., to reduce populations of black flies) often accompanies the early stages of construction activity. If pesticides are used, the reviewer should find in the EIS some mention of the application rates of the intended chemicals and the expected impact of such practices, not only to the water quality of the project and downstream areas, but to aquatic and terrestrial ecosystems in the area. It is important that the use and rate of application of such pesticides be consistent with existing rules and regulations as promulgated by all agencies with jurisdiction over the project site.

Significant impacts of early phases of project activities are related to the denuding and compaction of soil. Denuded soil surfaces cause sediment to accumulate in the stream channel and degrade water quality by increasing turbidity. And soil compaction hinders the re-establishment of vegetation and decreases infiltration potential, thereby increasing runoff. Though quantification of these impacts is imprecise, the reviewer should critically note if appropriate attention has been given to the following:

..Choice of equipment (e.g.: rubber-tired vehicles are less soil-disturbing than cleated vehicles; cable-skidding of logs by skidders bares less soil than does use of tractors)

..Timing of operations (e.g.: clearing during muddy seasons induces aggravated erosion from runoff; removal of logs skidded on snow causes less erosion than at other times)

..Roadway locations (e.g.: waterways-crossing should be kept to a minimum to reduce erosion; sensitive soils and steep slopes should be avoided; stabilized access roads should be provided for all points where periodic clean-out operations are anticipated)

At the beginning of the major phase of construction activity -- rough grading -- the generation of sediment will be exacerbated. Draglines, shovels, graders, scrapers, skidders and other earth- and log-moving equipment will remove sod, rooted vegetation, and/or other layers which normally protect the subsoil layers from dispersal (i.e. accelerated erosion) by rainfall, running water, wind, and gravity (on sloping surfaces). Erosion rates, by whatever transport medium (wind, water, or gravity), can only be approximated because of the variables involved. Sediment yield, however, is inversely related to areal extent of vegetative cover. State-of-the-art quantitative methods for erosion and sediment generation can be found in the literature; several are summarized in EPA reports issued under the authority of Section 304(e) of P.L. 92-500.[31]

A number of predictive techniques for sediment production have been proposed. These can be classified as: empirical, statistical, or simulation methods; and they have application to the three aspects of sediment involvement -- erosion, transport, and deposition. Empirical techniques are applicable to all three sediment-related categories, whereas statistical and simulation methods have been developed principally for transport and depositional processes. (Summary discussions of all of these methods can be found in: E.P.A.'s Methods for Identifying and Evaluating the Nature and Extent of Non-Point Sources of Pollutants.[32]

Both theoretical and regionally empirical formulae (based on local geological, soil and meteorological conditions) are applicable to the analysis of aeolian and fluid systems and their effect upon erosion of sediments of different types. (Earlier referenced publications and articles are sources for these formulae.)[33,34,35] The reviewer is advised to exercise the judgment of experience in determining whether sufficiently critical and analytical effort and expertise have been devoted in the EIS to quantification of sediment generation and subsequent turbidity effects.

It is important that the reviewer be informed about the statutory limitations on construction-induced sediment loads prescribed by state water quality agencies. Such limitations are expressed in water quality criteria for turbidity, for example, where they are usually measured in Jackson Turbidity units (JTU's); they are usually established for specific stream segments and are often expressed as maximum increases allowable within specified periods.

Impacts induced by turbidity in water bodies and traceable to construction/maintenance activities may include any of the following:

..inhibiting the survival -- or degrading the habitat -- of pelagic and benthic organisms,

..decreasing the rate of photosynthesis and production of aquatic vegetation,

..increasing surface water temperatures (by increased absorption of solar radiation), and

..increasing the concentration, in areas of sediment accumulation (e.g. lakes, reservoirs, deltas, shoals, etc.), of pesticide residues and other chemicals absorbed by sediment particles and oil films.

In addition to accelerating erosion the activities of rough grading will lead to compaction of some soils and sediment, especially on clayey and organic sediments with high liquid limits. Soil compressibility can be qualitatively assessed by reference to a number of manuals.[36] The inhibited re-establishment of grasses and other vegetation intended to serve as sediment-decreasing elements may adversely effect downstream water quality. The reviewer should note the possibility of this occurrence. The application of fertilizers (especially nitrogen and phosphorus) on revegetated areas to accelerate bank stabilization will, on the other hand, have a potentially adverse effect upon water quality.

Accelerated erosion by wind and surface runoff on denuded slopes and surfaces at channel construction sites, as has been implied, can be mitigated by both vegetative cover and non-vegetative cover. (Further discussion of these techniques will be found in Section IV.A.3.)

The following generalizations are important as guidelines in the review of impacts traceable to construction and maintenance activities. Timing of construction and maintenance activities, as well as their frequency, will have an influence upon the severity of environmental impacts. The reviewer should be aware of seasonal meteorological changes (rainfall patterns, runoff characteristics, etc.) and land-use influences in assessing the adequacy of the EIS discussion on these points. Construction impacts on project-related environmental parameters are a "one-time" occurrence; maintenance activities, on the other hand, are implicitly considered to be recurring. The improvement of hydraulic efficiency by periodic clearing and cleaning-out of the channel will be accomplished only at the expense of some downstream effects on water quality. The choice of emphasis, therefore, between improved project functions (i.e. hydraulic efficiency) and amelioration of the impacts thereby induced (i.e. degraded downstream water quality) is one involving the same "tradeoff rationale" as that supporting the decision to construct the channel in the first place. The evaluation of net benefits resulting from the consideration of conflicting goals therefore must be as clearly stated in the EIS as possible -- both in regard to initiation of the project and in its maintenance.

It is important that schedules for inspections and procedures for monitoring operations of the channel and its adjunct elements (drains, culverts, etc.) be included in the EIS. Malfunction of drains, accumulation of debris at points of channel constriction (at bridges, culverts, drop structures, etc.), shoaling, and bank-slumping or undercutting are examples of the sorts of problems which should be anticipated, reported, and remedied quickly in order to minimize impacts to downstream water quality and hydraulic efficiency. Recurrent operations, such as the periodic removal of vegetation growing on side slopes and in the channel, should also be anticipated and a schedule for such work should be estimated in the EIS.

Changes in Groundwater Levels. The reviewer's task of identifying sources of impacts upon groundwater, though not a simple one, is greatly aided by published hydrologic studies of watersheds. These are available, in areas where they exist, from the U.S. Geological Survey, and from state geological surveys. Engineering studies of municipal water supplies -- especially those derived from wells -- are an additional source of information on groundwater conditions in a project area.

The United States can be divided into four regions and at least 24 sub-regions (see Figure IV-3) with regard to groundwater characteristics and conditions. The four regions are:

(1) the East-Central "old rock" region,
(2) the Atlantic and Gulf Coastal Plain region,
(3) the Great Plains region, and
(4) the Western Mountain region.

To the extent that generalizations apply these areas -- especially the sub-regions -- each contain rock types as well as morphological and meteorological conditions which are relatively homogeneous. Channel construction within each of these different regions may be expected to encounter generally similar groundwater conditions.

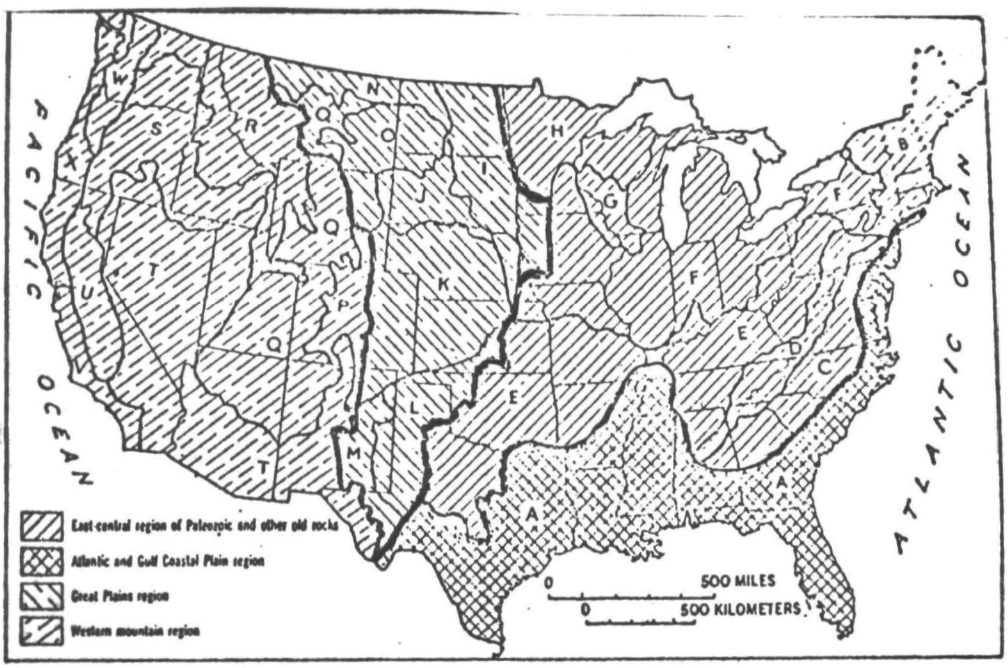


Figure IV-3. Map of the United States
Showing the Four Major Groundwater Provinces

Source: Meinzer, O.E., Hydrology, Dover Publications, 1942, p. 440.

Influences upon groundwater levels such as those caused by: rates of precipitation, volumes of surface waters, infiltration rates, pumped withdrawal rates, vegetation withdrawals, etc. -- with or without the presence of man-made channels -- can only be predicted if local meteorological (supply), geological (intake), and hydrological (transport) conditions are known. Snow-melt and rain, for example, will not recharge groundwater reserves until underlying frozen ground melts and becomes permeable. And only that rainfall which occurs after a deficiency in soil moisture has been satisfied will recharge groundwater reserves. Moreover, and in addition to temporal variations, recharge potential differs still more from place to place because of geological differences in stratigraphic, topographic, and structural conditions.[37] Channels, it is agreed, introduce new pressure-potential surfaces and new sources of entry and exit for groundwater producing an imbalance in the preproject ground and surface water system and leading to new equilibrium conditions.

The flow of groundwater, following Darcy's Law, is calculated from: 1) average sediment (or rock) porosity, 2) the cross-sectional area through which flow occurs, and 3) the average velocity of flow (derived from Darcy's fundamental equation which assumes a measurement of hydraulic gradient, and varies from one foot/years to 10's of feet/day). Most, but not all, groundwater movement is parallel to the bedding of permeable strata; it may move up the dip of strata as well as down the dip. In areas of artesian pressure the piezometric surface (coincident with the hydraulic head) of an aquifer is above the land surface. Contour maps of the piezometric surface of an aquifer will permit deductions about the horizontal directions of groundwater movement; vertical groundwater movements between aquifers, sometimes resulting in recharge of one aquifer by another, depend upon differences in the hydraulic heads of the two aquifer systems.

The coefficients of "transmissibility" or of "permeability", terms applied to the permeability of a water bearing aquifer, can be measured in the laboratory or in the field and thereafter applied to the several methods and formulae used to model groundwater movement. (The above coefficients are related terms, differing only in the dimensions defining their measurement.) Natural aquifer materials have coefficients of permeability which generally vary from 10 to 5,000. Thus in the formulae:

$$v = \frac{Ph}{l}$$

or

$$Q = PiA$$

where v = velocity of water flow through an aquifer
Q = volume of water flow
h = hydraulic head
l = length of flow to be measured
i = hydraulic gradient
A = cross section area of aquifer
and P = coefficient of permeability

it can be seen that both velocity and volume of groundwater flow bear a direct relationship to the permeability of the aquifer being studied.

Commonly used methods and data that have application to groundwater recharge studies in general include:

..lysimeter tests (to observe infiltration and percolation rates);

..precipitation records, from which runoff and evaporation losses (i.e. amounts not infiltrating the subsoil) may be subtracted;

..periodic tests of soil-moisture conditions below the influence of vegetation;

..charts of water table fluctuations in wells -- in equilibrium or while being pumped -- combined with calculations of "specific yield" for relevant aquifers (i.e., calculations of that specific volume of groundwater which is not held by molecular attraction in the interstices of saturated rock and the determination thereby of that volume available for yield or exploitation);

..and measurements of the decrease in the flow of influent streams (or unlined channels) between gaging stations - a measured loss which is theoretically equal to the amount of water added to (or recharging) groundwater reserves - after losses due to evapotranspiration have been subtracted.

The last two techniques on the above list are those most commonly used for determining the excess of recharge over discharge of groundwater volumes.

Channels are man-made intrusions, or interruptions, in the natural hydrologic cycle of groundwater and surface water systems. The water table responds three-dimensionally to changes caused by such disturbances of hydraulic gradients; lateral components of these gradients develop and the directions of groundwater movement change. And because channels, unlike wells, are not points on a contoured pressure surface, but are instead complex surfaces of a pressure system independent of and intersecting those of the natural groundwater system, the interaction between the two (i.e. the pre-project hydraulic system and the system which is in a state of nonequilibrium induced by flow in the channel) requires complex mathematical analysis and approximation. (Several of these analytical techniques are available as references.) 38,39,40,41

It is unlikely, however, that the EIS reviewer will find technical analyses of groundwater conditions in the EIS document. But, results of such analyses, which make possible predicted changes in groundwater levels, may be included in the EIS, as well as references to studies supporting these findings. In cases where groundwater impacts are judged to be critical, the reviewer in regional EPA offices should contact EPA headquarters for assistance in evaluating both the studies undertaken and the conclusions reached.

IV.A.3. Assessment of Impacts

An assessment of hydrology and water quality impacts should relate identified and quantified impacts to appropriate environmental standards and criteria and also determine the need, applicability, and effectiveness of alternative mitigative techniques. Alternatives to the proposed project in terms of project scope, location, or alternative means of meeting water resource objectives should be addressed in the EIS. In many cases the reviewer will not be able to relate specific predicted values for various water quality parameters to the applicable numerical criteria. Instead the assessment may have to be somewhat judgmental, basing assessments on the scope of the project and the subjective characterizations of the affected resources in order to be able to estimate whether water quality standards will be violated or whether impacts of an unacceptably high level will result from project implementation.

Both direct inputs of pollutants due to construction, maintenance, or land use changes and indirect effects on assimilative capacity and pollutant transport should be evaluated.

Water Quality Standards. Criteria and standards of water quality are essentially those established by state environmental agencies. The categorization, specificity, comprehensiveness, and rules for exceptions to these statutorially defined standards vary appreciably from one state to another across the nation.

Most states have established minimal criteria for all waters defining, in broad terms, universally objectionable pollutants which may be found in public waters. They include:

- sludge, residues, and other settleable materials - in amounts that are unsightly, create odors, or otherwise degrade water quality;
- floating debris - that which is waste-derived and in amounts creating unsightly conditions and impairing normal water usage;
- material attributable to waste-generating activities - in amounts creating unsightly conditions, odors, or otherwise degrading water quality;
- oils and greases - in visible amounts on water surfaces;
- and toxic, corrosive or deleterious materials - in amounts harmful to human or biological uses of water and otherwise interfering with water usage.

