National Rivers Authority - Water Research Centre
Autorità di Bacino del Po - Istituto di Fisica dell'Atmosfera, CNR
Istituto di Ricerca sulle Acque, CNR

Rome, 4 May, 1993

C. Hager

FLOODING PROBLEMS IN THE PO BASIN

GUIDELINES FOR THE COORDINATION OF THE FLOOD RISK PREVENTION SERVICES

PROBLEMS:

- Lack of co-ordination among the public Organisms operating in the field of ground protection with reference to:

  - river maintenance and waterways police;
  - water abstraction control;
  - land use control;
  - discharges control.

- Inadequate legislation.

- Lack of personnel and of personnel control.

- Inadequate management of the State areas beside the river main courses.

PROPOSED ACTIONS:

- Re-classification of the water bodies to clarify the areas of responsibility of the Bodies involved.

- Re-organization of the public Bodies operating in this field.

FLOODING PROBLEMS IN THE PO BASIN

GUIDELINES FOR THE COORDINATION OF THE HYDROLOGIC MONITORING NETWORKS

PROBLEMS:

- Lack of coordination among networks existing by several public Bodies.
- Incompatible informative systems among them.
- Lack of maintenance and control on the expenditure for minor networks.
- Characteristics and total number of exsisting stations in the Po basin unknown to date.
- Lack of personnel in the State Technical Services.

PROPOSED ACTIONS:

- Set up the National Informative System and start the National Monitoring Network as prescripted by the fundamental Law 182/89.
- Define common technical standards to be applied to all the public networks.
- Clearly define roles and responsibilities of the public Bodies operating in the field of prevention and emergency Services: Civil Protection, Prefects and Police (Minister of the Internal Affairs); Po Magistracy (Minister of the Public Works), Hydrographic and Geological Services, Regions and Municipalities.
- Involvement of the private users of public waters, that are obliged to install monitoring instruments as requested by the Administration following Art. 8 of Law 275/93 .

FUNDAMENTAL LEGISLATION

Law 18 may 1989, n° 183 and further modifications

"SOIL CONSERVATION MANAGEMENT AND REORGANISATION"

MISSION

CATCHMENT PLANNING.

PROTECTION, CONSERVATION AND RECLAMATION OF THE CATCHMENT AREA BY MEANS OF PROJECTS RELATING TO HYDRO-GEOLOGY, REFORESTATION, AGRICULTURE, POLLUTION ABATEMENT

- SOIL CONSERVATION
- WATER RECLAMATION
- OPTIMISED MANAGEMENT OF WATER RESOURCES
- PROTECTION OF ENVIRONMENTAL BEAUTIES

FUNDAMENTAL LEGISLATION

Law 18 may 1989, n° 183 and further modifications

"SOIL CONSERVATION MANAGEMENT AND REORGANISATION"

CORE FUNCTIONS AND RESPONSIBILITIES:

a) Protection, conservation and reclamation of the catchment area;

b) Defence and regulation of water bodies and bank consolidation;

c) Flood regulation and prevention;

d) Regulation of quarrying, to prevent damage to the land;

e) Defence and consolidation of unstable areas;

f) Control of subsidence;

g) Coastal protection;

h) Surface and groundwater reclamation;

i) Rational distribution water resources;

l) Reorganisation of the River maintenance and Flood emergency Services;

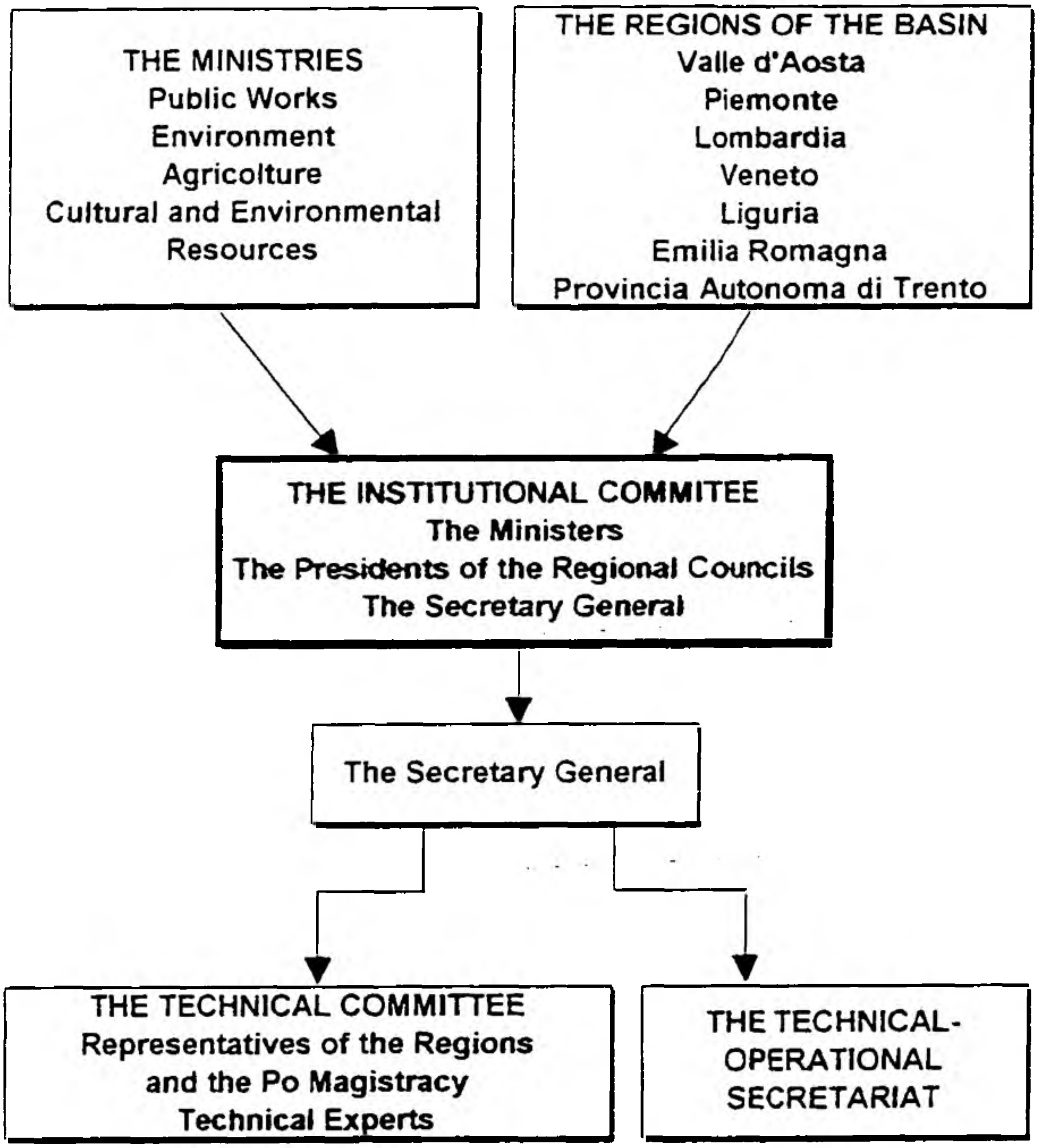
m) Waterworks and plants maintenance;

n) Protection of natural parks and reserves; assesment of criteria for the conservation of the natural beuty of inland waters and related areas;

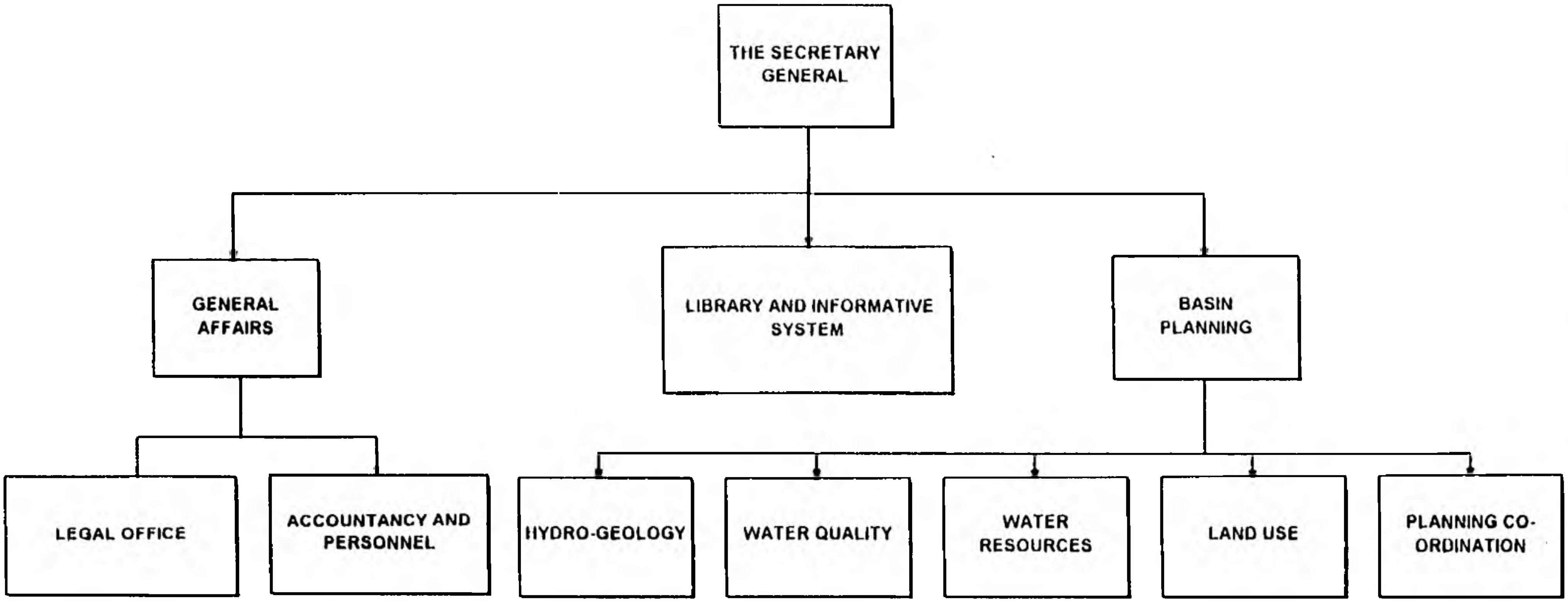
o) Optimisation of the Public Services in the field of water resources, on the basis of efficiency and costs;

p) Re-definition of the areas covered by hydro-geological constraints.

ADMINISTRATIVE ORGANIZATION



THE TECHNICAL-OPERATIONAL SECRETARIAT



GROUND DEFENCE CRITICITIES IN THE PO BASIN

PROBLEM :	Estimate of the investment needs for the most urgent interventions in the field of ground protection
ANALYSIS CARRIED OUT	The evaluation was conducted on the basis of the information given by the Regions, the Po Magistracy, the Local Bodies (Provinces, Municipalities, Mountain Communities) and the on site visits of the Authority's technicians.
OBTAINED RESULTS	- General evaluation ane classification of the existing hydro-geological disorders in the whole Po basin. - Definition of the need of interventions (punctual - local - prevention - recovery) - Evaluation of the planned projects and analysis of their priority degree - Expenditure extimation

INTERVENTI URGENTI E RELATIVA SPESA PREVISTA PER LA DIFESA DEL SUOLO NEL BACINO DEL PO

(costi in miliardi di lire)

INTERVENTI	STIMA DEL COSTO TOTALE	ASSEGNAZIONI triennio 94/96 (legge finanz. '94)	SPESA NON DOTATA DI COPERTURA in totale	SPESA NON DOTATA DI COPERTURA di cui appaltabili
1) - Interventi di manutenzione e di tipo diffuso	1.000	30	970	200
2) - Interventi strutturali di difesa idraulica del territorio di pianura				
2.1 Adeguamenti arginature del Po e tratti rigurgitati degli affluenti	1.000	20	980	200
2.2 Completamento difesa area urbana di Milano	200	4	196	18
2.3 Completamento difesa altre aree urbane (Alessandria, Bergamo, Como, Mantova, Modena, Novara, Vercelli, Busto Arsizio, Gallarate)	190	6	185	60
2.4 Completamento casse espansione sui corsi d'acqua emiliani (Parma, Enza, Secchia, Panaro)	80	12	68	48
3) - Interventi di difesa idraulica del delta	300	5	295	15
4) - Interventi di difesa dei centri abitati e delle infrastrutture nei bacini montani				
4.1 Appenini Liguri ed Emiliani	170	10	160	80
4.2 Fondovalli Alpini e prealpini (Valle Susa, Valli di Lanzo, Valle Orco, Toce, Olona, Valle Sesia, Ogliolo-Oglio)	140	13	127	20
5) - Altri interventi urgenti previsti negli schemi previsionali	300	59	241	50
TOTALI	***3.380***	***158***	***3.222***	***681***

FLOODING PROBLEMS IN THE PO BASIN

PROBLEMS:

The analysis carried out by the Authoriry pointed out that floods and landslides largely depend on a non adequate territorial management.
The consequences are particularly grave due to the hydro-geological vulnerability of the Po catchment area.

Even in case of rainfalls and hydrological events presenting a 5 - 10 year period the catchment territory reveals a **higher vulnerability if compared with the past;** damages and disorders are definitely more intense nowadays than in the past for events having the same physical characteristics.

ACTIONS:

- Checking the efficacy of the existing regulations defining the areas covered by hydro-geological constraints; re-organisation of the legislative framework concerning ground defence .

- Issuing guidelines for rebuilding of hydraulic works distroyed and/or damaged by the flood of september-october 1993 and november 1994.

- Reducing bureaucratic procedures and monitoring times of approuval and realization of the planned projects.

- Issuing guidelines to co-ordinate the hydrologic monitoring networks existing by several public Bodies and to improve the flood prevention systems.

- Issuing guidelines to re-organise prevention and warning police Services carried out by several public Bodies.

- Definition of the areas subject to hydro-geological risk.

- Definition of the river corridors to be covered by hydro-geological constraints.

FLOODING PROBLEMS IN THE PO BASIN

GUIDELINES FOR THE PLANNING OF URGENT INTERVENTIONS FOR GROUND DEFENCE AND FOR THE REBUILDING OF PUBLIC WORKS DAMAGED OR DESTROYED BY FLOODING

PROBLEMS:

- To preserve the territory in the catchment from works not compatible with the aims of the Basin Plan.
- To overcome the frequent delays in the relization of the planned interventions.

PROPOSED ACTIONS:

- Detailed planning at a sub-basin scale.
- Classification of the interventions according to their importance and their local and extensive influence on the hydraulic system.
- Application of local safeguard constraints in case of relevant risk.
- Reduction and/or acceleration of the bureaucratic procedures for the approuval and realization of the planned interventions, promoting agreements among the Bodies concerned.
- Follow-up of the interventions:
  a) state of the art;
  b) effective application of the territorial constraints.
- Update of the planning.

NATIONAL RIVERS AUTHORITY (U.K.) - PO RIVER AUTHORITY COLLABORATION PROGRAMME

PROBLEM ▶ TO IMPROVE THE WATER QUALITY MONITORING PRACTICES AND ITS COST-EFFECTIVNESS

▼

ACTION ▶ IMPROVEMENT OF WATER QUALITY MONITORING IN RIVER CATCHMENTS

AUTORITA' DI BACINO DEL PO

NATIONAL RIVERS AUTHORITY

ISTITUTO DI RICERCA SULLE ACQUE

WATER RESEARCH CENTRE

▶ PROJECT MANAGEMENT

▼

▶ **STAGE 1**: REVIEW EXISTING LEGISLATION AND MONITORING PRACTICES
REVIEW MONITORING NEEDS

▼

▶ **STAGE 2**: IDENTIFY BEST PRACTICES
PRODUCE DRAFT MANUALS

▼

▶ **STAGE 2'**: IDENTIFY TEST CATCHMENTS

▼

▶ **STAGE 3**: REFINE/DEFINE TOOLS
TEST AND EVALUATE IN CATCHMENTS

▼

▶ **STAGE 4**: PRODUCE FINAL MANUALS

▼

DISSEMINATION

PROGRAMME TIMETABLE

	1994	1995	1996
STAGE 1			
STAGE 2			
STAGE 3			
STAGE 4			

FUNDAMENTAL LEGISLATION

Law 4 August 1989, n 283
URGENT MEASURES AGAINST THE EUTROPHYSATION OF THE ADRIATIC SEE

MISSION

REDUCTION OF THE POLLUTANTS, AND IN PARTICULAR OF NUTRIENTS, IN THE WATER COURSES, TO IMPROVE THE WATER QUALITY IN THE ADRIATIC SEE, BY MEANS OF THE FOLLOWING ACTIONS:

a - DEPURATION OF URBAN AND INDUSTRIAL DISCHARGES
b - DEPURATION OF ZOOTECHNICAL DISCHARGES
c - RE-DISTRIBUTION OF THE LIVESTOCK IN THE COUNTRY
d - REDUCTION OF PESTICIDES AND CHEMICAL FERTILIZERS IN AGRICOLTURE

FUNDAMENTAL LEGISLATION

Law 5 January 1994, n°36
PROVISIONS IN THE MATTER OF WATER RESOURCES

AIMS

RE-ORGANISATION OF THE PUBLIC SERVICES OPERATING IN THE FIELD OF:

a - POTABLE WATER DISTRIBUTION
b - SEWERS
c - WASTEWATER DEPURATION

WITH THE AIM TO:

- IMPROVE THE COST-EFFECTIVNESS OF THE SERVICES
- GUARANTEE A GOOD QUALITY STANDARD AT A FAIR PRICE

MISSION

- GUIDELINES AND CO-ORDINATION OF THE TERRITORIAL AND FUNCTIONAL RE-ORGANISATION
- UPDATE THE WATERWORKS PLANNING AT THE CATCHMENT SCALE
- GUIDELINES FOR COST-ANALYSIS
- CO-OPERATION WITH THE SURVEILLANCE COMITTEE

MAIN CRITICITIES IN THE FIELD OF WATER QUALITY : POLLUTANTS AND GEOGRAPHIC AREAS

PROBLEM

POLLUTION OF GROUNDWATER DUE TO NITRATES. ERBICIDES AND PESTICIDES
POLLUTION OF FRESHWATER DUE TO NITRATES AND PHOSPHATES

INTENSIVE AGRICULTURE AND STOCK-FARMING

STOCK-FARMING
4.919.000 PIGS
3.561.000 CATTLE

CRITICAL AREAS
-PIEDMONT - HIGHLAND
-LOMBARDY - S-W MILAN
-BRESCIA-CREMONA-MANTOVA PROVINCES
-ENZA. CROSTOLO. SECCHIA CATCHMENTS

INTENSIVE AGRICULTURE

RICE-FIELDS IN THE PROVINCE OF NOVARA

INTENSIVE MAIZE COLTURE NORTH OF THE RIVER PO

PROBLEM

POLLUTION OF GROUNDWATER AND FRESHWATER DUE TO HEAVY METALS. PHENOLS. HYDROCARBONS. SURFACE-ACTIVE AGENTS, ORGANIC SUBSTANCES

AREAS PRESENTING HIGH POPULATION AND INDUSTRIAL DENSITY

LAMBRO CATCHMENT (MILAN)

TURINESE AREA

OTHER AREAS:
MODENA. REGGIO. PARMA. CUNEO. MANTOVA. VICENZA. BRESCIA. BERGAMO

PROBLEM

POLLUTION IN ALPINE LAKES DUE TO NUTRIENTS, PHOSPHATES, NITRATES. BACTERIA

ALPINE LAKES:
MAGGIORE. COMO. GARDA. IDRO. ORTA. ISEO. MANTOVA. BRIANTEI

MINIMUM ACCEPTABLE FLOW

PO RIVER AUTHORITY FIRST REMARKS

1. FRAMEWORK

1.1 First acknowledgement

Aim of the activity is to individuate the reference technical elements necessary to assess Minimum Acceptable Flow (M.A.F.) within Po river catchment.

The activity will start with the review of current strategies and methods for M.A.F. assessment in surface waters, developed according to legislative and scientific issues on a national and international level.

Among the methods individuated, the most representative ones will be selected. The representativeness depends upon the degree of applicability to the various hydro-morphological realities of the Po river catchment.

In a following stage, by applying these methods to some river catchments representative of the morphological-climatic condition of the Po valley, it will be possible to individuate the related problems and to evaluate the impact of the M.A.F. assessment.

The activity will proceed with the arrangement of a framework synthesizing the tested methods and with the definition of some proposals about the application of strategies for M.A.F. assessment to Po river catchment.

Among the strategies employed, we refer particularly to those implementing normative established by:
- PORA for Valtellina experience,
- Region Piemonte;
- Region Valle d'Aosta;
- Autonomous Province of Trento.

IL MINIMO DEFLUSSO VITALE

PRIME DETERMINAZIONI DELLA AUTORITÀ DI BACINO DEL FIUME PO

1. PRIMA RICOGNIZIONE

1.1. OBIETTIVI

L'obiettivo dell'indagine è rappresentato da una prima predisposizione ed analisi degli elementi tecnici e di riferimento per la definizione di indirizzi in materia di calcolo del "Deflusso minimo vitale" (in seguito definito sinteticamente con la sigla D.M.V.) negli ambiti idrografici del bacino del Po.

