Working Aids

Environmental Appraisals for Agricultural & Irrigated Land Development

Good Stewardship for Environmentally Sound Agricultural and Irrigated Land Development

The following criteria must be met to ensure an environmentally sound development:

1. The choice of site must take account of the **land use plan** - by following national and local zoning and plans which allocate natural resource uses to different groups, resolve conflicts over scarce resources and avoid disturbance or mismanagement of ecologically sensitive areas. In the absence of any existing land use plan or equivalent sector plans:

   - operation in **ecologically sensitive areas** (see WA 7) should be carried out only in consultation with and under the guidance of all relevant institutions and interest groups, and taking adequate mitigation and compensation measures. General environmental risks associated with land development in such areas should be known and technical means or operational guidelines to minimise such risks must be available and applicable. Significant impacts on protected areas should be avoided or adequately compensated for losses or disturbance.

   - intrusions into areas that support **traditional ways of live**, cultural heritage and archaeological sites should be avoided or minimised. Compensation and mitigation measures should be accepted by all groups affected, economically feasible and there must be strong political commitment for implementation of such measures.

2. Locations for intensive agriculture and irrigation should meet criteria for high **land suitability** classes, such as sites with fertile soils, favourable micro-climate, suitable topography, and sites which have low risks of irreversible soil and water degradation under agricultural use. The site-specific risks must be assessed and recommendations made for adequate technical solutions and management during operation.

3. The use of water for irrigation should take account of **water master plans** where the allocation of water to different users and measures to secure the water quality standards in a watershed are regulated mutually. In the absence of such plans any project should establish site-specific criteria for sound water uses.

   Water consumption in irrigation should continuously be monitored, preferably under supervision of a coordinating watershed catchment agency. Annual and seasonal river or groundwater abstractions need to be controlled and intervention levels defined, for example to reduce abstraction under conditions of seasonal water shortage.

   Subsurface flow from agricultural fields should be controlled to avoid significant water pollution or hazards associated with rises in the water-table.

   Significant modifications of sensitive water resources such as international rivers or lakes or wetlands, fossil groundwater aquifers, or important potable water resources should be avoided. Critical impairments are for example, irreversible changes in river systems which affect important wetlands or conflicts over water used by various users such as navigation, fisheries, industry or agriculture. Mitigation measures need to be developed with all relevant institutions and interested groups.

4. **Farm water management** should be optimised by design and operation of water use systems (supply, conveyance, irrigation method and scheduling, field distribution, drainage) as well as soil and crop management systems (tillage, crop selection, rotation) for efficient use of scarce water.

5. **Water pollution** must be minimised by site-specific irrigation and drainage design and associated soil and water management practices. Critical impairments of surface and groundwater resources by sedimentation or by contamination with livestock wastes, salt, fertilizer and pesticides that cause significant and irreversible changes of sensitive ecosystems and create conflicts with water users downstream.

Best-management-practices and *tools for preventing water pollution* must be applied and monitored especially at marginal sites (e.g. infertile, saline and wet soils, slopes) under intensive cultivation with high inputs of fertilisers and pesticides.

Reuse of sewage for irrigation must take account for internationally accepted standards of design and operation regarding health protection, soil and water contamination and eutrophication of wetlands. Technical control and remedial methods include adequate wastewater treatment, desinfection of contaminated crops, occupational health guidelines, suitable irrigation methods, crop selection, and associated agronomic techniques.

6. Soil and water management at field level should aim at reducing risks of **soil degradation** associated with intensive agriculture and irrigation, such as salinity, sodicity, wetness, erosion, compaction, and humus degradation. Site-specific assessments are required to identify important risk factors associated with irrigation, cropping systems and livestock.

7. *Integrated technologies and processes* in land husbandry and farm management should be promoted to maintain or increase productivity. The use of **agro-chemicals** or other farm inputs should be minimised and site-specific *best-management-practices* be adapted, for example regarding crop selection, cropping pattern, soil tillage, integrated pest management and weed control, and efficient nutrient management.

8. **Farm wastes** should be integrated into the farm management cycle; solid or liquid wastes as well as wastewater must be disposed. Compliance with safety regulations and pollution control standards need to be monitored.

   Farm wastes must be identified to develop feasible concepts: crop and livestock residues, solid wastes of farm inputs such as petroleum products, fertilisers and pesticides, wastes from construction or farm operation, liquid farm or household wastes.

9. Additional **health risks** associated with crop and livestock production, irrigation, drainage and flood control need to be identified. Environmental management includes monitoring and remedial measures such as on-farm agronomic and irrigation measures to prevent health hazards from developing, as well as occupational health safeguards, vector control, and the use of public health services. Large reservoirs and irrigation canals require a *health plan* with engineering, biological and chemical control measures.

10. The disturbances of natural ecosystems by intensive agriculture and irrigation should be mitigated by the integration of **nature protection** measures in project design. A *landscape development plan* can define site-specific conservation measures such as the preservation of wetlands and other habitats important for biodiversity or endangered species. Also, the design of (natural) landscape segments within agricultural areas or bordering larger fields can be valuable, such as hedgerows or woodlots. In large projects such *ecological niches* should cover a minimum of 10% of the total development area.

11. Resource conserving technologies and processes should be developed that minimise use external inputs associated with consumption of energy, fuel and other **non-renewable natural resources**.

ACTIVITY CHECKLIST - AGRICULTURE & IRRIGATION

Irrigation activities which have potential to affect environmental qualities

W water resources development: irrigation, flood control, drainage
L land development
A agricultural development
I infrastructure development
H health control

Water Resources Development

Water Supply System

W 1 surface water reservoirs, e.g. lakes and large reservoirs
W 2 surface water storage, e.g. tanks, small reservoirs
W 3 surface water abstraction, e.g. from rivers or reservoirs
W 4 groundwater abstraction, e.g. from wells
W 5 sewage supply, e.g. from sewage treatment plants
W 6 drainwater re-use, e.g. from drainage systems
W 7 saline water use, e.g. from rivers, saline reservoirs or groundwater

Flood Control

W 8 embankments, bunds, dredging, operation of weirs and sluices

Irrigation System

W 9 delivery systems
- W 9p planning & design
- W 9o operation & maintenance

W 10 water use systems
- W 10p planning & design
- W 10o operation & maintenance

Drainage System

W 11 field drainage systems
- W 11p planning & design
- W 11o operation & maintenance

W 12 drainage outlet systems
- W 12p planning & design
- W 12o operation & maintenance

W 13 drainwater disposal systems
- W 13p planning & design
- W 13o operation & maintenance

Land Development

L 1 Land occupation, such as land clearing, fencing
L 2 Landscape modification: filling, grading, terracing, diking, dredging
L 3 Land manipulation: erosion control, land preparation for irrigation
L 4 Soil amelioration: leaching, deep subsoiling, topsoil sanding, soil conditioning, soil amendments

Agricultural Development

A 1 crop selection
A 2 cropping systems, e.g. rotation, intercropping
A 3 tillage and planting systems, e.g. ploughing, seedbed preparation
A 4 livestock production, aquaculture
A 5 pest & weed controls
- A 5 m mechanical
- A 5 c chemical
- A 5 i integrated pest management

A 6 fertilizer use
- A 6 o organic
- A 6 s sewage, excreta
- A 6 c synthetic chemicals, minerals

A 7 harvesting operations
A 8 post-harvest operations
A 9 on-farm processing
A 10 on-farm waste disposal
- A 10 s solid wastes
- A 10 p petrochemical products
- A 10 w wastewater, other liquid wastes

Infrastructure Development

I 1 housing
I 2 domestic water supply
I 3 rural roads
I 4 off-farm waste disposal
I 5 storage & processing

Health Control

H 1 environmental modification, such as drainage, dyking, deepening, fillings, gradings, stream velocity alterations,
H 2 environmental manipulation, such as vegetation clearing, shading, level fluctuations, flushing of waterways
H 3 chemical controls, such as residual house spraying, aerial spraying

Screening-Checklist 1: Project Screening

1. Type of Development

- Consolidation of farmland ______________
- Intensification of crop production ______________
- Agricultural water development ______________

The project is subject to further assessment if one of these project types applies

(Source: EIA Guidelines of the European Union)

2. Characteristics of the project

Are there substantial changes planned:

⇒ Hydrological modifications ______________
e.g. groundwater or river water abstraction, sewage re-use, flood control

⇒ Water surface areas ______________
e.g. reservoirs, supply systems, irrigated areas, drainage systems

⇒ Land & infrastructure development ______________
e.g. construction for irrigation system, farm roads, flood control, soil & water conservation, drainage system, housing

⇒ Crop production intensification ______________
e.g. cropping systems, mechanisation (tillage, planting, harvesting), fertilisation, soil amelioration, chemical pest & weed control, irrigation methods

Further indicators of significant changes in the environment

⇒ Size of project area or potential areas of impact ______________
e.g. > 500 ha (national standards apply);
Is there extra risk associated with pilot projects?

⇒ Ecologically sensitive areas being affected ______________
Protected areas, wetlands, sensitive water resources

⇒ Culturally sensitive areas being affected ______________
Livelihood of ethnic minorities

⇒ Conflict potential with other land users ______________
Conflicts over traditional rights

Further assessment are required if one or more of these substantial changes applies.

SCREENING CHECKLIST 2: FRAMEWORK CONDITIONS RELATED TO ENVIRONMENTALLY SOUND DEVELOPMENT

A. Pre-project evaluation (existing status)

Environmental elements

river regime (e.g. supply shortage, over-exploitation) ____________
groundwater regime (e.g. high water table) ____________
river system (e.g. channel degradation) ____________
local system (e.g. hinterland degradation) ____________
local wetness, drainage) ____________
water quality (e.g. saline water) ____________

soil erosion hazard (e.g. high susceptibility) ____________
soil phases imbalances (salinity, sodicity, acidity) ____________
physical soil status (internal drainage, tilth problems) ____________

bio-chemical soil status (fertility, biotic activity) ____________
endangered terrestrial fauna and flora ____________
biological imbalances (pests, diseases) ____________
sensitive wetland (freshwater) systems ____________

land use competition ____________
economic development conflicts (other sectors) ____________
public health hazards (e.g. water-related diseases) ____________
regional disparity, migration ____________
conflicts over land and resource tenure ____________

Note: further explanations of each element can be entered in an accompanying form

scoring: ++ favourable status, minor constraints/conflicts, unlikely significant impairments
0 moderate status, probably relevant, possible constraints
-- unfavourable status, complex and likely significant impairments, conflicts