Criteria are specified for relevant constituents - depending, in most instances, on: 1) an adopted classification of public waters (in terms of named bodies of water or reaches of a stream or river), and 2) existing and projected uses of those waters (e.g., raw water supply, recreation, aquatic life, etc.). Such criteria are defined as maximum values allowable, for degrading constituents - or minimum values required, for beneficial constituents (e.g., dissolved oxygen), and they normally state the average, or mean values not to be exceeded by a given percentage of the samples taken over a specified period of time. Thus, because criteria are subject to a wide range of specifications (even within a state), the assessment of water quality parameters must necessarily be in the context of local regulations.

A list of project-related activities which may occur during construction, operation, and maintenance phases follows:

<u>Land-Disturbing Activities</u>

- clearing and grubbing
- levee-building
- excavation
- sediment and debris removal
- bank stabilization
- machine operation

<u>Structure-Building Activities</u>

- in-channel or channel-bank revetments
- masonry and grouting
- bridge erection
- machine operation

<u>Vegetation-Removal</u>

- brush-cutting and mowing
- tree-felling
- grazing

<u>Miscellaneous</u>

- sanitary waste generation
- pesticide application

Many of the activities listed above will cause impacts to the same water quality parameters, though some more severely than others. It is not of practical aid to the reviewer, therefore, to associate specific water quality parameters or constituents with the separable impact-inducing activities of a channel project.

Table IV-6 lists most of those constituents which are relevant and critically appraised in channel projects. As earlier noted the constituent criteria are not universally applicable to all U.S. waters - or even to all waters within a state. Therefore, for the reviewer's guidance, only a range of significance is indicated, values below which (or above, in the cases of minimum standards), if anticipated, should arouse the critical concern of the reviewer. Listed also in Table IV-6 are those water-use categories usually found in conjunction with stream channelization projects and to which the criteria, in general, are applicable. The table should not be construed as interpretive of any state's established standards but simply as a convenient reference; applicable criteria should be sought by the EIS reviewer from the appropriate water quality agency in the project area.

Table IV-6. Average Range of Water Quality Criteria*
Adopted by States for Selected Constituents and Generalized Water-Use Categories

nstituents	Public Water Supply Intake	Wildlife and Aquatic Life	Body Contact Recreation	Livestock & Irrigation
ssolved Gases				
Dissolved Oxygen	4-5 mg/l or 60-75% saturation	4-5 mg/l - warm-water fish, 5-7 mg/l coldwater fish*	---	3 mg/l
ysical-Biological				
Turbidity	25-50 JTU above background or base flow values	25-50 JTU, warm-water fish, 10 JTU coldwater fish*	---	---
Clarity	---	---	4-feet visibility of secchi disk*	---
Fecal Coliform	1000-2000/100 ml	---	100-200/100 ml*	1000/100 ml
kalinity				
pH (or alkalinity as $CaCO_3$)	6.0 - 9.0	6.0 - 9.0* (20 mg/l)	---	---
emical Constituents				
Chloride	250-500 mg/l*	---	---	---
Sulfate	100-500 mg/l*	---	---	---
T.D.S.	---	---	---	250-500 mg/l
Mercury	.0005-.005 mg/l*	---	---	---
Lead	.05-1.0 mg/l*	---	---	---
Zinc	.5-5.0 mg/l*	---	---	---

sterisk indicates water use for which constituent is most critical. Data on organic compounds and esticides not listed because of diversity of specifications in state regulations.

JRCES: Annotated Compendium of "State Water Laws," appearing in: Environment Reporter, Bureau of National Affairs, Washington, D.C.,1973-76; U.S. EPA, Proposed Criteria for Water Quality, Vol. Oct. 1973; National Academy of Sciences & National Academy of Engineering, Environmental Studi Board, Water Quality Criteria-1972, A Report of the Committee on Water Quality Criteria, Washington,D.C., March 1973, (EPA-R3-73-033).

On the single but important subject of contamination by pesticides and/or petroleum products the reviewer is advised that the EIS should cite not only those standards applicable to water quality but to the marketability or acceptability of fish, shellfish, and other aquatic products from an impacted area. Aquatic organisms, in particular, are well known for their ability to magnify the taste of petroleum in their flesh and to concentrate levels of pollutants which are toxic to higher orders of life.

Changes in Hydraulic Parameters. The importance of the hydrologic and water quality impacts caused by changing the alignment, dimensions, gradient, or bottom composition of a watercourse must be assessed in the context of the land and water uses within, upstream, and downstream from the proposed project area. Information contained in Proposed Criteria for Water Quality, Volume 1,[42] should be used in conjunction with state water quality standards as primary references on the acceptable levels of various constituents for major water uses. In addition, the proposed project must be reviewed in light of water quality management programs initiated under the 1972 FWPCA Amendments, particularly areawide waste treatment management planning and the state basin planning program.

If the review indicates the likelihood that assimilative capacity in the proposed channel will be decreased due to removal of riffle areas or channel realignment, existing and probable waste discharges and water uses will influence the importance of the impacts. On a headwater stream that does not receive any point source wastewater discharges and is protected under the state's antidegradation policy, the water quality implications of reduced assimilative capacity may not be significant. In watersheds where numerous pollution sources exist, however, any reduction in the purification ability of a stream may jeopardize the attainment of water quality standards. Thus, an assessment has to include consideration of present and probable future water quality in order to identify potential problems. Downstream water uses are equally relevant. The increased hydraulic efficiency of a channel will normally cause more rapid transport of water and associated pollutants to downstream sections. In the case of nonconservative constituents for which assimilation is time-dependent, such as biochemical oxygen demand/dissolved oxygen and fecal bacteria, water quality degradation may persist further downstream. If erosion and turbidity in the channelized reach have been identified as probable impacts, increased sediment transport to and deposition in downstream reaches may also occur. When these kinds of problems are expected, the reviewer should base his assessment on the nature of stream uses below the proposed project, paying particular attention to water supply and recreation which may be adversely affected by water quality impacts of channelization.

Regarding effects on downstream flood potential caused by channelization, the reviewer should ensure that the impacts have been addressed and that the conclusions reached in the EIS are substantiated by adequate hydrological analyses, as discussed in Section IV.A.2. A basic concern is that channelization in an upstream portion of a watershed may contribute to the need for structural flood protection measures further downstream and cumulative impacts on stream ecosystems.

Numerous mitigative measures and alternatives may be applicable to channelization to reduce hydrologic and water quality impacts. Table IV-7 describes several techniques that may aid in reducing the impacts of channelization. They may be necessary for engineering or channel stability reasons or used for mitigating identified water quality impacts. In either case, the effects of a particular mitigative technique may not always be entirely beneficial. Possible drawbacks of various impact abatement methods are also included in the table.

The key to minimizing water quality, ecological, and other environmental impacts is the preservation or restoration of diversity in the channel, whether in flow velocity, shape, substrate, or other characteristics. The need for and use of impact-mitigating features within a proposed channel should ordinarily be viewed with consideration of the length of channel alteration, the value of the water resource for fishing, recreation, or other uses, and assessment of the significance of expected impacts. When assessing mitigative measures proposed in the EIS, the reviewer should be cognizant of the overall effects, both beneficial and adverse, of the particular modifications and make sure they have been addressed. Incorporation of facilities or techniques described in Table IV-7 into the design will usually increase project costs. Therefore, the nature of the impacts as quantified in the EIS or as perceived by the reviewer should be cited to support comments on possible ways of minimizing adverse effects.

Construction of ancillary facilities to alter water depths, velocity, or sediment transport in a channel, such as grade control structures, low-level weirs, pools and riffles, or sediment basins, may help to reduce water quality problems by decreasing sediment loads in and downstream from the channel and perhaps increasing the assimilative capacity of the channelized section. However, impacts on aquatic habitat and migratory species may be associated with these measures and have to be assessed as well.

A variety of materials, ranging from vegetation to smooth concrete can be used for protecting the channel bottom and banks. Control of scouring and erosion is essential in those parts of a channel where soils cannot withstand the design velocities. Grade control structures can be used in combination with direct bank and channel protective measures. Use of concrete lining,

Table IV-7. Mitigative Measures and Probable Effects

Mitigative Measures	Applicable Situations	Problems to be Mitigated and Other Probable Effects
Grade Control Structures Drop Spillway Chute Rock-armored sections Cascade structures	For channels with excessive slopes or those for which soil and stability analyses suggest excessive erosion under design flow condition. (Especially cut-offs or channel realignment.) Drop spillways may not be feasible on larger streams.	Reduction of potential for channel erosion. Increase in water depth. Increase in velocity diversity.
Low-Level Weirs, or Dams (Concrete, rock or gabion)	For widened or otherwise altered channels where water depths would be reduced substantially especially those in subhumid or arid regions.	Creation of aquatic habitat. Improvement of groundwater recharge. Inhibition of terrestrial (phreatophyte) vegetation growth, perhaps reducing maintenance requirements. Collection of sediment and debris (which) may negate value of aquatic habitat creation. Possible hindrance of upstream fish migration.
Pool-riffle Sequences (Vertical Meanders)	For channels where natural pools and riffles would be modified or eliminated by construction or where addition of such variations would be desirable. Design may take advantage of varying erodibility of soils within channel alignment (e.g. riffles in erosion-resistant stretches).	Increase in channel stability. Protection against meander development. Reduction of sediment from channel and bank erosion. Enhancement of reaeration. Creation of greater substrate, velocity, and depth diversity
Sediment and Debris Basins in Channel	For channels subjected to substantial inputs of suspended or bedload sediments or debris from upstream or in-channel sources. Upstream impoundments (existing or proposed) may also trap sediments.	Reduction of sediment transport to downstream reaches. Requirements for periodic maintenance and disposal of sediments. Provision of resting areas and shelter for fish. Possible substratum instability unsuitable for benthic colonization.
One-sided Channel Construction	For channels that will follow existing alignment, where existing banks and riparian vegetation are stable, or where land uses needing protection or drainage are concentrated on one side of a channel.	Reduction of loss of riparian vegetation and shade cover. Reduction of amount of excavated material requiring disposal. Preservation of aquatic habitat and cover.
Change in Channel Cross-section	For most channels, within limits of hydraulic and soil constraints. Adjacent land values and uses must be considered.	Reduction of loss of riparian vegetation and shade cover. Reduction of amount of excavated material requiring disposal.
Random Rocks	For any channel.	Increase in turbulence and reaeration at lower flows. Provision of stable and greater area of substrate for benthic organisms. Provision of cover and refuge from high water velocities for fish.
Wing or "V" Deflectors	For most channels.	Protection of bank from erosion (particularly on curves). Provision of cover and refuge from high water velocities for fish. Introduction of more diverse velocity patterns. Cause scouring of holes providing deeper water and cover.

grouted rip-rap, or other smooth, homogeneous materials is not desirable from a water quality standpoint, because such a substrate will not be conducive to maintaining an abundance and diversity of benthic organisms or to inducing significant turbulence and reaeration. Linings of this type are normally necessary and feasible only for channels traversing heavily developed areas where adjacent land is either unavailable or too costly for construction of a trapezoidal-shaped earth channel. Although such linings will eliminate or significantly reduce channel erosion, it is important that their aesthetic and water quality implications be brought out in the EIS. In addition, impervious materials used for channel and bank protection will prevent groundwater recharge and bank storage, which may be an important consideration if the channel is located in an aquifer recharge area or if groundwater contributes substantially to the baseflow of the existing stream.

All channel banks should be protected from erosion. Herbaceous cover that can be maintained regularly by mowing is one of the most common stabilization measures, as discussed in greater detail below. Well-graded coarse stone or rock rip-rap will provide a high degree of erosion resistance in steep channel sections through erodible soils, and is often used for a distance upstream and downstream from channel structures or at transitions. A gravel and cobble bottom would cause turbulence and vertical mixing beneficial to reaeration; however, because the nature of the channel bottom depends on the water velocity and sedimentation characteristics, the probable effects of channel aging on the ultimate bottom composition of rip-rapped or gravel-armored reaches should be addressed. It is possible, for instance, that fine-grained silts and clays or other sediments will, over a period of time, cover and reduce the roughness of the channel bed. These changes would have ecological as well as water quality significance.

Changes in Watershed Land Use. The influences of watershed land uses on hydrology and water quality can be great and are often more important than the direct effects of channelization. The major issues are not only the hydrologic/water quality concerns discussed herein but they also range to basic ecological questions in the regional or national perspective concerning drainage of wetlands, conversion of bottomland hardwood forests to other uses, development of natural flood plains, and cumulative impacts of all resource development activities, discussed further in Section IV.C.

With respect to the relationship of hydrology and land use, the reviewer should assess the degree that trends in land use, in both the project area and the watershed, have been sufficiently described, and whether hydrologic data and predictions used for channel design have been modified to include probable effects of land use changes on runoff and peak flows. Effects of urbanization, silviculture, agriculture, drainage, and upstream flood storage capacity are of primary interest, in particular on smaller watersheds where hydrologic response may have a significant influence on channel design and operation.

Water quality/land use interactions should be assessed primarily for the project area of influence and secondarily for the watershed in general. Salient points in the review include the adequacy and completeness of:

- existing and projected land use descriptions in project area of influence;

- descriptions of existing and projected fertilizer, pesticide and other pollutant loads in project area of influence;

- discussion of consistency of project-related land uses and pollutant loads with applicable plans and planning programs (208 areawide waste treatment management planning, 303(e) basin planning, and others);

- conclusions concerning effectiveness of any land treatment measures in reducing erosion and introduction of sediment to the watershed and channel;

- conclusions concerning the overall effect of the channel and related land uses on water quality.

Construction and Maintenance Activities. Construction and maintenance activities, by their very nature, will produce hydrological and water quality impacts. These impacts will occur both in the channel (at the site and also upstream and downstream from it) and adjacent to the channel. Tree and vegetation removal, excavation, the building of levees and the disposal of spoil, the installation of outlets, spillways, culverts, etc., and the construction of travelways and access roads adjacent to the channel typify those activities which should be addressed in the review process.

The purposes of assessing these impacts are:

(1) To relate all unavoidable impacts to appropriate environmental standards and criteria,

(2) to determine the significance of identified and quantified impacts, and

(3) to assure the use of feasible methods for avoiding or mitigating pollution stemming from construction and maintenance.

The water quality standards and criteria applicable to construction and maintenance activities of channelization are the same as those applicable to other potentially degrading activities in waterways. (See Table IV-6). The sole distinction in applying these standards is that, because of the episodic timing and nature of construction and maintenance activities, a degree of flexibility--or even an exception--may be incorporated in the state-specified criteria for certain impacting activities. Arizona, for example, exempts from water quality standards those impacts resulting from the mechanical maintenance of irrigation systems; Vermont makes an exception to its criterion for turbidity if a temporary pollution permit or an executive order has previously been obtained; and other states specify that measurable turbidity standards may be either absolute (as defined by Jackson Turbidity Units), or above background or base flow conditions, or averaged over specified time periods. It is important therefore that the review of such impacts not only be within the context of the appropriate and applicable water quality criteria but also be coordinated with the agencies having jurisdictional authority in the project area.