L'attività prevede la ricognizione dello stato dell'arte in materia di metodi e criteri di determinazione del D.M.V. nei corsi d'acqua superficiali, sia a livello normativo che scientifico, in campo nazionale ed internazionale, giungendo ad una standardizzazione tipologica degli stessi.

L'analisi critica delle metodiche individuate potrà condurre alla scelta di quelle ritenute più significative per l'areale padano, con riferimento all'applicabilità specifica nelle diverse realtà idro-morfologiche del bacino del Po.

Una successiva fase di applicazione di tali metodiche, su alcuni ambiti fluviali sufficientemente caratteristici delle differenti condizioni morfo-climatiche dell'intero bacino, permetterà l'individuazione delle problematiche connesse e una prima valutazione dell'impatto dei valori di D.M.V. ottenuti con diversi metodi, in relazione agli ambiti idrografici considerati.

L'analisi prevede infine la strutturazione di un quadro di sintesi relativo alle metodiche esaminate, nonchè alcune considerazioni propositive circa gli aspetti più significativi individuati, in merito all'applicazione di tali metodologie di calcolo del D.M.V. nelle realtà idro-morfologiche del Bacino del Po.

Tra le norme operanti nel bacino del Po ci si riferirà in particolare alle norme:
- Valtellina dell'Autorità di bacino;
- Regione Piemonte;
- Regione Autonoma Valle d'Aosta;
- Provincia Autonoma di Trento.

2 OBSERVATIONS

Tests carried on in several physical-climatic realities proved that the most efficacious method is the one established in accordance with Piemonte normative (see the attached paper in Italian).

In order to apply this method to the whole catchment area, it is necessary to collect more information about the territory; this is particularly true for Emilia Romagna and Lombardia, with respect to the following aspects:

1) methods application;
2) specific flow use with a duration curve of 355 days (q_{355});
3) definition of a standard water environment protection for different catchments and river sections.

Also the method employed in the Tevere river catchment could be applied to the Po river, in fact it is concerned with minimum flows running in the generic section.

As regard the point 2), it will be necessary to define a function to correct the minimum specific flow of 7 days with a backflooding time of 10 years $f(q_{7,10})$ in order to increase low values and reduce the exaggerate ones, assuming that minimum value ($q_{7,10}$ and "adjusted" flow) may be maintained only for short times.

M.A.F. values obtained, or which may be obtained, applying one of the "regional" methods, are only indicative. In fact to obtain more objective minimum flows values, it would be necessary a study on the morphology of the river beds in the sections and authochtonous fishing species existing in a condition of natural flow.

From a technical point of view, to define a valid criteria of M.A.F. assessment in the entire Po river catchment, it is necessary to carry on the following activities:

2. OSSERVAZIONI CONCLUSIVE

Dall'analisi dei metodi di calcolo del D.M.V. ritenuti più significativi (rif. allegato in italiano) pare di poter affermare che quello più completo e che ha dato i migliori risultati applicativi, entro alcune, diverse, realtà fisico-climatiche del bacino del Po, sia quello legato alla Normativa Piemontese.

La possibile applicazione di tale metodo all'intero bacino richiederebbe comunque una più approfondita analisi, in particolare per i territori lombardo ed emiliano, in relazione:

1) ad una più ampia indagine applicativa;
2) all'utilizzazione ottimale della portata specifica di durata 355 giorni;
3) alla definizione del livello di protezione ambientale da assicurare per i diversi bacini e tratti fluviali.

Anche il criterio utilizzato sul bacino del Tevere può ritenersi esportabile al Po, essendo legato a valori minimi di deflusso in transito nel generico tratto; sarà peraltro essenziale l'adozione dei tre approfondimenti di cui sopra, relativamente all'intero bacino.

Per quanto riguarda il punto 2) occorrerà definire una funzione di correzione della portata specifica minima di 7 giorni con Tr = 10 anni al fine di incrementare i valori ritenuti troppo bassi e di ridurre quelli eccessivi, assumendo eventualmente che il valore minore tra i due (q7,10 e deflusso "corretto") possa essere mantenuto solo per tempi brevi.

I valori di D.M.V. ottenuti, od ottenibili, con uno qualunque dei metodi di "regionalizzazione" proposti devono comunque essere considerati soltanto a livello indicativo. Infatti, per pervenire a portate minime più oggettive, occorrerebbe anche un'indagine relativa alle caratteristiche morfologiche degli alvei nei tratti e alle specie ittiche autoctone presenti in condizioni di portate "naturali".

Per la messa a punto di un valido criterio di calcolo del D.M.V. sull'intero bacino del Po risulterebbero, da un punto di vista tecnico, comunque necessarie le seguenti attività:

1) naturalization of minimum flows (q_{355}, $q_{7,10}$ or something-else) on a considerable number of sampling sections placed by Hydrographic Service within the Po river catchment;
2) definition of functions to adjust specific low flows (q_{355}, $q_{7,10}$ or something-else) in order to avoid "extreme" values and to regularize the intermediate ones;
3) individuation of the best practice;
4) regionalization within the whole river catchment of a datum low flow;
5) individuation of the environmental protection standard for different areas, taking into account water quality too;
6) field analysis on an adequate number of test sections representative of the various geo-morphological, climatic and naturalistic features of the Po river catchment, in order to compare flow values defined with local needs, with particular reference to autochthonous fishing species and water quality needs;
7) local adjustment criteria, according to what maintained at point 6).

1) rinaturalizzazione delle portate minime (Q355, Q7,10 o altro) su un congruo numero di sezioni di misura del SIM di Parma;
2) taratura di funzioni di correzione per le portate specifiche di magra (Q355, Q7,10 o altro) al fine di evitare valori "estremi" poco plausibili e di regolarizzare quelli intermedi;
3) scelta ragionata del metodo;
4) regionalizzazione sull'intero bacino della portata di magra di riferimento;
5) definizione delle aree a diverso grado di protezione naturalistica con riferimento anche alla qualità delle acque;
6) analisi di campo su un congruo numero di tratti scelti quale campione rappresentativo tra le diverse realtà geo-morfologiche, climatiche e naturalistiche del bacino, per ottenere un raffronto tra i valori di deflusso individuati e le esigenze riscontrate in loco con particolare riferimento alle specie ittiche autoctone attualmente presenti o che lo erano in passato e alla situazione qualitativa delle acque;
7) criteri locali di correzione sulla base dei riscontri di cui al punto precedente.

IMPROVED ENVIRONMENTAL MONITORING

MANUAL OF BEST PRACTICE

Po Valley Authority version
(with rewriting and adaptation of the English text)

DRAFT

DIVISION OF THE MANUAL

SECTION 1

SECTION 2

INTRODUCTION

DIVISION OF THE MANUAL

The manual is divided into five Sections dealing with the following aspects:

SECTION 1

Indicates the purpose and scope of the manual, describing the different types of monitoring and defines the aims and strategies for a monitoring program

SECTION 2

Illustrates the procedure for the initial planning, execution and setting up of the sampling program.

SECTION 3

Provides detailed suggestions, work instruments and examples for each of the monitoring strategies.

SECTION 4

Contains the appendices in which the technical support information is supplied.

SECTION 5

Describes the procedures followed for programming and carrying out monitoring system experimental activity in sample areas.

SECTION 1

INTRODUCTION

This section indicates the purpose and scope of the manual, describes the different types of monitoring activities and defines the aims and strategies of a local monitoring program

1 PURPOSE OF THE MANUAL

The reasons for setting up a system for water quality monitoring stem from two essential requirements: one of a statutory nature and one linked to the solution of problems specifically linked to the management and protection of the waters. The principles indicated in this manual can be applied to all types of monitoring

The procedure chosen here is highly appropriate for the solution of many local problems. There is an increasing need to plan and revise the monitoring programs, as well as provide different approaches to the analysis and interpretation of the data. This need is often felt by the local authorities who, in various ways have attempted or intend, on the basis of specific programs, to set up initiatives of this kind.
This manual is addressed to all those present in the catchment area. It deals therefore mainly with the definition of techniques and strategies for the solution of local problems. Its application on a limited scale will make it possible to set up standard techniques for typical problems and, on the basis of the experience gained from these, to adjust the regional or interregional networks already existing or planned for the future.

The manual makes it possible to formulate a framework for the planning of monitoring programs and for monitoring data analysis, to cover all the surface waterways. The methods used for each control activity will depend on various factors such as

- the nature and importance of the problem
- the availability of resources
- the nature and degree of development of the users
- the accuracy of the information
- the features of the water body
- development of the territory

For these reasons the application of a manual to two different types of problem, in different localities, will almost certainly provide different indications concerning the control systems to be used: the important point is that the decision-making process which leads to the definition of these systems must be consistent

It should be emphasized that the manual is designed as a complement to knowledge of the area, experience acquired and the opinion of experts and does not replace these. In many cases in fact, it is likely that the manual must limit itself to confirming the system suggested by experience.

An important recurring theme throughout the manual is the need to assess in advance the value of information that is likely to be generated by a specific monitoring program Only in this manner will it be possible to make decisions about the allocation of resources to different problems, and the most cost-effective design can be achieved for any particular problem

2 TYPES OF MONITORING

In Italy, on the basis of the purpose of business need for which they are undertaken, there are three different types of monitoring for the quality of surface waters, these are:

- statutory monitoring as an implementation of Community Directives
- national statutory monitoring
- non-statutory monitoring

These three monitoring spheres require different sampling programs, in part due to the different purposes for which the monitoring is performed and, in part, due to the restraints imposed by the law, where present.
All this is reflected in terms of the different degrees of flexibility allowed in the sampling and measurement programs. Since all three types of monitoring have different degrees of flexibility, some of the parts of this manual may be applicable to all three cases, even though they are particularly relevant for local operational monitoring

a) Statutory monitoring as an implementation of Community Directives

The need to carry out this type of monitoring derives from some EEC Directives implemented in the Italian legislative system, that require the control of set quality standards.

These dispositions, as for example

Presidential Decree no. 515 dated July 3rd 1982	Implementing Directive no. 75/440 concerning the quality of surface waters used for the production of drinking water;
Presidential Decree no. 470 dated June 8th 1982	Implementing Directive no. 76/160 concerning the quality of bathing water;
Health Authorities Decree no. 130 dated January 25th 1992	Implementing Directive no. 76/659 on the quality of fresh water supplies that require protection or improvement to provide a suitable environment for fish.

generally provide, on the basis of the use for which the water is intended, precise indications on the quality standards for the water, while many of the organizational, structural and management aspects are assigned to the local authorities (regional, provincial, municipal).

This type of monitoring is therefore based on the determination, in strategic points of the waterway, concentrations of specific chemical-physical and microbiological parameters, or the measurement in specific terms (temperature, turbidity, etc.) to be compared with reference standards.

The relative authorities, in selecting the types of sampling to be made have attempted to combine the sites identified for an assessment of the quality standards with points selected for quantitative surveillance, where necessary adjusting the frequency of the measurements and the parameters to be determined.

b) National statutory monitoring

The general criteria for surveying the quali-quantitative features of waterways are derived from the Resolution of the Interministerial Committee for the Protection of the Waters against Pollution dated February 4th 1977, implementing the provisions of art. 2, letters b), d) and e) of the Law no. 319 dated May 10th 1976, concerning the regulations for protecting the waters against pollution.
These provisions indicate the waters which must be protected "on the basis of their subsequent uses, which are not necessarily limiting".

1. use as drinking water.
2. used for agricultural purposes,
3. use for industrial purposes,
4. maintenance of aquatic life;
5. recreational activities;
6. navigation.

They also define:

- the waterways that must be subject to surveillance;
- the minimum number of sampling and flow measurement stations, on the basis of the catchment area;
- the minimum frequency of the measurements,
- the essential chemical and microbiological parameters.

The detailed preparation of the monitoring network was assigned, in art. 7 of Law no. 319, dated May 10th 1976, to the Regions, who dealt with this task in a fully autonomous manner.

This type of mid-scale monitoring is mainly based on the need to acquire better knowledge of the territory, in terms of the overall pollution load at the various sections of the basin.

The information to be collected under Resolution 4.2.77 differed according to the subject to be controlled. The various peculiarities can be summarized as follows:

- For the natural or artificial waterway

  - the main uses;
  - the concentration patterns in typical points of the waterway,
  - the water height and the flow rates,
  - the load of the main chemical indicators in the strategic sections of the waterway;
  - the microbiological features.

- For lakes and reservoirs
  - the main uses,
  - the concentration patterns of chemical-physical and biological parameters on the surfaces (lake surface and shores);
  the concentration patterns of chemical-physical-microbiological parameters and nutrients especially in columns in the centre of the lake down to the bottom,
  - the different water levels,
  - the pattern of lake currents and manner in which the water is mixed;
  - the supply of pollutants and eutrophic elements from the effluent basin

- For coastal waters
  - the main uses and the discharges from inland activities;
  - the different warer levels;
  - the pattern of currents,
  - erosion and reforming of the coast;
  - the nutrient concentration pattern and the biotic components;
  - the microbiological indices.

- For transition waters
  - the load emptied into the sea through inlets or estuaries;
  - the salt concentration pattern in the water,
  - the flow direction of water power and the capacity to mix and dilute the substances added.

More than ten years after the setting up of the regional networks it can be seen that only a part of the legislative measures have been implemented and organized to provide routine information. Although there are great differences between one case and another, most of the programs not considered priority or, due to the complexity of their execution, considerod as feasible only in an occasional manner can today be considered as LOM, as specified above.
Amongst these, it is possible to list specific monitoring of lakes, biological monitoring, analysis of the loads emptied into the waters, subject of overall verification during the revision of the Regional Water Recovery Plans.

Functional features of some monitoring networks

The use of questionnaires at a regional and provincial level, the amount of knowledge and the availability of reports and publications on monitoring systems have made it possible to analyse, on the basis of the proposed aims, the procedures adopted by each authority concerning the siting of the stations, the statistical processes adopted, the parameters examined, etc. The aim being to assess the possibility of adopting them and representing them when these networks satisfy the envisaged aims.
A first assessment is one that in addition to the information on the quality-quantity of surface water bodies, contributes other aspects such as the state of the environment and public health matters.

The detailed forms with all the data collected are presented in Appendix A.

Almost all the networks which envisage the collection of monthly samples, within a fairly wide time span provide a good picture of the water quality which is fundamentally the main aim, besides that of observing the letter of the law.
Systems with higher sampling frequencies do not appear to guarantee a sound knowledge of the water body monitored; the possibility of using a data homogenisation method (such as IRSA) makes it possible to arrive at a preliminary acceptable overall assessment even with non-homogeneous data.

An interesting example is the biological monitoring network (Reggio Emilia) and the discharge controls (Acna in Liguria) which fully achieve the set aims, in this case more complex than the simple knowledge of the quality features.

A second problem is the variability of the "water course flow" parameter which affects the quality aspects, and therefore the sampling routines must be correctly defined on the basis of a thorough knowledge of the hydrological regime and the polluting loads present in the territory considered.

The use of instruments for the continuous analysis of parameters does not appear to lead to a validation of the monitoring system, except as regards the control of discharges or the need for better knowledge about the quality of a stretch of river in a certain period of the year and under certain climatic conditions.

It is also necessary to point out that for hydrometric monitoring, of strategic importance for the Po Valley, some Regions have not set up their own controls since they intend to make use of the national technical Services which, through the Hydrographic Office in Parma, deal with the hydrological monitoring for the entire basin.

c) Non-statutory monitoring

An analysis of the previous points makes it easy to understand the spheres of application in Italy today and in particular in the Po Valley, where there are monitoring initiatives not strictly linked to the legal requirements, that can be defined as non-statutory.

These can in fact concern territorial realities not sufficiently investigated due the specific nature of the area, sectors that the official bodies give occasional attention to, new applications that the law did not contemplate, local problems or involving large stretches of territory menaced by the risk of a deterioration in the quality of the water resources.

Due to the underlying problem, there is a high degree of flexibility in formulating programs, in particular as regards financial resources, the duration of sampling, the number of control points, the frequency, the methods and the parameters to be determined.

Amongst the initiatives adopted in the Po Valley and the areas affected by this basin, there has been a widespread use of monitoring, promoted by regional, provincial and at times national bodies, to investigate and assess the specific problems indicated below, that can be considered the most significant examples:

- assessment of effects of the use of herbicides on the waters;
- assessment of effects on the waters linked to the massive use of pesticides;
- assessment of effects on the ecosystem linked with widespread industrial pollution;
- measures for the control of emergencies and for monitoring waters in the event of accidental spillages;
- campaigns to control eutrophication of the coastal and off-shore waters to monitor the dispersion of polluting substances in the sea,
- experimental activity for the application of rules on the release of minimum levels;
- specific monitoring activities during Environmental Impact Studies to be submitted for assessment in accordance with the law on Assessment of Environmental Impact;
- biological mapping campaigns, using different methods;
- monitoring to assess the exchange of pollutants between surface and underground waters;
- assessment campaigns of polluting loads under extreme hydrological conditions;
- detailed monitoring of the trophic state of lakes.

Amongst the users of this type of monitoring, there is also the Po River Basin Authority, which has already promoted initiatives in this direction (classification network) and which, in order to understand important phenomena concerning the entire basin, in accordance with the authority assigned to it with the Law 183/89, intends to coordinate, where necessary, activity even beyond the regulated regional monitoring.

3. LOCAL OPERATIONAL MONITORING (LOM)

The above highlights the widespread demand for a more specific type of monitoring, designed to examine some aspects which, due to the homogeneous nature of the existing systems, regulated or linked to customs, are not easy to identify. On this point, there are many requests for the adoption of an innovative and flexible instrument that can be adapted to the different preset aims of the various authorities.

In particular, it is the contributions possible with the "non-statutory monitoring" that may provide the aims and the organic strategies for a more effective response to the interpretation of environmental problems at a local as well as a wider territorial level.

Thus the indications below provide the elements for a monitoring approach, capable of providing answers and techniques for the above-mentioned requirements. The most appropriate definition would appear to be that of a "finalized operational monitoring" rather than "local operational" which, in Italy, would appear to be less in keeping

However, the contents can certainly be understood to be the same as that described in English for "local operational monitoring", which will be indicated from now on as LOM for brevity.

3.1 Monitoring aims

There are various aims which can be adopted when setting up a finalized monitoring program. For example:

a) characterisation of part of a body of water,
b) authorization for discharge or review;
c) effluent impact assessment;
d) diffuse source impact assessment,
e) development impact assessment,
f) incident detection;
g) post-remodial assessment,
h) real-time management;
i) making the most of the water resources linked with use and compatible exploitation

The above are only a few of the initiatives which could be included under LOM. This list also includes typical problems which generate techniques and strategies leading to local solutions which, appropriately reformulated and integrated, can be applied to a much wider area.
Finally, it is necessary to remember that the monitoring aims may be the end purpose of the activity, or they may be part of a more general project, as for example in the planning of an entire basin.

a) Characterisation of part of a body of water;

This aim covers any monitoring that, in a given part of a water body (in this phase limited to water courses and lakes), is mainly undertaken to collect information on the quali-qualitative aspects or the ecosystem in the waters not subject to control or where monitoring is limited to a few parameters.

This type of monitoring is very similar to what is currently being done by the regional monitoring networks.

The program can only be set up to acquire further information not provided by the current monitoring network, or following the specific request on the part of the authorities appointed to use and protect the resource.

The program drawn up must envisage that the sampling and measurements take place in points which are the most representative of the water body. It must also define, in relation to the possible indicators present, the chemical-physical and microbiological parameters to be sought and assess the need to go-ahead, where appropriate, with measurement of flow rates and biological indices.

The chemical-physical and microbiological data collected must also allow possible comparisons with quality standards for the specific uses for which the waters can be kept.

The values derived from the flow rates will also make it possible, combined with the concentrations of pollutants, to determine the loads in transit, while the biological indices will provide indications on the degree of alteration of the water ecosystem.

The relative questionnaires have revealed that for the Regions, the knowledge of the quality of water bodies represents one of the two most important problems (mean score 9.6 on a scale of 1-10) and that all the strategies identified are used with a greater availability of quality features, in the upstream and downstream comparisons, and investigations of the pattern over time.

The most commonly used method is discontinuous chemical monitoring, with laboratory analysis and occasionally with portable instruments or test-kits. Piedmont and the Autonomous Province of Trento indicate the presence of permanent monitors in their control networks.

Biological monitoring with the analysis of communities of macroinvertebrates is present in some regions, while almost all the others perform microbiological analyses.

Amongst the factors involved when selecting the fundamental type of monitoring, the most important are the type of parameter and the second the cost and the historical continuity of the analyses, whereas the exclusion of continuous chemical monitoring is linked to the potential intermittent nature of quality (e.g. daily variations) that lead some regions to choose biological monitoring.