SCREENING CHECKLIST 2: FRAMEWORK CONDITIONS RELATED TO ENVIRONMENTALLY SOUND DEVELOPMENT

B. Management-related potentials

User-related environmental management potentials

- technical knowledge and skills ______________
- natural conservation perceptions ______________
- organisational skills and experience ______________
- social systems and group strength ______________
- land use pressure and resources scarcity ______________
- land and natural resources tenure ______________

overall assessment of user-related potential ________

Institutional and administrative capacities

- environmental competence of sector agencies ______________
- environmental competence of agricultural services ______________
- conservation perception of sectoral agencies ______________
- integrated land use/water resources planning ______________
- environmental education programmes ______________
- environmental information systems (national) ______________
- environmental information systems (district) ______________
- environmental monitoring programmes ______________
- financial resources for environmental management ______________

overall assessment of institutional potential ________

Environmental policy and legislation

- national environmental policy/strategy ______________
- sector environmental policy/strategy ______________
- national environmental management plan ______________
- district environmental management plan ______________
- statutory standards for environmental controls ______________
- pollution and waste monitoring & control programmes ______________
- environmental laws and regulations for agriculture ______________

overall assessment of policy and legislation ________

- capacity of national environmental agency ______________

Availability of environmentally sound techniques

- irrigation techniques and methods ______________
- land husbandry ______________
- extension packages and concepts ______________

overall assessment of techniques and methods ________

FACTORS INFLUENCING ENVIRONMENTALLY SOUND DEVELOPMENT OF AGRICULTURE & IRRIGATION

Direct Factors

Land husbandry & agricultural production

- crop selection
- cropping pattern
- tillage system
- amelioration
- pest control
- weed control
- access roads & infrastructure
- harvest and post-harvest measures
- processing of products
- other production systems (livestock)
- mechanisation (use of energy)

Water use systems

- design, operation & maintenance (O&M) of reservoirs, tanks
- design, O & M of supply systems
- water treatment (sewage/drainwater)
- water distribution (design, O & M)
- design, O & M of field drainage
- design, O & M of water disposal
- pumping systems (use of energy)

Relation to other land/water users

impacts of irrigation on other users and vice-versa

- water quality conflicts
- water abstraction conflicts
- land use conflicts
- groundwater table changes
- changes of river regime
- impacts on wetlands

Natural hazards

- floods, bank erosion
- fluctuations in water flow/level
- changes in water quality
- high winds
- biological imbalances (weeds,pests, diseases)

Natural resources availability

- groundwater or river water supply
- soil quality(chemical, physical, biotic)
- air quality
- climate (rainfall, temperature, evaporation)

Public health hazards

- communicable disease hazards
- community vulnerability
- environmental receptivity
- vigilance of health services

Indirect Factors

User potentials, socio-economic factors

- technical skills and knowledge
- participation in decision-making
- instruments of efficient self-help organisation (e.g. water groups)
- cost allocation techniques
- access to credit, market etc.
- environmental attitude
- flexibility to adopt new techniques

Political, legal & institutional framework

- application of economic instruments for environmental protection
- environmental laws & regulations for agriculture and water management
- enforcement of regulations
- education and training
- efficiency of agricultural extension
- efficiency of irrigation agency
- efficient planning for integrated land and water resources uses
- coordination and decision-making between line agencies
- attitude towards involvement of local people (land & water users)
- resource allocation (funds, staff)

Environmental monitoring systems

- monitoring and evaluation programmes at national/district level
- technical facilities and data management
- funds, staff, coordination between line agencies

KEY QUESTIONS FOR SITE SELECTION AND SPECIFIC PROJECT TYPES

- Does the project interfere in existing land or water use rights?
- Which conflicts over land/water use rights are anticipated, and what options exist to reduce actual or potential user conflicts?
- Is the project design based on land evaluation for irrigation, and which limiting factors exist?
- Are there other development options or alternative land uses?
- Are major ameliorative measures required to develop the area?
- Is the project in line with existing land use plans and water master plans?
- Is there a need for coordination between the project and other land/water users?

Questions at an early planning stage:

- What land and water resources development activities may result eventually in environmental problems? Note: consider also framework conditions and existing local environmental impairments.
- Which environmental qualities are affected? (on-site and off-site impacts)
- What significant and irreversible changes may occur and what new user conflicts are anticipated?
- Are there additional risks due to water-related diseases?
- What measures are in place or planned to reduce or mitigate irreversible and important environmental changes?

Questions for a rehabilitation project are

- What problems of land & water management exist? Which environmental elements are affected? What are the causes of impairment or degradation?
- What user conflicts (inside and outside the project area) exist? What are the causes of these conflicts?
- What public health hazards exist in the area? What are the causes? Are new risks anticipated with project rehabilitation?
- What specific environmental management actions are in place or planned? Are these measures effective? If not, indicate why.
- What rehabilitation or amelioration measures are planned? Define the effects of such activities on different environmental elements?
- What mitigating measures are planned, and how can these measures contribute to reduce or compensate for significant impairments?

Questions for post-hoc appraisals (e.g. project evaluations)

- Are environmental management (plus monitoring) planned or implemented in the project? What are the components of environmental management? Which components are effective? What measures are in place to control pollution and resources degradation?
- What problems related to the efficient use of natural resources exist? What are their causes? What public health problems exist?
- What user conflicts occur in the project area and neighbouring areas?

POTENTIAL USER CONFLICTS OVER LAND AND WATER RESOURCES

Water resources (upstream or downstream)

- domestic water for urban areas
- domestic water for rural areas
- other uses for settlements (gardening, etc.)
- water for industrial processing or mining
- water for small-scale industry or handicraft in urban or rural areas
- <u>other upstream or downstream irrigation schemes</u>
- water for livestock
- aquaculture or other fish habitat (lakes, reservoirs, rivers)
- for aquatic plant habitat (plants for human consumption)
- other aquatic ecosystems (wetlands)
- non-renewable or fossil groundwater

Land resources

- building land for urban agglomerations
- building land for rural settlements
- building land for industry and commerce
- sites for mining
- aquaculture, floodplain fisheries
- forestry, agro-forestry
- rainfed farming
- shifting cultivation
- pastures
- protected areas (for nature conservation)
- other ecologically sensitive areas

Conflicts are frequently encountered between the following land & water users:

- irrigation versus urban settlements — driving force: **urban areas**
- irrigation versus rainfed farming — driving force: irrigation
- irrigation versus rangeland — driving force: irrigation
- irrigation versus protected areas — driving force: irrigation
- irrigation versus rural settlements — driving force: **settlements**
- irrigation versus domestic supplies — driving force: irrigation

CHECK LIST FOR ECOLOGICALLY SENSITIVE AREAS (ESA)

Does irrigation development influence the following habitats which are considered as ecologically sensitive areas?

1. **Impacts on protected areas and landscapes**
all protected areas which fall under the IUCN categories (IUCN 1994) or national systems of protected areas such as
   - strict nature reserves
   - national parks, natural monuments/landmarks
   - managed nature reserves, biosphere reserves, wildlife sanctuary
   - protected landscapes, biosphere reserves
   - natural resource reserve
   - natural biotic areas/ anthropological reserve.

2. **Impacts on wetlands and other ecologically valuable areas**
   - wetlands of internationally/nationally important functions, attributes or uses
   - other wetlands of regional/local importance (e.g. mangroves, lakes, swamps, marshland, river delta)
   - water quantity or quality regulatory or purifying functions)
   - habitats which provide protection against wind or water erosion
   - habitats which support important natural vegetation on soils of inherently low productivity and low regeneration potential
   - habitats which provide conditions essential for the perpetuation of species of medicinal or genetic conservation value
   - habitats of endangered species of flora and fauna.

3. **Impacts in sensitive water resources**
   - international water bodies (rivers, lakes, groundwater aquifers)
   - important national water reserves
   - potable water reservoirs of regional or local importance
   - fossil groundwater reservoirs
   - ecologically sensitive aquatic habitats (e.g. lakes without natural outlets).

4. **Impacts on land belonging to traditional groups**
Resettlement and land taking from traditional groups or ethnic minorities.

POSSIBLE ENVIRONMENTAL IMPACTS OF AGRICULTURAL & IRRIGATION DEVELOPMENT

Water regime impacts

- river flow, flood pattern, groundwater fall or rise, saltwater intrusion

Stream morphology & water body changes

- stream degradation (bank erosion, river bed changes)
- creation or alteration of impoundments, lakes
- estuary degradation (coastal erosion, delta formation)

Pollution of water, soil or air

- particulate pollution (erosion, siltation, sediment transport, turbidity)
- organic contamination (nutrients, organic compounds, pathogens) of ground- and surface water
- eutrophication (nutrients) of ground- and surface water
- toxic concentrations of substances (heavy metals, salts, agro-chemicals) in ground-and surface water
- toxic concentrations in soils (heavy metals, salts, agro-chemicals)
- gas emissions
- aerosol emissions (pathogens, toxic concentrations of pesticides)

Soil degradation

- soil loss or accumulation (caused by wind & water erosion)
- waterlogging
- salinity, sodicity, acidity
- soil compaction and structural degradation (tilth)
- loss in soil fertility (biotic activity and diversity, nutrients; pest & weed increase)

Ecological imbalances

- impairment or loss of wetlands and riparian forests
- plant community changes; plant diversity loss, loss of endemic species,
- loss of migratory & dispersal corridors
- loss or impairment of endangered plant species
- habitat loss, restriction of wildlife migration

Conflicts over land use & economic development

- competition with other agricultural land uses or other land uses (settlements, mines, infrastructure)
- conflicts with other water users (industrial, domestic, rural)
- conflicts with navigation (through changes in water regime)
- conflicts with fishery
- conflicts with rural industry and handicraft over natural products
- conflicts with forestry/woodland uses
- conflicts with planning or other sector developments

Public health risks

- communicable diseases risk (communal vulnerability and environmental receptivity)
- non-communicable diseases risk (occupational, water & air pollution, phytotoxic contamination; crop contamination, accidents)
- risks associated with general well- being (water supply, nutrition, housing, sanitation)

Impairment of scenery, natural beauty

- loss of landscape diversity and aesthetic quality

Cultural heritage sites

- archaeological buildings and monuments, sanctuaries, sacred forests

Social and economic impacts

- regional disparity
- population change/migration
- community facilities, infrastructure
- group development; participation
- ethnic minority development
- farm employment, income
- agricultural production
- gender equity

Resettlement effects

- migrants, evacuees

PROJECTS WHICH MAY NOT REQUIRE DETAILED EIA

Agricultural and irrigation development projects may integrate environmental issues into the standard procedures for project planning and operation. If required, an EIA or/and Environmental Management Plan (EMP) can be conducted at a later stage.

Selected projects and their characteristics which may not require EIA at early planning stage:

- *Advisory services*, if such services are not directly related to engineering design, supervision of construction or the establishment of operational guidelines.
- *Training programmes*, if not directly related to engineering design and construction works.
- *Small-scale pilot projects*, although, during implementation and operation, a rapid or semi-detailed environmental appraisal should be conducted. An EMP should be developed which includes monitoring activities to gain experience about actual impacts for future larger projects.
- Small or medium-scale *rehabilitation projects*, if the activities include measures aiming at the promotion of environmentally sound land husbandry and sound water management methods. During implementation and operation, a rapid environmental appraisal should be conducted; an EMP should include selected monitoring activities.
- *Extension projects*, where an EIA and an EMP are already available, and if expanding does not interfere with neighbouring ecologically sensitive areas. During implementation and operation, a rapid environmental appraisal should be conducted. An EMP should define selected monitoring activities.