The anticipation of pollution expected to result from construction and maintenance is more certain than is the quantification of the resultant impacts. The reviewer should be informed not only of the location, magnitude and scope of the activities proposed, but also of the instream criteria and standards which are relevant. The reviewer will then have to make a before-the-fact judgment on the anticipated severity or criticality of anticipated impacts. Such judgments should be, if the occasion warrants, translated into appropriate comments in the review of the EIS. Of special concern, for example, may be the impact of sediment generation and resultant turbidity on a coldwater fishery for such sensitive species as smallmouth bass, trout, and other salmonids.

An important reason for assessing impacts on water quality during the construction and maintenance phases of a project is to assure the use of all feasible methods for reducing or avoiding pollution with mitigating or alternative measures. The scheduling and timing of operations, for example, or the location of access facilities or temporary sediment basins may be among the mitigating measures which could or should be proposed. (Further discussion of impact-reducing measures will be found in subsections on this topic which follow.)

<u>Potential Mitigating Measures During Construction and Maintenance Operations</u>. Alternatives to be discussed in the sections following are applicable only to the functional and separable elements of a channel project and not to the concept of channelization in its entirety. Alternatives, in the latter sense, as they might be proposed for a flood reduction or drainage project, are briefly discussed in Chapter II.

Though the reviewer is not expected to assess the specific hydraulic design features of a project, the provision of such features to control channel stability - or the absence of them - should be apparent in project specifications. Such provisions may include features:

- to increase capacity of flow through specific reaches,
- to maintain optimum channel depth where there is a tendency for the channel to degrade or aggrade,
- and to prevent bank erosion.

The erection of structures in or alongside the channel is undertaken not only to prevent destabilizing the banks but to guide channel flow so that sediment deposition, for example, occurs in designated areas.

Bank erosion may be prevented by the placement, at critical points, of revetments of various designs. Prevention may also be accomplished by controlling, with upstream impounding structures and release schedules (e.g., at sediment basins, sills, weirs, dams, drop basins, etc.), an appropriate sediment volume-to-capacity ratio in critical channel reaches. The control of channel flow and alignment is usually undertaken with "training structures" (e.g., groins, pile dikes, jacks, etc.) at critical deflecting points where channel scour, for example, will aid in sediment transport and thus maintain hydraulic efficiency.

The assessment of project features designed to insure channel stability is relevant to reduction of sediment generation and therefore to both the construction and maintenance phases of a project. But because the EIS does not usually include pertinent design analyses the reviewer's judgment and comments on the adequacy of the treatment of these topics in the EIS must be critically inferential rather than specific.

It is also important that consideration be given in the review process to those aspects of a project which may be remedial in nature - the repair of banks and scour holes, for example, or the accommodation within banks of flows in excess of an earlier designed capacity (e.g., irrigation return flows added to channel volumes subsequent to the project's initiation). In such cases the reviewer should note the possibility that proposed remedies may simply shift problems to other areas. Measures taken to prevent scour, for example, may subsequently cause the channelized stream to erode laterally; or the construction of a straightened channel (to replace a meander curve) may cause the accumulation of sediments at its downstream end without, at the same time, providing sufficient stream capacity beyond that point to transfer these sediments to a more appropriate area of deposition.

The exposure of denuded and disturbed soils (on berms, spoil banks, or the banks of unlined channels) and the resultant increase in erodibility, especially during seasons of high intensity rainfall, can be mitigated by the prompt planting of vegetation on these areas or by the application of several kinds of nonvegetative mulches to retard runoff-produced erosion. On berms, spoil areas, and banks where grasses requiring periodic mowing are to be established, the reviewer should be aware that such maintenance is not feasible on slopes in excess of 3:1. Seeding or mulch application during construction should, moreover, be scheduled on a continuing basis rather than at the end of all project construction activity.

The reviewer should also note the appropriateness of vegetational material selected for bank stabilization in terms of its germination period (in the case of herbs and grasses) and the inclusion of perennial species, as well as its adaptability to site conditions. The selection of specific materials will usually be governed by local climatic conditions; county agricultural agents are sources of information on such subjects.

Soil conditioning by physical compaction (e.g., sheep's-foot roller) or the replacement of a loose soil with one more easily compacted may be an alternative to mulching in some areas.

Scarification of slopes with horizontal furrows, or the construction of berms, terraces, or diversion channels (on the tops of channel cuts) may be alternative or supplemental to the application of runoff-retarding materials during construction and maintenance operations.

Removal of bankside vegetation during construction or maintenance phases may be justified in terms of increased hydraulic efficiency but this activity may also have several adverse effects, one of which may be that of destabilizing soil in the area. In some cases vegetation may overhang the channel thus shielding the water from solar radiation and thus restricting water temperature increases and thereby maintaining high levels of dissolved oxygen. Bankside vegetation, in addition, may enhance terrestrial and aquatic habitats. The reviewer should appraise project values in light of the possibility that these conflicting impacts can both stem from vegetation removal. (See Sections IV.B. and IV.C.)

Rodent burrows in channel banks and berms may impair the hydraulic functioning of these features of the project. Discouragement of such animal activities may have to be a part of maintenance procedures and should probably be accomplished physically (e.g., blocking burrows with stones, trapping or shooting the animals) rather than with poisons which may find their way into the water system.

Entrance of cattle and other animals into channels, culverts, etc. should be carefully controlled. In some grassed channels for intermittent and predictable flows grazing animals may help to control vegetation and thus provide inexpensive maintenance. But channel banks steeper than 2:1 will deteriorate from animal traffic as will water-saturated banks of even gentler slopes. The reviewer should note from the description of existing and projected land uses adjoining the project the potential problems associated with unrestricted movement of livestock.

The reviewer should be particularly concerned with points of channel curvature, or other changes in alignment, to insure that undercutting and other flow-induced and impinging erosive forces will not cause either slumping or sediment deposition at these points before as well as after the project is placed in operation. In addition to nonstructural measures it is common to also find structural measures employed at these critical points along a channel. Such measures may include, in channels both lined and unlined, revetments of various design and combinations -- pilings, bulkheads, permeable jetties, retards, gabions, emplaced rocks, riprap, skeletal frames, etc. The reviewer should determine that the points of vulnerability to erosive channel forces have been identified and that the specifications of project design provide reasonable (i.e., efficient and economical) remedial measures at these points.

It is important that the assessment of those measures proposed to insure bank stabilization be made in the context of the water quality standards established for the project area and for an appropriate length of stream upstream and downstream from construction sites. These criteria will include standards for: turbidity, pH (occasioned, for example, by the use of some acidic masonry construction materials in or adjacent to the channel), nutrients (particularly N & P from fertilizers applied to vegetative cover planted on exposed soils), pesticides and other toxic chemicals, and solid wastes of various kinds.

The maintenance of hydraulic efficiency and water quality requires that the accumulation of sediment and debris in the channel be held to a minimum and that provision for its removal be incorporated in routine maintenance procedures.

The installation of basins, spillways, culverts, traps, weirs, and other grade-control structures may be incorporated in the project in order to decrease channel gradient, thereby protecting channel materials from high velocity and erosive forces. At the same time these structures will entrap and reduce sediment loads (both in suspension and traction) moving down the channel; they may also have the adverse effect of accumulating flood-borne debris and trash.

It is important that project review assess the adequacy of these structures as to type and scale, and their compatibility with site configuration (i.e., channel width, maximum anticipated hydraulic head and capacity, etc.). Maintenance procedures should, for example, require the removal during or after floods of log jams at bridges and other points of channel constriction. And cluttered trash racks in front of culverts and spillways may cause the channel waters to cover areas not intended to be flooded or to erode unprotected areas beside wing walls. The reviewer is not expected to review hydraulic engineering calculations, but he should compare the range of channel flows anticipated with the dimensions of the project elements so as to assess their effectiveness under operational conditions. It is important also to estimate the dimensions of pools and basins which may form as a result of unintended retention of waters at these structures.

The reviewer may find that sediment basins (so defined in project designs) have adjunct functions as well. These may include: water aeration (as part of a pool-and-riffle section of the channel), improvement to fish or wildlife habitat, retarding vegetation growth in the channel, and/or aesthetic improvement (to relieve the monotony of an artificial channel). In these cases the adjunct benefits should be added to those derived from sediment removal and recognized as enhancements in the impact assessment.

Scheduled removal of sediment, debris and trash from the channel and inlets is a project maintenance requirement. The provision for enforcement of safety regulations or for physical measures (e.g. fences, grills, cattle guards, flood gates, etc.) restricting the entry or encroachment of humans, domestic animals, or rodents into the environmentally sensitive or dangerous areas of the channel, or appurtenances thereto, may also be a routine requirement of those charged with maintenance.

The flow of some channels is seasonal and the schedule for removal of accumulated materials can often be anticipated. And in channels which pass through urban areas there is often a predictable rate of accumulation of trash and rubbish which is not only unsightly and odor-producing but degrading to water quality. Maintenance procedures to minimize such impacts should be specified in the EIS.

Project design and maintenance procedures outlined in the EIS should encompass not only regularly scheduled monitoring surveys of the project's functions but also provisions for repair and periodic cleanout of the sediment-and debris-accumulating structures and the convenient access for equipment to such locations.

Measures are frequently taken to intercept runoff across bared soil and so to diminish the contribution of sediment to waterways. They may also serve solely to collect flows emanating from diverse sources and to prevent ponding of such waters. Such measures, by restricting runoff flows from proscribed areas (construction sites, unstable soils, polluted areas, etc.) will divert flows to waterways, chutes, drains, culverts, and other places where their flow can be controlled.

Interceptors are effective during construction and operational phases of a project. They may be either temporary (e.g. berms) or permanent installations (e.g., subsurface tiles or drains); they may intercept surface and/or subsurface flows. Seep or spring lines and breaks in slope are typical sites chosen for the placement of interceptors.

The comprehensive review of such measures and their effectiveness requires that the reviewer have information about the local drainage patterns, both surface and subsurface. Maps of regional and project topography as well as maps showing groundwater flow directions, elevations, and known points of groundwater outflow are minimal requirements to satisfy these needs of the reviewer.

The review of measures taken to control surface and subsurface flows is of particular significance in areas with complex surface drainage patterns and/or areas with numerous natural outlets for subsurface flows.

Excavated materials removed from channels must be disposed of. The removal of such materials occurs during both the construction and maintenance phases of a project. Utilization of the excavated materials, or their other disposition, is a function of: the nature of these materials, the requirements for adjunct project features (e.g., berms and levees), and the constraints imposed by adjacent land uses or topography.

The reviewer should find in the EIS specifications for: the dimensions of the areas required for spoil disposal, characteristics (e.g., organic content and compressibility) of the excavated materials, and plans for stabilizing these materials (e.g., with vegetation, retaining walls, terraces, etc.). Periodic maintenance implies the removal of trash and debris, sometimes to off-project sites, and it is important that the resultant impacts of such operations be assessed (e.g., as impacts to air quality, filling wetlands, over-loading solid waste programs, etc.).

It is also important that all impacts associated with spoil disposal be at least qualitatively assessed in the review process and that the reviewer exercise both imagination and judgment in determining if all alternatives have been addressed and if the mitigating measures proposed for pollution abatement are feasible.

Groundwater Protection. During construction, operation, or maintenance of a channel project there may be disturbances to the groundwater regime in the project vicinity. Typical of the impacts which may have to be assessed are those which intercept, augment, or diminish groundwater flows in the project area. These may be caused by: 1) excavation of the channel itself -- or by collecting drains, 2) the placement of spoil on top of recharge areas, or 3) the ponding of waters (behind weirs, dams, or logjams) in temporary or permanent collecting basins. In some situations in marine coastal environments the excavation of a channel may induce an outflow of fresh groundwater into the channel thereby permitting the inland encroachment of underground saline waters. The reviewer may find the existence or probability of such impacts explicity stated in the EIS -- or their significance may have to be deduced.

Remedies, mitigating measures and alternatives may be considered. Some of these can be: 1) lining permeable channel banks to reduce losses (outflow) to permeable strata and/or prevent inflow of degraded waters (for example: from waters which have leached undesirable quantities of soil minerals) from intercepted aquifers; 2) installation of subsurface drains or construction of off-channel recharge basins to counteract the loss of natural areas where groundwater recharge previously occurred; and 3) locating ponding and recharge areas so that degrading influences on groundwater quality and volumes are minimal.

None of the above-mentioned ameliorating measures, however, are impact-free. When upstream sources of pollution exist and have degraded surface waters that are thereafter induced, or allowed, to recharge aquifers there should be critical concern about water quality standards. The addition of non-consumptively-used water from irrigated lands (i.e. "return flows" with high mineral salt content) to channel flows is a related example of this same sort. But, on the other hand, in a watercourse where water temperature is of critical concern (for example, to sustain certain aquatic species) the addition of appreciable groundwater flows -- which normally have a temperature equivalent to the area's mean annual temperature -- may be purposefully and beneficially induced to lower the ambient water temperature. In water-poor areas the reviewer should expect to find that evaporative losses which might affect groundwater reserves have been considered. And where potential recharge areas are being considered there should be concern about the influence of abutting land-use practices.

In summary, the reviewer's task in assessing impacts on groundwater resources will be focused on those affecting water quality in both the surface and underground systems. Standards and criteria for these inter-connected systems have been previously discussed in this section and their importance to aquatic and terrestrial ecosystems is to be found in subsequent sections (IV.B and IV.C).

IV.B. Review of Aquatic Ecology Impacts

Aquatic ecology impacts are discussed in this section under the broad categories of physical habitat alteration and changes in land use and water quality. Since aquatic ecosystem response is closely linked to the nature and extent of hydrology and water quality impacts, the reviewer should refer freely to the guidance on sources and quantification of these impacts found in the previous section.

Although some of the impacts of channelization activities are of relatively short duration, many ecological effects have been observed to persist for long periods, even after cessation of all maintenance activities. Channelization must be viewed as a long-term commitment of environmental resources which is perhaps not fully recoverable at least in the space of years or decades. In reviewing the EIS sections dealing with ecological impacts, this concept should be kept in mind.

IV.B.1. Sources of Impacts

Channelization can profoundly affect the ecology of a project area. Channelization activities generally elicit substantial alterations in the physical and chemical characteristics of affected aquatic habitats. Clearing and snagging, removal of obstructions, channel excavation, disposal of excavated material, construction of ancillary facilities such as grade control structures or sediment basins, and new hydrological regimes all leave their mark on the ecology of the watercourse. The degree to which various impacts will occur is a function of project-specific features. Hence, project evaluation must be predicated in large part on local and regional environmental and institutional conditions.

Most of the ecological impacts of channelization can be related to the introduction of uniformity into a naturally diverse system, whether by straightening, removal of obstructions or bank vegetation or any other actions. The theme of diversity recurs throughout this section and is basic to impact evaluation.

Three basic ecological principles underlie the identification and assessment of impacts:[43]

1. The greater the diversity of the conditions in a locality the larger is the number of species which make up the biotic community.