Contributions towards the criteria most appropriate to achieve this aim will emerge from the operative program being experimented on the Enza river and the Sesia river.

b) Authorisation for discharge or review;

Concerning this aim, it is necessary to point out that currently in Italy, the legislation does not offer particular opportunities for applying surveys to receiving water bodies to assess the acceptability of a discharge except for those designed to certify the conformity of the discharge with the existing limits imposed. It should also be emphasised that some authorities, on their own initiative, have set up measuring systems for receiving water bodies with consistent discharges, but merely for environmental monitoring purposes.

By focusing the aim on the hydraulic component of a discharge and its sustainable effects on the receiving water body, in the future this could be usefully applied when defining regulations, restraints and criteria for the protection of the land, especially for those aspects linked to the carrying capacity of an effluent which is added to the natural flow of a water course, at times concomitant with the diversion of water from the bed for primary uses.

The questionnaires on this aspect have revealed a very low priority (1.6 on a scale of 0 to 10) only second-last in the series of 10 aims. The only region to consider this aim important was the Valle d'Aosta. The strategies identified were equally divided between the site of the discharge, the upstream and downstream comparisons and the survey of the quality pattern over time. The monitoring envisaged is discontinuous chemical with laboratory analyses even at a microbiological level.

c) Effluent impact assessment;

The purpose of this type of monitoring is to assess the nature magnitude and extent of the impact on the water quality in a water body and the overall ecosystem caused by a source-point effluent, measured under routine everyday conditions, in the presence of extreme exceptional events (drought, flood) or generated by the same effluent in an anomalous manner (leaks, accidental spills, etc.). This concerns not just the quality aspect but also that of the diversion of part of the current in stretches of the water course (weirs, etc.).

In the case of source-point effluent the activities adopted to estimate the impact of a discharge may include, besides the characterisation of the effluent, sampling and controls upstream and downstream of the discharge, for quality comparisons, even with historic data. In some particular situations, it may be very significant to associate those measurements with that of flow rates to check the acceptability of the water conditions.

The questionnaires on this point have revealed an average priority (4.80 on a scale of 0 to 10); the monitoring envisaged is of the discontinuous chemical type, with laboratory analysis and in part portable instruments. In addition, analysis of macroinvertebrate communities and microbiological analyses are also envisaged.

d) Diffuse source impact assessment;

The aim in question is strongly linked with the previous one and assumes an adequate knowledge of the territory. It is in fact often hard to attribute the effects to a diffuse type of source, where there are numerous local effluents or particular elements released by the land which are not caused by polluting phenomena but by the geochemical features of the areas in the basin.

In intensive farming areas, where there is widespread use of fertilisers, herbicides and pesticides, in those with intensive animal breeding and heavily populated areas (effects of flash waters or first rainfall), the assessment of the impact of pollutants on the receiving water can certainly not concern just one point, but must consider the water bodies of the entire drainage area, thus also providing possible indications on the interaction and exchange between surface waters and underground waters.

When the water body of possible interest is a lake, the monitoring program should be appropriately designed to assess the particular indicators with a strong impact on the lake.

The questionnaires on this point have revealed a medium priority (4.2) with the adoption of strategies of the following type: establishing the quality, surveys of space and time patterns and comparison with situation before and after. The current monitoring is always of a discontinuous chemical type with laboratory analysis and the possible use of portable instruments and permanent monitors. To achieve the aims envisaged, biological monitoring and microbiological analyses are used.

Contributions to the criteria that can be used to achieve this aim will emerge from the operative program being experimented on the Enza river and the Sesia river.

e) Development impact assessment;

This aim is intended to create activities that make it possible to collect knowledge and details on the impact and the transformations induced on water bodies and on water ecosystems by the modifications and by the extension of urban settlements, agriculture, industry, large communications systems, etc.

It is strongly linked with the previous aim. In this case however, the monitoring action is much more strategic and complex since it interacts with numerous different mechanisms which, especially in urban areas, are concomitant and characterised by increasing degrees of environmental degradation.

In some cases, in fact, besides the usual information linked to the quality of the water, it may be essential to find monitoring instruments to identify and interpret the balance of the vehicled resource, in terms of requirements (e.g. irrigation) as well as restitution and final use, following treatment processes (with modifications in quality).

The questionnaires on this point have revealed a medium priority (3.8) with the adoption of strategies characterised by water quality and investigation of changes over time. The monitoring is still of a discontinuous chemical nature with laboratory analyses.

f) Incident detection

This covers monitoring designed to detect pollution incidents when they occur, in areas where there is a high risk of pollution, and where there are important water uses to be protected, such as drinking water supplies, fish breeding areas, etc.

It may be considered as an emergency operation, following external reports, to be activated by the authorities responsible for monitoring and for intervention to deal with polluting phenomena.

Different types of system can be adopted, depending on whether we are dealing with a water course or a lake.

When the event is signalled, it is possible to set up a further series of distinct or automated monitoring systems to estimate the degree and extension of the event, characterise the phenomenon and establish the cause.

On this point the questionnaires revealed a medium-low priority envisaging discontinuous chemical and laboratory analyses. The use of biological monitoring and the search for microbiological parameters are adopted to identify and localise the source or the event. Authorisation for effluent discharge is the source of information most frequently used to select the parameters to be sought.

g) Post-remedial assessment;

This is one of the most important aims when programming and planning water resources. If appropriate control instruments are used, it is possible to establish the effectiveness of improvement measures, i.e. any action taken to treat the waters, whether this involves the direct reduction of the polluting source or reducing its impact on the receiving waters.

The measures to be taken, as similar to those indicated in letters c), d) and e), but should be adapted for each type of operation with a different approach as part of a large overall strategic plan.

The questionnaires on this point have identified a medium-high priority, the second for all the aims proposed. In two regions this aim was given the maximum score, an indication of the need to obtain experimental validation of the measures adopted to deal with pollution in the territory.

h) Real-time management;

To achieve a better knowledge, for applied research purposes, of the control of particularly important events or those with a high risk for the users, i.e. for the management of community services, it is important to have a monitoring system able to supply real-time information, easy to poll continuously or as preset times.

Where considered necessary, the monitoring can be designed as an early-warning system, using specific indicators which trigger an alarm and sampling system.

The various sampling and measuring stations, besides examining the quality aspects, must also be able to measure flow rates (under the various hydrological conditions) and allow the continuous transmission of information to structures assigned to the assessment of the data collected and/or for the management of the resources.

The questionnaires on this point have revealed little interest on the part of the authorities in giving priority to this aim: 4 regions out of 5 gave a score less or equal to one.

Contributions to the criteria that can be used to achieve this aim will emerge from the operative program being experimented on the Enza river and the Sesia river.

i) Making the most of the water resources linked with use and compatible exploitation.

This aim covers numerous environment recovery targets

In increasing portions of water bodies, with sufficient quality levels, the identification of further elements such as those concerning the aquatic life and vital aspects linked to water is becoming more important and involves the use of specific monitoring instruments.

Furthermore, the current and envisaged uses must be examined in terms of compatibility with the resource to satisfy other requirements which, if not deal with adequately, will in the short or midterm lead to affect the quality of the solution as a whole.

It is therefore essential to establish a specific monitoring system , which can be adapted to the peculiarities of each water body, supplying elements able to confirm compatibility with certain uses, to make it possible to establish in the field some of the phenomena to be monitored (e.g. minimum vital flow).

Once the system has been identified, it will be possible to acquire elements to define an innovative classification of the waters, linked to the possible uses, which can be used as a homogeneous instrument to control quality.

Contributions to the criteria that can be used to achieve this aim will emerge from the operative program being experimented in the Idro lake basin and the Chiese river.

3.2 Monitoring strategies

To achieve the aims of a monitoring program, various strategies can be adopted which will contribute towards defining the monitoring system as a whole.

The identification of the strategies to be adopted is the initial phase for the drawing up of a monitoring program and each one of these is associated with its own statistical design tools and data analysis.

The monitoring strategies identified to deal with the different monitoring aims are:

1) Quality characterisation
2) Definition of quantity
3) Spatial comparison
4) Temporal comparison
5) Spatial step-change analysis
6) Temporal step-change analysis
7) Spatial trend analysis
8) Temporal trend analysis

1) Quality characterisation

This strategy can be used to define the quality of the water in a site or a stretch of a water body and can be directly applied to achieve the specific aims of the characterisation of a portion of a water body and in making the best possible use of the water resource.
The use of instruments for measuring and continuous transmission of some parameters makes it possible to know in real-time the water body quality variations.
On the basis of the different parameters examined, it will be necessary to process the analytical data, using appropriate statistical instruments (means, percentages, etc.).

2) Definition of quantity

This strategy can be used for a quantitative characterisation of the flow rate in a section of a water body and is particularly appropriate for the aims linked with making the best use of the water resource, where abstraction and derivations can interfere with the use of the resource for certain purposes, as well as for determining the polluting loads under normal and extraordinary hydrological conditions.

3) Spatial comparison

Spatial comparison can be used to compare quality and/or quantity features in a stretch of a water body subject to an impact and one that is not.
In the most simple example, it is possible to monitor upstream and downstream of the impact site, to assess the effect on the water body.
The impact source may consist of a discharge point (continuous or discontinuous) or an abstraction or derivation point.

4) Temporal comparison

The temporal comparison is the strategy with which monitoring is carried out in one or more sites before and after the occurrence of a known event that is assumed to have an impact on the receiving waters.
The event may occur as the result of the construction or development of infrastructures, the starting up or closing down of a discharge or derivation, the creation of structures to reduce pollution or reclamation operations.

5) Spatial step-change analysis

This strategy is used to locate and measure the changes in quality and/or quantity through space, such as those caused by a discharge or by an abstraction or derivation point and consist of a series of measurements in various parts of the water body.
The assumption for the application of this strategy is that there is an *a priori* expectation of measurable spatial changes in the quality and/or quantity features in the stretch of water examined.

6) Temporal step-change analysis

This type of strategy refers to the identification and measurement of changes in quality and/or quality over time induced in a stretch of water by any polluting event or by abstraction or derivation and, it is performed with repeated measurements in various points over a set period of time.
For its application it is assumed that the stretch of water examined will undergo measurable changes over time in the quality and/or quantity features.

7) Spatial trend analysis

The analyses in question are performed to identify the gradual or continuous changes in the quality and/or quantity features through space.
It may be used to determine the size of the problem to assess the impact of an effluent, whether this is a discharge or a diffuse source, in determining the impact of an area and its development, in making the best use of the water resources.

8) Temporal trend analysis

This strategy is applied for the detection of gradual or continuous changes in the quality and/or quantity aspects over time.
It can be used to assess the impact of an discharge or a diffuse source to collect information on the long-term trends, and to assess the efficacy of remedial measures.

SECTIONI 2

INTRODUCTION

This section illustrates the procedure for the design, execution and setting up of a monitoring program.
The diagram in figure 1 illustrates the stages necessary for a definition of the entire program.

1. INITIAL PLANNING OF MONITORING PROGRAM

This section describes the initial planning steps needed to:

a) establish the various aims that go to make up the whole monitoring program;
b) decide on the relative priority of the aims;
c) allocate the available resources.

These steps are set out in the top half of Figure 2; in the first part of the flow diagram in Figure 2.1 they are shown as follows:

- the activities in the boxes refer to tasks or actions
- the activities on the horizontal lines refer to data or information
- the lines with the arrows refer to data flows.

1.1 Establish the monitoring program aims

On the basis of the aims listed in Section 1, and the problems to be faced and the available information, the first step to be taken is that of deciding the various specific enquiries that the program is to address.

1.2 Decide on the priority of the aims

Amongst the aims identified, it is necessary to define a scale of priorities, i.e. decide on the priority to be attributed to each aim.

Amongst the factors that contribute to the definition of the priorities, there are:

- the statutory requirements;
- social expectations;
- plans and projects for resource management.

1.3 Allocation of resources

To start with it is necessary to allocate the available resources on the basis of a scale of priorities assigned to the previously defined aims.
On the basis of the economic resources, the strategies can then be defined to achieve the various aims(see next chapter).
Subsequently, an assessment will be made of the capacity of the strategies to achieve the set aims (limited proposal on pages 61-62 or some other procedure to be established).
Consequently, the need for a new allocation of resources will be examined.

2. PLANNING FOR A SPECIFIC AIM

Chapter 1 described the initial planning stage in which the overall goals of the Monitoring Program were divided into a number of distinct enquiries. This chapter indicates the first steps to be taken to plan the details of the monitoring program for each specific Aim.
This planning stage is indicated in the shaded boxes in Figure 3 while the discussion of the activities to be carried out is illustrated in the flow diagram in Figure 3.1.

2.1 Strategies

For each Monitoring Aim there are a number of Strategies that may be employed. For example, the effluent impact assessment is likely to include a spatial (upstream-downstream) comparison, and quality characterisation to assess the downstream quality against water quality standards defined by the technical specifications.
The recovery of water quality downstream could be quantified by spatial trend detection or by repeated spatial comparisons with upstream quality.

Depending on the Aim, each of these strategies have different requirements in terms of the planning of the monitoring program and data analysis.

2.2 Selection of parameters

In general the parameters to be monitored are already known in the initial stages when the program is set up, whether these are quality aspects (chemical-physical, microbiological and biological parameters), or hydrological measurements.

The reference parameters are essentially based on:

- knowledge of the pollution sources present in the area
- standard analytical methods
- site inspections
- nature of recent polluting events
- historic data for quality and/or quantity features
- other parameters depend on the specificity of the monitoring aims

In certain cases it may also be appropriate to consider the possibility of using alternative parameters that can offer advantages as regards the information as well as economic advantages. In this case it is possible to use non-specific determinands, such as toxicity tests for example.

Environmental parameters

2.2.1 Chemical-physical parameters

The survey of these parameters is generally considered a constant in a monitoring program since, often, the quantification of a few important chemical-physical parameters provides a great deal of information on water quality. Chemical parameters are particularly useful for monitoring any kind of intermittent or variable quality problems under normal and critical hydrological conditions.

The analytical methods to be used to determine the parameters are those described in the volumes "Metodi analitici per le acque" (Water analysis methods) published by the Water Research Institute (I.R.S.A.) of the National Research Council (C.N.R.).
While the presence of these parameters is only important in connection with particular problems (metals, hydrocarbons, pesticides, solvents, etc.) other, for example pH, temperature, conductivity, dissolved oxygen, nitrogen compounds and phosphorous, are commonly used to characterise water quality.
For some of the these parameters, the possibility of continuously determining with fixed or mobile instruments, increases their possible use.
Chemical monitoring is often associated with biological monitoring. This is justified by the fact that even if knowledge of the behaviour of a few important chemical characters can provide a great deal of information on quality, there are limits to chemical monitoring, in particular in the case of non-continuous monitoring. The use of biological parameters can make it possible to overcome these limitations.

2.2.2 Microbiological parameters

The survey of microbiological parameters in water is aimed at detecting the micro-organisms present. It is generally combined with an assessment of quantity and is particularly important when these waters are assigned for specific uses with hygiene-health requirements.

For water quality definition, the difficulty of using routine techniques to detect the presence of all possible pathogenic micro-organisms has made it necessary to identify micro-organisms that are indicators of contamination and whose presence can be an indication of the presence of pathogens.

The micro-organisms that are considered indicators of faecal pollution, which are commonly sought for the definition of water quality of different kinds and for different uses, are the faecal coliforms and the faecal streptococci, salmonellae.

The methods defined by IRSA-CNR are also used to determine these parameters.

2.2.3 Biological parameters

The two main advantages of biological monitoring are the capacity to:

- reconstruct quality trends for the recent past;
- provide greater knowledge on the water characteristics and the possibility of interpreting the causes of pollution.

The decision to use biological parameters depends on different factors, amongst which the main ones are the following:

- problems of intermittent quality;
- little known main pollutants, hard to analyse, or only detected with costly analysis;
- recent polluting events followed by improvements in the chemical features.

Where the aim of the control system is to establish a linear understanding (space-time), biological monitoring plays an important role due to the possibility of integrating quality with the time changes. A particular use is that concerned with problems linked to certain hydrological situations (floods, medium water).

Biological monitoring of flowing waters includes a vast range of parameters resolved with "macrobenthos". The most common in Italy consists of the EBI, that (modified by Ghetti) is mainly performed at six-monthly intervals during a medium water and during a low water stage.

In the majority of cases, biological monitoring is performed at the same time as chemical monitoring, or using an integrated program, or using chemical data collected for other purposes. This use of chemical and biological parameters is destined to provide greater details on the matters under study.

2.2.4 Hydrological measurements

To be delivered during the meeting

As regards lakes, there are frequent surveys of phytoplankton and zooplankton to assess the structure and density of the populations, the biomass variations, the chlorophyll values and primary production.
The hydrological measurements used to extend the interpretation of pollution phenomena and understand the balance of the loads in sections of the basis, can be mainly obtained with the flow rate that can be measured continuously or at preset intervals with automatic instruments. Otherwise it is sufficient to fit the preselected section with an appropriate flow scale that can be used to establish the flow rate on the basis of the hydraulic and morphological features of the section.

CO-OPERATION BETWEEN THE BRITISH NATIONAL RIVERS AUTHORITY, THE PO RIVER AUTHORITY AND SCIENTIFIC INSTITUTIONS ON THE DEVELOPMENT OF A MONITORING SYSTEM AT BASIN SCALE

TERMS OF REFERENCE

The collection and the storage of data concerning climate, hydrology and water quality are an indispensable step of any rational activity aiming at water resources management and protection in a river basin.

As regards the Po River Basin, numerous Bodies and Organisations, at various level of jurisdiction and with different aims, normally collect a conspicuous amount of data, using different criteria and methods that are not always one another comparable.

The co-operation between the NRA and the Po River Authority shall be addressed to the development of criteria able to provide a Monitoring System, a very important component of which is the setting up of a general project of forecast and control measures. This will represent a reference point in defining the parameters to be measured, the localization of sampling sections and the frequency of analytical determinations, for the various Organisms acting on the area coordinated by the Po River Authority:

The main purposes for the development of such a Monitoring System are:

a) to assess the natural phenomena or those caused by human activity and their development upon the years:

b) to identify the main interventions, which must be engaged for the purpose of water quality protection and for the regulation of hydrological events;

c) to assess the efficacy of the interventions engaged, within the more general activities of environment protection, keeping in mind the necessity of a rational resource utilisation and taking into account the statutory duties of the Po River Authority and its relations with the socio-economic context of the territory under its jurisdiction.

According to the above, the Monitoring System must establish:

a) the survey, in real time, of meteorological and hydrological events;

b) the availability of surface and groundwater in relation to their possible uses;

c) the quality of surface and groundwater in relation to point and non-point discharges and to specific hydrological conditions.

To carry out these objectives, the Monitoring System shall deal with the following activities:

a) definition of criteria to select monitoring stations;

b) selection of the fundamental parameters to be measured in the defined stations;

c) development of a programme to control the reliability and the significance of the collected data;

d) development and realisation of proper instrumental practices for an automatic, continuous data survey and transmission to a central information structure;

e) development of an automatic warning procedure, to be put into action by significative gauges chosen in relation to the various uses of water resource;

f) standardization of the operating costs.

Parma, April 28, 1993.

CO-OPERATION BETWEEN THE BRITISH NATIONAL RIVERS AUTHORITY, THE PO RIVER AUTHORITY AND SCIENTIFIC INSTITUTIONS ON THE DEVELOPMENT OF A MONITORING SYSTEM AT BASIN SCALE

GUIDELINES FOR A MONITORING SYSTEM OF THE PO RIVER BASIN.

In systematic planning and management of water resources of major hydrographic basins, hydrologic and meteorologic data may serve two distinct purposes: <u>the development of project measures and programmes of operation as well as prevention or recovery actions</u>, to be taken even in real time. This involves two different procedures of data collection and processing, although data collected and processed in a short time, and suitably stored, can be obviously utilized in deferred evaluations.

It does not seem out of place to point out that data necessary to the purpose refer not only to the hydrologic aspects, but also to the more complex climatic aspects, in their small- and large-scale evaluations. It should be noted as well that such data may go beyond specific problems of water management and very soon take on great importance in fields such as agriculture and transport, in which information concerning climate, and microclimate in particular, is increasingly necessary.

Therefore, an activity designed to collect, store, process and provide hydrologic and meteorologic data must primarily aim at real-time access to information, even if this is not to be used immediately. Based on these premises, therefore, we can try to define fundamental problems in planning and management of water resources and to identify necessary hydrologic and meteorologic data.

a - Precipitation

Precipitation in liquid and solid forms reaching the basin and giving rise to the hydrologic cycle in the affected area is the result of complex climatic occurrences, which affect not only the basin but also its surrounding areas: the Appenines and the Alps play a very important role.

b - heavy showers

Information concerning intense rains of short duration is of fundamental importance to fully define the hydrologic characteristics of the basin as well as in designing sewage networks, sewage treatment plants and natural drainage networks, while real-time prediction may facilitate operation of networks and plants.

c - Floods and inundations

Patterns of formation, propagation and behaviour of floods in a river bed are, by historical tradition, one of the major problems affecting the Po river basin, even if the numerous measures taken over the last few years allow great expectations for a decidedly better situation in terms of risk and reliability.

d - Droughts

Needs of environmental protection, connected above all with the possibility of minimizing the effect of pollutants carried into bodies of water, entail the maintenance of a high flow rate, capable of reducing pollutant concentration and increasing natural phenomena of conveyance and abatement.