ENVIRONMENTAL QUALITY GOALS IN AGRICULTURE & IRRIGATION

Goals. It is important to establish a site-specific balance between production and conservation in order to meet the social and economic objectives of success and to sustain the resource base. Goals are used to determine - for a specific agricultural production system - the demand for environmental management to achieve sustainable development. They are relevant for planning and technical design, monitoring, evaluation and to prompt action, for example to control pollution, soil degradation or to manage conflicts over scarce water resources. The joint establishment of management goals between farmers, planners, agricultural extension or other technical staff, policy makers and local groups affected are not only important to achieve acceptance, but also to make implementation more successful because planning and decision-making become more transparent.

Management goals of environmentally sound agriculture and irrigation are directed towards the appropriate use of technologies which optimise energy flow and natural resources (e.g. water, nutrients) cycling while enhancing productivity to meet social and economic goals. At the same time, impairments or changes of affected natural systems should be minimised or compensated adequately.

Within the framework of integrated land use (and water resources) planning of a particular region, irrigated agriculture should be developed as a highly productive agroecosystem with a (relatively) high level of resource uses, farm inputs and system control. Therefore, the conservation of ecologically sensitive areas (see Working Aid 7) or other biodiversity goals (protection of endangered natural fauna and flora) need to be addressed within a greater planning area in order to segregate different - but complementary landscape functions: conservation areas and land with extensive and intensive agricultural production. Land evaluation and land use planning can identify areas suitable for intensive agricultural production, i.e. areas with high potentials and low risks, thus avoiding marginal sites. Irrigation development needs to be planned in the context of water master plans to ensure the adequate allocation and management of water resources in a catchment.

Environmental conservation goals. These are specific goals derived from national environmental protection laws and directives (see Working Aid 16). Renewable natural resources need to be used efficiently and the use of non-renewable resources (e.g. fuel, fossil water) need to be controlled to ensure their best use for current and future generations. Soil resources should be protected from degradation or pollution and fertility maintained. Water resources should be protected from pollution and wetlands must be adequately preserved by integrated land use planning and landscape engineering measures. Intensive agriculture and irrigation must, therefore, be oriented towards:

- compliance with laws and directives, for example technical standards or safety regulations for environmental protection; compliance with agricultural (or other relevant sector) policy, and land use and water master plans;
- efficient use of renewable natural resources, water, soil, air, fauna, flora;
- integration of solid or liquid wastes and other by-products into the agricultural production system and an ecologically sound waste management
- minimising the use of non-renewable resources such as fossil fuels and water;
- minimising conflicts over resources such as scarce water, land, and wildlife habitat
- minimising pollution of water, soil and air;
- minimising human health hazards or natural hazards;
- adoption of agricultural practices which protect the environment while aiming at (i) a local, voluntary approach that is based on local knowledge and perceptions of farmers, (ii) minimising risks for farmers and consumers, and (iii) maintaining the functioning of the natural base of the agroecosystem and (iv) preventing irreversible impairments of neighbouring natural ecosystems (modified after Heyland 1990. p.10).

At the same time, the agricultural production systems must be accepted and economically attractive to the local farmers. This requires the development of localised environmental management practices (for example best management practices) through effective partnership of all institutions involved and local farmers. Each must be committed to the process, fully participate in the process, and respect the positions of the other partners.

The following environmental quality goals may be developed for irrigated agriculture:

- **watershed management**: sustaining long-term base of water resources in the whole catchment for the benefit of various users; maintaining important hydrological and ecological functions of the river system. *Indicators*: water regime (surface and groundwater), water quality, river system morphology and local waterbodies;
- **water resources management**: effective and efficient use of water for agricultural production (including irrigation) while avoiding or minimising conflicts over water supply and pollution. *Indicators*: sedimentation, pollution of surface or groundwater by agrochemicals; surface and subsurface water balances;
- **soil management**: maintaining or enhancing soil fertility with respect to the specific use. *Indicators*: soil phases (e.g. salinity, sodicity, acidity), potential and actual biochemical fertility, physical conditions (water and aeration status);
- **plant production system**: economically feasible systems which are well suited to local conditions. *Indicators*: soil suitability, water availability, social needs and perceptions, market demand, knowledge of agricultural practices, agro-economic conditions;
- **fertilisation and plant protection**: minimising long-term impairments and accumulative effects on water, air, soil, fauna and flora and minimising health risks. Restricted use of agro-chemicals that balances the amounts of inputs against the degradation of pesticides or the plant uptake of fertilisers. *Indicators*: soil and water contamination and impairments (e.g. eutrophication), pesticide residues in agricultural products, occupational health hazards and health risks for consumers;
- **nature conservation** which may comprise: (i) integrated land use plans that aim at mitigating or compensating for losses of ecologically sensitive areas due to intensive agricultural development within a regional context; (ii) protection of nationally or regionally important habitats within a large-scale development scheme, (iii) landscape engineering measures within a large-scale development scheme, for example establishment or maintenance of natural habitat networks, woodlots, pools, hedgerows, border strips and (iv) additional development programmes to protect the hinterland: erosion control, watershed management, afforestation, agro-forestry. *Indicators*: compliance with integrated land use plans or sector plans or programmes of nature conservation or forestry agencies;
- **public health**: minimising water-related diseases (water-borne, water-related vector-borne, water-based; see Birley 1989; Oomen et al. 1990). *Indicators*: implementation of integrated public health programmes; incidence and prevalence of relevant diseases.

These broadly defined environmental quality goals may be addressed in **localised management goals** which can be achieved at local level, for example:

> protect water, save water, soil protection, control land pollution (waste disposals, dumping) comply with land use plans at national and district level (or relevant sector development plans), control air pollution, reduce energy and fossil fuel consumption, conserve nature and biodiversity, control public health risks, and preserve cultural heritage.

These management goals need to be described by environmental indicators and standards in order to (i.) determine the actual status of degradation and pollution, (ii) define threshold levels of acceptable changes or damages and (iii) elaborate management objectives to reduce, minimise or compensate for unacceptable changes or damages.

ENVIRONMENTAL QUALITY GOALS: EXAMPLES

Example 1: Environmental quality goals to protect water resources

Guidance principles are:

⇒ Minimise soil contamination and water pollution by site-specific and demand oriented fertilisation and safe pesticide application & storage or integrated pest management practices.

⇒ Use scarce water resources optimally, taking account of water availability (to minimise user conflicts in the watershed) and the water master plan.

Site-specific goals are:

1. Control of surface water quality (rivers, lakes, etc.) by:

- minimising seasonal pollution (e.g. by toxic compounds, heavy metals, salts, nutrients);
- minimising pollution during the low-flow season;
- leaching only during or before the high-flow season;
- minimising sediment transport (canal or field erosion) during low-flow season;
- minimising pollution by pathogenic organisms/excreta, especially in low-flow season.

2. Control of surface water volumes by:

- optimising seasonal and total water requirements;
- minimising peak requirements or peak requirements during low-flow season, while increasing water requirements during high-flow or flood season;
- using reservoirs or interception tanks during low-flow season;
- seasonal changes in ground- and surface water use.

The following agricultural policy instruments and technical measures are available:

Institutional interventions:

water master plans; watershed management plans, formation of water user groups; local or regional steering committees or boards to allocate water resources; waste water management plans;

Legal interventions:

water tariffs, water rights, wastewater discharge regulations, regulations of use for slurry; regulations of safe handling, storage and application of agro-chemicals;

Technical interventions:

agronomic: crop and variety selection, cropping pattern;

irrigation system: selection of irrigation system; efficient water scheduling and effective use of rainfall; efficiency of all system components: water abstraction and storage, canals, efficient water application at field level;

drainage system: effective layout of subsurface and surface drains; seasonal rising of groundwater table.

Example 2: Project-specific goals and environmental monitoring

Related to water protection, soil conservation and integrated land use

1. Water protection goals (examples)

- Avoiding a significant reduction of river discharge during low flow season
  Indicator: discharge measurements
  Possible standard: threshold limits in % of minimum discharge or gauge levels, e.g. 30%
  Monitoring: twice weekly total discharge or daily gauge level recording
  Mitigation: reduction of total water abstraction; reduction of water requirements through change of crop rotation, crop selection

- Avoiding critical rise in groundwater table (possible hazards: wetness, salinization)
  Indicator: depth of groundwater, groundwater salinity, groundwater fluctuation
  Possible standards: soil wetness classes, groundwater table classes, capillarity classes
  Monitoring: monthly or weekly recording in piezometers or wells
  Mitigation: irrigation scheduling, water requirement: crop selection and crop rotation, drainage system

- Minimising surface water pollution (e.g. by uncontrolled leaching practices)
  Indicator: total salinity (mS/cm) in surface water
  Possible standards: threshold levels of water salinity, for example 2 mS/cm, depending on the use of water for domestic supply, livestock or irrigation (type of irrigation)
  Monitoring: weekly or monthly records of total salinity at selected sites (drains, river)
  Mitigation: various measures are possible, depending on the site specific causes of salinization: change of crop type and cropping pattern; change of field water management; blending of irrigation water

- Minimising soil contamination and water pollution by agro-chemicals (e.g. pesticides)
  Indicators: (i) ecological toxicity of the specific pesticide in use; (ii) mobility, e.g. distribution coefficient, adsorption constant, leach-characteristics; (iii) fixation and degradation: half-time values, degradation; (iv) sensitivity of sites: factors are e.g. low groundwater table, soils with low fixation capacity, permeable soils;
  Possible standards: use of pesticides with (i) low activity period, e.g. >60 days; (ii) low mobility; (iii) high degradation, e.g. classes 3 to 5 (75% degradation within 1 year); (iv) low application quantities (standard of 1kg/ha active substance); (v) only one application of the same substance per year. The groundwater screening index (see Bishop/Lawyer) may be used as water pollution standard.
  Monitoring: (i) compilation of data from manufacturers, agricultural services or environmental agencies; (ii) records on pests; (iii) control of restrictions of handling, storage, application and disposal of containers; (iv) once/twice annual measurements of pesticide residues in drains, wells or rivers and in soils; (v) registration of pesticides in use, records on storage facilities, application characteristics, pesticide distribution, site characteristics, records on disposal; (vi) records on indicator plants (natural flora), records on pest population and establishment of pest predators. Preferable are pest surveillance systems established by the local agricultural extension services.
  Mitigation and control measures: special restrictions in the use of pesticides in areas with sensitive water resources, e.g. in the vicinity of drinking water reservoirs, well fields, important breeding habitats for wildlife; systematic assessment of pesticide pollution problems and controls (e.g. risk assessment tools, flow charts, prognostic tools); optimising pesticide formulation and use of pesticides specific to particular pests; recommendations by national plant protection services regarding safe and correct handling, storage, application (pesticide selection, timing, rate and method) and disposal; treatment of infected spots only; application of integrated pest management (IPM); mechanical and biological pest controls; cultivation methods such as changes in cropping pattern, crop rotations, mixed or strip cropping; training of farmers and staff of agricultural services; strict control of health safeguards and application of guidelines provided by manufacturers.

2. Soil protection goals (examples)

- Minimising water erosion in canals and fields (irrigated agriculture)

  Indicator: sheet or rill erosion on fields; erosion in canals and irrigation furrows;

  Possible standard: visible erosion damage; downslope sedimentation and in canals;

  Monitoring: weekly control of fields and irrigation canals

  Mitigation: agronomic measures, soil management and mechanical methods to control on-farm erosion, such as conservation tillage, mulching, crop management, terracing, waterways and structures, e.g. sediment retention basins, vegetative filters; irrigation management, e.g. avoiding run-off and high raindrop impacts under sprinkler, minimising overland flow velocity during surface irrigation applications; surge flow systems; field lay-out.