2. The more the conditions in a locality deviate from normal, and hence from the normal optima of most species, the smaller is the number of species which occur there and the greater the number of individuals of each of the species which do occur.

3. The longer a locality has been in the same condition the richer is its biotic community and the more stable it is.

The information contained in the following subsections should help the reviewer to identify those impacts and sources of impacts that need to be considered for channelization projects in various settings and with various activities involved in the construction, operation, and maintenance of the channel.

Habitat Alteration by Debris and Riparian Vegetation Removal. Stream channelization projects frequently involve removal of instream debris which acts as a flow retardant, and clearing of bankside debris and vegetation which can retard flow during flood-stage periods. Clearing of instream debris oftentimes constitutes habitat destruction for some of the more important members of the aquatic community. Debris-laden areas often serve as shelter, feeding, and reproduction areas for fish, insects, and other organisms. Roots, stumps, snags, and other obstructions are important to the ecology of both cold- and warmwater streams; elimination of these elements from the ecosystem can adversely affect the carrying capacity of a watercourse for fish species and may reduce species diversity as well. Snagging operations are a part of virtually all channelization projects where debris accumulation affects hydraulic capacity and may be carried out apart from or in conjunction with other channel modifications as well as during channel maintenance.

Clearing of bankside vegetation may be deleterious to the aquatic environment in several basic ways. First, the potential for erosion of the stream or channel banks may be increased considerably, especially if bank stabilization measures are not included in the proposed project for all affected areas. Sediment eroded from unprotected or cleared channel banks may impact on the biota in the project area and also affect downstream habitat either as a suspended solids load or by sedimentation on the stream bed.

Streambank vegetation and overhanging branches often produce a mottled sunlight-shade pattern that is conducive to organisms with differing preferences for light intensity, thereby contributing to habitat diversity. Elimination of riparian vegetation for channel improvement works would decrease this aspect of variability in the aquatic ecosystem. A great increase in rooted aquatic and algal vegetation was observed in many sections of the channelized streams investigated in the CEQ channel modification study.[44] Increased light with the clearing of bankside vegetation and additional nutrients brought about by increased sedimentation or changes in land use may both be partly responsible for these changes. Such growths would greatly alter the channel habitat and probably cause a decrease in species diversity.

The other potentially critical impact is the alteration of thermal regimes when trees and other shade-producing vegetation are removed. Maximum summer stream temperatures may be appreciably increased following canopy destruction, but the diurnal range of temperature variation may also be greater. In streams where coldwater species are living close to their critical thermal maxima during the summer months, further temperature increases might preclude habitation of affected areas, particularly in shallow waters and riffle areas under low-flow conditions. Temperatures above the optimum range for trout may cause mortality, decrease growth rates due to higher metabolism, or increase susceptibility to disease. Fryer and Pilcher,[45] in studying several species of trout and salmon, found that the progress of infections was accelerated and mortality rates were greater at higher water temperatures. Warmwater biota can also be affected, since higher temperatures reduce the capacity for oxygen absorption. Temperatures do not have to approach critical maximum limits for important impacts to occur. Most organisms exhibit a temperature range within which optimum growth and development take place and deviations toward the extremes of this range may reduce productivity without eliminating a species entirely.

For many streams, particularly those in unpolluted headwaters, natural vegetation along the banks is an important source of organic matter and nutrients for supporting aquatic life. Leaves, terrestrial insects, and other inputs are contingent on the maintenance of riparian vegetation, the removal of which could contribute to a decline in the productivity of aquatic biota. These impacts cannot be isolated from the related probable effects on temperature, sediment production, and other environmental factors; rather, their interrelatedness with respect to the aquatic ecology must be recognized.

Habitat Alteration by Channel Excavation and Maintenance. Excavation of new or existing channels typically causes turbidity and sedimentation due to the operation of construction equipment directly in or adjacent to a watercourse, and temporary bank instability may also lead to sloughage and erosion. Changes in gradient and flow regime brought about by channel modification may alter erosion and sedimentation patterns during the operational phase of a project. These physical changes can result in severe impacts on aquatic ecosystems in the project area and in downstream sections. Perhaps the most obvious effect is that of marked habitat alteration in the reach which is directly affected by dredging or excavation. Besides destroying resident benthic organisms and perhaps fish, channel excavation may produce long-lasting changes in the nature of the stream bed and banks which will influence the diversity and productivity of aquatic life. Replacement of a gravel substrate with an unstable sandy bottom, for example, will probably eliminate many species of benthic invertebrates that cannot live on sand and favor establishment of a reduced faunal assemblage.

An even more fundamental consideration is the impact of channelization on the total amount of aquatic habitat which can act as a productive resource. Channel straightening will result in the elimination of backwaters and meanders and a net reduction in stream length. Substantial alterations of an existing channel, such as the removal of shoals and creation of a uniform channel bed, may also decrease the habitat available for native aquatic organisms. Maintenance of aquatic habitat in stream sections isolated by channel straightening may reduce losses, but sedimentation often causes them to fill in rather quickly and complicates effective management. Unless an adequate supply of freshwater is circulated through an oxbow, little potential exists for maintaining the aquatic environment in a condition approximating that of the original stream prior to channelization.

Both increased suspended and settleable solids can have adverse effects on populations of aquatic organisms in the tributary systems where stream channelization is usually conducted. High suspended solids loads can abrade fish gill filaments and adversely affect feeding by reducing vision and olfactory sensitivity. If organic fractions of the suspended load are increased, dissolved oxygen deficits may cause active avoidance of the stressed areas by sensitive fish populations. These stresses may be especially important for channelization or dredging activities in or near estuaries where they may delay or bar the upstream migration of anadromous salmonids or clupeids (shad, for example).

Suspended solids loadings can also have indirect effects on fish populations by affecting other elements of the food web in aquatic ecosystems. Turbidity increases can cause reductions in primary productivity and the particulate materials can inhibit the productivity of benthic macroinvertebrates, particularly those which depend on trapping or filter feeding for their existence.

Downstream sedimentation can alter the physical characteristics of the substratum, thus affecting habitat values. Sedimentation of fine particulates can have adverse effects on reproductive success of any or all fish populations which may utilize the affected area for spawning. Sedimentation can smother eggs, alevins, or frys by decreasing intragravel water flow and dissolved gas exchange, and can render the bottom unsuitable for redd or nest construction.

The hydraulic changes brought about by channel excavation will influence the aquatic ecosystem over the long term, modifying erosion and sedimentation processes and flow regimen. The probable erosional and depositional patterns discussed in Section IV.A.1 for channel straightening, widening, deepening, and other modifications will have an impact on ecological diversity and productivity, depending on the extent and environmental features of the channel and stream segments that are involved. Species that require clean gravel for spawning or as habitat would not adjust well to areas where the flow regime resulted in deposition of fine-grained sediments but might be benefitted where scouring increased due to channelization. The tendency of a stream to regrade following construction of a meander cutoff (Figure IV-1) would, for example, result in degradation above and aggradation below the shortened reach, with resultant effects on the benthic communities.

Water velocity is one of the most important ecological features of the stream environment, influencing in large measure the bottom composition, erosion and sediment transport patterns, and the kinds and abundance of aquatic organisms that may inhabit a given area. Not only velocity but also differences in velocity affect the ecosystem. A natural stream may exhibit a great diversity of velocity patterns and "microhabitats," both longitudinally and laterally, due to the presence of meanders, vertical variations in slope, obstructions, pools and riffles. Even a single species depends on this habitat diversity; for example, adult trout occupy habitat with velocity, substrate, and other features that are often quite different from those characterizing habitat for fry or fingerlings. Channel excavation and maintenance very often introduce greater uniformity of velocity and substrate characteristics, to the detriment of the aquatic species inhabiting the reach. Channel projects that increase flow velocity and entail the removal of rubble, snags, and other cover are likely to support fish populations much reduced from those prior to channelization. Even strong-swimming fish such as trout which actively feed in fast-moving water cannot maintain that position for long and must have access to deep water or cover where velocities are lower.

A variety of current regimes and patterns enables more species to live in a given area than would be possible under channelized conditions. The hydraulic effects of channelization may be important under all flow conditions. Velocities associated with flood discharges will be greater than the unaltered stream because flow is confined to the channel instead of spreading over adjacent flood plains. In the same channel, water depths at low flows may be decreased if obstructions and debris have been removed or the channel bottom widened. Diversity of species in an aquatic environment contributes to stability and the ability of the communities to withstand floods, droughts, and other adverse natural occurrences.

Effects of channelization on groundwater and thus on surface water hydrology have ecological implications as well. Reduction of flooding frequency and modifications of the stream cross-section by deepening, widening, and levee construction or land disposal of excavated materials can decrease or eliminate riparian flood plains as a part of the aquatic ecosystem. Some aquatic species are floodwater spawners and utilize as breeding areas flood plain ponds that are interconnected with the stream during high water. Channelization can upset this important ecological interrelationship between flood plains and rivers as, of course, flood plain land use changes may also. Likewise, reduction of overbank flooding would result in the transport to downstream reaches of suspended solids, nutrients, and other constituents normally removed by sedimentation on riparian areas.

Main channel excavation and related construction of field drains for the purpose of improving drainage of agricultural lands, riparian wetlands, or other areas are likely to decrease groundwater recharge, accelerate runoff, and lower the groundwater table in affected areas. The result may be a decrease in base flow in the channel during dry periods when the majority of discharge is supplied by groundwater. In some instances, effects on groundwater levels can be sufficient to cause intermittent flows in streams tributary to a channelized reach, even in water-rich areas such as North Carolina.[46] Obviously, impacts on the aquatic ecosystem would be severe in this situation. The subsections on groundwater in Section IV.A should be consulted for further information on the physical and hydrologic conditions under which problems of this sort may occur.

Realignment of a channel that results in creation of backwater areas in the old stream bed may have important ecological consequences. In the extreme, such areas would be drained or converted to dry land thus eliminating aquatic habitat. More commonly, however, reduction of water velocities will induce establishment of a different species composition from that of the stream environment. The aquatic habitat values associated with backwaters will depend on the type of ecosystem which develops in response to sedimentation, water levels and flow, depths, water quality, and other environmental variables.

Ecological impacts of channel maintenance depend largely on the nature and frequency of maintenance activities, which in turn vary with project purposes, design and setting, and the specific arrangements made for carrying out maintenance work. Channel maintenance may consist of mechanical removal or herbicide treatment of unwanted vegetation that has encroached on the banks, removal of sediments and debris from the channel and sediment basins and repair of eroded banks, rip-rap, lining, and ancillary structures. Once construction is completed, exposure to natural forces causes adjustments of the channel bed and banks to the new conditions. Indigenous vegetation may displace or supplement grasses or herbaceous cover planted on the banks, possibly contributing to their stability and erosion resistance. The channel itself may aggrade and degrade at various locations in response to the imposed hydraulics, and debris areas may be formed. These factors of aging work toward restoring ecological diversity and stability in the modified channel, but may impede hydraulic efficiency. The maintenance activities mentioned above arrest the trend to ecological recovery of the channel and cause recurring habitat instability. In general, then, channel maintenance perpetuates ecological impacts but is necessary to insure that the project serves the flood control, drainage, or other purpose for which it was designed.

Habitat Alteration by Changes in Land Use and Water Quality. Channelization usually allows more intensive or productive use of existing agricultural or urban lands, and may additionally induce changes in land use in areas that: (a) are readily be drained or (b) receive flood protection by the project. The aquatic ecology aspects of land use changes have already been alluded to and relate basically to the role of flood plains as an integral part of the aquatic ecosystem and potential changes in water quality. Agricultural lands have been shown by many studies to be greater contributors of pollutants such as sediments, nutrients, and pesticides, than are forests, grasslands, and other natural vegetation associations. Similarly, urban areas can produce a wide variety of polluting substances that may be conveyed to waterways with storm runoff and through storm drainage systems, or as wastewater treatment plant effluents.

The impacts of sediments on organisms and habitat stability have been discussed earlier. Increases in nutrient loads from agricultural or urban runoff may stimulate the growth of algae and rooted aquatic vegetation in and downstream from a channel, thereby altering primary productivity. Introduction of pesticides is of concern not only because of potential toxicity but also because of possible bioaccumulation and concentration in aquatic organisms and species higher in the food chain. These impacts may vary considerably, and may be negligible in certain cases, depending on existing water quality, the probable nature and extent of land use shifts in areas affected by a channel project, and the use and effectiveness of land treatment measures proposed for the watershed, if any.

IV.B.2. Review of Impact Quantification

A substantial amount of scientific literature has been developed which relates to ecosystem structure and function in stream habitats. Investigations have focused on a variety of natural streams and those subjected to channelization at one time or another. Although consistent qualitative changes are frequently observed, such as reduction of fish standing crop or alteration of benthic community composition and diversity, prediction methods for changes which may occur due to channelization have not developed to the point where reliable quantitative estimates can be made. The difficulty arises from two fundamental factors: stream channels and their ecosystems are quite heterogeneous, and no two channelization projects are exactly alike.

Essential to ecological impact quantification is an understanding of aquatic ecology in the area to be altered and the physical features and design of the channel, combined with prediction of changes in hydrology and water quality (see Section IV.A.2). Most EIS's will contain such information and analyses in varying detail and comprehensiveness. Estimates of impacts are usually based on general knowledge of ecological requirements and interrelationships of the affected species and experience at other projects in the region rather than sophisticated modelling or other advanced techniques. Evaluation of impact quantification therefore requires judgment as to the adequacy of the information from which ecological conclusions are drawn, in terms of the scope of the project and the overall environmental setting. The manner in which hydrology and water quality issues are treated is especially important; if the EIS description of these factors is insufficient, then it is likely that estimates of aquatic ecology impacts will be similarly deficient.

The guidance in this section should aid on conducting these evaluations.

Habitat Alteration by Debris and Riparian Vegetation Removal. Because of the complexity of aquatic ecosystems, predictions of impacts may be largely quantitative or judgmental although some relevant factors can be described quantitatively. Information presented in the EIS should cover basic clearing and snagging operations from at least the perspectives of the affected stream areas and the resulting differences of habitat from preproject conditions that such work would cause. Thus, the reviewer should expect the EIS to contain as fundamental data: the lengths and locations of stream segments where debris removal or clearing would be conducted, and the nature of the material to be removed.

Impacts will depend on the relationship of bankside vegetation and instream debris to the overall available habitat; that is, clearing and snagging on a fairly wide and deep stream will probably not be as ecologically damaging as on a small stream where riparian vegetation and debris provide much or most of the shelter suitable for fish populations. Also, relatively permanent debris-laden areas formed, for example, by large trees that have fallen into or near a stream may furnish very favorable aquatic habitats as contrasted with temporary obstructions that are vulnerable to washout during high water periods. The magnitude of impacts of debris removal will thus depend on the character of the area to be altered. In general, the elimination of cover due to clearing and snagging will almost always have an adverse effect on fish populations, and should be recognized in the EIS. The width and depth of the stream, the amount and type of cover and habitat affected by clearing and snagging, and other channelization activities in the affected areas are the principal variables the reviewer should expect to be addressed.