Therefore, the first negative effects produced by low flowrate in a river bed are increased pollutant loads and reduced self-recovering capacity, which, together with the difficulty in meeting users' requirements, especially of those based on water abstraction (for agricultural, drinking and industrial uses), increase incompatibility and conflicts.

The recurring drought of the last few years has made these situations worse, causing problems in the management, not always solved rationally, also on account of the lack of basic data.

e - Levels and quality of groundwaters

Groundwaters account for a very important resource in the entire Po valley and the knowledge of groundwater behaviour is of fundamental importance not only for water withdrawal but also to control liquid and solid waste on the ground.

f - Tides and seiches

The Adriatic Sea plays a determining role in the behaviour of the mouth and final stretches of the river, and of coastal "recesses". High levels in the sea hinder the flow of river waters and cause floods, particularly frequent in the Delta areas.

g - Salt-water wedge

The salt-water wedge present in the final stretches of the river makes uses of water abstraction more difficult, especially irrigation.

h - Sediment transport

The Po and its tributaries, especially those from the Appennines, have been always affected with conveyance of solid material deriving from erosion of slopes and banks and, in turn, resulting in silting of many areas of the river bed and coastal waters as well as in the formation of meanders, the well-known "braiding" phenomenon and mouth bars.

The conveyance of solid material, which the construction of dams has already modified to a great extent, is also connected with the correct balance of the shoreline. In terms of water quality, information concerning behaviour patterns of sediment transport is necessary to better evaluate the various phenomena of absorption and release of pollutants reaching bodies of water.

Obviously, all these data are to be integrated with those, of various origin, required to solve problems of environmental protection, soil conservation, and rational exploitation of resources, within the correct implementation of all forms of economic and social development in the territory concerned.

For the achievement of such objectives, accurate and quick access to data in the following fields is necessary:

- climatology and meteorology
  . air temperature at different altitudes
  . barometric pressure
  . winds
  . humidity
  . solar radiation
  . precipitation (rain, snow, hail)
  . fog
  . evaporation and evapotranspiration
- surface hydrology
  . water levels
  . flowrates
- underground hydrology
  . hydrogeological nature of soils
  . groundwater levels
  . groundwater circulation
- behaviour of glaciers and snowfields
- sediment transport
  . total, on the bottom, or in suspension
  . volumes of erosion and deposit

With regard to quality of surface and groundwaters, the setup of a monitoring system must aim at collecting data to be used in models capable of:

a) providing, at any stage, the overall picture of water quality;

b) evaluating, in "key sections" of important territorial systems, changes in quality resulting from improvement or prevention actions;

c) predicting, on the basis of such changes, evolutionary trends of the territories in terms of quality;

d) taking action, under exceptional conditions, by giving practical directions to face states of emergency.

Such objectives reveal a series of sectors in which wider knowledge is required.

In particular, cataloguing of bodies of water must be necessarily completed, in that a monitoring network cannot be conceived without taking into account the characteristics of such monitoring.

To this end, it is necessary:

a) to fill the existing gaps in the field of natural lakes and artificially regulated lakes, investigating in particular the aspects of the eutrophication according to OCDE's policy.

In the case of drinking water reservoirs, monitoring must take into account also sanitary aspects connected with the appearance of toxic algae. A similar problem arises in lakes with regard to bathing purposes.

b) With regard to flowing waters, the issues which are still to be discussed refer not only to parameters to be measured, but also to flowrate gauging. In general, monitoring may be set up in accordance with the Italian regulations, while a more comprehensive analytical picture will be required in particular situations (closing sections of basins, water intakes for drinking ese, etc.).

c) Problems referring to qualitative and quantitative cataloguing of groundwater resources are not less important. They require in the first place a monitoring network for pilot wells setup on the territory depending on the size of the population to be served, vulnerability of aquifers, location of pollution sources, etc. The water supplied by these wells will be tested according to both common parameters for the entire basin and specific parameters for areas subject to particular pollutant loads (e.g., herbicides in agricultural areas).

In all the cases considered, water quality monitoring raises problems concerning:

- sampling frequencies, planned to suit monitoring requirements (general problems, local problems, etc.), hydrologic and climatic cycles, water uses, etc.
- standardization of sampling procedures and analyses;
- the use of automatic instruments in sampling and analyses:
- the introduction of new analytical methodologies (e.g., the study of biocenoses).

The data thus collected in suitable centralized and peripheral hardware are intended not only for analyses of significance and representativeness but also for large-scale applications within the entire basin or in specific areas.

Therefore, data collection must have at its disposal not only the most advanced statistical "packages", but also dedicated software, the knowledge of which will orient toward typology and amount of data.

The following items are to be taken into due consideration and, if necessary, suitably developed and modified:

- automatic mapping programmes (G. I. S.)
- flood and low-water propagation models
- salt-water intrusion models
- air circulation models
- pollutant propagation models in surface waters
- groundwater circulation models
- pollutant propagation models in groundwaters

The development of the co-operation programme with scientific authorities of the United Kingdom should be based on these aspects, trying to get the best out of what has been already put into practice in both Countries. The methodologies taken into account and developed during these meetings must be adapted for use by the Po Basin Authority.

Planning meeting on liaison between NRA and Po River Basin Authority

Date: 4 May 1993 **Location: IRSA, Rome**

Discussion paper presented by NRA

1. **Basis for collaboration**

The NRA recognises that other European organisations share similar duties and responsibilities to itself, and therefore that opportunities exist for collaboration in areas of mutual interest. Potential areas of particular interest to the NRA for such collaboration include (a) improving the efficiency of water management activities, and (b) examining the application and interpretation of EC Directives.

The discussion paper looks at the possibilities of undertaking a bi-lateral project with the Po River Basin Authority, and involving other technical and scientific experts within the UK and Italy. The project needs to have specific objectives which are measurable in terms of success. The NRA - as a public and professional body - must fully justify its involvement in any new activity. Therefore, the particular areas proposed are based on achieving the benefits of collaboration within new initiatives and ongoing activities which are already approved within the NRA's Corporate Plan for 1993/94. For the NRA, the R&D project on Efficiency of Integrated Environmental Monitoring will form the principal focus for collaboration.

2. **General background information on NRA**

Various background papers are available which will enable our Italian Colleagues to understand the duties and responsibilities of the NRA. These will be reviewed at the meeting, but the NRA recommends that the following are circulated beforehand:-

(a) Corporate fold-out on NRA
(b) Annual Report and Accounts 1991/92
(c) Summary Corporate Plan 1992/93
(d) Annual R&D Review - 1992

3. **Specific objectives for collaboration**

(a) <u>Integrated Environmental Monitoring (Water Quality and Water Resources)</u>

- to develop techniques for optimisation of environmental monitoring networks for water management purposes. Emphasis will be on the optimisation of integrated monitoring networks covering principally water quality and water resources (quantity) determinands, but including ecological monitoring.

- in particular, to rationalise a programme of water quality monitoring as a high-priority new initiative for Water Quality function. An R&D project on Efficiency of Integrated Environmental Monitoring has already been approved for the start of the 1993/94 programme.

(b) Research and Development

- to seek solutions to common problems in water (quality and quantity) management through the exchange of technical know-how and collaborative research.

- to develop collaborative links with similar European research-funding organisations to the NRA and with other major European research centres to improve the efficiency and effectiveness of its research.

(c) External Affairs

- to raise awareness among European organisations, such as the Po Valley Authority, of the NRA's role and its significance as a regulator and a centre of expertise.

- to build up the NRA's scientific/regulatory network in the area of water resources (quality and quantity) management with other EC countries to ensure future EC initiatives for legislation are based on sound scientific and technical principles.

4. R&D project on Efficiency of Integrated Environmental Monitoring

The NRA currently spends about £75M each year on monitoring related to its Water Quality and Water Resources functions. This includes the monitoring of the environmental quality of Controlled Waters (rivers, lakes, groundwaters, estuaries and coastal waters); hydrometric monitoring (flow and water level); and also monitoring of industrial and sewage effluent discharges. Its procedures for sampling programme design and data interpretation have largely been inherited from the old Water Authorities in England and Wales whose regulatory duties it replaced in 1989. Recent developments in new techniques and equipment offer good opportunities for improving the efficiency with which monitoring information is obtained and used.

The proposed project would run in two main stages. In **Stage 1**, a draft protocol (i.e. standard procedures, methods and tools) would be developed for:

1. reviewing all the environmental monitoring currently undertaken in a catchment area by the NRA, examining its objectives, and quantifying its costs and benefits;

2. comparing the monitoring information currently generated with the NRA's actual information needs; and

3. producing and costing a new, integrated monitoring programme that meets the NRA's required needs in the most efficient and effective manner.

The draft protocol would then be tested in **Stage 2** - the implementation stage of the project. Case studies would be carried out in two widely different catchments within the NRA, and parallel studies in the Po Basin catchments. The resulting practical feedback would enable the protocol and associated data analysis tools to be refined; the final documented account of the case studies would serve as a working blueprint for the adoption of the protocol nationally and to promote common bilateral and European approaches.

The project would have two main **outputs**:

1. **the monitoring protocol** - a comprehensive set of procedures, manuals and software that could be used to underpin the efficient implementation of environmental monitoring throughout the NRA. (These would address statutory, technical, operational and cost-benefit issues); and

2. **the case study reports** - a detailed description of the practical steps needed to implement the monitoring protocol, serving as worked examples for anyone applying the protocol elsewhere.

More generally, the project would provide the NRA with confidence that the data collected and the information derived from it was consistent across the Regions and was statistically sound and necessary and sufficient to meet the needs of the NRA. Broader issues which could be addressed within the project.

<u>Project Outline</u>

(i) **Catchment Selection**

The project would address all the types of sampling points covered by the NRA's routine monitoring, including effluents, groundwaters, lakes, rivers estuaries and coastal waters. The extent to which special investigations and continuous monitoring activities covering weather, flows and water levels are covered should be reviewed during the planning stage of the study, particularly in relation to extreme storm events. It is proposed to run two catchment-based case studies within the NRA, representing between them the main features and activities found in rural, agricultural and urban areas.

(ii) **Determinand Selection**

The intention would be to cover all types of NRA data relevant to environmental monitoring as it relates to water resources (quality and quantity) management. This arises principally from chemical, hydrometric and biological monitoring. The integration of fish stock assessment and conservation monitoring would also be considered. Existing data analysis tools will probably need to be revised to accommodate these various non-chemical measures, and others may need to be created.

(iii) **Work Programme**

The first task for each catchment would be to review what monitoring is done currently, assess how much it costs and determine what useful information it provides, and whether it fulfils present and future anticipated management scenarios (in particular for the NRA the likely implications of implementing water quality objectives). These tasks would enable the sampling and analytical requirements to be specified in a practical and statistically robust way. Then, after taking due account of operational and other constraints, an integrated monitoring programme could be planned, costed, optimised in economic terms, and put into operation. The tools used for developing and implementing this overall programme would subsequently be available for use in other catchments and regions. Such tools would include manuals, software, simple expert systems and perhaps videos.

(iv) **Timescale and Phasing**

It is envisaged that the preparation of the draft protocol - including the development of any new methods of data analysis identified at that stage - would take 6-9 months. The effort subsequently needed for conducting the case studies will depend upon a variety of factors including the size of catchments chosen, the intended degree of involvement by NRA staff, the periods for which it was decided to scrutinise the existing and proposed future monitoring programmes. It is envisaged that this phase of the work would take around 18 months. In order to define the work programme and timetable more precisely, a planning study should be carried out prior to drawing up detailed proposals for the main project (i.e. Stages 1 and 2).

Related generic issues

The project could also provide a means of:

(i) assessing the available monitoring equipment and technologies available to measure the determinands;

(ii) reviewing data capture, analytical methods and quality assurance/control techniques;

(iii) reviewing the applicability and appropriateness of EC Directives to practical monitoring of environmental quality on an integrated catchment basis.

Issues (i) and (ii) would be particularly appropriate for specific scientific and technical collaboration between experts in each country.

5. **Decision of whether to proceed**

The meeting on 4 May should reach a clear conclusion on whether or not collaboration will provide real benefits.

The benefits of collaboration will be gained by each organisation learning from the parallel programmes of research. Both parties must be prepared to play their programmes in such a way that comparable outputs can be achieved from each national programme. A principle of liaison must be that the success of the NRA's component programme is not dependent on that of the parallel Italian programme.

6. **Next Steps**

If a decision to proceed with the planning stage is reached, each organisation should prepare a project definition paper for discussion at a workshop to be held in, say, July 1993.

The objective of the workshop will be to agree a collaborative programme of research aimed at specific outputs (which can be implemented to achieve improved effectiveness and value for money, as well as improvements in the related science or technology).

The coverage of papers for the workshop should be agreed at the meeting on 4 May. Some liaison would be needed between the two organisations in preparing the papers. Issues to be covered should include:-

(a) Objectives of monitoring programmes
(b) Present operational networks and gaps in knowledge
(c) Research issues and options
(d) Programme of research, exchange visits, meetings etc.
(e) Outputs from the collaborative programme
(f) Framework plan for management of the project, including cost and manpower estimates
(f) Links with other European Commission, EC states and international/national bodies

Particular consideration should be given to the development of links with the new EC ministerial group (EC Network of Enforcement Authorities).

National Rivers Authority
27 April 1993

QUADERNI

DELL'ISTITUTO DI RICERCA SULLE ACQUE

QUADERNI DELL'ISTITUTO DI RICERCA SULLE ACQUE*
(Autorizzazione del Tribunale di Roma n. 17228 del 14.4.1978)
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ALLEGATO I

Metodi analitici per le acque* - Piano dell'opera

Codice	Metodo	Anno	Lire
Sezione A - (Parte generale)			
**A-001	Strutture, attrezzature e reattivi di laboratorio		in ristampa
**A-002	Lineamenti di tecniche analitiche		in ristampa
**A-003	Metodi di campionamento		in ristampa
**A-004	Elaborazione dei risultati		in ristampa
Sezione B - (Determinazione di parametri fisici e chimico fisici)			
B-001	pH	1981	1.500
B-002	Temperatura	1979	1.000
B-003	Colore	1980	500
B-004	Materiali sedimentabili	1979	1.000
B-005	Materiali in sospensione	1979	500
B-006	Conducibilità		
B-007	Salinità		
B-008	Odore		
B-009	Torbidità		
Sezione C - (Determinazione di metalli e di specie metalliche)			
C-001	Alluminio	1988	2.000
C-002	Argento		
C-003	Arsenico	1983	3.500
C-004	Bario	1980	1.000
C-005	Berillio	1990	1.000
C-006	Boro	1982	1.000
C-007	Cadmio	1986	2.000
C-008	Calcio	1986	1.000
C-009-010-025	Cromo	1982	3.000
C-011	Ferro	1980	1.000
C-012	Litio	1986	1.000
C-013	Magnesio	1986	1.000
C-014	Manganese	1980	1.000
C-015	Mercurio	1986	2.500
C-016	Molibdeno		
C-017	Nichel	1980	1.000

Codice	Metodo	Anno	Lire
C-018	Piombo	1979	1.500
C-018	Piombo	1984	1.000
C-019	Potassio	1986	1.000
C-020	Rame	1980	1.000
C-020	Rame	1987	1.000
C-021	Selenio	1986	1.500
C-022	Sodio	1986	1.000
C-023	Stagno	1981	1.000
C-023	Stagno	1987	1.000
C-024	Zinco	1980	1.000
C-026	Tellurio	1991	1.000
Sezione D - (Determinazione di sostanze e parametri inorganici non metallici)			
D-001	Acidità e basicità		
D-002	Azoto ammoniacale. Metodo A:potenziometrico	1981	1.000
D-002	Azoto amm.le. Metodo B: spettrofotometrico	1982	1.000
D-003	Azoto nitroso	1981	1.000
D-004	Azoto nitrico	1986	2.000
D-005	Biossido di carbonio		
D-006	Solfuri	1984	1.000
D-007	Cianuri	1980	1.500
D-008	Cloro		
D-009	Cloruri	1979	3.000
D-010	Fluoruri	1983	2.000
D-011	Fosforo	1981	1.500
D-012	Ossigeno disciolto		
D-013	Silice		
D-014	Solfati	1979	1.500
D-015	Solfiti	1982	1.000
Sezione F - (Determinazione di sostanze e parametri organici)			
E-001	Azoto albuminoideo		
E-002	Azoto organico		
E-003	Sostanze oleose totali		
E-004	Oli minerali	1984	1.500
E-005	Grassi e oli animali e vegetali		
E-006	Carbonio organico		
E-007	Richiesta chimica di ossigeno (COD)	1981	1.500
E-008	Richiesta biochimica di ossigeno (BOD)	1981	2.500

Segue Allegato 1

Codice	Metodo	Anno	Lire
**E-009	Pesticidi clorurati		in ristampa
**E-010	Pesticidi fosforati		in ristampa
**E-011-012	Policlorodifenili e Policloroterfenili		in ristampa
E-013	Tensioattivi non ionici	1979	1.500
E-014	Fenoli	1979	1.500
E-015	Aldeidi	1978	1.000
E-016	Solventi aromatici	1984	2.500
E-017	Tensioattivi anionici	1983	1.000
E-018	Solventi organici clorurati	1978	2.000
**E-019	Erbicidi triazinici ed altri azotati		in stampa
Sezione F- (Determinazione di parametri biologici e microbiologici)			
F-001	Saggio di tossicità		
F-002	Coliformi totali		
F-003	Coliformi fecali		
F-004	Streptococchi fecali		

* I relativi raccoglitori sono in vendita al prezzo di Lit. 15.000 cad.

** Pubblicati in volume nella serie "Quaderni"

ALLEGATO 2

Metodi di analisi per acque di mare*

Codice	Metodo	Anno	Lire
	Indicazioni generali:		
	Fattori di conversione e di calcolo		
	Campionamento		
100	**Caratteristiche chimico-fisiche:**		
110.1	Trasparenza	1984	1.000
120.1	Temperatura		
130.1	Colore		
140.1	Salinità	1983	4.000
150.1	Materiale in sospensione	1984	1.000
160.1	pH		
170.1	Ossigeno disciolto		
200	**Specie metalliche:**		
210.1	Alluminio		
215.1	Argento		
220.1	Arsenico		
225.1	Cadmio	1983	1.000
225.2	Cadmio	1984	1.500
230.3	Cromo	1984	1.000
235.1	Ferro	1983	1.500
240.1	Manganese		
245.1	Mercurio		
250.1	Nichel	1983	1.500
255.2	Piombo	1983	1.000
260.1	Rame	1983	1.000
265.1	Selenio	1983	1.500
270.1	Zinco		
300	**Specie inorganiche non metalliche:**		
310.1	Azoto ammoniacale	1984	1.500
315.1	Azoto nitroso		
320.1	Azoto nitrico		
325.1	Azoto totale		
330.1	Fosforo ortofosfato solubile	1982	1.000
340.1	Fosforo totale	1982	1.000
350.1	Silice disciolta	1983	1.000

*

Codice	Metodo	Anno	Lire
400	**Composti organici:**		
410.1	Fenoli		
420.1	Oli minerali. Determinazione gravimetrica	1984	1.500
420.2	Oli minerali. Determinaizone spettrofotometrica (IR)	1984	1500
420.3	Oli minerali. Determinazione spettrofluorimetrica (UV)	1984	2.000
430.1	Tensioattivi anionici		
440.1	Pesticidi clorurati	1986	7.500
500	**Saggi biologici e microbiologici**		
510.1	Coliformi totali		
520.1	Coliformi fecali	1983	4.500
530.1	Streptococchi fecali		
540.1	Salmonelle	1984	2.500
550.1	Enterovirus		
560.1	Determinazione dell'adenosintrifosfato (ATP)	1988	1.500
570.1	Clorofilla	1990	1.500
600	**Prove di tossicità:**		
610.1	Saggio di ittiotossicità		

* In funzione delle esigenze che man mano si presenteranno, il piano dell'opera potrà subire modifiche ed integrazioni. I raccoglitori sono in vendita al prezzo di Lit. 10.000 cad.