- Minimising soil salinization (irrigated agriculture)

  Indicator: total salinity (electric conductivity) within 1 m soil depth (or average root depth)

  Possible standard: crop specific EC threshold limits with >10 or 50% yield reduction; e.g. 3.5 mS/cm in the saturation extract which yields to 50% reduction in most rice varieties

  Monitoring: bi-annual control in the saturation extract; monthly controls in 1:5 soil-water extracts (calibration with saturation extract is required) or in irrigation and drainage water

  Mitigation and management options: amelioration by additional irrigation (leaching), subsoiling and application soil amendments; improvement of field drainage and drainage outlet; selection of appropriate irrigation method and optimisation of field water management; optimisation of irrigation water quality (blending of saline water; alternating use of fresh and brackish water); optimisation of cropping pattern and crop rotation; selection of salt tolerant crop varieties; appropriate soil management and agronomic practices such as tillage to improve soil structure, planting techniques and positioning of crops, or manures that improve physical conditions; measures to reduce canal seepage or lateral seepage from elsewhere.

- Minimising soil degradation by compaction (mechanised farming)

  Indicator: plough horizons, topsoil wetness

  Possible standard: favourable tilth; soil density

  Monitoring: bi-annual control of soil profiles (compacted horizons); field measurement of penetration resistance; determination of soil density (probably also pore size distribution) in core samples; percolation and infiltration measurements; humus formation, pH-values

  Mitigation: recommendations on mechanical and biological measures to improve tilth; no-tillage practices or minimising tillage operations; mulch farming; amelioration such as subsoiling; crop rotation; measures to improve humus status.

- Maintaining soil fertility status (in intensive crop production)

  Indicator: reduction in humus contents; increased fertilizer demand to compensate nutrient extraction by crops

  Possible standard: nutrient balance of a specific field; humus contents; pH, plant available nutrients N, P, K in topsoils, preferable also micro-nutrients

  Monitoring: 1 to 3 times annually determination of: pH, C and N contents; humus (%), C/N-ratio, plant available P and K, total P and K, micronutrients: Fe, Mn, Zn, Cu, Mo and B

  Mitigation: Improved nutrient management combines applications of mineral and organic fertilisers with other measures aimed at rising soil fertility, e.g. by limiting losses (leaching, runoff, nitrification, denitrification, method and timing of applications), improving tillage practices, manuring and green manure crop, crop rotation, and efficient application practices, especially for N-fertilisation. Test and apply minimum amount of mineral fertilizer at rates that replenish seasonal up-takings by plants; fertilizer rates should only be increased after all other agronomic techniques had been utilised.

3. Nature protection goals (examples)

- Maintaining biodiversity in heterogeneous landscapes

  Indicator: total area of non-arable land such as hedgerows, woodlots, border and buffer strips; networks of habitats to allow migration of fauna and flora

  Possible standard: at least 10% of an area should be left permanently in a semi-natural status and used as terrestrial or wetland habitats for wildlife and birds (potential predators of agricultural pests)

  Monitoring: annual inventory of land use pattern; inventories of indicator fauna/flora

  Mitigation: integrated land use plans that promote semi-natural habitats (terrestrial and wetlands)

Example 3: Project-specific goals: Molapo Development Project (Botswana)

Background. The Molapo Development Project (MDP) started in 1983 to improve traditional floodplain agriculture in Boro-Shorobe floodplains (near Maun, northern Botswana). Villagers have been practising a flood recession farming system for some 200 years, using residual moisture in soils that have been inundated in the dry season, and from which the waters then recede in time for crop production in the rainy monsoon season. Though dependent on subsequent rainfall, the best crops are grown in pre-flooded soils. The natural risks are very high, through unreliable and unfavourable timing of floods (too early, too late, too long) and erratic rainfall (rainfall variability is 34%). In 35% of years floods are very low (30-year observation period), in 20% of years floods are very high and prolonged.

MDP was aimed at improving flood control structures (bunds, sluices, culverts and turn-out gates) to reduce natural risks as well as improving and diversifying crop production. MDP activities were focused on the Shorobe nuclear zone with some 1200 ha suitable floodplain and some 700 ha arable land. The area lies at the southern fringes of the Okavango Delta which is internationally regarded as a magnificent wildlife and unique wetland area in Southern Africa.

The following recommendations on environmental management for sustainable agriculture are abstracted from a semi-detailed EIA study prepared for the project (Petermann 1992. GTZ-MDP Botswana). All recommendations were developed jointly with the Molapo Farmers Committee in order to reflect the visions and perceptions of local people.

Environmental management should include mitigation measures and safeguards:

<u>Flood control</u>. Technical design criteria are developed to minimise interference in river flow regime and to limit the area affected by reduced groundwater recharge and associated impacts on rural water supply, riparian woodland and wildlife. Gated structures can provide for discharge equivalent to natural flow under average floods, in the case of "no operation". Bunds and gates are as close as possible to the protected croplands, so that natural floodplains - which are used as extensive rangeland and for wildlife - remain largely unaffected. Operation of gates should allow high discharge immediately after harvesting (usually mid-May) and closing gates latest one months before early planting in November. Very high floods should not always be controlled to permit periodic local groundwater recharge, unless standing crops are endangered. Operation and maintenance should be under control of the Molapo farmers committees with technical advise and control (bund safety, structures) of the Regional Agricultural Office.

<u>Crop production</u>. Soil erosion, deteriorating tilth, depletion of nutrients, and enhancement of biological activities and organic matter need to be addressed in concepts for sustainable agriculture. "Best-management-practices" for cropping pattern, tillage, farm mechanisation and fertilisation need to be developed by the Maun agricultural research station and to be verified by on-farm trials. The introduction of integrated pest management practices, improved post-harvest management and the controlled use of crop residues by cattle are strongly recommended. Future use of pesticides and herbicides would require the establishment of additional safeguards and farmer's training under the guidance of the Plant Protection Unit, Gaborone.

<u>Nature Conservation</u>. At least 25% of the total flood controlled area should be left under natural conditions. A Molapo land use plan should propose zones for rainfed farming, irrigation, extensive rangeland, wildlife corridors, seasonal waterbodies and buffer strips under natural vegetation. Riparian forests which have a high biodiversity and are valuable habitats for wildlife should not be cleared for agricultural development. Border and buffer strips surrounding arable land should be established in close cooperation with the farmers Molapo committees. Wildlife corridors for migratory species should be considered in future development and the layout of group fences; also access to seasonal ponds and river sections should be secured. Eco-toxicological risks from agro-chemicals must be minimised by observing the FAO Code-of-Conduct and propagating integrated pest management practices. Only low toxic and rapidly degradable chemicals should be allowed and under close supervision of occupational health safeguards during storage and application. The application of agrochemicals should be strictly controlled if fields are close to seasonal pools or main rivers and if there is evidence of erosion.

Environmental monitoring focus on those environmental elements which are affected by the flood control and agricultural development activities:

- Changes in river regime: discharges at main sluice gates or gated culverts. Hydrological data collection from the Hydrological Service (Boro River flow and gauge levels at selected stations along the Upper Thamalakane). Discharge rates at main MDP sluices.

- Flood pattern & inundation depth: water level records at MDP sluices and selected floodplains;
- Changes in groundwater table and groundwater quality in piezometers and selected traditional wells (depth, salinity, pH, if salinity exceeds 3mS/m, the ionic composition should be analysed);
- Soil salinity observations at 20 representative sites (topsoils only) annually, or more frequently if there is a significant increase in the range of >2mS/m. Soil profile observations on same sites to check on the possible development of compacted horizons (plough layer); all soil sampling and analysis in collaboration with the soil survey staff of the Regional Agricultural Office;
- Land use monitoring: arable land, fallow land, type of cropping annually by ground checks.

Extra monitoring for future **smallscale irrigation** (groundwater abstraction):

- Listing of all agro-chemicals (fertilisers, pesticides, herbicides) in use. Recording of field applications, application methods and storage of agro-chemicals;
- Groundwater monitoring in wells (monthly water table depth and salinity records);
- Water abstraction (from pumping data) daily figures and monthly summaries;
- Field water application, weekly figures and monthly summaries;
- Surface water sampling in affected pools (micro-catchments): bi-annually analysing N and P;
- Water salinity tests every second month; soil salinity tests twice annually;
- Soil sampling for plant available nutrients: N, org C, P, before and after the cropping season;
- If fertilisers are applied, groundwater sampling at locations within 500 m distance from the irrigated fields or the nearest available well or piezometer (N-analysis).

Recommended **indicators** of significant environmental impacts are:

- River regime: discharge into Shorobe molapo as percentage of total Boro outflow;
- Groundwater regime: water table fluctuations under natural and controlled conditions;
- Groundwater quality: salinity, nitrate, pH;
- Soil salinity and pH. Bio-chemical fertility: org C and P contents of soil samples;
- Soil tilth, erosion and compaction (simple field checks);
- Soil contamination: recording use of pesticides and herbicides;
- Ecosystems. mapping of border and buffer strips within arable land and riparian woodland; land use intensity: fallow areas in % of total arable land;
- Forage: accessibility of molapo fields for dry season grazing (post-harvest);
- Communicable diseases: incidents of malaria and schistosomiasis;
- Planning: integration of flood control and agricultural services into district development plans (institutions: Regional Agricultural Office, District Land Use Planning Unit, Land Board);
- Group development: formation and functioning of molapo farmer committees with sufficient representation of female farmers.

Recommended **regulatory standards** for future smallscale irrigation:

- Annual groundwater abstraction should be equivalent to the long-term replenishment by controlled floods or natural infiltration. Precise recharge rates must be determined if more than 15 ha are being developed under irrigation;
- Only sites with moderate or high suitability for irrigation should be developed, e.g. very sandy (>90% sand) or very clayey (>70% clay particles) soils should be avoided;
- Soil fertility should be maintained. Threshold levels are to be determined prior to land development for individual fields. Indicators: org C, N and P, total salinity, pH, CEC, PBS and ESP;
- Surface drainage of effluents should not lead to eutrophication of temporary pools. Water quality indicators in pools are: pH and NH_4-N, total P. Possible standards for aquatic fauna are 0.5 mg/l NH_4-N, total P<0.2 mg/l (90-percentile), pH range 6.2 to 7.8. Possible threshold levels for human consumption are 25 mg/l NO_3 and 0.2 NH_4 mg/l (95-percentile).
- Groundwater nutrient enrichment should be measures in piezometers. Indicators: nitrate threshold levels are 50 mg/l NO_3^- and 1.5 NH_4^+ . Note: local pollution with N and colibacteria can be found in some wells at present without use of agro-chemicals (sources: cattle, human);
- Fertilisers should be used on a demand basis; selection of a realistic target yield. Regular soil and plant analysis are required on N, P, K and micronutrients.