Clearing of streamside vegetation is one of several channelization activities that may cause an increase in suspended solids loads. Impacts would be most severe during construction and probably decline as new vegetation is established or bank protection measures are installed. As pointed out in the section on quantification of construction and maintenance impacts, precise numerical estimates of turbidity or suspended solids concentrations may not be made in the EIS; rather, the reviewer's concern should be to ensure that reasonable controls will be applied in the construction phase to minimize erosion and sedimentation.

Resulting effects on the aquatic ecosystem will depend on the types of organisms present and the area subjected to increased turbidity. Many benthic invertebrates, such as the larvae of caddisflies, many mayflies, and stoneflies, are typically associated with clean gravel substrates and are intolerant of sedimentation. Trout and other species of fish cannot spawn successfully in stream reaches where fine sediments cover the bottom. Sedimentation from clearing and snagging may not be critical, for instance, if the stream segments that would be affected are currently characterized by fine, unconsolidated, and unstable sediments and a benthic community adapted to such conditions.

The effects of clearing bankside vegetation on water temperatures will be greatest on narrow streams where trees form a closed canopy or shade a significant portion of the water surface, whereas impacts may be minor on wide streams. Temperature increases of several degrees (C^{o}) may result from removal of trees along a shaded watercourse. Ecological implications of a given change, however, are difficult to quantify. Brown[47] noted that no mortality of coho salmon attributable to high temperatures occurred in a clear-cut study stream even though temperatures more than $8^{o}F$ above the reported lethal limit for the species ($77^{o}F$) were recorded. He pointed out the present lack of ecological information on the effects of high but sublethal temperatures on stream organisms. It is, nevertheless, important that the EIS contain information on existing water temperatures and the probable impact of riparian vegetation clearing (see Section IV.A.2). As long as regrowth of bankside vegetation is prevented by channel operation and maintenance, the altered thermal regime will persist. The EIS should relate anticipated changes to the thermal requirements of species inhabiting the project area; this is particularly important in the case of salmonids whose optimum temperature range is lower than that of most other fish.

Habitat Alteration by Channel Excavation and Maintenance. Relevant to all channelization projects is quantification of the aquatic habitat in the project area and the nature and extent of proposed modifications. Data on the following are essential:

- Total length and normal surface area of unaltered stream and proposed channel.

- Length and location of pools, riffles, and various bottom types under existing and channelized conditions.

A channelization project involving realignment of a stream typically reduces (a) biological productivity because the new channel is shorter with less overall habitat available and (b) the carrying capacity for aquatic biota due to channel straightening and alteration of hydrologic and morphologic characteristics. On the other hand, widening an existing stream channel may produce a net increase in the water surface area and habitat for aquatic organisms. Reduced water depths, loss of riparian vegetation, and removal of instream obstructions and cover would, however, detract from the ecological value of the added water area.

Beyond quantification of habitat gains and losses, estimates of aquatic ecosystem response should be contained in the EIS. Methods for arriving at these estimates range from simple predictions based on a knowledge of the kinds of fish inhabiting the area to detailed assessments based on quantitative surveys of fish, benthic communities, and habitat. The level of detail necessary for adequate estimation of impacts varies with the scope and complexity of the project as well as the natural, scenic, recreational, or commercial value attached to the stream and fishery. Collection of baseline data on aquatic organisms requires considerable time, effort, and skill. In quantitative studies considerable numbers of samples may need to be taken in order to obtain representative, reliable results. It is desirable to sample many different types of habitats within the area of interest. Because data requirements depend on the nature of a project and probable impacts, specific guidance on what information should be included in the EIS cannot be given. However, the following descriptions should help in understanding the relevance of various categories of biological data to a particular channel project. Chapter 5 of the report by Cooper et al.[48] discusses the time, personnel, and equipment requirements for aquatic flora and fauna measurement techniques, and should be consulted for supplemental guidance.

- Fisheries. As a minimum requirement for all channelization projects, an inventory of the fish species inhabiting a proposed project area should be conducted. Reliable information sources include the state fish and wildlife agency and possibly the U.S. Fish and Wildlife Service if involved in reconnaissance or field investigations during project planning. Or, the channel planning agency may carry out such data gathering using its own staff. The nature of any fish stocking or management programs and data on fishing pressure and harvest should be included in the EIS, if available and applicable. Data on fish populations and production are important because:

(1) Fish are normally the major usable, renewable resource of the aquatic ecosystem, and

(2) the condition of fish populations is an indication of habitat conditions and cumulative productivity.

Besides being useful for estimation of impacts, quantitative information on preproject fisheries as well as other biota is valuable as a basis for comparative follow-up studies should the channel be constructed.

- Benthic Invertebrates. A survey of benthic fauna may be undertaken to furnish information supplemental to fisheries data. Benthic invertebrates are the major food source of stream fish. Generally, only very rough quantitative estimates are obtainable and extrapolation of several sample results to a biomass estimate for a stream segment is likely to lead to erroneous conclusions. Difficulties in accurate benthic sampling are to some extent inherent in the sampling methods which often have different selectivity for different organisms, and in the wide variations of organism abundance both spatially and temporally. For most purposes, the types of organisms present, observations of their relative abundance, and the nature of the substrates from which samples were taken are of interest for impact quantification. In particular, knowledge of benthic fauna common to the project area and their habitat preferences can be related to the bottom characteristics, velocity, and other conditions expected after channel construction.

- Algae, periphyton, and larger aquatic plants. Useful measurements of phytoplankton in streams are complicated by problems of seasonal and diurnal differences as well as sampling difficulties. Therefore, any quantitative estimates should be described in terms of the probable limitations of the data. Generally, phytoplankton populations are greater in the low-gradient, quiescent reaches of a stream than in rapids and riffles. Turbidity may also limit their abundance. For channelization projects that may indirectly cause increased nutrient loads due to changes in agricultural or urban land uses, knowledge of existing population distributions among the major groups of algae (generally diatoms, green, and blue-green) may be helpful. Aquatic macrophytes ordinarily do not occur in any abundance in swiftly flowing water, but may be an important component of the ecosystem in slow, meandering flood plain streams. Visual observations or sampling may suffice to indicate types and distribution in a project area. General descriptions of the location, kinds, and abundance of weed beds should be included in the EIS.

Effects of Suspended Solids and Sedimentation. Suspended solids can have adverse effects on all aquatic biota. The magnitude of ecological impacts is directly related to concentration, although the size, angularity, and composition of the particles also influence organism response. The duration factor is also relevant, as most organisms can tolerate very high levels of suspended solids for short periods of time, but will suffer adverse effects if the conditions persist. Estimates of the impacts should follow from quantification of suspended solids loads associated with construction, maintenance, bank erosion, land uses, and land treatment measures. Effects on primary production due to reduction of light intensity are difficult to quantify; construction-induced turbidity will probably not have significant effects whereas a general longer-term increase in suspended solids may cause a downward shift in productivity.

The biological impacts of sedimentation are perhaps more readily discernible than impacts of suspended solids. Proper quantification entails identification of areas that will be affected both in and downstream from a channel project. For both the periphyton (or Aufwuchs) and benthic invertebrates, substratum stability is one of the main determinants of abundance and diversity. Table IV-8 categorizes several groups of bottom-dwelling macroinvertebrates according to their general tolerance to pollution, which would include effects of sedimentation of inorganic solids or organic matter. Although there may be exceptions, the organisms are listed in the usual order of disappearance below pollution sources. The morphological structure of benthic fauna is an important factor in this pattern:

> Species with complex appendages and exposed complicated respiratory structures, such as stonefly nymphs, mayfly nymphs, and caddisfly larvae, that are subjected to a

Table IV-8.

General Tolerance of Representative Benthic Macroinvertebrates to Pollution

Sensitive		Intermediate		Tolerant	
Stonefly nymph	(Plecoptera)	Black fly larvae	(Simuliidae)	Leech	(Hirudinea)
Mayfly nymph	(Ephemeroptera)	Scud	(Amphipoda)	Sludgeworm	(Tubificidae
Hellgrammite or Dobsonfly larvae	(Megaloptera)	Aquatic Sowbug	(Isopoda)	Sewage fly larvae	(Psychodidae
Caddisfly larvae	(Trichoptera)	Snail	(Gastropoda)	Rat-tailed maggot	(Tubifera-Eristalis
		Fingernail clam	(Sphaeriidae)		
		Damselfly nymph	(Zygoptera)		
		Dragonfly nymph	(Anisoptera)		
		Bloodworm or midge fly larvae	(Chironomidae)		

Water-Quality Improving ⟵⟶ Water Quality Deteriorating

SOURCE: Sinclair, op. cit., p. 22-4.

constant deluge of settleable particulate matter soon abandon the polluted area because of the constant preening required to maintain mobility or respiratory functions; otherwise, they are soon smothered.[49]

In reviewing predicted impacts of suspended solids and sedimentation on fish, both direct and indirect effects should be considered. Gravel is probably the most commonly used substratum for spawning of many species of fish found in running water. Even many species which normally live over sandy bottoms move to gravel areas in faster water to spawn. If the proposed project area contains spawning areas of important fish species, the degree to which the spawning sites will be altered or destroyed and the resulting impacts on population levels of affected species should be examined. Impact predictions should be based on:

- the extent of the area used for spawning;

- an estimation of the number of eggs deposited within the area, the proportion which hatch, and the survival rate to reproductive maturity by species;

- knowledge of impacts on spawning habitat gained from studies of other channel projects;

- knowledge of spawning frequency and timing;

- estimates of the magnitude, duration, and extent of construction-generated turbidity and sedimentation;

- estimates of substrate composition with aging of the channel, from the knowledge of channel gradient, geometry, flow, and other hydrologic characteristics.

Channel construction, operation, and maintenance may similarly have adverse effects on reaches of a stream used as a migratory corridor by important fish species during specific times of the year. Upstream migration for spawning is a behavioral trait common to many species of fish, although the distances travelled and the importance of the movements for reproductive success vary widely depending on the size and type of stream, geographic location, and numerous other factors. Disruption or blockage of migration may be caused either by the creation of physical barriers such as impoundments or grade stabilization structures, or by creation of behavioral or physiological barriers such as extensive turbidity and sedimentation. In general, the construction phase of a project has the greatest potential to produce turbidity conditions adverse to fish migrations, with spring and autumn the critical periods for migration and spawning in most temperate streams. Channelization conducted in coastal steams or estuaries may especially impact on anadromous species that have established annual runs into or through the proposed project area. The reviewer should expect the estimates of these impacts to include consideration of migratory frequency and periodicity, the size of the migrating populations, and the timing and duration of construction and maintenance activities. It should be noted that construction and maintenance may inhibit migratory movements of fish and affect reproductive success for only a relatively short period, whereas the presence of ancillary structures could have an effect year after year.

Indirectly, suspended solids and sedimentation may be detrimental to resident fish populations due to their effects on benthic communities which serve as a major food source for fish. Generally, the types of organisms used extensively for food are those which are less tolerant of sediment and other forms of pollution, as indicated on Table IV-8. Also, an overall decrease in productivity of a channel bottom because of sedimentation may be reflected in a corresponding change in fishery potential. These interrelationships should be considered in the EIS.

Effects of Altered Hydrologic Conditions. Besides their relevance to erosion and sedimentation, hydrologic conditions of a channel have other major influences on the nature of the aquatic habitat and its favorability for various kinds of stream-dwelling organisms. Quantification of impacts necessitates an understanding of the physical changes caused by channelization and interpretation of those changes with respect to habitat preferences and biotic requirements of the species involved. The magnitude of ecological impacts will be related generally to the reduction in diversity which can be brought about by channelization. It is imperative that the EIS compare hydrologic regimes of the existing watercourse and proposed channel. Estimation of impacts should include quantification of the following:

- Dimensions of pools and riffles for unaltered and altered channel (including proposed water level and grade control structures, etc.)

- Abundance and distribution of important fish species in the reach to be channelized.

- Water velocities in representative segments under channelized conditions, for representative flow conditions.

- Water depths under channelized conditions, at least for low flow.

- Changes in low flow regime due to drainage or alteration of groundwater contributions.

Generally, elimination of pools and riffles will disrupt the aquatic floral and faunal assemblages characterizing each habitat. The nature of the aquatic community that develops in the channelized reach depends on, among other things, the expected velocity and depth patterns. High velocities produced by channel shortening and decreases in roughness, for example, may inhibit re-establishment of any of the indigenous fish species. Under different circumstances of moderated flow velocities and an unconsolidated, unstable substratum as might occur with widening or deepening an existing stream channel, less desirable fish species than those present prior to channelization may be favored. Larger fish of most stream species seek out the cover afforded by deep water; elimination of pools and deep holes formed at the outside of meander bends reduces the amount of habitat suitable for larger fish and can jeopardize the overwinter survival of both fish and other organisms. Since low flow conditions impose a variety of stresses on aquatic biota, any expected decrease in discharge as a result of channelization will have adverse effects which may be more severe if deep pools have been eliminated from the affected reach.

The magnitude of aquatic ecological impacts associated with reducing the frequency of flooding on riparian wetlands adjacent to a channel depends on: (a) the existing amount of such habitat, (b) frequency, duration, and area of flooding on a seasonal basis with and without the channel, and(c) the species of fish and other aquatic organisms that utilize the areas as foraging, spawning, and nursery habitat. Generally, freshwater and coastal backwaters, marshes, and bottomland lakes that are interconnected with a stream and whose water levels fluctuate with river stage have an expecially important influence on productivity of the aquatic ecosystem, and are also vulnerable to drainage or major alteration by channelization. Many species will inhabit riparian wetlands at some period during their life cycles; therefore, detailed guidance cannot be given. The principal considerations for impact prediction are, as mentioned above, the area of wetland habitat that will be altered, the nature of the alterations, and the species that will probably be impacted. If these factors are not fully discussed and quantified where possible in the EIS, the reviewer should suggest the acquisition of further information to permit an adequate assessment of impacts.

The cause-effect relationships among flow, cover, velocity, depth, numerous other environmental variables, and ecological response are not well understood when viewed collectively. Nevertheless, many post-construction case studies confirm that channelization usually results in a reduction of species diversity and/or productivity for fish, benthic invertebrates, and other organisms. The reviewer should not expect the EIS to contain detailed predictions of impacts on standing crops of fish or benthic invertebrates, total production, or other ecological measures. Rather, it is important to ensure that the EIS establishes the nature and value of the biotic resources that would be affected by the proposed action. Judgments of the adequacy of ecological impact quantification should then be made according to the EIS description and treatment of physical, hydrologic, and other environmental variables that will be altered.

Ecology of Channel-Created Backwaters. The fate of oxbows, meanders, or channels that are cut off from the main discharge by channel realignment must be addressed. Specifically, the EIS should describe plans for channel design features that would influence the hydrology of isolated backwater areas and forecast the probable ecological changes that would take place over time. For example, expected hydrologic conditions, sediment loads, water depths, and similar factors should be analyzed to estimate the rate at which the old channels will fill in. With this knowledge, predictions should also be made of ecological succession, from marsh to swamp to meadow or some other sequence, and the time periods involved. The possibility that stream cut-offs will be drained by a channel, filled and reclaimed for agriculture or other uses must also be evaluated, as such activity would destroy the aquatic or wetland habitat.