ALLEGATO 3

Metodi analitici per i fanghi*

		Anno	Lire
Parametri biochimici e biologici:			
1	Generalità sull'esame microbiologico	1983	1.500
2	Valutazione dei raggruppamenti funzionali di microrganismi	1983	2.000
3	Microrganismi indicatori di inquinamento fecale	1983	1.000
4	Virus	193	1.000
5	Lieviti e ifomiceti	1983	1.000
6	Misure di attività e biomassa		
6.1	- Richiesta di ossigeno	1983	1.000
6.2	- Determinazione dell'adenosin trifosfato nei fanghi biologici	1983	1.000
6.3	- Determinazione dell'attività deidrogenasica	1983	1.000
6.4	- Determinazione del contenuto proteico	1983	1.500
7	Analisi della microfauna	1983	1.500
8	Analisi della fitotossicità della sostanza organica in decomposizione mediante bioassaggio Lepidium Sativum	1983	1.500
Parametri tecnologici:			
1	Solidi sospesi	1984	2.000
2	Solidi totali	1984	1.000
3	Densità	1984	1.000
4	Potere calorifico	1988	2.500
5	Distribuzione granulometrica		
6	Caratteristiche reologiche		
7	Sedimentabilità	1984	1.500
8	Tempo di suzione capillare	1984	1.000
9	Resistenza specifica alla filtrazione	1984	1.500
10	Compribilità	1984	1.000
11	Filtrabilità sotto vuoto	1984	1.000
12	Filtrabilità con nastro pressa	1988	1.000
13	Centrifugabilità	1984	2.500
14	Trattabilità per digestione anaerobica	1988	1.500
15	Appendice: Procedura di condizionamento chimico	1984	1.000

		Anno	Lire
	Parametri chimico-fisici		
1	pH	1985	500
2	rH	1985	500
3	Alcalinità e acidità		
4	Acidi volatili		
5	Sostanza organica	1988	1.000
6	Azoto	1985	1.000
7	Azoto ammoniacale	1986	500
8	Azoto organico		
8a	Azoto nitrico	1986	500
9	Fosforo	1985	1.000
10	Metalli pesanti totali	1985	1.500
11	Boro totale	1988	1.000
12	Solfuri	1986	1.000
13	Cloruri	1986	1.000
14	Fluoruri		
15	Silice		
16	Cromo esavalente	1986	1.000
17	Cianuri totali e clorabili	1992	3.000
18	Ossigeno disciolto		
19	Fenoli		
20	Tensioattivi anionici		
21	Oli e grassi	1988	1.500
22	Pesticidi organoclorurati	1988	1.500
22a	Pesticidi organofosforati	1989	2.500
23a	Solventi organici clorurati	1990	2.000
23b	Solventi organici aromatici	1990	1.500
24	Composti clorurati	1988	3.500
24a	PCB con colonne impaccate	1990	3.500
24b	PCB e PCT con colonne capillari	1990	
25	Idrocarburi policiclici aromatici	1990	2.000

Segue Allegato 3

	Anno	Lire
Parametri chimico-fisici		
Appendicc I: Campionamento	1985	2.000
Appendice II: Tests di cessione	1986	500
a) con acido acetico 0,5 M	1986	1.500
b) con acqua satura di CO_2	1986	1.000

* I relativi raccoglitori sono in vendita al prezzo di L. 10.000 cad

NATIONAL RIVERS AUTHORITY (U.K.) - PO RIVER AUTHORITY COLLABORATION PROGRAMME

PROBLEM

TO IMPROVE THE WATER QUALITY MONITORING PRACTICES AND ITS COST-EFFECTIVNESS

ACTION

IMPROVEMENT OF WATER QUALITY MONITORING IN RIVER CATCHMENTS

AUTORITA' DI BACINO DEL PO

NATIONAL RIVERS AUTHORITY

ISTITUTO DI RICERCA SULLE ACQUE

WATER RESEARCH CENTRE

PROJECT MANAGEMENT

STAGE 1: REVIEW EXISTING LEGISLATION AND MONITORING PRACTICES
REVIEW MONITORING NEEDS

STAGE 2: IDENTIFY BEST PRACTICES
PRODUCE DRAFT MANUALS

STAGE 2': IDENTIFY TEST CATCHMENTS

STAGE 3: REFINE/DEFINE TOOLS
TEST AND EVALUATE IN CATCHMENTS

STAGE 4: PRODUCE FINAL MANUALS

DISSEMINATION

PROGRAMME TIMETABLE

	1994	1995	1996
STAGE 1			
STAGE 2			
STAGE 3			
STAGE 4			

FUNDAMENTAL LEGISLATION

Law 4 August 1989, n° 283
URGENT MEASURES AGAINST THE EUTROPHYSATION OF THE ADRIATIC SEE

MISSION

REDUCTION OF THE POLLUTANTS, AND IN PARTICULAR OF NUTRIENTS, IN THE WATER COURSES, TO IMPROVE THE WATER QUALITY IN THE ADRIATIC SEE, BY MEANS OF THE FOLLOWING ACTIONS:

a - DEPURATION OF URBAN AND INDUSTRIAL DISCHARGES
b - DEPURATION OF ZOOTECHNICAL DISCHARGES
c - RE-DISTRIBUTION OF THE LIVESTOCK IN THE COUNTRY
d - REDUCTION OF PESTICIDES AND CHEMICAL FERTILIZERS IN AGRICOLTURE

FUNDAMENTAL LEGISLATION

Law 5 January 1994, n°36
PROVISIONS IN THE MATTER OF WATER RESOURCES

AIMS

RE-ORGANISATION OF THE PUBLIC SERVICES OPERATING IN THE FIELD OF:

a - POTABLE WATER DISTRIBUTION
b - SEWERS
c - WASTEWATER DEPURATION

WITH THE AIM TO:

- IMPROVE THE COST-EFFECTIVNESS OF THE SERVICES
- GUARANTEE A GOOD QUALITY STANDARD AT A FAIR PRICE

MISSION

- GUIDELINES AND CO-ORDINATION OF THE TERRITORIAL AND FUNCTIONAL RE-ORGANISATION
- UPDATE THE WATERWORKS PLANNING AT THE CATCHMENT SCALE
- GUIDELINES FOR COST-ANALYSIS
- CO-OPERATION WITH THE SURVEILLANCE COMITTEE

MAIN CRITICITIES IN THE FIELD OF WATER QUALITY :
POLLUTANTS AND GEOGRAPHIC AREAS

PROBLEM

POLLUTION OF GROUNDWATER DUE TO NITRATES, ERBICIDES AND PESTICIDES
POLLUTION OF FRESHWATER DUE TO NITRATES AND PHOSPHATES

INTENSIVE AGRICULTURE AND STOCK-FARMING

STOCK-FARMING
4.919.000 PIGS
3.561.000 CATTLE

CRITICAL AREAS
-PIEDMONT - HIGHLAND
-LOMBARDY - S-W MILAN
-BRESCIA-CREMONA-MANTOVA PROVINCES
-ENZA, CROSTOLO, SECCHIA CATCHMENTS

INTENSIVE AGRICULTURE

RICE-FIELDS IN THE PROVINCE OF NOVARA

INTENSIVE MAIZE COLTURE NORTH OF THE RIVER PO

PROBLEM

POLLUTION OF GROUNDWATER AND FRESHWATER DUE TO HEAVY METALS, PHENOLS, HYDROCARBONS, SURFACE-ACTIVE AGENTS, ORGANIC SUBSTANCES

AREAS PRESENTING HIGH POPULATION AND INDUSTRIAL DENSITY

LAMBRO CATCHMENT (MILAN)

TURINESE AREA

OTHER AREAS:
MODENA, REGGIO, PARMA, CUNEO, MANTOVA, VICENZA, BRESCIA, BERGAMO

PROBLEM

POLLUTION IN ALPINE LAKES DUE TO NUTRIENTS, PHOSPHATES, NITRATES, BACTERIA

ALPINE LAKES:
MAGGIORE, COMO, GARDA, IDRO, ORTA, ISEO, MANTOVA, BRIANTEI

INFORMATION PAPERS

A procedure for evaluating aquifer vulnerability on a regional scale using computerized systems, a case study

Angelo Cavallin[1] and Giuseppe Giuliano[2]

ABSTRACT

The first results of research on the assessment of aquifer vulnerability of the Po plain are presented. The goal of this research is to produce a pollution risk map of the Po plain for planning purposes. The first step in this work has been the production of an aquifer vulnerability map using the distribution of factors that control the groundwater pollution potential: depth to water table, recharge, aquifer media, soil media, topography, impact of the vadose zone and conductivity of the aquifer. Data were digitized with Arc/Info and processed in raster format using ILWIS.

The area selected for procedure validation includes the Po river valley and the Veneto-Friuli plain (northern Italy), which covers an area of approximately 45,000 km^2. The aquifer system represents a primary source of public water supply, but it is also used intensively by industries and to some extent for agriculture.

Groundwater is contained in a thick Quaternary cover comprising fluvio-glacial sediments in the pre-alpine zone, fluvial sediments in the central and pre-Apennine zone and deltaic-lagoon sediments near the Adriatic coast. The sediments fill a tectonic depression affected by subsidence since the Tertiary.

The area has one of the highest concentrations of human/economic activities (industrial, agricultural, cattle-breeding, etc) in Europe. They present a very prominent potential for contamination of groundwater resources, caused by different production functions, land covers and uses, as well as liquid and solid waste disposal. Frequent episodes of groundwater contamination have been recorded in the recent past, with serious consequences for the conditions of public water supply to cities and communities. These episodes clearly demonstrate the necessity of preventive action to protect water supply sources in the area, taking into consideration the new legislative regulation (DPR 236/88) and the recent re-organization of water resource planning and management processes and structure (law 183/89).

The Water Research Institute of the National Research Council has promoted a research programme on experimental mapping of vulnerability and pollution risk of important hydrogeologic systems, such as the study area. The aim is to define a reference method for designing a framework and tool for evaluating planning alternatives for groundwater protection. The representation should be dynamic and combine the concepts of (1) natural systems' vulnerability, (2) pollution loading caused by human activities and (3) the potential pollution risk, which is derived from the combination of the first two.

Computerized methods and tools are used for mapping—from the input of geo-referenced data, to the construction of databases, application of algorithms and evaluation models, and output production. The research is being carried out in collaboration with the National Geological Service, and has included the collaboration of experts from universities in the project area, the Group for the Geomorphologic Map of the Po Valley and other scientific bodies.

HYDROGEOLOGIC FRAMEWORK

The area is made up of sediments (of different facies and of Quaternary age) which vary in texture from coarse gravels in the piedmont band, to silts and clays in the lowland zone [10, 11, 12, 13]. Both porosity and permeability are highly variable.

The structure of the tapped aquifers varies from the undifferentiated type in the piedmont zone, to the multilayered type in the middle zone of the plain and the confined type in the lowland zone (Figure 1). The depth of free water tables ranges from several tens of meters in the piedmont zone to a very few meters in the middle and low plains. Although aquifers are always found in the plains, they are rarely used for public water supply.

The hydrogeologic system is recharged by effective

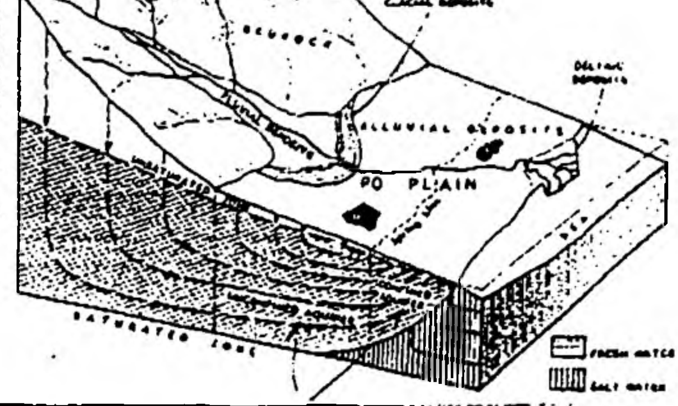

FIGURE 1 Schematic representation of the hydrogeologic system

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The research described here was carried out in the context of the research programme on the vulnerability and pollution risk of aquifer systems, promoted by the Water Research Institute (IRSA) of the National Research Council (CNR).

precipitation in the upper plain, dispersion of fluvial water in the piedmont zone and transmission of the groundwater contained in the permeable parts of the substratum where there is direct contact with the permeable deposits of the plain. The free aquifer flows toward the Po course valley, and it discharges into the sea in the Veneto-Friuli plain as well as in the Romagna plain.

AQUIFER VULNERABILITY

The term "vulnerability" is used here to identify the set of features of a hydrogeologic complex that gives rise to its susceptibility to receive and diffuse a soluble or water-transported pollutant [7]. These features are related to different natural processes which can affect the pollutant pathway, resulting in an irregular pattern of acceleration and attenuation of the front. This definition of vulnerability refers here to the natural system alone, and includes several variables, each having its own relative weight.

The evaluation of aquifer vulnerability does not take into account the properties of the pollutants, which are considered non-reactive. This should generally give more conservative evaluations, and is actually true in a large number of cases because the liquid-liquid or solid-liquid interactions lead to a significant decrease in concentrations because of different physical-chemical processes. Furthermore, diffusion features of solutes are not considered in the evaluation of transport phenomena because of their low incidence, at least at a regional scale.

The application of the concept of vulnerability to aquifers excludes any human interference in the set of mechanisms responsible for contamination. In this sense, the likelihood of contamination by direct injection of pollutants into the aquifer (from discharging wells) is not taken into account. Vulnerability may be considered as one of the key variables for evaluating pollution risk using the equation proposed by UNDRO:

Risk = hazard x vulnerability x value

In hydrogeology, hazard is related to the probability that an event of given intensity will occur within a given return period [5, 6]. Vulnerability is the aptitude for accepting the event; the value, expressed in social and economic terms, refers to the object affected by the event.

There are essentially two types of methods that can be used for either evaluation of groundwater resource vulnerability or risk distribution over the territory:

(1) mathematical analysis, numerical or analytical, of the phenomena which can be schematized as models of physical processes. They are mainly deterministic methods, highly appreciated for their reliability, but requiring huge amounts of input data. They are used in the design of water supply systems, for delimiting protection areas of wells and for designing restoration projects.

(2) procedures based on the value ranking of attributes. They are dependent on a general knowledge of the physical processes and their controlling factors. In this sense they are a substitute for a physical description of the phenomena.

The discussion here is limited to this last type. The greater the number of variables involved, the greater the usefulness of such procedures, though it can be difficult to manage, compare and superimpose a number of matrices as large as the variables set.

There are several different proposals of this type [4] and they are applicable to various situations, with special reference to risks associated with landfills, based on rating criteria (SRM, see [14]), or on situation classification (HRS, see [3]). The outcome of such procedures is always a relative evaluation.

The advantage of methods that use a multiple criteria type approach is represented by the possibility of making a comparative evaluation of situations that are structurally different and geographically distinct. The procedure discussed here is a standard one called "Drastic" [1] based on the classification of the seven factors most relevant in respect of pollution propagation. The result is a zonation of the territory concerned.

THE METHOD ADOPTED

The research was developed in several steps (see Figure 2):

- analysis of documentation sources and information available from different public bodies, scientific institutions and both private and public consortia [10, 11, 12, 13] and integration of the relevant data
- data storage with geo-referenced coding of base maps and their attributes on electronic spreadsheets
- data processing with filling and interpolation of spatial data (gridding), rating of variables with appropriate weighting, and calculation of the final index of vulnerability by means of a GIS able to process data in raster format [2]
- representation of results using computerized mapping methods able to solve problems associated with amount and density of data and the necessity of updating.

The need to store and represent large amounts of spatial data requires the use of automated systems. The effectiveness of studies and the usefulness of the results depend to a large extent on the evaluative capacity of the GIS adopted. Arc/Info was used for data storage; ILWIS was used for overlaying the different thematic maps [15] in raster format. In this context, a thematic map is represented by a matrix covering the entire area (2041 x 1081 pixels), where each territorial unit element (250 x 250 m) is characterized by an attribute.

The vulnerability of a hydrogeologic system can be estimated by applying the "Drastic" method [1], through a complex sequence of ranking and evaluation operations based on seven variables:

(1) Water table depth from topographic surface. This is the minimum distance that a pollutant has to travel to reach the saturated zone. In this case, the depth map was obtained by subtracting the water table elevation (m asl) from the topographic surface elevation (m asl).

(2) Natural system recharge. This process was here limited to vertical feed. It brings about an increase in vulnerability in two ways: indirectly because a greater recharge gives a higher degree of saturation and thus a higher value of permeability of the unsaturated zone; directly because infiltration acts as a pollutant transport vector. In the area concerned, the recharge

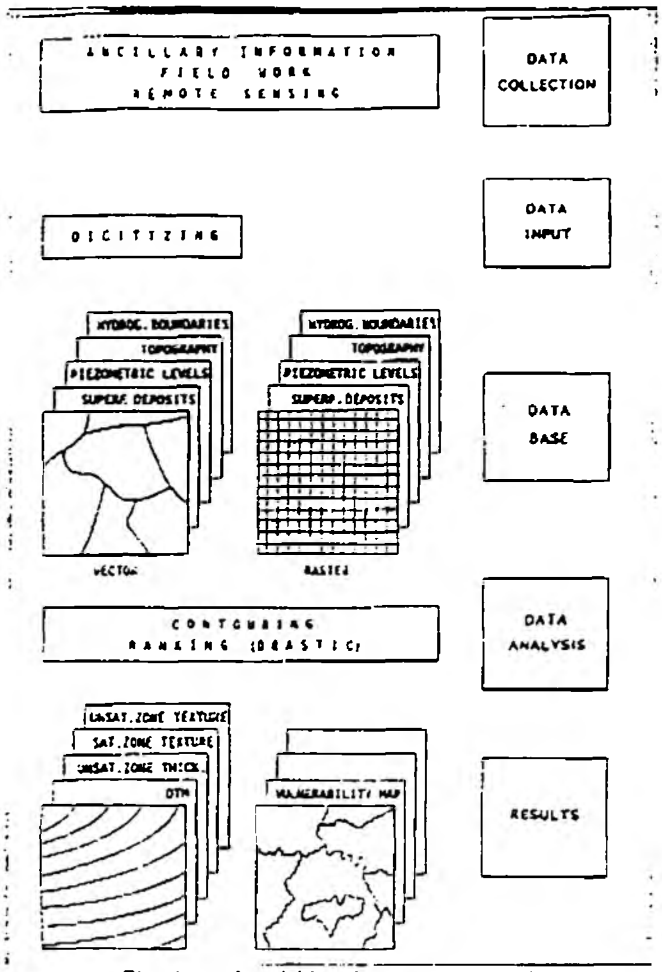

FIGURE 2 Phasing of activities for map production

was estimated on the basis of the mean annual isohyetes of the period 1921-1970.

(3) Lithology of saturated zone. Textural and formational features of aquifers are control factors of pollutant diffusion when they reach the saturated zone. The characteristics that play an important positive role are grain size heterogeneity and vertical anisotropy in the case of groundwater reservoirs with primary permeability. The data were drawn from literature.

(4) Soil features. Here it is intended to define the role played by the uppermost soil layer in the pollutant transfer process down towards the water table. There is a well-known direct relationship between pedogenesis, on the one hand, and soil permeability and purifying capacity on the other. The more advanced the process, the greater the protection of the aquifer. Synthetic data made available by the Group for the Geomorphologic Map of the Po Valley were used; they refer to texture at 1 m depth.

(5) Topography. This was defined as steepness, all other conditions being equal. The greater the steepness, the greater the surface runoff, *ie*, the less likelihood there is of infiltration and pollutant transfer. The orginal map drawn up by the Group for the Geomorphologic Map of the Po Valley was used, along with processed data from regional technical maps (scale 1:10,000 or 1:25,000 for the piedmont) for the necessary integrations.

(6) Lithology of non-saturated zones. The characteristics of the vadose zone through which the pollutant passes, flowing down to the water table, were evaluated. It was assumed that the degree of protection is proportional to the occurrence of fine-grained fractions in the unsaturated one, considering the increase induced in the exchange capacity and the decrease in permeability. Data from literature [10, 11, 12, 13] were used with some integrations.

(7) Hydraulic conductivity of the aquifer. This is the relationship between groundwater resources and aquifer permeability. Values obtained from textural data were used in the evaluations.

After the preparation of the seven thematic maps for these seven variables, seven other maps were produced in which a relative value was assigned to each data range. A correlation function (data vs value) was defined where the value in any case ranged from 0 to 10. Figure 3 shows an example of a thematic map.

After the same ranking range (0-10) was assigned, it was necessary to distinguish the different values obtained for each variable in relation to the role or weight it plays in the evaluation of vulnerability.

The weight scaling gives a value of 5 to water table depth and non-saturated zone lithology, a value of 4 to recharge, 3 to saturated zone lithology and conductivity, 2 to soil and 1 to topography. The index of vulnerability is obtained as the product of weight times value. The final index is obtained by summing the seven indices and a subsequent normalization. The final evaluation of vulnerability thus lies in the range 100 (maximum value) to 0 (minimum value); the resulting map is shown in Figure 4.

CONCLUSIONS

The proposed procedure for evaluating regional vulnerability can be applied only to situations where free surface aquifers with main vertical recharge are found. A territorial information system was used, which is able to update and perform synthetic mapping. It is necessary to emphasize that both static (soil characteristics, saturated and non-saturated zone lithologies, topography, hydraulic conductivity of aquifers) and dynamic conditions (depth of water table and recharge) are to be considered in the vulnerability evaluation.