Example 4: Environmental monitoring (case study Botswana Molapo)

Potential monitoring activities in flood recession farming and small scale irrigation

- **Water resources monitoring**

Hydrological monitoring. Standard investigations are:

annual and seasonal discharges in rivers, main canals and conveyance system; field water distribution; run-off conditions; flow characteristics: depth, velocity, turbulence

water areas (area, depth, volume, exposure): lakes, ponds, wet areas, river, creeks (further details in UNESCO 1997. p.116 cont.)

water balance: inflow, outflow, precipitation, evaporation, seepage

groundwater: watertable depth and seasonal fluctuation, volume of aquifer, movement (vertical, lateral)

river bed configuration: morphometric characteristics of cross sections; suspended and bed sediments; longitudinal slope of river; bank erosion, relationship between river bed and floodplain

estuary conditions: salt water intrusion, littoral drift, sediment deposition and erosion

Overall water quality index. Standard investigations are:

BOD, NH_4-N, NO_3-N, dissolved oxygen, chlorides, temp, pH, suspended solids (SS), total coliforms

Water quality monitoring for irrigation use and livestock. Standard investigations are:

EC, pH. Additional tests: B, Cl, SO_4, HCO_3, Na (SAR-value), Ca+Mg, Fe, NH_4-N, NO_3-N, PO_4, suspended solids (SS). Special tests: heavy metals, trace elements, hardness, O.M.

Potable water quality monitoring. Standard investigations are:

EC, pH. Special investigations: NH_4-N, NO_3-N, Cl, Chlorophyll *a*

Sewage effluent and excreta monitoring. Standard investigations are:

physico-chemical tests: Temp, EC, pH, SAR, N, P, K, SS, BOD, bacteriological tests: faecal coliform, helminthic eggs, intestinal worms. Additional tests in industrial wastewater: heavy metals, TDS, BOD, COD, B. Special tests on trace elements: Fe, Al, Mn, Cd, Co, Zn, Pb, Cu, Cr, Hg, Ni, As, Mo

Drainwater/Seepage quality monitoring. Standard investigations are:

EC, pH. total and seasonal discharge. Additional tests: total P, NH_4-N, NO_3-N, PO_4, CSB, BSB5. Special tests: pesticide residues (mostly gaschromatographic analysis)

- **Soil Protection**

Soil erosion monitoring. Standard investigations are:

All rapid field methods are applicable: levelling, determination of solid solids in run-off or drainwater, sand traps at hydraulic structures

Soil fertility. Standard investigations are:

pH, EC. Additional tests: ESP, O.M., available N and P, K, total N. Special tests: B, Ca, Mg, BSP, Al:CEC ratio, gypsum, heavy metals for wastewater re-use, pesticide residues. Plant tissue analysis if irrigation with sewage effluents or excreta. Bioindicators such as earthworms, macropores

Soil physical monitoring. Standard investigations are:

infiltration rate, saturated hydraulic conductivity, bulk density, water content. Special investigations: texture, unsaturated hydraulic conductivity, field capacity, available water capacity, penetration resistance, strength

- **Public Health Monitoring**

Water-related diseases. Standard investigations are:

vector population, disease prevalence and incidence, disease controls in the domestic environment: vector-borne, water-washed, water-related and vector-bome, water-based diseases, e.g. malaria, schostosomiasis, lymphatic filariasis, onchocerciasis, Japanese encephalitis, African tyranosomiasis

(Overview in: Petermann (GTZ) 1993. Details in Birley 1989, Oomen et al. 1990)

Sewage water quality related to pathogenic micro-organism

Bacteriological/nematodic indicators: intestinal helminthic eggs, faecal coliform. Special tests: total coliform, viruses, etc., epidemiological surveys of exposed groups (Overview: Petermann (GTZ) 1993. Details in Mara and Cairngross (WHO) 1989, Feigin et al. 1991)

- **Nature conservation**

Ecological standards are rare, mostly site-specific and there is still much work needed for the understanding of complex ecological systems. Hence, the selection of appropriate indicators is difficult. Standards can be developed for changes in abiotic and biotic components. Acceptable changes should not exceed the natural background of a given value which is derived from ecological systems analysis.

Hydrological changes: water volumes in rivers, lakes, wetlands; water balance: evaporation, groundwater recharge, etc.. water quality changes (see standards above)

Biomonitoring: indicators should be selected for each site and ecosystem individually.

Biotic changes (further details in: e.g. UNESCO 1987):

pattern of natural or man-made land and water bodies

structure of animal and plant communities: e.g. species number and diversity

food web structure: long or short food chains

metabolism of the system: ratio of oxygen production versus oxygen consumption as an expression of the character of the system

vulnerability of the system

rarity of the ecosystem and/or individual species in the regional context

capacity of regeneration of the ecosystem and/or individual species

toxic effects of components of the system: excrement, chemical substances

saprophity with respect to the demand of the system

trophic status: organic or inorganic nutrients which regulate the structure and primary production

The sensitivity and importance of an ecosystem can also be monitored by the classifying:

habitat importance for endangered or threatened plant or animal species

rarity of the ecosystem and/or individual species in the regional context

capacity to regenerate and to be replaced in the spatial and time context

PRINCIPLES FOR BEST MANAGEMENT PRACTICES

Adapted from: Waskom and Walker. in: ASAE (1994). p 27

Best Management Practices can be defined as recommended methods, structures, and/or practices designed to prevent or reduce water pollution while maintaining economic returns. Implicit within the BMP concept is a voluntary, site specific approach to water quality problems. Many of these methods are already standard practices for many farmers, and are known to be both environmentally and economically sustainable.

A set of general Guidance Principles is outlined to focus the local BMP groups on primary water quality problems. Specific BMPs and production alternatives fall under these guidance principles. The BMPs chosen for use at the local level ultimately must be selected by the actual chemical applicator because of the site-specific nature of groundwater protection. Site characteristics such as depth to water-table, soil type, water holding capacity, and irrigation method determine the feasibility and risk of specific practices. For this reason, a basic premise is that agricultural chemical users must know the site specific variables at the application site, and have a good understanding of agricultural chemical properties and the influence of management practices in order to protect groundwater resources. The way Colorado's groundwater protection act is structured allows operators significant control of actual BMPs, as long as they meet the water quality goals outlined in the guidance principles.

The following guidance principles were developed to serve as general, goal-oriented guidelines to protect water resources. Under each guidance principle, site specific BMPs must be selected which are tailored to specific crops and local management constraints. BMPs listed after each of the following guidance principles are examples selected from among the BMPs developed by the local working groups.

Guidance Principle 1. **Protect wellheads from potential sources of contamination.**

- Periodically inspect and maintain well construction as needed.
- Install backflow prevention devices.
- Stay at least 100 feet from the well when mixing, loading, and storing of agricultural chemicals.
- Monitor well water quality periodically and know site-specific variables affecting aquifer vulnerability.

Guidance Principle 2. **Manage irrigation to minimize transport of chemicals, nutrients, or sediments from the soil surface or immediate crop root zone.**

- Schedule irrigation according to crop needs and soil water depletion.
- Upgrade irrigation equipment to improve application efficiency.
- Time the leaching of soluble salts to coincide with periods of low residual soil nitrate.
- Reduce water application rates to ensure no runoff or deep percolation occurs during chemigation application.
  (agrochemical & water)

Guidance Principle 3. **Manage nitrogen applications to maximize crop growth and economic return while protecting water quality.**

- Sample soil to a minimum depth of 2 feet., preferably to the effective rooting depth, to determine residual NO_3-N.
- Establish yield goals for each field,based upon a documented previous 5-year average plus no more than 5 percent.
- Credit all sources of available N toward crop N requirements, i.e., organic matter and previous crop residues, irrigation water nitrate, soil nitrate, and manure.
- Use slow release N fertilizers and nitrification inhibitors as appropriate.
- Split N fertilizer into as many applications as economically and agronomically feasible.
- Avoid fall application of N fertilizers, especially on sandy soils and over vulnerable aquifers.
- A yearly N management plan should be developed for each field and crop.

Guidance Principle 4. **Animal wastes should be properly collected, stored, and applied to land at agronomic rates for crop production to ensure no discharge to surface or ground water.**

- Analyze manures for nutrient content and percent dry matter
- Reduce N fertilizer recommendations according to the amount of available N in the manure
- Document that the land base for manure application is sufficient for the size of the animal feeding operation
- Avoid manure applications on frozen or saturated soils, and always incorporate after application.

Guidance Principle 5. **Manage phosphorus requirements for crop production to maximize crop growth and minimize degradation of water resources.**

- Implement standard SCS soil erosion practices and structures.
- Sample the tillage layer of soil to determine available soil levels and apply fertilizers according to soil test recommendations.
- Credit all available P from manures and other sources.
- Employ grass filter strips around erosive crop fields to catch and filter P in surface runoff.
- Incorporate surface applied P into the soil.

Guidance Principle 6. **Utilize an Integrated Pest Management (IPM) approach in pest control decisions.**

- Monitor pest and predator populations.
- Select crops and varieties which are resistant to pest pressures.
- Time planting and harvest dates to minimize pest damage.
- Rotate crop sequence to break up pest cycles.
- Spot treat or band pesticides instead of applying broadcast treatments.
- Employ beneficial insects and other biological controls.

Guidance Principle 7. **Employ pesticides judiciously and use in a manner which will minimize off-target effects.**

- All chemical applicators should receive thorough training and EPA certification prior to any use.
- Select pesticides based on site and management variables to minimize potential groundwater contamination.
- Chemical applicators should know the characteristics of the application site, including soil type, depth to groundwater, and erosion potential.
- Chemical leaching hazard, persistence, and toxicity should be compared to site specific conditions to determine suitability of the pesticide at that location.
- Application equipment should be inspected, calibrated, and maintained on a regular basis.
- Minimize pesticide waste and storage by purchasing and mixing only enough chemical to meet application needs. Utilize mini-bulk or refillable containers wherever possible to minimize container disposal problems.

Guidance Principle 8. **Maintain records of all pesticides and fertilizers applied.**

Records should be kept on:

- Irrigation water analysis.
- Soil test results.
- Projected crop yield goals.
- N fertilizer recommendations.
- Fertilizer and/or manure applied.
- Amount of irrigation water applied.
- Actual crop yields.
- All pesticides applied, including: brand name, formulation, EPA registration, amount and date applied, exact location of application, name, address, and certification number of applicator.
- Records should be maintained for at least three years.

GUIDING PRINCIPLES FOR WATER POLLUTION CONTROL

Management tools for preventing water pollution on farms (from: Nevers et al. in: ASEA.1994. p 30)

The Farmstead Assessment Program

To protect his or her drinking water, a farmer needs to consider the following risk factors associated with the farmstead:

- facility design and location
- associated management practices
- proximity to wells
- soil and geology of the site

To help farmers, ranchers, and rural residents prevent pollution, a multi-agency coalition developed a voluntary Farmstead Assessment System, called Farm*A*Syst. With support from the Extension Service, Environmental Protection Agency and the Soil Conservation Service, the program has grown in a little over two years from two pilot programs in Wisconsin and Minnesota to a national network. Through an expanded partnership of farm organizations, private industry, and governmental agencies, the program has grown to more than forty states and one Canadian province.