As mentioned earlier, the inlets and outlets of a cut-off stream segment would be subject to rapid sedimentation and could be difficult to keep open without periodic maintenance.

Generally, the aquatic ecosystem in backwaters created by channelization will change appreciably. Lentic species will predominate, soft-bodied forms will tend to dominate the benthic assemblages, and the backwater will be particularly susceptible towards dominance by insects. In addition to sedimentation rates, water level fluctuations and nutrient loadings are important determinants of the ecology of cut-off meanders or oxbows. Provisions for water level control in the cut-off and their effect on water surface fluctuations should be detailed in the EIS. An oxbow may serve as a trap for incoming nutrients with the result that eutrophic conditions may occur which can reduce the diversity of aquatic species. Therefore, nutrient levels in runoff reaching the area, as well as expected flushing and sedimentation rates, should be estimated to obtain an estimate of the potential for eutrophication. Excessively high productivity can ultimately cause adverse reductions of dissolved oxygen concentrations and general water quality. Low rates of water exchange along with high sediment and nutrient inputs will be most conducive to eutrophication of cut-off meanders. Terrestrial habitat implications for waterfowl and other wetland species should also be considered, as discussed further in Section IV.C.2.

Effects of Altered Land Use and Water Quality. Estimates of probable land use patterns in the area of influence of a proposed channel project and the resultant changes in pollutant loads should form the basis for ecological impact quantification. There may be considerable uncertainty in forecasting future land uses, fertilizer and pesticide applications, urban runoff-related pollutants, the application and effectiveness of land treatment measures, and other water quality influences, which complicate the prediction of ecological impacts. Generally, those projects which involve drainage of agricultural lands or wetlands offer the greatest potential for increasing pesticide residues in a stream course, particularly in small streams during low-flow periods.

Baseline data on pesticide and other pollutant loads from the watershed and resulting concentrations in stream segments should be presented in the EIS to establish existing water quality conditions or problems. Increases in nutrients from agricultural or urban runoff may affect the aquatic ecosystems by stimulating growth of algae or rooted aquatic plants in the channel, especially if water velocities are expected to be fairly low, the water is shallow, and a silty substrate develops. These conditions, along with increased exposure to light following bankside vegetation clearing may all contribute to development of rooted aquatic and algal mats on the channel bed. Ecologically, large populations of algae and aquatic plants help induce a change in the faunal associations, typically to the detriment of species that are commercially or recreationally important.

Prediction of impacts must involve quantification of those anticipated environmental conditions discussed above in order that susceptible areas of the channel can be identified. It is likely under the conditions described that fish species would shift to a composition similar to that characterizing shoal areas further downstream in the watershed. As examples, trout might be replaced by bass and perch, or the latter by carp and catfish. Project and watershed specific inventories of fish species and populations are, however, necessary to estimate distributional changes.

IV.B.3. Assessment of Impacts

Assessment of aquatic ecology impacts should be viewed as a synopsis of EPA's concerns from the perspectives of the agency's legislative mandates, regulatory authority, and responsibilities for management and protection of the environment. Objective criteria do not exist by which all of the potential ecological impacts of channelization can be assessed. In some cases, therefore, reference may have to be made to other measures of the importance and value attached to natural streams and their biotic resources. These might include the extent of recreational fishing use of the project area, the regional availability of unaltered streams with characteristics similar to the project area, the probability of cumulative losses of natural streams in the region through water resource development activities, and the presence of unique, rare or endangered fauna in the vicinity of the proposed project. The guidance of this section should alert the reviewer to (a) the applicability of criteria for water quality protective of aquatic life, (b) considerations in assessing ecological impacts for which less explicit criteria exist, and (c) the need for and effectiveness of impact-mitigation measures.

Judgments should first be made as to the adequacy of identification, description, and quantification of probable impacts in the EIS, aided by the discussions in Sections IV.B.1. and IV. B.2. Any inconsistencies, insufficiency of baseline data, or other aspects of the EIS that hinder a proper evaluation of impacts should be noted and reflected in the project rating. Ecological impacts should be viewed in as broad a context as possible, in terms of overall and combined effects on aquatic biota and the nature of the resource commitment. Water quality standards and criteria only partially serve this approach, since impacts such as loss of aquatic habitat or habitat modifications that produce a shift in species composition may not be specifically addressed by the criteria. Thus, the reviewer must assess concurrently the ecological implications of water quality impacts and the physical and other changes brought about by channelization.

The assessment of thermal regime alterations should be based essentially on the thermal criteria for growth and spawning of commercially or recreationally important fish species inhabiting the project area. Tables 5 and 6 and Appendix A in EPA's Proposed Criteria for Water Quality, Volume I, (October 1973) should be consulted, as well as applicable state water quality standards relating to temperature alterations. The ecological significance of clearing bankside vegetation and thereby increasing maximum water temperatures and fluctuations depends on (a) the magnitude of the expected temperature increase and (b) the suitability of existing temperature patterns for the species involved. For example, an upward shift in maximum temperatures by "x" degrees in a stream whose thermal regime is currently above the optimum for certain species may eliminate them, whereas the same temperature change in a stream whose temperatures at key periods are near optimum may stress the populations but not eliminate them entirely. For projects where water temperatures are likely to be increased by riparian vegetation clearing, comments on the degree and significance of probable impacts should be supported by specification of the relevant criteria.

The importance of the ecological impacts of suspended solids generated during channel construction, operation, and maintenance, and from changes in land use can be ascertained by relating expected conditions to the criterion of 80 mg/l as the maximum acceptable total concentration of suspended solids in fresh water. However, a complete assessment involves evaluation of other factors, including the duration of sediment inputs and the expected erosion and sedimentation patterns in, above, and below the project area following channel modification. If there are no reasons to expect that erosion and resulting turbidity will persist after completion of the construction phase, impacts may be short-term and amenable to control by institution of proper construction management practices.

Sediments that are deposited on the channel or stream bed may be equally or more important than suspended materials with respect to aquatic ecology. The relationship between suspended and bed load sediments is dynamic in time and space; it does not necessarily follow that no unacceptable impacts will result if suspended solids concentrations are kept below a prescribed value. For instance, an unstable channel bed made up of shifting sand could exist under conditions of low suspended solids and yet support few benthic fauna and be of no value as a fish spawning area. This example emphasizes the importance of assessing ecological impacts from a perspective encompassing the variety of changes that may result from channelization; the reviewer should not limit his evaluations to consideration of water quality parameters and criteria alone.

Other pollutants that may originate from lands affected by the drainage or flood control functions of a channel, particularly nutrients and pesticides, require special attention since they are usually nonpoint in nature and thus may be difficult to control. The reviewer must assure that the EIS has examined the issues of land use and related pollution potential adequately in a geographic or area-of-influence sense and over a suitable time period. Since accurate estimates of pollutant loadings associated with induced changes in land use would be highly speculative at best with effects difficult to separate from other watershed influences, direct comparisons with appropriate criteria probably cannot be made. Trends in agricultural and urban land use in the basin, information on the present water quality status in and downstream from the proposed project, and projections of future waste loads from all sources should be factored into an assessment of runoff-related pollutants and resulting ecological impacts. Basin and areawide plans for water quality management prepared under the 1972 FWPCA Amendments should furnish supporting data for assessing the land use and water quality issues of channelization from an ecological perspective.

As was brought out previously, many of the ecological impacts caused by channelization involve physical modification of habitat elements such as velocity, cover, substratum, and light patterns to which no explicit criteria can be applied. In these situations, the guidance contained in earlier sections should help in determining whether the EIS has identified and appropriately quantified probable impacts or, if not, in arriving at rough estimates of the types of changes that would be likely. Impact assessment then requires judgments of the importance and value of the existing aquatic ecosystem and biota, and the degree to which the resource would be committed or altered by the project. Although a comprehensive enumeration of critical impacts on aquatic ecology cannot be presented, the following types of effects should be considered as serious and may warrant special mitigation measures, alteration of the project design or location, or selection of a nonchannel alternative for meeting water resource development objectives:

- Adverse effect on habitat of rare or endangered species

- Significant disruption of spawning areas for commercially or recreationally important fish species

- Significant destruction of cover and habitat essential to important species.

Inherent in channelization activities is the reduction of environmental diversity which in turn reduces biotic diversity in an aquatic ecosystem. Mitigation or rehabilitation measures in general have the effect of restoring or preventing loss of elements of diversity in the environment that are sacrificed in the course of channel modification. Table IV-7 describes those techniques that may be incorporated into a channel design to serve various purposes, including aquatic habitat enhancement. Although these measures would produce notable benefits for fish and other stream life in many cases, they also add to the project cost and perhaps maintenance requirements.

In assessing whether mitigative measures have been adequately treated in an EIS, the reviewer should examine the reasons for selecting or rejecting the measures that were considered and the characteristics and extent of proposed mitigation in relation to the stream resource to be altered. Table IV-7 may be used as a guide to both the beneficial and possible detrimental aspects of mitigation techniques. Comments on the EIS should be directed to the need and desirability of maintaining reasonably diverse habitat features for the survival of aquatic biota, especially when values of scarcity, uniqueness or recreational use are known to exist.

IV.C. Review of Terrestrial Ecology Impacts

The impacts upon terrestrial ecology, like those on aquatic ecology discussed in the preceding section, may be categorized either as changes in habitat or as changes in land use. Nonetheless -- and the same point has earlier been made -- there are complex interrelationships between land and water systems so that separation and classification of impacts -- in a wetland, for instance -- is not always easily made on the basis of either the location or nature of those impacts.

The conveyance of excess water, whether for flood control or drainage, from one environment in which it occurs naturally to another selected for convenience must be viewed in its appropriate locational context. Intended land use is often the rationale for such actions and, moreover, the definition of "excess" is not always generally agreed upon by all concerned. Furthermore, lest the problem of impact evaluation be oversimplified, there are wide ranges of terrestrial conditions -- from pristine and undisturbed to very much man-altered urban situations -- to which channelized solutions are applied; resultant impacts, and the public responses to them, differ greatly.

Terrestrial systems have been conventionally arranged for both land use and habitat classification purposes as either upland, riparian, or wetland. Each of these is differently defined in terms of the land-water interfaces found there. The land use and habitat characteristics are dependent upon the nature and dimension of these interfaces. Impacts upon terrestrial ecosystems may be further differentiated, for categorical purposes, on the basis of their occurrence within either an arbitrarily restricted zone of influence or within a more regional context; such distinctions may also be considered as stemming from direct or indirect land modifications.

The concept of recovery time for an impacted ecosystem is of significance in the evaluation of terrestrial impacts. The recovery of a channelized area's aesthetic values may occur over a period of only a few years after which the raw scars may disappear. Ecological impacts, on the other hand, are less easily assessed. And because of complex interrelationships these may range in severity from permanent alteration or obliteration of ecosystems to subtle local changes -- in amphibian species on a streambank, for example -- which are barely distinguishable from evolutionary changes. The reviewer, therefore, must be careful to differentiate between those ecological impacts evaluated on short-term or easily observed evidence and those which may become apparent only after carefully studied changes in biological productivity of the trophic levels of an impacted ecosystem.

IV.C.1. Sources of Impacts

Terrestrial impacts are most easily and obviously associated with the construction activities responsible for alteration of existing soils, vegetation and habitats alongside channelized sections. Clearing and grubbing, excavation and levee-building, disposal of excavated spoil, channel relocation, and provisions made for tributary junctions, culverts and access roads are all land-disturbing activities resulting in the obvious alteration of land bordering a project. And changes in flow regimes will have profound, though not always obvious, influences upon riparian habitats, with the result that resident species must react to changed nutrient sources and levels. Land treatment measures, such as the building of diversions, drains, and grassed waterways, or the institution of contoured cropping programs in upland habitats some distance removed from the channel will affect species composition of that area's plant and animal life. The reviewer will find in the section which follows information on sources of impacts in areas affected directly and indirectly by channelization. Table IV-9 provides an overview of land uses and impact considerations.

Impacts on Riparian Habitat and Land Use. The distinction between "habitat" and "land use" is blurred by the interrelationship of defining criteria. Species diversity, ecosystem stability, and carrying capacity are biological parameters dependent upon land uses; land uses, on the other hand, whether they be recreational, agricultural, or residential are associated with and reflective of the biological productivity of the area in question.

Riparian habitats and land uses are closely associated with the channelized water body. Changes to the streambank have an effect upon water quality and aquatic ecology and, conversely, changes in water quality and ecological parameters within the stream influence habitats and land uses alongside channel banks. As was described in the preceding section (IV.B) the clearing of bankside vegetation induces not only accelerated erosion on unprotected slopes but also changed patterns of light intensity upon the water and temperatures within the stream. Such influences may have impacts upon aquatic plant and animal life such that, for example, coldwater species of fish are reduced or disappear, warmwater species supplant coldwater species, shade-tolerant vegetation is replaced by species preferring open sunlight, or whole populations of aquatic organisms are severely reduced by the absence of protective cover or the depletion of nutrients (e.g. the detritus derived from overhanging vegetation on which some aquatic organisms depend) previously provided by riparian life.

Changes in water quality and hydraulic parameters, occurring as a result of channelization, may bring about changes in species composition of streambank vegetation. A change in groundwater levels -- usually to lower elevations -- may be a strong influence upon vegetational changes alongside channelized streams. Plant-soil moisture relationships are thereby changed and plants more tolerant of xeric conditions may invade the area, or growth rates of existing species may be affected. Species more tolerant -- or less tolerant -- of pollution levels may replace those which were compatible with the preproject water quality parameters. Changes in stream velocities may cause changes in bank stability and therefore

Table IV-9. Overview of Channel-related Land Uses and Potential ımpacts on Terrestrial and Aquatic Systems

Induced Land Use Changes to:	Terrestrial Ecosystems: Vegetation diversity	Terrestrial Ecosystems: Wildlife diversity	Water Quality and Aquatic Ecosystems: Sediment generation	Water quality changes	Groundwater changes	Infiltration rate changes	Increased runoff	Pesticide application	Flood hazard
Recreation: (includes) picnicking, hiking, swimming, hunting, fishing, skiing, off-the-road vehicle use	–	+ –	–	–	+ –	–	–	–	+ –
Agriculture (irrigated or dry): row crop production, pasturage or range, orchard crops	–	+ –	–	–	–	+ –	–	–	+ –
Timber Harvest	+ –	+ –	–	–	–	–	–	–	–
Land Development: floodplain occupation, wetlands reduction, construction	–	–	–	–	–	–	–	–	–

- Potential detrimental impact

+ Potential beneficial impact

in the kind and/or maturity of plants and animals preferring such riparian niches. The height of flood waters, their frequency, and duration will have additional influences upon both plant and animal residents in riparian areas. Similarly, the construction of low-flow notches or grade-control structures may change water levels for specific stream segments with the result that riparian habitats are either created or destroyed.