The variability of dynamic conditions over time results in a variation in the degree of vulnerability. Thus any evaluation of vulnerability has to be made taking into account the possible variations in the relevant data. Using the proposed procedure, the following are also possible:

- to evaluate and compare different territorial situations at a national scale because variables, functions and weights can be used in a unique way
- to diminish the subjectivity of different operators, as well as their tendency to over-extend or over-reduce the vulnerability range
- to update with GIS data on time-variant factors, data-value functions and their relative weights.

Limitations to this method may be induced by:

- evaluations referring only to vertical vulnerability
- definition of variables, functions and weights based on an incomplete knowledge of the physical processes involved
- insufficient representativeness of available data to analyze the behaviour of the natural system.

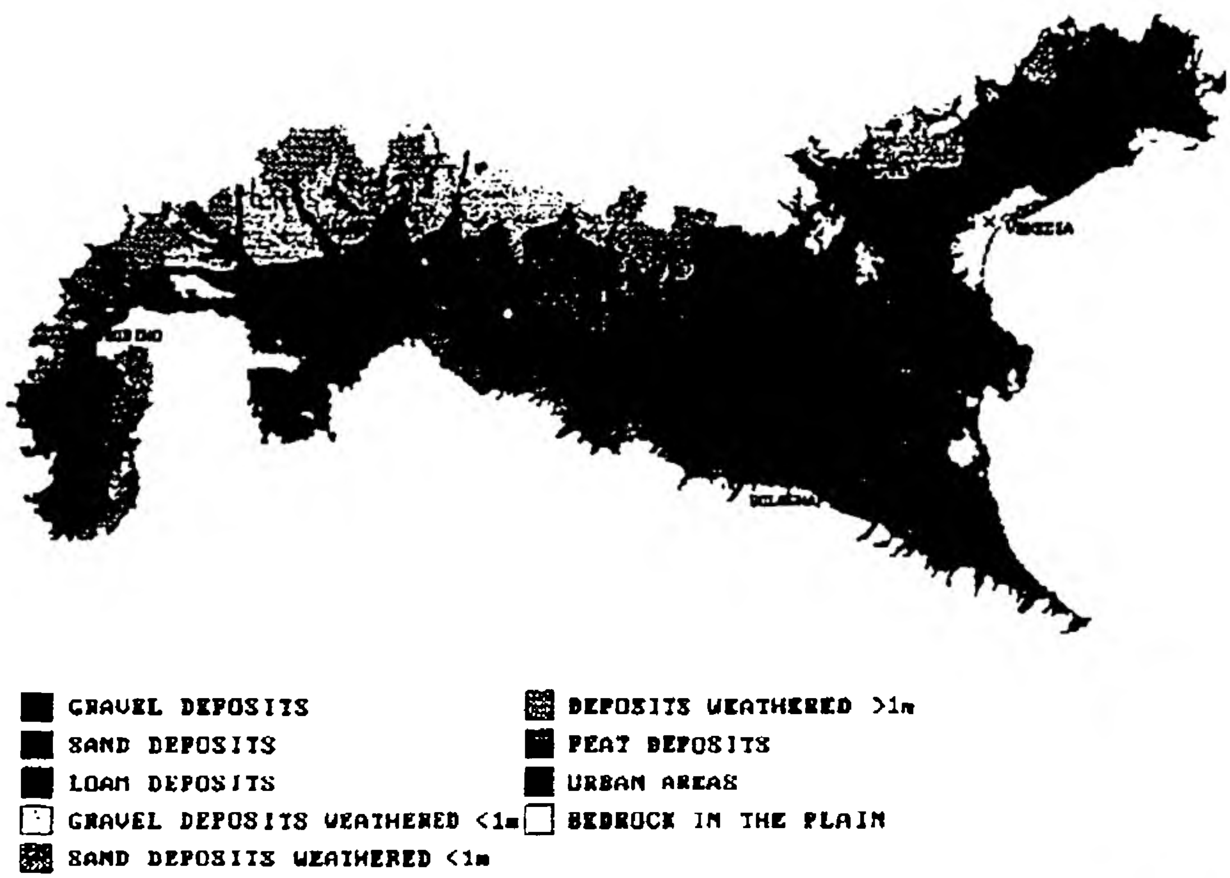

FIGURE 3 Output of the values of surficial deposit mapping

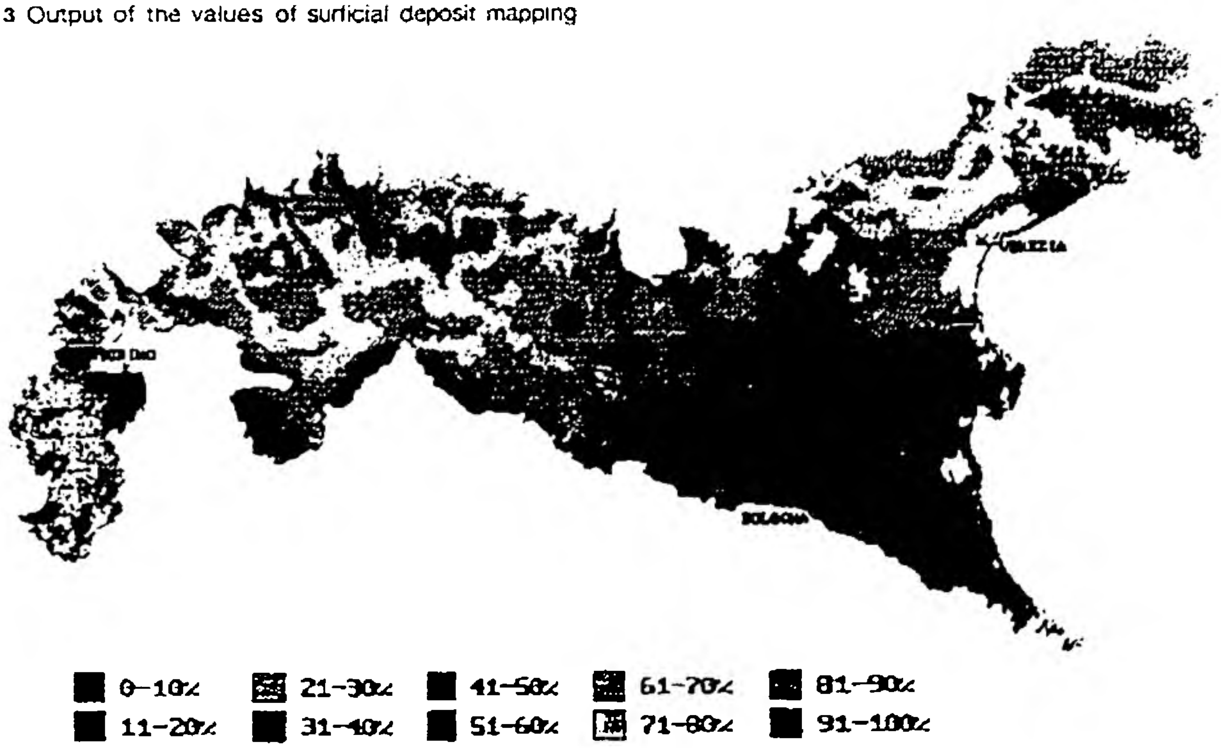

FIGURE 4 Output of aquifer vulnerability mapping

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RÉSUMÉ

Les premiers résultats des recherches sur la vulnérabilité aquifère de la Plaine du Po sont présentés. Le but de ces recherches est de produire une carte de risque de pollution de la Plaine du Po à des fins de planification. La première étape de ce travail a été la production d'une carte de vulnérabilité aquifère utilisant la distribution de facteurs contrôlant la pollution potentielle des eaux souterraines: profondeur jusqu'à la nappe d'eau, recharge, les moyens aquifères, les moyens du terrain, topographie, impact de la zone de percolation et conductivité de l'aquifère. Les données ont été numérisées avec Arc/Info et traitées en format raster à l'aide de ILWIS.

RESUMEN

Se presentan los primeros resultados de la investigación dela evaluación de la vulnerabilidad del acuífero de la planicie del Po. El objetivo de esta investigación es la de producir un mapa de riesgos de contaminación en la planicie del Po con fines de planificación. El primer paso en este trabajo ha sido la producción de un mapa de vulnerabilidad del acuífero usando la distribucion de los factores que controlan la polución potencial del agua subterránea: profundidad de la napa freática, recarga, condiciones del acuífero, condiciones del suelo, topografía, impacto de la zona vadosa y conductividad del acuífero. La información fue digitalizada con Arc/Info y processada en formato de celdas usando ILWIS.

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Aquifer vulnerability and groundwater resource management in the Po and Venetian Plain (Northern Italy)

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ABSTRACT: This paper describes the hydrogeological characteristics and the problems induced by groundwater exploitation and aquifer vulnerability of the largest Italian plain, where the most intense productive systems and the 37% of the total Italian population are concentrated. The aquifers are made up of prevalently alluvial thick sedimentary sequences defined as a monostratum system although large portions of it appear in many areas to be subdivided into several compartmented levels. At the foot of the mountains where the aquifers crop out and are characterised by a high permeability, several cases of pollution, deriving mainly from nitrates, have taken place. Indeed, in these areas the distribution of the richest groundwater resources coincides with the presence of the most intense industrial and farming activities. Also the groundwater protection and safeguard measures have been so far largely neglected by the responsible public boards which in most cases have simply increased the potability limits fixed by national and European laws, without enterprising adequate upgrading initiatives. Only in recent times the government has given to the Universities and other research Boards the task of investigating the hydrogeological characteristics of the Po and Venetian Plain in order to produce groundwater vulnerability maps, whose methods of elaboration are briefly illustrated.

1 INTRODUCTION

Northern Italy is characterised by a vast plain formed by alluvial sediments, deposited on an area of over 69,000 km² (23% of the whole Italy), stretching continuously from the Po Plain to the west (corresponding to the River Po and its tributaries) to the Venetian Plain to the east. To the north and west it is surrounded by the Alps, to the south by the Apennines and to the east by the Adriatic Sea (Fig. 1). Its maximum altitude is 600 m (western extremity) whilst its average height is less than 50 m. The humid-temperate climate is characterised by rainfall ranging from 600 mm along the southern margin to 2,000 mm on the north-eastern sector. Precipitations are prevalently concentrated in the spring and autumn. The summer months are the driest with a rainless period that can last up to three or even four months, with a consequent sharp increase, compared with the average amount, in the water demand for civil and farming purposes.

With relation to the favourable climatic and morphological conditions of this vast plain, which is the third largest in Europe, the highest population concentration, as well as the farming and industrial activities of the whole of Italy are here found (over 21 million inhabitants corresponding to circa 37% of the total national population, with a density of 310 people/km², compared with a national average of 186). The residing population is mostly concentrated in the numerous towns (urban population up to 90% in over 2900 municipalities) but many rural houses scattered in the countryside, where each farm has an average surface of c. 60 ha, are still inhabited.

The utilised farming surface is c. 40,000 km², with over 12 million heads of farm animals, and corresponds to 25% of the national farming surface. On it, though, about 50% of the total cattle farming and 70% of the pig farming is concentrated, while 3.6 million people work in the industrial sector (61% of the national industrial workers).

It is obvious that within this context of demographic and economic development the hydric demand is particularly high, both for water-supply purposes and for farming and industrial use. Nearly everywhere on this plain, the main hydric supplies are constituted by groundwaters although during the last decade widespread and serious cases of pollution have occurred, undermining the water quality and posing new problems, which are dealt with in this article, for a correct exploitation and management of this important resource.

2 HYDROLOGICAL SCHEME

The Po and Venetian plain is formed by the Quaternary alluvial deposits of the River Po, of its main and minor tributaries and other watercourses flowing in the eastern sector of the plain. The

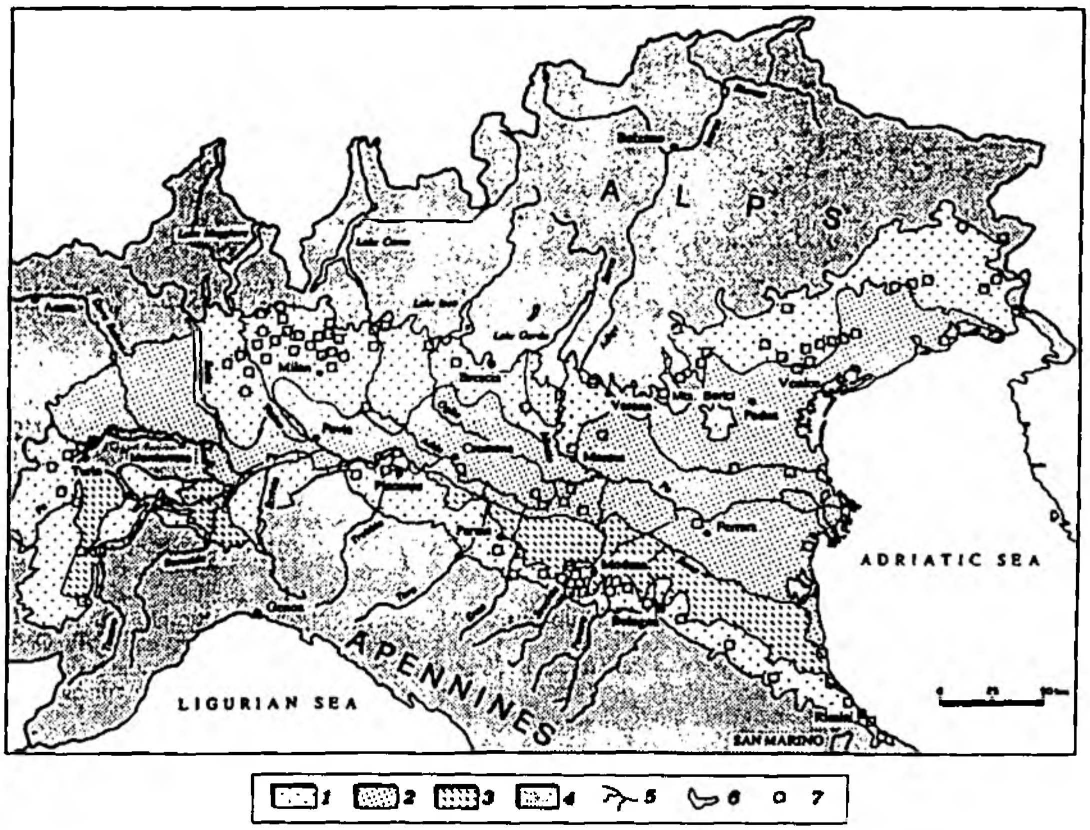

Fig. 1 - Schematic hydrogeological map of the Po Valley and surrounding areas. Legend: 1) gravels and coarse sands with high productivity aquifers; 2) sands and subordinate gravels and silts with high to low productivity aquifers; 3) silts, clays and subordinates sands with low to very low productivity aquifers; 4) Alpine and Apennine bedrocks; 5) main water courses; 6) lakes; 7) main wells for water-supply purposes.

sedimentary basin is strongly subsiding, although in a markedly differentiated way. In fact the base of the Pliocene which shows a very articulated surface, conditioned by the tectonic structures of the substratum, reaches in some points a depth of about 6,000 m, while the average thickness of the Pliocene-Quaternary sequence is c. 3,500 m of which over half are attributed to the Quaternary. Continuous and generalised marine sedimentation started in the lower Pliocene and went on until the end of the lower Pleistocene, even if the conclusion of this sedimentary cycle was not synchronous in all the area since several ingression and regression cycles are recorded in concomitance with different glacial episodes (in the Quaternary Europe was affected by at least four ice ages). Also the overlying continental deposits show an extremely variable thickness (up to 300 m and beyond) still controlled by the deep substratum structures. From the particle-size point of view, the sediments are made up of gravels and sands at the outlet of the watercourses into the plain, whilst in the central part and toward the coast silts and clays prevail.

The base of the aquifer does not correspond to a well defined physical limit but rather to the fresh water-salt water interface, whose trend is conditioned by the buried tectonical structures which determine differential squeezing phenomena of the coeval waters. In some areas (culmination of buried anticlines) located also in the centre of the plain, the thickness of the aquifer saturated by fresh waters is reduced to less than 50 m, whilst elsewhere, usually in correspondence with synclines, it can reach 700 m. One can estimate that the average aquifer thickness is about 200 m, although, as discussed later, the exploitable level is much thinner than that.

From a regional and structural viewpoint, the aquifer makes up a monostratum system (Castany & Margat, 1977), although in large portions in the central part of the plain and along the coast-line, it clearly appears to be subdivided into several layers.

At the foot of the Alpine and Apennine chains the gravels and sands of the fluvial and glacio-fluvial deposits form an indifferentiated stratum of unconfined groundwaters often without a low-permeability cover. Towards the centre of the plain it is subdivided into more layers ("multi-compartmental monostratum") characterised by the presence of thick covers of fine sediments and confined groundwaters.

Considering the particle-size distribution of the sediments, the aquifers' feeding takes place in the upper plain, at the margins with the hills, where the aquifers outcrop. The effective infiltration of meteoric waters, determined also by means of theorical models and direct measurement, is up to 25-30% and depends mostly on the soil permeability and local meteo-climatic characteristics. As for the relationships between surrounding mountains and watercourses, the situation appears to be extremely differentiated in the various sectors.

Hydric exchanges with the aquifers located along the hill margins are possible and have been found only in the upper part of the north-eastern plain at the foot of the Alps, east of Milan as far as Trieste, due to the presence of fissured carbonatic formations often of Karst-type (southern calcareous Alps). In other sectors (i.e. in southern Piedmont), these exchanges take place only locally and occasionally or are totally absent (southern plain, near the Apennine margin). In the Piedmont and Lombardy plain (north-western sector) the presence of terraced alluvial deposits with surfaces in some cases considerably high compared to the valley bottoms (up to 50 m) is quite common. They sometimes constitute important superficial phreatic aquifers with groundwaters often drained away by the underlying rivers. In their turn, these aquifers receive water also from the surface irriguous network, water reservoirs and storage basins connected with the cultivation of rice (Piedmont). In the Venetian plain (eastern part) and in the southern sector bordering the Apennines the watercourses together with the irriguous canals play a major rôle for the underground hydric balance and the feeding of the aquifers, owing to the different morphological conditions. Indeed, they contribute to at least 30% of the groundwater reserves as witnessed by some experimental measurements carried out on some rivers of the Venetian plain (Antonelli & Dal Prà, 1980): for each river investigated the annual flow-rates dispersed underground are evaluated as 2 to 3 m^3/s per kilometer of dispersing water-bed.

Due to these hydrogeological conditions (outcropping or nearly outcropping aquifers and feeding characteristics), all the high plain located at the foot of the mountain chains appears to be affected by a very high degree of vulnerability to pollutants. In these portions of the plain the highest transmissivity values are recorded and, when pollution phenomena are absent, the best water is pumped out of these aquifers, from the qualitative viewpoint. Instead, in the central part of the plain and along the sea-coast where the aquifers are confined, extremely long times of permanence of the waters underground are recorded (even more than 25,000 years, cfr. Venturini *et al.*, 1990). Therefore low or negative redox potentials are established with groundwaters showing NH_4, Fe and Mn concentrations much higher than the limits fixed for drinkable waters by the World Health Organization. Unfortunately, at least 30% of the Po Plain groundwater resources is characterised by these unfavourable chemical conditions.

3 EXPLOITED HYDRIC RESOURCES

Since ancient times (sometimes already in the Roman period) in all the Venetian and Po Plain groundwaters have constituted, apart from few exceptions, the most important or exclusive hydric resource for water-supply purposes and, in more recent times, for industrial and farming activities as well. Due to their hydrogeological conditions, to their quality and high transmissivity, the most important wells for water-supply uses are located in the upper plain sectors, at the foot of the mountain chains, where also the main urban centres are found together with the most important industrial and farming activities. A coincidence is therefore established between the areas characterised by the best hydrogeological conditions for groundwater supplying purposes and the production settlements, the latter being the main hazard sources for water quality maintenance.

Within the project of a complete restructuring of the water-supply sources, the problem of a consistent water demand in the northern sector could be in the long term overcome by turning to a more efficient exploitation of the mountains' groundwaters (Alps) and of the main watercourses, already characterised by the presence of numerous dams and reservoirs. Moreover, these rivers show a rather constant flow also in the summer while the great Alpine lakes (such as Garda, etc.) could constitute potentially exploitable extra storage basins. Instead in the southern sector, south of the River Po, the groundwaters are an irreplaceable resource since in the summer the watercourses are characterised by extremely low or next to nil flow rates. Even the geological characteristics represent an obstacle for the construction of water reservoirs, owing to the stability problems given by the widespread flysch and clayey soils which determine also a high solid transport of the rivers.