Farm*A*Syst has been designed to help farmers, ranchers, and rural residents identify site-specific well water and groundwater pollution risks and develop voluntary action plans to reduce identified high risks . It was developed in response to the grassroots concerns of farmers and rural residents about protecting well water quality. A recent Gallup survey shows that "farmers are more concerned about farm environmental issues today than they were five years ago." . With Farm*A*Syst, farmers have concrete and systematic methods to address water quality-related concerns.

More specifically, the Farm*A*Syst program aids farmers and ranchers in:

- understanding and identifying pollution risks associated with their farms and rural residences
- understanding how existing programs and policies can help prevent pollution
- identifying actions that will reduce pollution risks
- obtaining technical, financial and educational assistance to prevent pollution
- taking voluntary actions to reduce pollution risks

Farm*A*Syst translates these general objectives into practical results using a series of worksheets and factsheets. The worksheets provide a systematic framework for evaluating relative pollution risks at a specific site. The factsheets contain information on actions that reduce pollution risks and information on sources of educational, technical, and financial assistance. The potential pollution sources covered in the initial Farm*a*Syst materials include:

Wells	Pesticides	Livestock Waste
Hazardous Wastes	Fertilizers	Livestock Yards
Household Wastewater	Petroleum	Silage
Milking Center Wastewater		

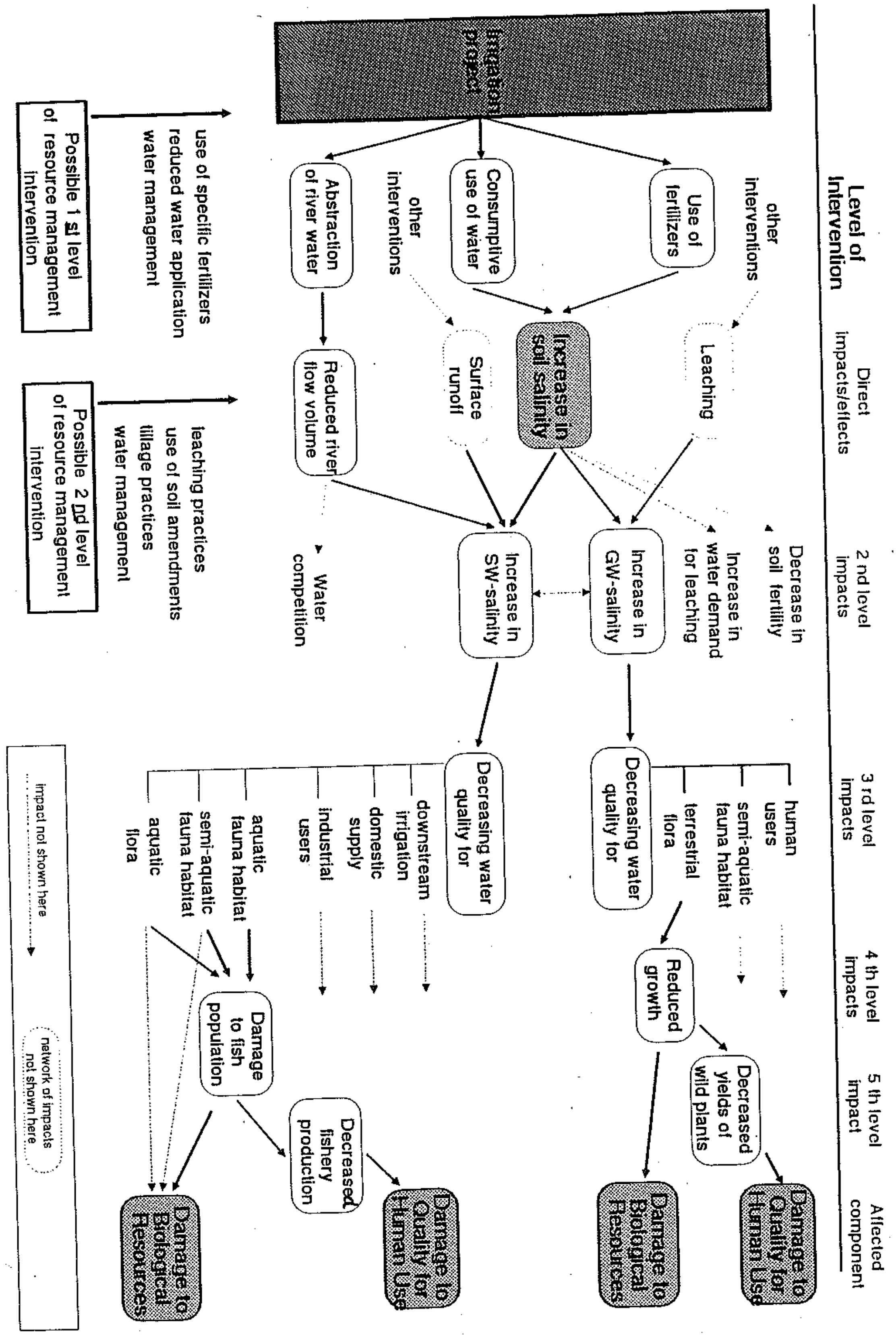
Dividing risks into four categories ranging from high to low, the worksheets allow users to evaluate specific criteria on their property and then rank pollution risks associated with particular design and management factors. The worksheets are free-standing, so users select only those worksheets relevant to their needs. Applying the information from these worksheets, participants use a separate worksheet to evaluate groundwater pollution risks in terms of the soil, and geologic and hydrologic features unique to their property.

An overall evaluation sheet combines the findings from the site evaluation and the assessments to develop a relative risk ranking for that farmstead or rural residence. All high risk practices and structures that are identified are addressed in a voluntary pollution prevention action plan to reduce high risks. Educational materials also provide information on local sources of technical assistance and emphasize the benefits and cost-effectiveness of corrective or preventive measures. The program was initially designed as a self-assessment and can be effectively used in that capacity. However, pilot implementation experiences indicate the program is more effective when conducted with technical and educational assistance.

Working Aid 11-1

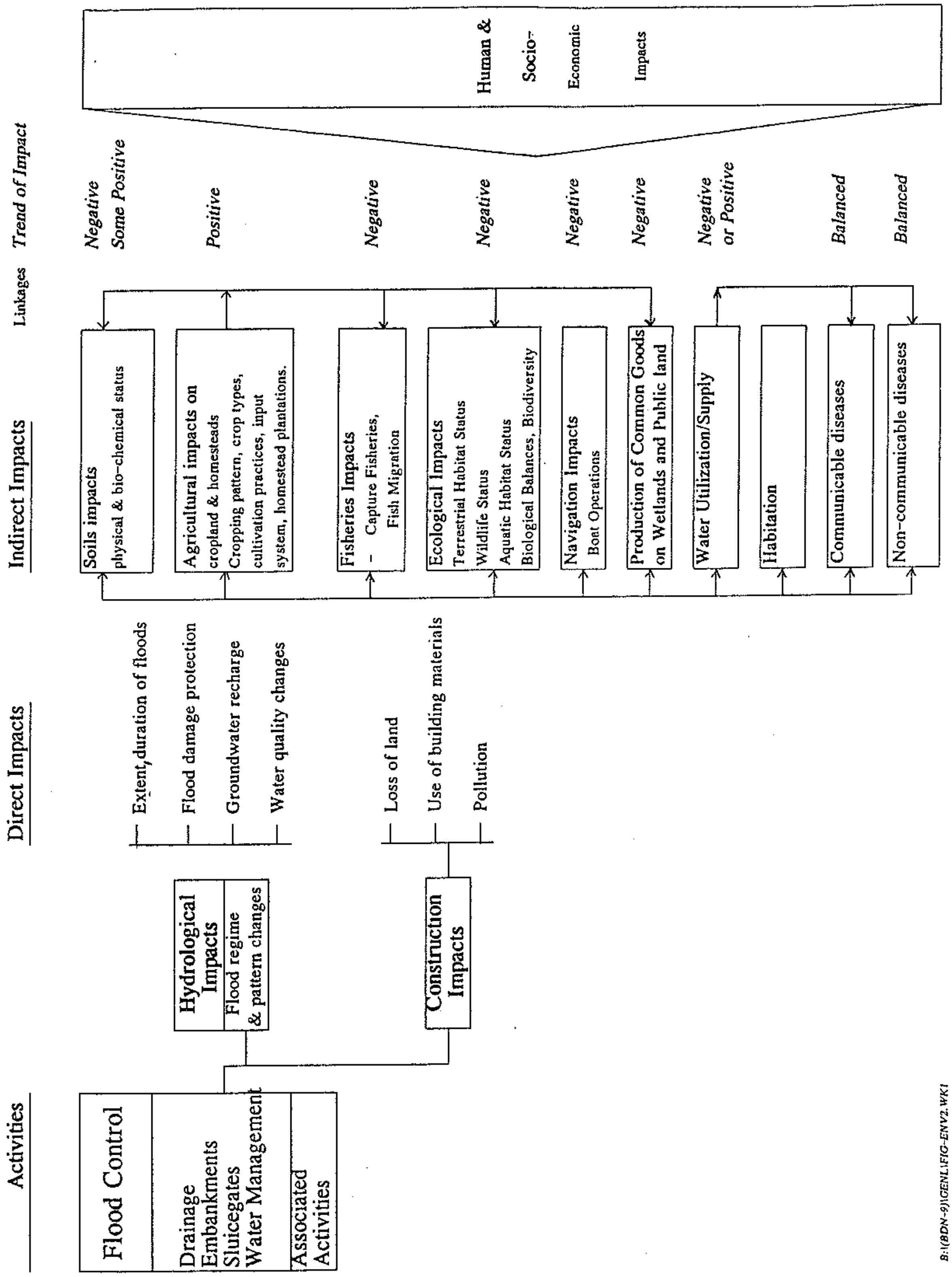
CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