Riparian habitats exist for aquatic, amphibian and terrestrial animals. Such habitats provide not only food for these species but shelter and protective cover. Disturbance or removal of this habitat by excavation, burying with spoil materials, clearing, or bank-stabilization measures introduces new factors in the area's population dynamics -- as, for example, in changing predator-prey relationships or limiting food supply. These impacts, though not always easily identified as to specific cause and effect, should be recognized as potentially significant influences on a terrestrial ecosystem.

Insofar as impacts upon, or changes to, riparian environments influence person-related activities (e.g. recreation, agriculture, and urbanization) the distinction between direct and indirect impacts is easier to perceive. The cutting-off of a meander, for example, may induce an increase in recreational activities (e.g. marinas and vacation homes) along the banks of the abandoned meander. This, in turn, may have far-reaching effects upon other socioeconomic supply and demand factors in the region -- as well as on the ecology of both the channelized and abandoned stream segments. In another instance, the building of access roads for construction and maintenance of the channel may open up previously undisturbed lengths of streambank to fishermen, campers, or lumbering operations. Again the impact may be principally an indirect one, increasing in severity years after the project has been completed. Or, in an urban setting, the channelization of a stream may result in a renewed emphasis on aesthetic values and water quality when dumps, derelict or decayed buildings are exposed to public view thus motivating concerted efforts to improve the environment alongside the channelized stream.

The reviewer should also note the potential impact of downstream flooding which may be caused by the debouchment of the channelized discharge into a stream channel section incapable of safely passing the increased volumes of water.

Impacts on Wetland Habitat and Land Use. It has been recognized by a growing percentage of the public in recent years that wetlands have a uniquely and irreplaceably important value in sustaining terrestrial and aquatic ecosystems. Because wetlands are of such diverse types the nomenclature has traditionally embraced other terms -- still technically nonspecific -- such as: meadow, marsh, pothole, swamp, and bog. Classification schemes now being proposed are reportedly more precise and more acceptable to both generalists and specialists.[50] Wetlands may be coterminous with other areas characterized as bottomlands and floodplains;

they may also be found at higher elevations in association with the headwaters of streams. Water levels of wetlands may be relatively constant or vary seasonally; they may contain fresh, brackish, or saline waters. But in any case their value is that of a food source and nursery upon which ecosystems are essentially dependent. In addition, wetlands serve as natural storage areas for floodwaters, as recharge and discharge reservoirs for groundwater volumes, as natural water-quality treatment systems for the degradation of such hard-to-handle pollutants as oil and chlorinated hydrocarbons, and for the removal of excessive amounts of such eutrophying nutrients as phosphorus and nitrogen.

Wetland drainage can be expected to lower groundwater levels as drained areas dry out. A shift in vegetational species will then gradually occur, followed by a change in resident wildlife species better adapted to the invading dryland vegetational types. In many cases drainage projects have decreased the diversity of both vegetational and animal species over extensive areas.[51] It is especially important for the reviewer to note, in this regard, that wetlands are hospitable environments for many of the floral and faunal species regarded as both rare and endangered.

Channels which pass through or alongside wetlands areas may have the unintended effect, because of either channel design or location of adjunct features (e.g., berms or spoil banks), of restricting or preventing periodic inundation and replenishment of adjacent wetlands. Such unintended effects may be extraneous to the project's purpose but the reviewer should appraise the likelihood of such occurrences and resultant damage to the nourishment of wetland areas.

The issue of impacts to bottomland hardwoods was one singled out for appraisal in the study[52] of existing channelization conducted for CEQ. That study found these impacts to be most serious in lowland deciduous forest stands where water is in abundant supply (i.e., wetlands) -- especially in the humid areas of the southern states. And the impacts were traceable to induced changes in land use which made the sequence of drainage, clear-cutting of bottomland forests, and conversion of the once-forested areas to agricultural cropland an economically attractive undertaking. Though the magnitude and extent of such inventoried land use changes are now largely a matter of historical record and unlikely to be repeated at anywhere near the same scale, the ecological implications are clear and applicable even to the small-scale and indirect effects which might occur today. Not only were soil-water conditions much changed in these once-forested areas with resultant impacts on elements of the hydrologic cycle (e.g., runoff and transpiration) but soil stability was impaired, wildlife habitats were destroyed, and diverse vegetation species were replaced by monocultured crops (e.g., soybeans, rice, and/or corn).

Coincident with drainage and/or flood reduction measures which have an impact upon wetlands may be the construction of access roads, some of which may be along spoil banks. Construction and subsequent use of these roads, in an area previously undisturbed, by recreational and exploitative activities may be a serious source of environmental impacts. Harvest and removal of timber in wetlands and floodplains may result in increased volumes of runoff and higher levels of both turbidity and nitrates in the waters of nearby watercourses.

Wetlands, when drained, may become highly flammable. Dense vegetational mats, no longer nourished by high water tables, may die and dry out. In addition, the organic soils of wetlands may include thick deposits of peat. Fires started in such areas may not only destroy resident wildlife and their habitat but inhibit the establishment of successional vegetative stages; fire, once started, may also be beyond the capability of local authorities to control.

Migratory birds, especially waterfowl, are notable users of wetlands on a seasonal basis. Such areas may serve either as transient resting places or as places of longer residence, depending upon their location along regional flyways.[53] The reviewer should note the significance of wetland disturbance or reduction not only to the migratory patterns of birds but to those species of aquatic life which have life cycles dependent upon natural and seasonal fluctuations of water levels for spawning runs, the development of eggs and juveniles, and then, at subsequent high water levels, the re-introduction of new generations to the waterways of the region.

The emplacement of spoil and dredged materials in wetlands adjacent to a channel will have the effect of destroying one kind of habitat and replacing it with another. The environmental implications of spoil placement are dependent upon the relative significance of the proportional changes in habitat composition in the project's locale. The addition of nutrients derived from dredged materials may add appreciably to the nutrient loading of the wetland in which they are dumped.

Though wetland drainage projects are not undertaken for the primary purpose of bringing additional land into cultivation[54] but rather to enhance the productivity of existing cropland, privately-installed or non-Federally supported tributary channels and drains connecting with the main channels may, in fact, have this result. The resultant effects are measurable not only as habitat changes but as changes in land use. Oftentimes these changes are not in type but in degree or intensity -- from poor pasturage, for example, to good pasturage or from marginal timberland to exploitable forestland. The reviewer should be careful lest these potential effects be characterized either generally or simplistically, as solely beneficial or adverse. These effects should be judged in the context of the project-specific antecedent conditions, existing potential for the area's soil types, vegetational species and wildlife species to be affected, predicted regional economic and land use implications (e.g. for water quality), and other relevant factors. It is important therefore that the reviewer find adequate descriptive material in the EIS on terrestrial ecosystems and the likelihood of induced land use changes so that resultant impacts may be adequately assessed.

Impacts on Upland Habitat and Land Use. Terrestrial impacts caused by channelization in upland areas may be as diverse as those taking place in riparian and wetland areas. Structural elements such as upland floodwater retention or retarding devices, check dams, drop structures, and deflecting wings are as appropriate in some upland situations as are land treatment measures in headwaters areas under other circumstances. Though water quality conditions in headwaters are generally of high order and upstream aquatic biota more sensitive to degraded conditions than are the species found farther downstream there are not the same differences in degree of sensitivity between terrestrial ecosystems in upland and bottomland areas; both systems are, in a general sense, equally sensitive.

One other generalization to be made is that because of the dendritic or branching tributary patterns of channelized systems larger channels are usually found in the lowlands and smaller ones in headwaters areas. Many smaller tributary channels are privately (i.e. non-Federally) installed by landowners and drainage districts during or after Federally-funded projects are completed.

Upland habitats, in general, may be classified as either agricultural or forested lands. Habitat alteration as a result of the implacement of structures can, in both cases, be characterized and quantified in degree by the impact to acres of land cover, species of wildlife and vegetation lost, and crop or timberland productivity foregone as a result of the area occupied or impacted by the structure.

Structures which serve to impound upstream water will have an impact upon both surface and groundwater regimes. Upland areas are often recharge areas by virtue of their elevation, and the retention of water over aquifer recharge zones will increase groundwater volumes in areas underlain by that aquifer. The installation of a structure with consequent impacts upon groundwater levels may gradually change soil-moisture conditions so that vegetation changes take place and terrestrial ecosystems are affected. In some situations an upland impoundment area may thus, in time, be changed to become a wetland.

Impoundments of surface waters in upland areas will also have an impact upon downstream wetlands and riparian areas as well as in-channel aquatic ecosystems. The release of impounded waters may or may not be on a predictable schedule. If streamflows are appreciably diminished this will have ramifying effects on downstream groundwater conditions and the terrestrial systems supported by such underground resources.

Land treatment measures are undertaken in upland areas to improve soil conditions and the vegetation growing thereon, reduce erosion, improve drainage, and prevent flooding. These practices are sometimes required as adjunct to and conditional for the installation of structural features (e.g. channels) in a watershed management project. Some of these measures are:

-- crop rotation practices

-- planting of cover crops

-- contour farming

-- crop residue utilization

-- field terracing

-- subsurface tiling

-- land grading

-- grassed waterways

-- farm ponds

-- fence row plantings

-- forestry improvement practices

-- wildlife area improvement

Upland land treatment measures, in many cases, are arranged with local "cooperators" and their installation or implementation, in the strictest sense, is not the responsibility of the initiating agency. Their net impact on systems is intended as beneficial even though component negative impacts may be identified.

The reviewer should be especially sensitive to situations in which downstream channelized flood protection, for example, is contingent upon upstream flood management practices -- such as floodplain zoning. The implementation of zoning restrictions is beyond the jurisdictional authority of Federal channel-building agencies. The issue raised in such situations, however, typifies the classic "upstream-downstream" conflict and involves questions of equity, compensation, etc. rather than those of ecosystem impact assessment. Land use questions, particularly when a channelized stream traverses jurisdictional boundaries, as it often does when impacts to both upland and lowland areas can be anticipated, are complex and seldom as easily resolved as third parties would like them to be.

Though they apply equally to riparian, wetland, and upland habitats the indirect terrestrial impacts of channelization may be felt beyond the region of physical influence. Drainage of wetlands, for example, may adversely affect migratory patterns -- and even population statistics -- of waterfowl.[55] The installation of upland impoundments, on the other hand, may have the opposite effects on these same biotic systems extending beyond the project's perimeter. In addition, land modification to terrestrial habitats in any location may cause a shift in overland migration routes of animals, the impacts of which are felt at considerable distances from the project itself. Impacts of this sort (direct and indirect) are also measurable in human socioeconomic terms -- as in the case of dislocation of corridors for transportation and other utility services. Similarly, recreational opportunities and development potential, even though not expressly specified as project purposes, may have complex interactions with supply and demand factors measurable over wide areas. The reviewer, therefore, should be sensitive to the possibility of indirect and induced impacts which are subtle and/or cumulative and measurable only in a regional context.

IV.C.2. Review of Impact Quantification

Guidelines for the quantification of impacts upon terrestrial ecosystems -- and also for aquatic systems (see IV.B.2), must necessarily be generalized because each project area is distinctive and characterized by different dimensions, adjacent land uses, and ecological values. Yet it is these distinctive categories (i.e. project dimensions, land uses, and ecological values), quantifiable for all projects, upon which the reviewer must focus. Changes in these characteristics from pre-project to post-project status (i.e. as envisioned and described in the EIS) should receive the reviewer's attention.

In many cases only qualititive estimates, rather than quantitative ones, can be made. This may be either because predictive techniques for quantitative measurements -- in ecosystem changes, for example -- are not sufficiently developed, or because induced and indirect impacts -- of land use changes, for instance -- are, in themselves, dependent variables.

Impacts Dependent Upon Project Dimensions. Descriptive material in the EIS will, or should, contain definition of both lateral and longitudinal dimensions of the project. The confines of the project within which construction, operational, and maintenance activities will take place therefore should be apparent to the EIS reviewer.

Both the characterization of land cover and the current land use practices which are to be directly affected by installation of the channel and adjunct facilities (e.g. access roads, tributary drains, borrow pits, spoil banks, etc.) should be described in the EIS -- and if they are not, the reviewer should find the absence of such information cause for critical comment. Areal coverage should be definable and perhaps even classifiable according to a systematized inventory. Though the EIS may not provide sufficient areal distinctions nor details to allow the reviewer to identify mappable categories of land cover, it should be sufficiently explicit to allow the reviewer to estimate: 1) the relative significance of different types affected by the project, and 2) the proportional changes in these categories expected to occur after the project is installed. From such approximate quantifications, impacts may be estimated so that their significance can be evaluated.

A suggested inventory classification might include:

- agricultural and open lands
- forest lands
- wetlands
- mining or waste disposal areas
- urban lands
- outdoor recreational facilities

The above classification can be adapted to reflect appropriate regional categories of land uses, vegetational types, and the nature of the land itself. The categories may be further refined to emphasize significant sub-categories. Under agricultural land, for example, distinctions may be made between: tilled, abandoned, pastured or range land.

Impacts upon productive forest and cropland may be quantified not only in acres gained or lost but in increased or decreased yields -- e.g. bushels or cords per acres. (Many EIS's treat this subject under "socioeconomic" rather than "environmental" sections; quantification may also be addressed in EIS's when comparing "alternatives to the proposed action.")

The productivity of wetlands is difficult to assay -- only one of the reasons being the ecological differences between wetland sites. Nonetheless the high productivity and ecological values associated with wetlands are generally recognized by ecologists and others. (Southern swamps, for example, are estimated to yield an average gross primary energy production of 20,000 kilocalories/square meter/year -- an output ranking them with such other extraordinarily productive ecosystems as those found at coral reefs and in estuaries.)[56]

It is important that the EIS contain, however, sufficient descriptive information on project-affected wetlands to make possible assessments of impacts in terms of acres lost or gained. And it will be of significant aid to the reviewer if material is available in the EIS enabling the distinction between types of freshwater wetlands.[57] A generalized classification of the sort still being used might be the following:

- Wet meadow:	Vegetation is primarily grasses, rushes and sedges; surface water is present only seasonally.
- Marsh:	Characterized by some open water, and emergent vegetation.
- Swamp:	Waterlogged soils with some standing water; vegetation is mostly woody shrubs and trees.
- Bog:	Characterized by mats of sphagnum moss in waterlogged soil; vegetation contains shrub thickets, black spruce, tamarack and red maple.
- Seasonally flooded flatland:	Floodable land -- usually adjacent to streams; often without sharply distinctive vegetational character.

The reviewer who is able to make generic distinctions between the above kinds of freshwater wetlands described in an EIS is thereby enabled to better appraise a channel project's impacts upon wetlands. Generalized criteria which may then be applicable to impact measurements in wetlands are some of the following:

- Diversity and dominance of wetland types:

  The greater the mix of wetland types in an area, the higher the value attached to a wetland type of rare occurrence; dominance of marshes and/or swamps, as contrasted with meadows and open water, results in greater numbers of inventoried wildlife and vegetational species.