The pumpage and distribution of the groundwaters takes place mainly through private wells (with a density of up to 10 wells per square kilometer) since the water-supply networks are extremely fragmentary and managed only at a local scale for civil and urban purposes. Only in very few cases centralised systems of distribution are present at a district level. In some urban centres, with populations up to 5,000 inhabitants, there are no water-supply networks and each household relies on its own well. Inevitably, in these situations there are no adequate controls on the drinking water quality. The water pumped from the subsoil and used for urban supply is subjected to treatment with sodium hypochlorite, for safety reasons. Instead, the groundwater rich in iron, manganese and ammonia is subjected to hypochlorite break-point treatment (induced advanced oxidation) for the same reason.

From a managemental point of view, the main problem is given by the fact that the pumpage centres, being very scattered and located in intensely populated areas, present serious difficulties for a correct safeguard and management of groundwaters. In nearly all the developed countries the safeguard of the water-supply sources is guaranteed by the definition of protection zones which are combined with specific monitoring systems. In this situation, however, these protection techniques would be ineffective and inapplicable since they imply such rigorous restriction measurements that no other use or development of the territory would be possible. In fact, in many large towns the pumpage points which originally were located in peripheral areas, are now well inside the urban centres, making the application of any protection norm impossible. The situation looks even more serious if compared with the aquifer high vulnerability to pollutants, since the development of vast industrial and urban areas has inevitably increased the proliferation of many kinds of real and potential groundwater pollution sources.

4 THE QUALITY OF GROUNDWATERS

During the last 40 years an intense urban and industrial development has occurred, in most cases without adequate and rational planning norms which could have prevented enivironmental degrading and pollution, thus determining a progressive decline of the quality characteristics of groundwaters. In nearly all the situations, the disposal of industrial waste has taken place in an uncontrolled way, directly on the soil or subsoil, whilst agricultural and farming procedures have used more and more chemical substances such as fertilizers, pesticides and weedkillers.

In the Po and Venetian Plain at least 60% of all national high hazard industrial plants is concentrated, as well as an undetermined amount of liquid and solid waste, while it has been assessed that agricultural and farming activities scatter into the environment 400 Mkg/y N equivalent and 80 Mkg/y of chemicals. Among the factors contributing to the deterioration of the groundwater quality one should mention the thousands of poorly bored and managed wells which link together the most superficial and often polluted aquifers with the deeper ones. Also quarrying activities of soil materials have noticeably increased the pollution risks by digging deep trenches as far as the aquifers' top, thus depriving them of the natural self-depuration processes that take place through the ground and the unsaturated soil layer.

The most characteristic problems of man-induced pollution in the territory of this area can be ascribed to three kinds of substances: organic-halogenic compounds, nitrates and weedkillers. The pollution cases referred to the first group of substances (tri- and tetra- ethylene chloride, chloroform, etc.) have been recorded in Lombardy since the early 1970s; in this region the groundwaters are used for supplying over 2 million people. Similar problems have also occurred in Piedmont and Veneto, with over 1.5 million people involved. The aquifers' natural high vulnerability to pollutants and the presence of well developed mechanical, textile and galvanic industries have sometimes determined in the groundwaters maximum concentrations up to 500 mg/l. The origin of pollution due to industrial waste disposal is also confirmed by the frequent association of organic-halogenate substances with toxic metals, in particular chromium. In some cases the extension and intensity of these pollutants has caused the total elimination of water-supplying sources and the resort to alternative resources. Otherwise, where possible, the waters have been chemically treated in order to make them suitable for human consumption. In some other situations provisional exceptions to the national and EC norms regulating the quality of drinkable waters have been granted.

The nitrate contamination deriving from fertilising and farming activities, as well as from leaks in the sewage pipes, reaches sometimes extremely high levels up to and beyond 150 mg/l. To the areas with the highest pollution values, still relatively limited, is nearly always superimposed a widespread constant level of pollutants of 5 to 15 mg/l (according to national and EC norms the recommanded values are 5 mg/l while the maximum admitted concentration is 50 mg/l).

As for weedkillers, the first recordings of pollutants go back to the 1980s, following the more reliable and detailed analyses performed in this period, and concern the rice and maize cultivations where atrazine, symazine and bentazone have been detected in the groundwaters. Generally the contamination of groundwaters has an extensive character, with peak concentrations only at a local level, affecting mainly the northern sector of the plain (Piedmont, Lombardy and Veneto regions), where pollutants can easily be transmitted from the superficial aquifers into the deeper ones through the hydric wells which intercept several aquifers arranged one above the other.

5 CONCLUSIONS: MANAGEMENT AND CONTROL TRENDS

As mentioned before, groundwaters make up one of the most important elements for the developing activities of the Po and Venetian Plain but, nevertheless, during the past ten years not much has been done to adequately contrast the rapid decline of these vital hydric resources. Rather than enterprise effective policies of control and safeguard, both on a national and local scale, up to now the government initiatives have just been directed to granting disputable exceptions to the potability limits fixed by national and European laws. In other cases, alternative hydric resources have been sought after or water has been conveyed from nearby areas. In any case, a global approach to the correct management and exploitation of groundwaters has always been lacking.

Even without the support of properly organised national and local geological and hydrographical boards, the Government Departments in charge of the protection and management of groundwaters have recently promoted, with the collaboration of the Italian National Council of Research and some University Institutes, an accurate and multidisciplinary analysis of the hydrogeological situation of the Po and Venetian Plain. The research has been carried out through specific methods of investigation, representing on appriopriate maps the intrinsic vulnerability characteristics of groundwaters to pollutants, the classification of the contamination sources in relation with the hydrogeological features and the water-supplying centres, the impact evaluation given by the extraction of fluids from the subsoil (land subsidence) and the depletion of the groundwater resources. This research programme ("VAZAR" = Evaluation of Aquifers Vulnerability in High Hazardous Areas) has been developed along several lines: lay out of conservation and safeguard techniques of the water catchment equipments and determination of appropriate protection zones defined by means of hydraulic and hydrogeological parameters (Francani & Civita, 1988), employment of effectual upgrading methods and elaboration of specific mapping of the aquifers' vulnerability to pollutants (Civita, 1990 a,b). Fig. 2 shows the first maps so far produced in the Po and Venetian Plain in areas representative of the different hydrogeological and man-induced impact situations. The elaboration of such maps will be progressively extended to the remaining areas as a means to aim for a correct management of the groundwaters and territorial planning and development (Muratori, 1990).

The evaluation of the integrated aquifer vulnerability to pollutants is deduced from specific maps which emphasize two different kinds of information. The first aspect to be pinpointed concerns the intrinsic vulnerability, that is all the hydrogeological elements which define the specific susceptibility to pollutants of an aquifer system in all its different components and geometrical and hydrodynamic situations. Thus the intrinsic characteristics of an aquifer to absorb, propagate and mitigate in space and time the effects of a pollutant on the natural groundwater quality is better assessed. The second kind of information contains instead the description of the hydric supplying sources, the pollution producers, the upgrading structures (such as waste liquids depurators, controlled dumping grounds, etc.) and the physical and man-made elements spreading pollution (karst landforms, leaking wells, soil pits and quarries, mining activities, etc.).

In the vulnerability maps, around the public water-supplying wells, zones of protection have been traced. They have been defined adopting a time-based criterion, that is choosing a dimension to attribute to the protection zones corresponding to the time necessary for the hydric flow to run through a certain distance (safety times at 60 and 365 days). Such times and therefore the perimetration of the different zones have been chosen through the determination of the hydrogeological parameters resulting from the elaboration of pumping tests. The

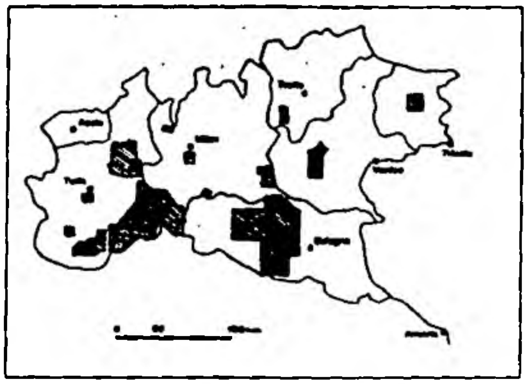

Fig. 2 - Vulnerability maps elaborated during the 1987-1992 period.

reconstruction of the piezometric surface has been determined with a permanent regimen condition and the time calculation procedures carried out applying Bear's (1979) expression with the finite differences method. Thus three areas have been defined (Francani & Civita eds., 1988):

"A" zone of immediate protection (10 to 20 m radius from the axis of each groundwater catchment).

"B" zone of limited protection, determined on the basis of the distance run in 60 days from a possible outer pollutant to reach the tray-well; that is its perimeter corresponds to the 60 day isochronal line. In this area the activities susceptible of altering the feeding trends and the groundwater natural flow are forbidden. It must also be guaranteed that no bacterial activity takes place, that non-biodegradable substance cannot reach groundwaters and the biodegradable ones do not constitute a supplementary biological load (oxygen consumption). Finally, in case of accident a sufficient time should be left in order to prepare adequate upgrading measures. In this zone it is forbidden to dig ditches, sewage works, canals, to use chemical substances on the ground such as most kinds of fertilizers, pesticides, etc.

"C" zone, defined adopting a distance corresponding to a 365 day safety time. The potentially polluting activities are here regulated and controlled limiting the number of industrial plants. A sufficient dilution of groundwaters should also be allowed before the pollutants can reach the water catchments. Theoretically this area should coincide with all the feeding area of the groundwater catchment but it is also allowed to consider administrative elements, such as municipal borders, and the presence of transport infrastructures (roads, highways, railroads, etc.).

The integrated vulnerability maps, thus elaborated, allow a reliable forecast of the aquifer system patterns of behaviour at a low cost and with simple investigation methods, performable also by local management offices. At the same time, these maps constitute a useful instrument for identifying priorities and strategies of intervention and subdividing the Po and Venetian Plain into areas characterised by different degrees of aquifer vulnerability to pollutants.

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THE PO RIVER BASIN (ITALY): PROBLEMS AND WATER MANAGEMENT POLICY

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1. INTRODUCTION

The main sources of information concerning the physical characteristics of the Po hydrographic basin and the quality of its waters are various hydrologic and hydraulic surveys carried out by the Ministry of Public Works (Ministero dei Lavori Pubblici, 1982), by the Ministry of Environment (Ministero dell'Ambiente, 1992) and by the Po Basin Authority (Autorità di Bacino del fiume Po, 1992 a,b). As to water quality, the overall picture was outlined by the Water Research Institute of the National Research Council in the proceedings of two congresses held in the '70s and '90s focusing attention on the Po river (IRSA, 1978 and 1991a).

Many other surveys concerning both physical and water quality characteristics were carried out by other institutions, first of all by the state electricity company (ENEL) and by water authorities and health units for sanitary control of water quality. Lastly, a recent survey of the overall situation was carried out in 1992 by the Italian ecology society (SItE, 1993).

Based on this knowledge, which is from many points of view incomplete and yet to be verified, this report will outline the main problems of the Po river basin and the short- and long-term programmes to be developed by the Po Basin Authority.

2. AN OVERALL PICTURE OF THE PO RIVER BASIN

The Po river basin measures about 70,000 km^2, that is 23.6% of the entire Italian territory (Fig. 1). About 16 million inhabitants live in the basin, distributed among 3,188 municipalities of which the most populous are Turin and Milan (respectively 1.4 and 2.2 million inhabitants).

Water consumption for the total population is estimated at 2.5×10^9 m^3 a year, which means 428 litres per capita a day. This estimate takes into account also water losses from drinking water pipelines, amounting to about 22%, with a 35% maximum peak in the oldest waterworks.

Sources of water supplies for domestic use are represented by wells (32%), springs (15%) and, to a smaller degree, by surface waters (3%). Ferrara and Rovigo (respectively 144,000 and 53,000 inhabitants) and Turin collect water for domestic use in part directly from the Po, while other smaller municipalities derive their water supplies from big lakes and other sources.

The industrial activities carried on in the Po basin account for 37% of the national production, with 47% of occupation and 48% of the national consumption of energy. Those based on the use of water count 235,000 units, 31% of which is located in the Milan area, and employ about 3,200,000 people. It is estimated that they consume 4-5 x 10^9 m^3 of water a year and that, in order to meet these requirements, they mostly rely on underground and surface waters as in the case referred to above.

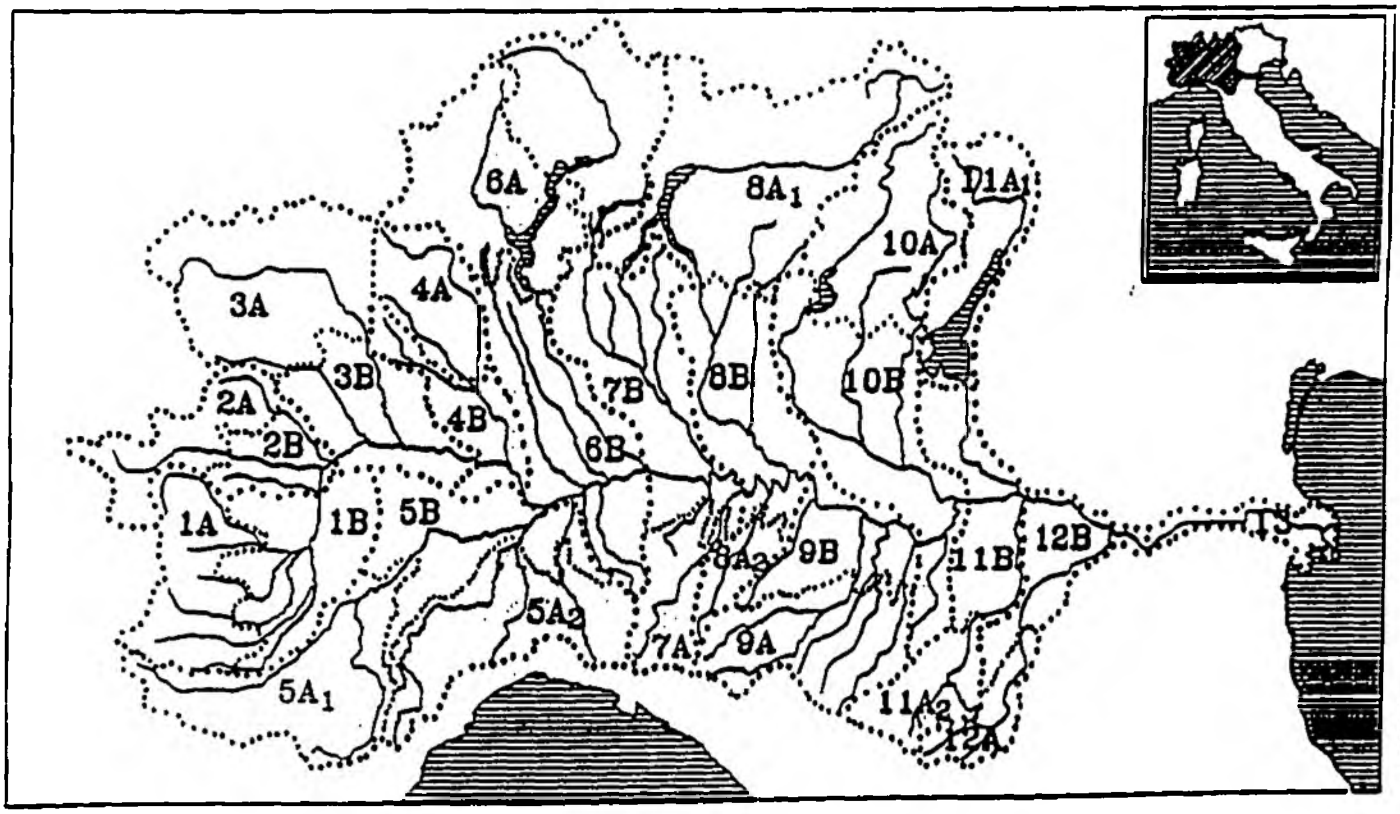

Fig. 1 Po Basin and sub-basis. The sub-basins are divided into mountain (A) and valley (B) sections. (From IRSA, 1991b).

Water is recycled only in very few cases.
The agricultural activities carried on in the Po basin, which account for 35% of the national production, use 34,000 km^2 of land for cultivation, about half of which is irrigated with a total consumption of water estimated at 10-20 x 10^9 m^3 a year.
Zootechnical activities have increased considerably: 4 million cattle, 5 million pigs, thousands of equines and sheep, and tens of millions of chickens and the like, mainly concentrated in 5 of the 27 provinces of the basin.

3. POLLUTANT LOAD

If the economic activities referred to above are converted into homogeneous units by means of the "equivalent population" procedure (IRSA 1991b), the total population of the basin will amount to 120 million inhabitants, distributed as follows (in millions):

Inhabitants	16 (13.3%)
Industrial equivalent population	39 (32.5%)
Zootechnical equivalent population	65 (54.2%)

This computation does not take into account agricultural activities for which there are no numerical coefficients of conversion available. It should be noted, however, that the consumption fertilizers exceeds 300,000 and 220,000 tons a year, respectively for nitrogen and phosphorus, and that the consumption of pesticides over the last few years is estimated at 4,100, 4,200 and 3,000 tons a year, respectively for synthetic insecticides (product sold on the market), organic herbicides (active product), and other fungicides.
Among the activities carried on in the Po river basin, reference should be made to the 282 power plants of 16,591 MWe total power of which 272 are hydroelectric (MWe 5,740) and 10 thermoelectric, 5 of which (MWe 7,260) located along the Po and 5 (MWe 3,591) along its tributaries. Furthermore there are two thermonuclear power plants, which have not operated since the '80s (Angelini *et al.*, 1991).
According to an evaluation by the Ministry of Environment, the population served in 1990 with sewers accounted for 85% of that living in the basin, 80% of such sewers being of the mixed type. The overall sewage treatment plants (STP) are 3,112, of which 1,535 carry out only primary treatment, while the remaining are designed for biological treatment with the following potential capacities (in equivalent inhabitants):

STP	Eq. Inh.
1,295	< 10,000
121	10,000 - 20,000
74	20,000 - 50,000
42	50,000 - 100,000
45	> 100,000

The total equivalent population treated amounts to 17 million inhabitants, who represent the 15% of the total equivalent population living in the basin. Among the plants of the greatest capacities is Turin's designed in 1984 for treating 300,000 m^3 of sewage a day and recently modified to treat 900.000 m^3. It should be stressed that Milan, the largest metropolitan area of the entire Po basin, is still lacking sewage treatment plants, and therefore its waste waters reach untreated the Po through the Lambro river.

4. PHYSICAL CHARACTERISTICS

The main physical characteristics of the Po river basin are listed in Table 1.

The basin is characterized by a tectonic depression bounded in the North by the Alps and in the South by the Appennine chain. The precipitation (annual average value 1,107 mm) is collected by a system of 141 watercourses (first and second order tributary), 95 of which are on the left and 46 on the right side of the Po.

Erosive action affects 40,000-50,000 km^2 of the 71,057 km^2 of the basin; the materials eroded are silted in the depression and transported towards the sea into the Po delta. The silted materials have created, in the course of geological time, a plain measuring about 29,000 km^2, reaching 1.300 m in thickness. At present, it is estimated that the Po waters transport materials for 15 million m^3 a year, either in suspension or on the bottom.

The course of the Po river, and in particular its central stretch, is characterized by many (34) meanders the radius of which measures up to 1,500 m. Meanders and braidings form a difference of 227 km between the lenght of the river and the distance from the source to the mouth.

The natural bed of the river has been considerably reduced in size by embankments. Today, they reach 2,500 km in length (510 along the Po), and the section of the natural bed they bound measures about 1,400 km^2 and 6 km in width. The outside land lies 1.2-2.5 m below the level of average floods, while in the final stretch it reaches 6 m below the level of maximum flood.

As to the delta, it is characterized by 5 branches and 14 mouths and its area (380 km^2) grows 30 to 60 ha a year, with periods of regression during which the phenomenon of subsidence is more pronounced.

The hydrological pattern of the Po, in the mountain stretch, is of the glacial type, i.e. it is fed by the glacier melting in summertime. This peculiarity does not apply to the remainder of the river course in which normally there are high flow rates in every season, with two maximum peaks in May and November, the former being lower.

Other hydrographic and hydrologic data referring to the Po are given in Table 1.