Example 1: Salinisation



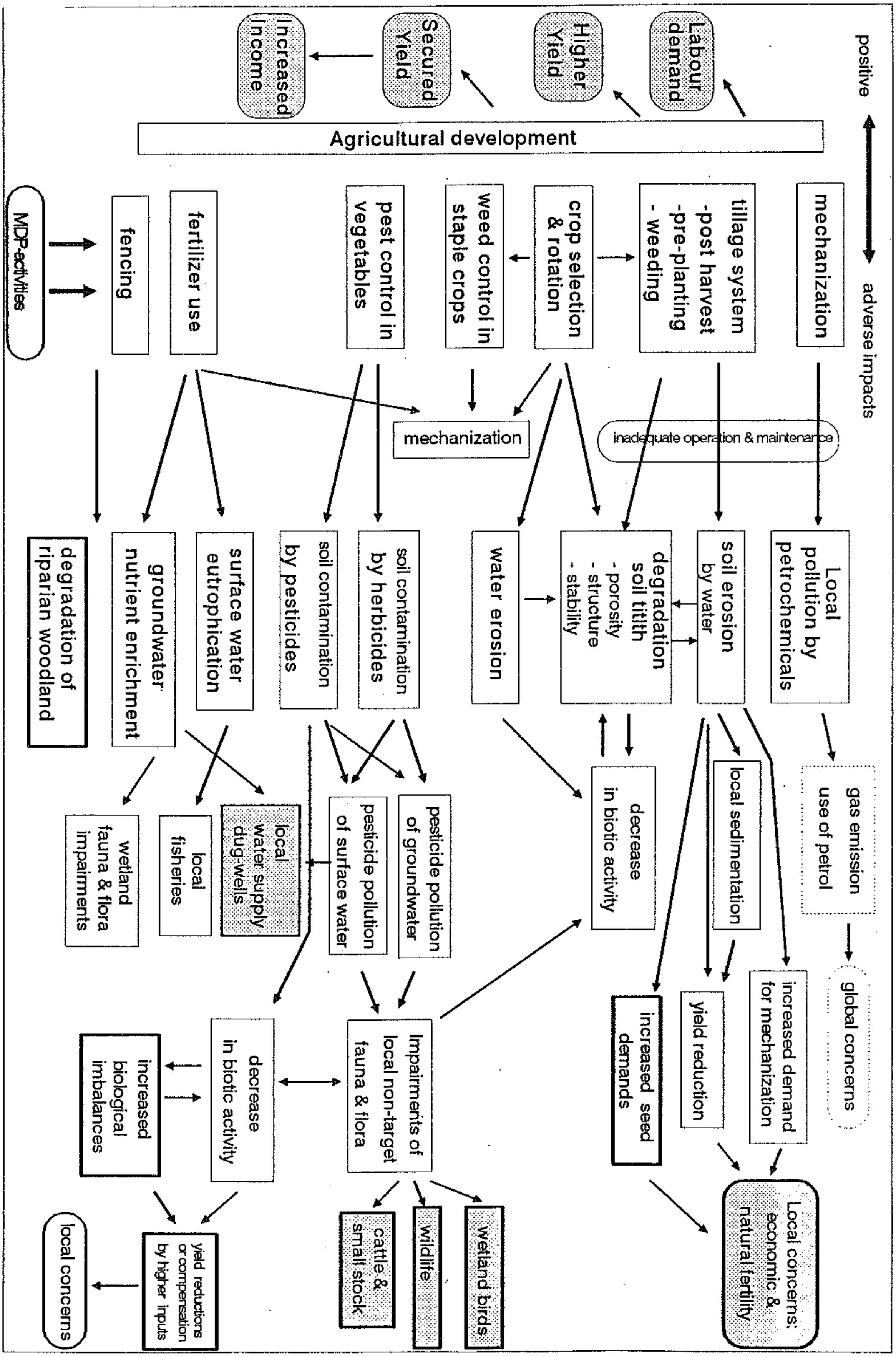
CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

Example 2: Flood Control



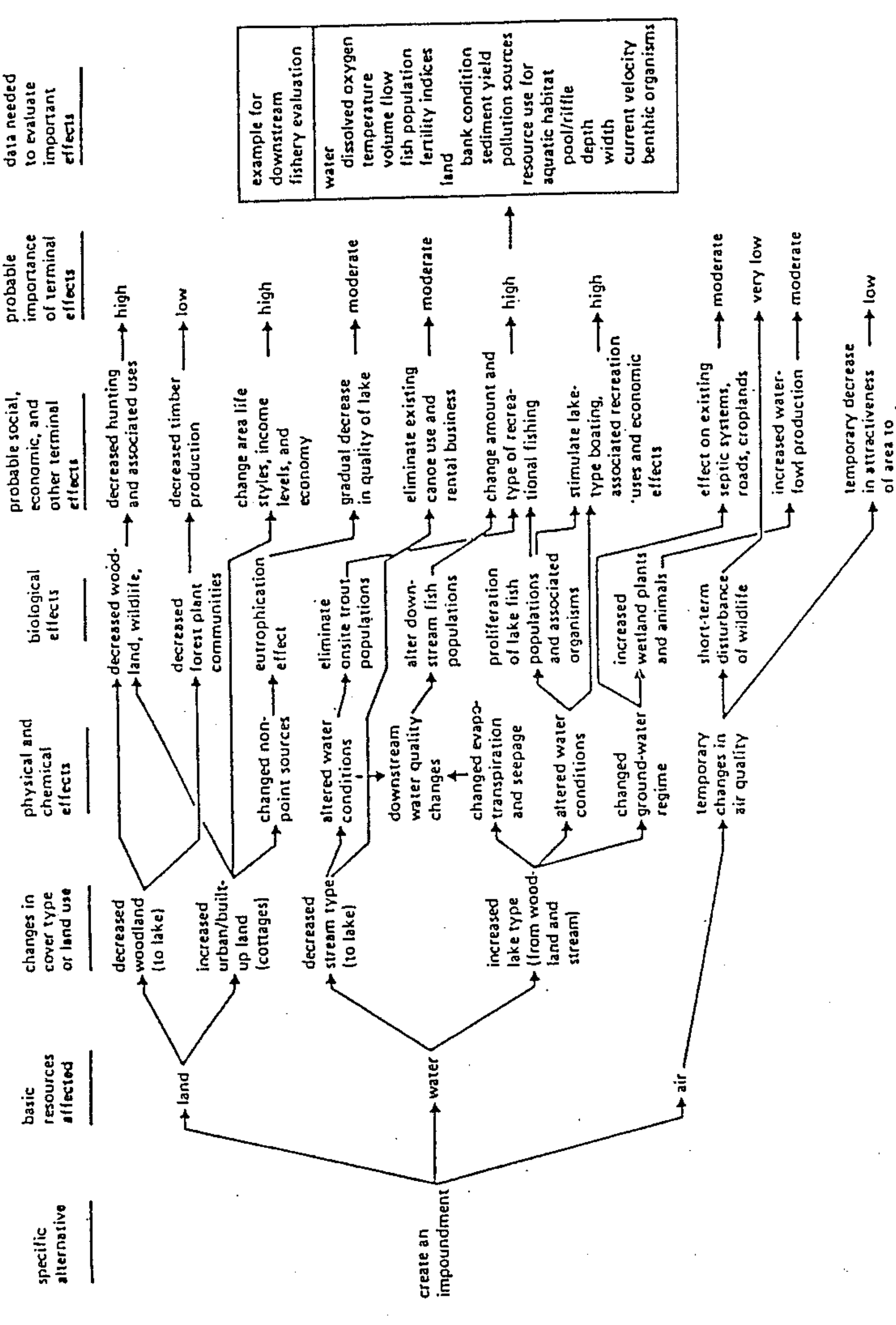
CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

Example 3: Intensification of Agricultural Production



CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

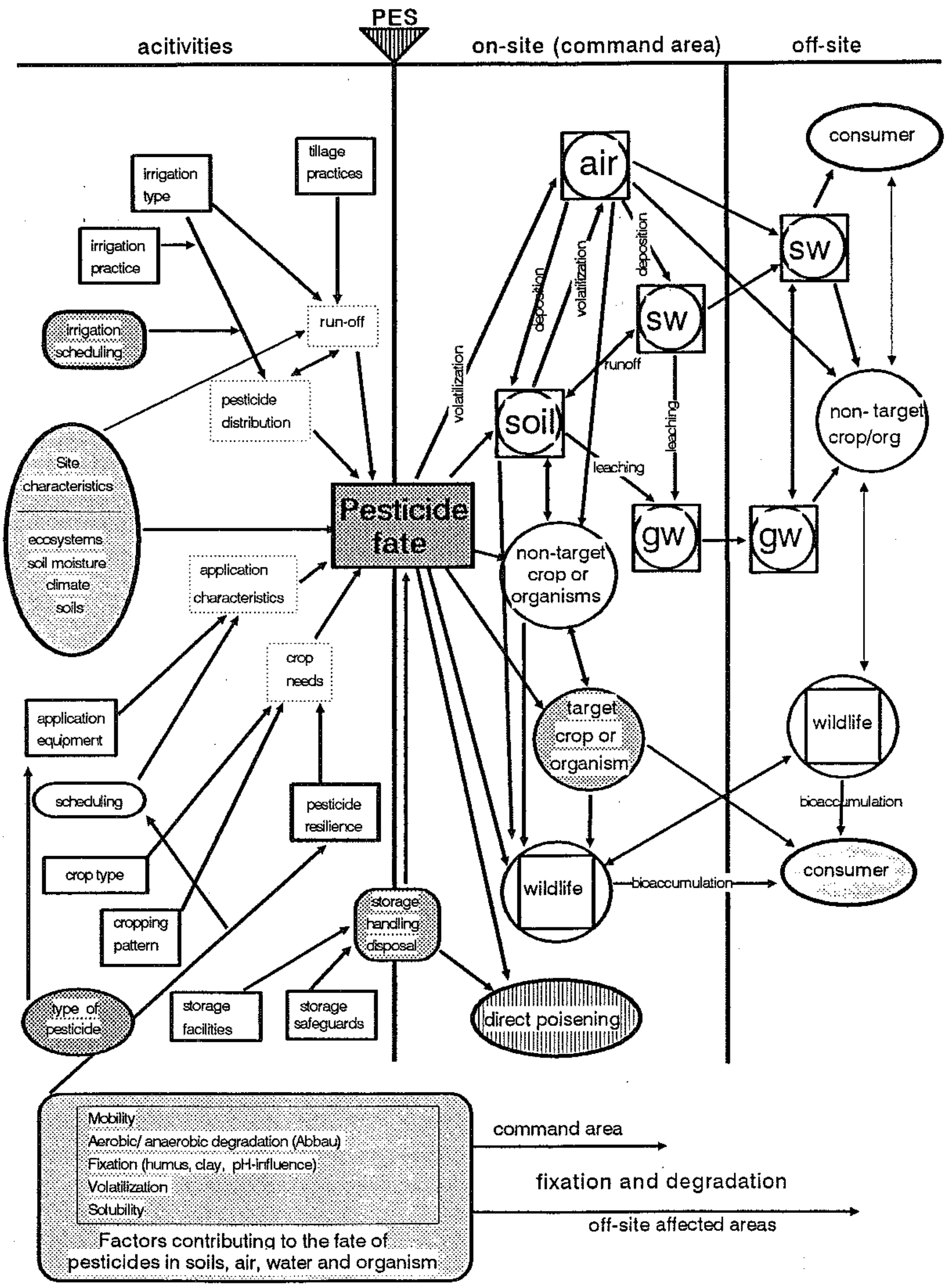
Example 4: Large Reservoirs Source: Canter 1983



Network diagram for analyzing probable environmental impacts.

CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

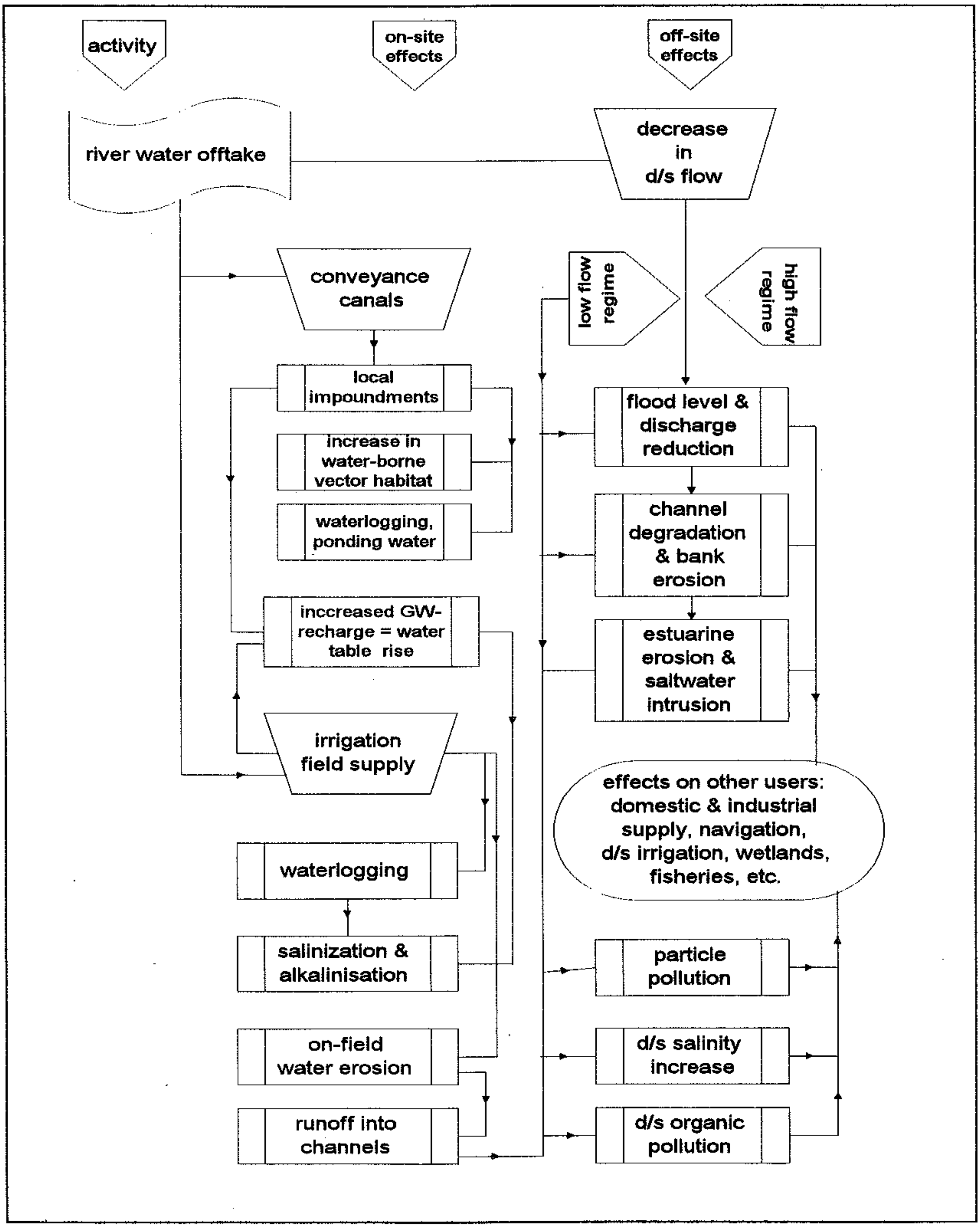
Example 5: Fate of Pesticides



Network showing the characteristics of the (left hand) and the fate of the pesticide (right hand)

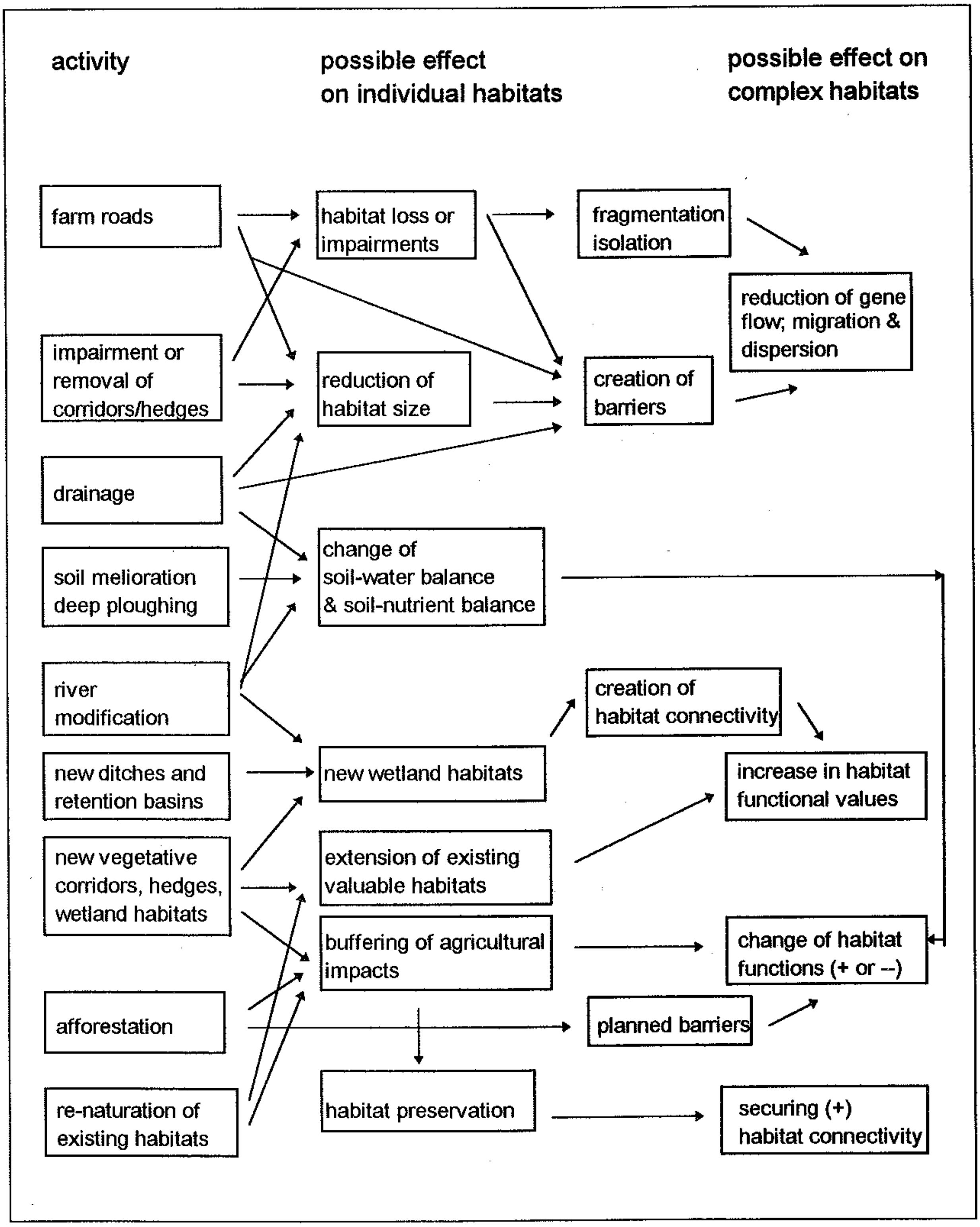
CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

Example 6: Water abstraction from river



CAUSE-EFFECT NETWORKS FOR ENVIRONMENTAL APPRAISALS

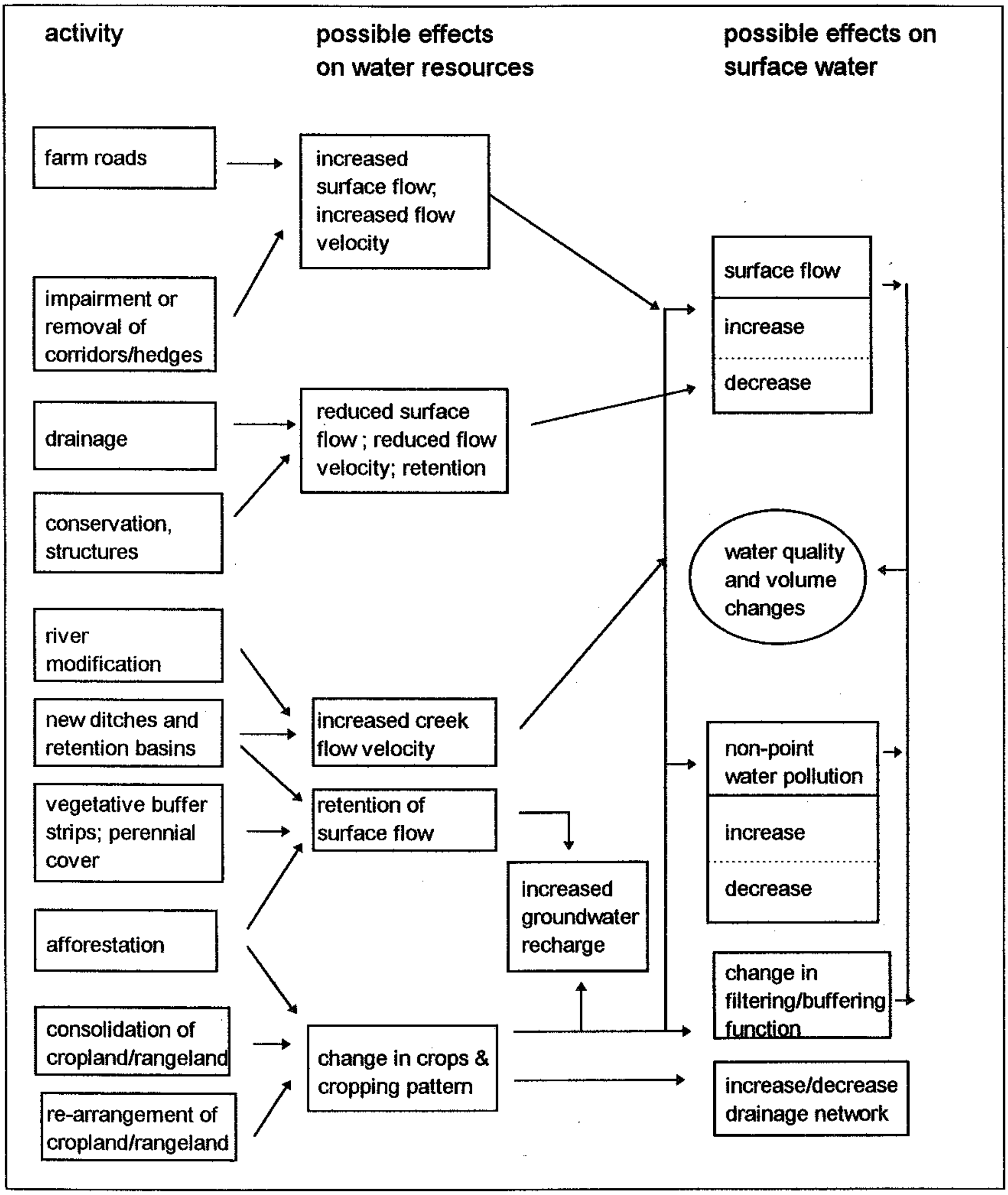
Example 7: Impacts of land consolidation on fauna/flora habitat



modified after Pirkl et al., 1994

Cause-Effect Networks for Environmental Appraisals

Example 8: **Impacts of land consolidation on water resources**



modified after Pirkl et al. 1994