- Diversity of wetland biota:

  Inventories of biota are indicative of wetland diversity; the greater the diversity of wetland types, the more diverse the species of plant and animal life; diminished diversity of wetland types will have a corresponding impact on resident biota.

- Character of wetland:

  The patterned arrangement of vegetation so as to cause maximum interpersion of vegetational species and increase the benefits of "edge effects" will enhance habitat values and increase diversity of resident aquatic and terrestrial species; a concentric arrangement of vegetational growth around open water in a marsh, for example, is less to be desired than a random interspersion of clumps and thickets of vegetation throughout the marsh.

- Wetland site:

  Wetlands associated with lakes and streams are more valuable than isolated ones; and wetlands which are interconnected one with another increase habitat and species diversity -- especially if they are of different types; wetlands located in lowlands generally have a richer substrate than those in the uplands.

- Wetland size:

  Habitat utilization is correlatable with wetland size -- small wetlands (less than 25 acres) are more valuable on a per acre basis for waterfowl nesting than large ones, and large ones are more attractive as resting places for migratory waterfowl; diversity, in general, is correlative with size; but the context and local, or regional, frame of reference is of importance in adjudging this wetland parameter.

- Adjacent land types:

  Diversity of type of surrounding areas (forest, cropland, saltwater bay, etc.) increases species diversity within the wetland.

- Wetland water chemistry:

  Hard and/or alkaline waters produce a greater value and diversity of nutrients than do soft or acidic waters.

The reviewer will usually have to be judgmental in assigning relative and qualitative values to impacted wetlands. Such values are also dependent upon interpretation of the descriptive environmental data presented in the EIS and the local or regional significance assigned to wetland areas.

It is important that the environmental values of wetlands not be confused with commercial or income-producing classifications.[58,59]

Impacts upon urban and recreational lands caused by channelization are often easier to quantify than those on other lands because of social and institutional interests in lands of these types and because of specifications, in project designs and plans, of the options, variable consequences, and the detailed cost projections of project installation. Terrestrial ecosystems in urbanized areas are principally riparian and it is important that the reviewer be able to identify and estimate the extent and dimension of riparian habitats. (Even the numbers of trees may be estimated in the EIS and a portion of the impact thereby more easily quantified.) The reviewer should be critical of scheduled removal of vegetation and other natural materials (during construction and maintenance), especially that which is justified solely to provide greater freedom of movement for equipment.

Riparian lands in urbanized areas not only have a special value as wildlife habitat but more especially serve to enhance aesthetic values. The textural (land vs. water) and landform (elevational) contrasts are important aesthetic elements along a streambank, as is the element of naturalness. Interference with or disruption of these elements should be minimized if pleasing landscapes are to be maintained in an urban environment. And the reviewer's task is to be critical not only of impacts attributable to unjustifiable lateral extension of the project but of physical design standards which conflict with aesthetic standards.

<u>Impacts Dependent Upon Land Use and Ecological Values</u>. Most channel projects are undertaken either: 1) to drain excess waters from areas where the presence of such waters is inimical to present land uses, or 2) to prevent the periodic incursion of flood waters into areas where they will cause damage to existing property values. Land use categorization therefore is an integral part of impact quantification.

It is important that the EIS differentiate between existing land uses and those forecast for post-project periods. Quantification of the former is more easily accomplished than for the anticipated future because of implicit and influential uncertainties. Such uncertainties include: changes which might occur in volumes of and market prices for agricultural products, growth-induced changes in residential, commercial and industrial land development patterns and optional plans and programs which may be instituted by local and regional institutions. Moreover, the time frame within which cumulative impact quantifications are to be estimated is usually not specified, though such periods of analysis can be expected to have relevance to the "useful" life of a project.[60]

Categorization of land has already been touched upon in the preceding subsection ("Impact Quantification Dependent Upon Project Dimensions") where an inventory classification of land types was suggested as a means of differentiating between and quantifying the effects upon nearby lands. In addition to the categorization of land types specific land uses may also be classified within a project area -- or within an area which may feel the impact of a channel project.

The rationale for categorization, whatever system, is to quantify the impacts of a project so that a degree of impact significance may be assigned the project. Pre- and post-project assessments are thus possible and attention can then be focused on critical categories as these are defined in a local or regional context.

Land use categories may be classifiable under the following format:

Residential
- (by zoning classification)

Commercial
- Essentially free-standing stores
- Shopping Centers

Industrial
- Light manufacturing
- Heavy manufacturing

Transportation
- Mass transit facilities
- Highway
- Others

Recreation
- Intensive
- Passive
- Spectator-oriented

Public Utilities
- Petroleum products
- Water and sewer
- Electric

Public & Historic Buildings

Agriculture
- Extensive (pastured or mowed)
- Intensive (tilled)
- Forested

Vacant Land
- Conservation restricted
- Cleared but abandoned

Water Bodies
- Lakes and impoundments
- Flowing water
- Wetlands

The EIS may not contain inventoried land uses outside of the area defined by a project's perimeter. The reviewer is advised that such regionally relevant inventories may be available, however, in reports of regional planning associations, river basin studies, Section 208 planning studies, transportation studies, and the like. It is possible, therefore, that project-related land use impacts, as described in or inferred from an EIS, may be better appraised in an appropriate and critical context when compared with other published documents on land utilization.

Criteria for land use impact quantification and evaluation, in the final analysis, are both economic and ecological. Economic criteria as they relate to terrestrial ecosystems are applied to measures of productivity--anticipated increases (or decreases) in yield or the expected changes in land values reflected by "higher" (or "lower") levels of "usefulness" to society. The reviewer is cautioned that the emphasis on such measures heavily prejudices impact quantification in favor of income-producing resources while overlooking less easily quantifiable resources or values for which measures of worth are less well understood or appreciated.[61] Also often overlooked as a result of this approach are the values of future options.

The ecological values of terrestrial ecosystems have been addressed in earlier parts of this section--the contribution of riparian vegetation to water quality and aquatic ecosystems, the nutrient values of wetlands, and the replenishing functions of uplands. These values are not easily quantified in terms customarily applied; they are dependent upon regional concepts of scarcity, need and demand expressed by both measures of ecosystem functions and definitions of politically oriented issues.

Wildlife habitat values, species diversity (of plants and animals), and levels of productivity are elements which the reviewer can only qualitatively appraise in areas adjacent to a channelized stream. And project-related impacts which on balance are beneficial and non-degrading ones may result from and be appraised for such purposeful management programs as wildlife management, reforestation, and water quality improvement (e.g. with land treatment measures). Wildlife management programs that are on a put-and-take basis are differently valued than are those emphasizing habitat improvement or protection. And reforestation that has as its purpose the re-establishment of growing stock in areas once ravaged by fire is different from enhancement of watershed areas with plantations of conifers. Land treatment measures in areas of high relief are more significant than those in more gently rolling tilled areas. Impact appraisal in such cases is subjective and it is the reviewer's task to insure that such appraisals are reasonable, comprehensive, and in the context of the project being addressed.

Impacts, including those related to project installation and operation but induced and stemming from the encouragement or introduction of new or intensified land uses, may be less easily appraised. As was earlier noted these impacts, although traceable to land-based activities, are in most cases transferred to water systems. (See Table IV-9.) There the impacts can be quantified in terms of the standards and criteria of water constituents or water quality parameters. The reviewer's responsibility therefore is to be sure that impacts traceable to land-based activities and induced land changes are properly addressed as ecosystem impacts.

IV.C.3. Assessment of Impacts

An assessment of the anticipated impacts to terrestrial ecosystems should relate identified sources and degrees of impacts to the capacity and ability of the land and its biota to sustain or recover from those impacts. Established or mandated limits to terrestrial impacts are usually not quantified specifically but instead are estimated in relation to resource scarcity, resource demand schedules and projected cumulative impacts. Mitigating measures as well as alternative means of meeting proposed project objectives should be included in the EIS and reviewed in the assessment--such measures to include changes in project scope and channel dimensions as well as redesign or relocation of project elements; and project alternatives to include both structural and nonstructural solutions to the water resource problem for which channelization is being proposed. The reviewer's task in impact assessment therefore involves judgment on both the adequacy of the definitions of anticipated impacts described in the EIS and the comprehensiveness of the considerations by the initiating agency to reduce these impacts to minimum and acceptable levels.

Impacts on Biota. Ecological impacts should be considered in as broad a context as possible. Interdependencies of plants and animals at the land-water interface are especially important in sensitive riparian and wetlands environments. Species productivity and diversity are dependent in such places on water quality, water levels and soil or substrate conditions. Criteria exist for water quality parameters on toxicity and pollutant loadings, for example, which are pertinent to the productivity of marsh vegetation. The reviewer's task therefore is to relate, wherever possible, quantifiable impacts (see Sections IV.A.2 and IV.B.2) to resource values. Habitat values for indigenous waterfowl, terrestrial animals, and vegetation can be related to acreages and intensity of modification. But judgmental assessments of relationships between direct or indirect impacts and ecological productivity and diversity must be the basis for the reviewer's critique in most instances.

Wetland drainage must be assessed not only for impacts on the species composition of resident biota but for reduction of natural flood storage and lowering of groundwater levels. Those impacts, in turn, affect recharge potential, consequent low flow volumes in streams, and eventually water quality parameters. Flood storage effects must be assessed in the context of damage potential to areas downstream from the impacted wetland.

Alteration of riparian areas may result in vegetation losses with resultant effects on both animal habitats and food sources as well as impacts upon components of aquatic ecosystems. Some of the aquatic effects may be quantifiable estimates (e.g. turbidity values and thermal effects) whereas most terrestrial effects will be less well defined in the EIS (e.g. species productivity and nutrient source availability). The reviewer should assess the completeness of impact identification and supporting baseline or inventory data to determine the significance of a channel's modification to existing (or potential) environmental values. "Significance" may be related to acres of riparian areas modified as a percentage of total streambank area or to locations of impacted areas relative to the patterns of diversity and productivity of similar environments in or near to the project area.

Estimations of the regenerative potential of impacted areas should be part of an assessment. Construction and maintenance activities should be viewed therefore in the context of project schedules, timing and frequency of occurrence, and scope of operations. Activities scheduled during vegetative dormant periods, for example, are less serious than at other times. Selective removal of vegetation instead of clearcutting, and identification and preservation of rare species result in less serious impacts on an ecosystem. Distinctions between installation of some structural elements (e.g. rip-rapping, berms, and abutments) and others less environmentally disturbing (e.g. subsurface drains, and diversion terraces) should be noted and related to the permanence and severity of their impact.

Some rare and endangered species have their last refuge in undisturbed wetlands. It is important that the EIS contain assurances that species inventories at the project site have been compared with lists of rare species compiled by the U.S.Fish and Wildlife Service and the appropriate state agencies so that irreparable environmental consequences are avoided.

The context in which impacts to migrating animal species are evaluated often requires that relevant information of a regional--and even continental (in the case of some waterfowl)--scale be included in the EIS.

Impacts on Land Uses. Land use implications traceable to channel modifications are both direct and indirect, immediate and induced. Guidance for review of assessments of those impacts may be found in Section IV.C.2.

The EIS may or may not make distinctions between site-specific impacts and those felt beyond the boundaries of the project. However they are addressed, both should be included. Recreation, agriculture, commercial and residential uses of land are essentially related to interwoven social, economic, and environmental values. These values change and so, in response, do land uses, with notable changes in emphases on: recreational styles and demand, crop selections and the intensity of agricultural enterprise, land settlement or development patterns. Boundaries of resultant impacts are seldom coincident with project boundaries. The reviewer, in evaluating complex interactions of value changes and land uses, and the impacts thereafter anticipated must find in the EIS an overview of pattern changes that have already taken place and data from which future changes can be estimated. International grain market fluctuations, for example, may make soybean cultivation on marginal land temporarily much more attractive than the raising of hay. This sort of change in crop selection may have impacts on sediment runoff, fertilizer application rates, and wildlife habitat values. Impairment or improvement of fishing and hunting opportunities at the project site may create changes in land use intensities--even on land somewhat removed from the project--with resultant impacts on access roads, second-home development patterns, and the provision of utility services. Local and regional population projections may presage other kinds of land use changes. It will be up to the reviewer to assess the comprehensiveness with which the EIS evaluates such potential impacts.

The installation of a drainage channel may induce landowners and other private interests to construct adjunct drainage facilities tying in with the subsidized project. Both the EIS and the reviewer should be sensitive to the likelihood that this may happen.

Flood management measures, both structural and nonstructural, have land management implications. In the absence of local development restrictions the installation of damage-reducing measures may induce occupation of floodplains to a degree exceeding the scope of designed protection. This possibility falls within the purview of both the EIS and the reviewer of impact assessments.

The subject of aesthetics is closely related to land use. Criteria applicable to assessments of impacts upon aesthetic values do not exist. Nonetheless, local and regional standards may be estimated from a consensus of reactions to similar projects and from public discussions. Criteria also can be related to the degree of change anticipated from preproject conditions, proximity of interest parties to a project, and the areal extent or severity of a channel's modification. It is important that attention by paid to the impacts measured by aesthetic values because, though non-quantifiable, such values are often firmly held and strongly defended.

Alternative and Mitigating Measures. Selection of alternative measures is strongly influenced by economics. In addition, engineering options include choices ranging from clearing and snagging to deep channel excavation, with correspondingly ranked impacts on lands adjacent to the channel. Levees, floodways, upstream flood retention dams and land treatment measures are alternatives to accomplishing the purposes of channelization in some cases and adjunct to others--especially where relocation or mitigation of impacts is desired.

Nonstructural measures--principally to reduce flood damages--are classifiable as regulatory, technical-administrative, or economic-financial. Each of these measures involves programs, policies, and funding stratagems specifically tailored to project specifications and institutional responsibilities. (An extensive discussion of applicable nonstructural alternatives may be found in the ADL Report.)[62]

Mitigating measures aimed at alleviating impacts to terrestrial systems are related to those affecting water quality and aquatic ecology impacts (see Table IV-7, Section IV.A.3.) These measures are specifically addressed in a number of relevant EPA publications[63] on the subject of land-disturbing activities. The reviewer should also consider the need for substitution or enhancement of resources outside of project boundaries when the proposed project destroys or degrades resources of appreciable public value within the project area.

Many mitigating measures have relevance to enhancement of animal and vegetative habitat. Spoil banks, for example, instead of being smoothed down or leveled may have value as animal habitats when left undisturbed but planted with appropriate and soil-binding vegetative materials. Restriction of excavation to one side of the channel and the resultant distinction between habitats on opposite sides of a channel may increase habitat diversity. The use of bankside spoil to create or enlarge abutting wetlands may also be an option.

The reviewer must be imaginative in appraising the environmental data contained in an EIS, the impacts anticipated, and the opportunities presented for impact mitigation. Value rankings attached to terrestrial elements such as rare or valuable species of trees (e.g. walnut and pecan) or wildlife species (e.g. ospreys or eagles) if not explicitly enumerated in EIS inventories should be sought by the reviewer as a guide to impact assessment.

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