5. OVERVIEW OF THE PROBLEMS

5.1 THE PHYSICAL STRUCTURES

The problems affecting the various physical components of the basin are due to:

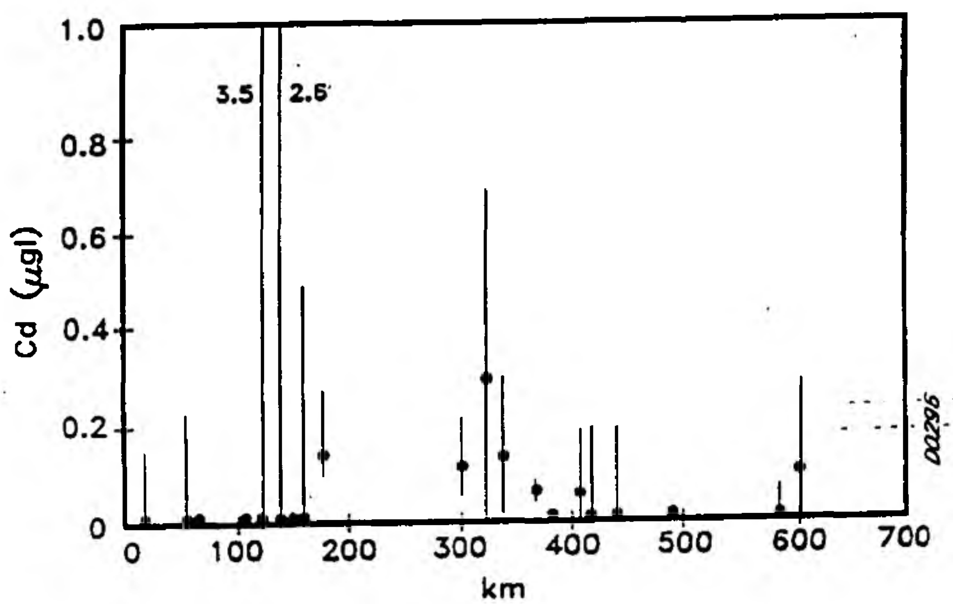

Fig. 2 Dissolved oxygen (%) and its variability along the Po from the spring (0 km) to the mouth (667 km). (From IRSA, 1991a).

- The construction of reservoirs in the mountain section of the basin for hydroelectric use which has resulted in levelling the annual runoff variation and in diverting water from natural streams into hydroelectric pipelines. The changes in the flow rate have not only caused serious damage to the biotic communities, but they have also created conditions unsuitable for other uses of waters, such as irrigation.
- The construction of dams in various sections of the Po and its tributaries for irrigation purposes.
- The reduction of river section to facilitate navigation. The reduction of naturally branched beds into one only bed for about 140 km of the central stretch of the river has increased erosion processes and decreased the variety of the habitat to the detriment of flora and fauna.
- The construction of flood walls for protection or recovery of arable land (the result being the reduction of the high-water bed). The new arrangement of the banks has reduced the high-water bed by hundreds of km^2, thus proving detrimental from the point of view of protection against floods as well as from the point of view of the ecological role of the area.
- The extraction of sand and gravel from the beds of the Po and its tributaries. This activity, which reached 12 million m^3 a year in the period 1978-1982, at present remains constant at 4 million m^3. This, together with dams and rectification of the river course, plays an important role in determining a serious lowering of the river bed. Such process has reached 4 m in the central and final stretches of the river, thus causing serious problems to the stability of embankments, bridges, and other works located in the bed and at water intakes for irrigation purposes.

5.2 SURFACE AND GROUNDWATERS QUALITY

With regard to oxygen, BOD, COD, ammonia, phosphates and faecal coliforms, the surveys carried out in 463 sections of the overall hydrographic basin and the 10,000 analytical findings obtained over the last 10 years, lead the Po Basin Authority to the following evaluation (Autorità di Bacino del Po, 1992 a): 2% of the sections surveyed can be considered unpolluted, 28% scarcely polluted, 25% polluted, and 45% severely polluted. This judgement proves to be even more unfavourable when considering that the degradation of the Po basin waters are not only due to organic matter and bacteria, but also to inorganic micropollutants (metals), organic micropollutants (mainly pesticides), nutrients (phosphorous and nitrogen), nitrates in the case of groundwaters, and acid-bearing chemicals of atmospheric precipitation.

As to BOD, the Po is characterized by low values, about 3-6 mg/l, reaching maximum peaks downstream Turin (about 100 km from the spring), where the Po flow rate is still very low, and downstream the Lambro river (about 330 km from the spring), which carries the organic load from Milan (Marchetti & Provini, 1991). Such peaks drop quickly, but the river reaches the closing section of the basin under slight oxygen deficit (Fig. 2), which do not depend only on the BOD of the waters, but also on oxygen consumption by the biotic communities living in sediments or in areas adjacent to the river (bacteria, algae, macrophytes, microfauna, etc.) (Marchetti & Provini, 1977; Bozzani *et al.*, 1991). Biotic communities are responsible for the frequent periods of hypoxia and anoxia in the recesses of the delta. Except for this area the BOD does not represent the main problem among those affecting water quality.

With reference to micropollutants, metals and to a higher degree pesticides cause serious damage to

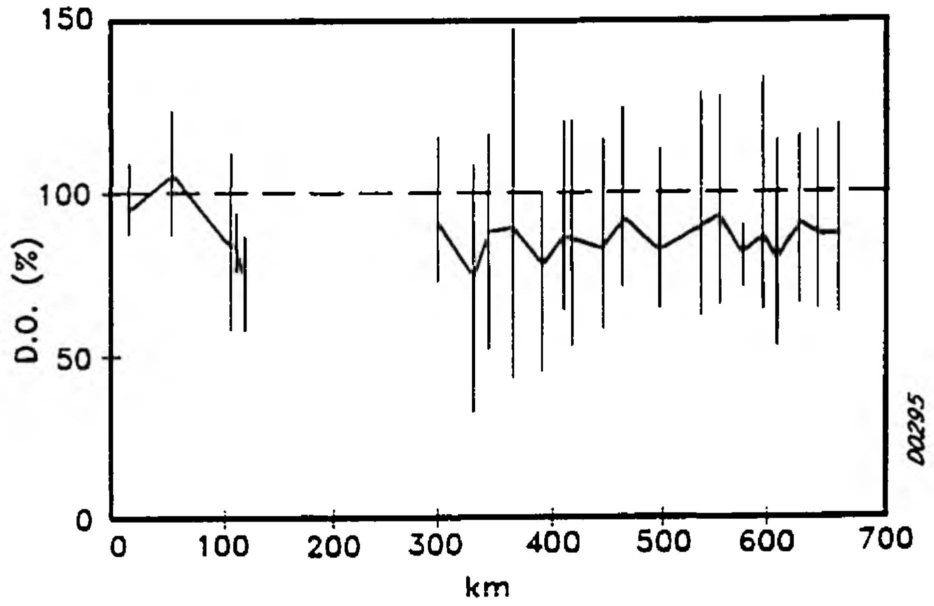

Fig. 3 Cadmium concentration along the Po. Solid circles = mean values; lines = interval of values including 25% of data close to the mean value. (From IRSA, 1991a).

the quality of surface and underground waters in the basin.

Total cadmium (Fig. 3) and mercury (dissolved or in particles) are found in concentrations which sometimes exceed the values considered typical of unpolluted waters. In some cases, the concentrations found (for example, 75.5 ngHg/l) exceed the limits set for aquatic life (Brondi *et al.*, 1991; Pettine *et al.* 1991; Queirazza *et al.* 1991). Other metals, such as chromium, copper, zinc, nickel, and arsenic, on the contrary, are found in concentrations only occasionally just over natural values.

The problem of chromium pollution, which affected groundwaters during the '60s and '70s, is at present solved while, due to the natural causes, the problem still exists for iron, manganese and, to a smaller extent, for nickel.

The herbicides which very frequently occur are Atrazine (97% of the 300 samples taken from 1988 to 1990 in the lower stretch of the Po), Simazine (73%), Alachlor (55%) and Molinate (45%). The concentrations reach very high levels, such as for example 8,700 ng/l of Molinate in the period in which it is widely used (May - June) (Baraldi *et al.*, 1991; Galassi *et al.*, 1991).

Among phosphorated insecticides, tests have been carried out for Phorate and Diazinon, which occur in low concentrations (maximum 19 ng/l), whereas chlorinated insecticides are found in higher concentrations and frequencies (Lindane 70% and 111 ng/l). Many other organic micropollutants have been found in the Po waters: various organic phosphates, among which TCEP, tris(-chloroethyl)phosphate, is present in 100% of the cases with maximum peaks of 466 ng/l, various phthalates, among which diisobutyl phthalate (82% and 8,400 ng/l peak) and, finally, compounds such as PCB, fatty acids, anionic and nonionic surfactants, and many others not identified.

Many of these micropollutants can be found in sediments and fish (in particular the PCBs); some of them have been found in high concentrations in the eggs of birds of the delta which feed on the fish.

Organic micropollutants took on great importance in the deterioration of groundwaters in the '80s as a result of the presence of organohalogenated compounds and pesticides. The limit set for organohalogenated compounds (30 ng/l) are still exceeded the values found in wells which supply water to 2 million, 1 million and more than 500,000 inhabitants, respectively in Lombardy, Veneto and Piedmont Regions. Trichloroethylene and Perchloroethylene are the compounds which contribute to the highest degree to this type of pollution. As to pesticides, Atrazine, Molinate and, in the rice-growing areas, Bentazone, occur in the highest concentration and frequency, while in the fruit-growing areas also organochlorinated insecticides (Lindane, DDT) and phosphorated insecticides (Parathion, Azinphos, etc.) have been found (Baraldi *et al.*, 1991; Galassi *et al.*, 1991).

Taking into account eutrophication problems, almost all lakes in the Po river basin, showed in about 40 years an increase in the trophic level, quicker and more pronounced in the case of small lakes. With greater delay, also major lakes today show a tendency towards mesotrophy, including Garda which, with its 50 km^3 of volume, is the largest Italian lake.

Eutrophication problems go beyond the basin itself, reaching the coastal waters of the Adriatic Sea. The Po carries to the Adriatic Sea (Fig. 4), according to the different meteorological and hydrological conditions, about 10,000-20,000 and 100,000-150,000 tons/year, respectively phosphorus and nitrogen. While episodes of eutrophication in the coastal waters of the Adriatic sea can be correlated with the contributions by the Po, at the time no evident relationships between the nutrients loads of the Po and the processes of mucilage formation have been found. Such processes have affected in the

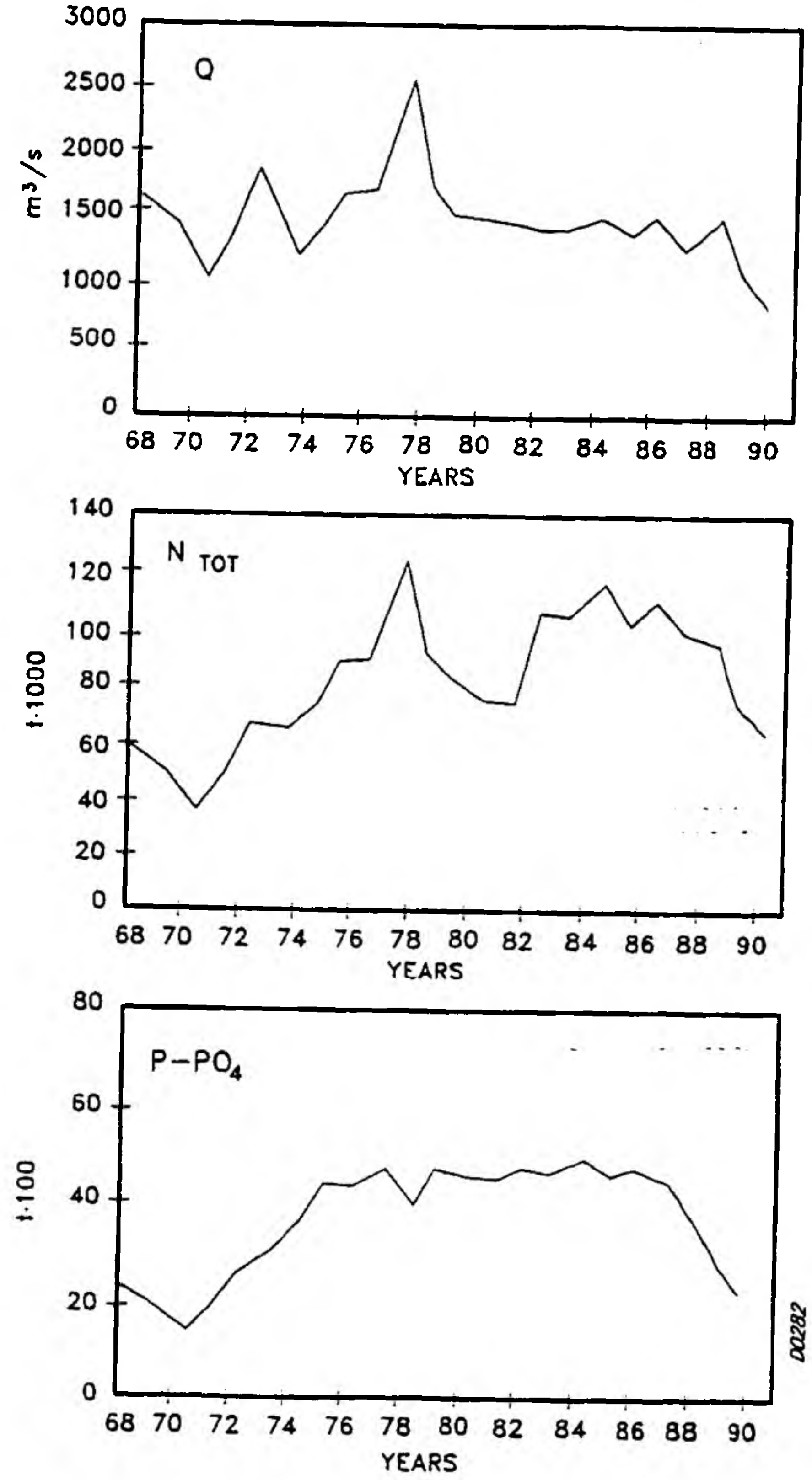

Fig. 4 Multi-year plots of flow rate, total nitrogen load and orthophosphates phosporus load at the closing section of the Po Basin. (from IRSA, 1991a).

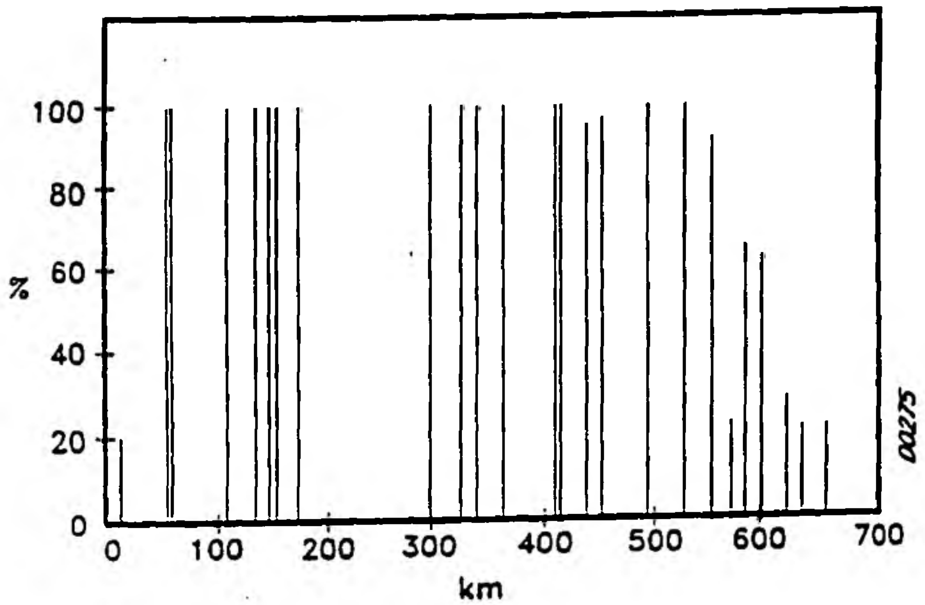

Fig. 5 Frequency of samples exceeding the faecal coliform limits set for bathing purposes, according to Italian national law (DPR 470/82). (From IRSA, 1991a).

last five years the Adriatic sea for thousands of km^2 (Provini *et al.*, 1980; Marchetti, 1991).
Nitrates, which when present in drinking water may induce a toxic action, is a great problem for the groundwaters of many areas of the Po plain. The origin of this is due, to a great extent, to synthetic fertilizers and farm sewage used in agriculture. More than one hundred municipalities use well waters in which NO_3 is found in the amount of 90 mg/l, thus exceeding the EEC limit of 50 mg/l.
A very significant polluting component in the waters of the Po river basin is represented by the microbial components (Coli, Streptococci and other groups). These components are present in the entire basin, except for the sections furthest up in the mountains, and reach levels of density which always exceed the values considered acceptable for such uses. If, for example, reference is made to the standard of 100 faecal coliforms in 100 ml of water (set in Italy for bathing purposes), in practice the course of the Po shows, throughout its length (Fig. 5), values over that limit (Crosa, 1991; Marchetti, 1991; Sansebastiano *et al.*, 1991).
Lastly, with regard to the problem of thermal discharges, all the power plants operating within the Po basin comply with the Italian law, which establishes that in the area upstream and downstream the points of the discharge the temperature mean value, 3°C, must not be exceeded. This limit may turn out to be inadequate for aquatic life protection, if power plants are located very close to each other. This is a condition which should apply to the Po basin, where there are two power plants at a distance of only 13 km one from the other.

5.3 BIOTIC COMMUNITIES

The biocenoses living in the Po river, as far as macroinvertebrates are concerned, are still sufficiently rich in species, though they are affected with problems of various origins.
In the mountain sections dams represent the main factor of disturbance; in fact, as said above, they may leave long sections of the river with no water, the result being the disappearance of very important ecological niches.
The plain sections are characterized by deterioration of the biocenoses as a result of pollution, and this is particularly evident in many tributaries of the Po, as well as downstream the point in which they flow into the river. Furthermore, the plain sections are affected not only with pollution, but other disturbing factors are present such as dams, excavations in beds, construction of embankments, reduction of land adjacent to the river. They all have had their part in determining a stop to migrations, a great reduction of species variety, dominance of opportunistic species belonging to rheophile taxa, thus levelling the biocenotic communities.
All the species of fish which were present at the beginning of the century can still be found in the Po, but many of them (sturgeon, shad, etc.) show a great reduction in the distribution area. The variety of fish populations too, as a result of water quality deterioration, decreased as already seen in the case of macroinvertebrates. This phenomenon is particularly evident in lakes, where Cyprinid populations have definitely prevailed over Salmonid populations; at present, *Alburnus alborella* (bleak) and *Scardinius erythrophthalmus* (rudd) are the dominant species.
As to the biotic communities of amphibians and reptiles, there are not so many data available, but also in this case, the reduction of the land adjacent to the rivers, the reduction of the plain woods, the construction of embankments, etc., have endangered trophic and reproductive habitats of great

importance for these vertebrates.

Data obtained from more exhaustive surveys are available in the case of birds and mammals, which are still present in great number of species and individuals in a state of precariousness.

Lastly, as far as vegetation is concerned, in the mountain stretch the construction of reservoirs has resulted in the reduction of habitats, such as peat-bogs, in the invasion of the shores by species living around the river beds, and in the loss of trees of greatest interest, such as the white alder.

In the valley sections, the canalizing of the river system and the recovery of land for agricultural use have led to the disappearance of alder woods, willow groves, and groves of maples and ash trees.

Changes of great importance are also affecting alluvial forests, which at present have disappeared from almost the entire basin. The manteinance of these forests, which needs large water supplies and an annual cyclical variation of the groundwater depth, has been made quite difficult by the levelling process of flow rates.

6. MEASURES AND PROGRAMMES

The programmes designed to solve the above mentioned problems are being developed by the Po Basin Authority, which was established in 1989. The law according to which the Authority was set up divides the activity into two steps: the achievement of a final objective, represented by the Po Basin Plan, and the solution of current problems by means of three-year programmes.

As far as the Plan is concerned, the Authority has created a series of subprojects, the purpose of which is to collect in a single project ("Progetto Po") all the necessary information for its development. Many data collected by the Ministry of Environment in the "Po Master Plan", (Ministero dell'Ambiente, 1992) become the basis for the activity of the Authority.

A document recently issued (Autorità di Bacino del fiume Po, 1992 b) lists 11 subprojects:

1)-*Floods and natural aspects of river beds*. The aim is the predictive evaluation of dangerous floods, the identification of areas in which such floods may take place, and the definition of possible measures to be taken.

2)-*Stability of slopes*. The aim is the evaluation of the existing and potential instability of the territory, with the view of identifying critical areas, causes and possible measures. Furthermore, the subproject provides for a cost analysis of these measures in relation to different levels of acceptable risk.

3)-*Subsidence*. The objective is to identify areas subject to subsidence and reveal evolutionary trends, causes, and possible measures.

4)-*Extraction from river beds*. The scope is to restore the river's correct arrangement and to bring embankments for protection against flooding back to an adequate level of safety through systematic planning and control of exctractive activities.

5)-*Surface water and soil pollution*. Through the identification of pollution sources and the determination of water quality for the entire basin, the subproject should, by means of simulation models, evaluate the selfdepurating capacity, identify critical areas, define the measures to be taken (prevention and treatment), and analyze costs.

6)-*Shallow and deep groundwater*. The aim is to provide for a preliminary analysis on how aquifers are recharged and pollutants spread, the objective being the implementation of a hydraulic model which can help identify critical areas, and evaluate effects and costs of alternative management policy for groundwaters.

7)-*Balance of water resources*. The scope is to reconstruct an overall picture of available water resources, taking into account the needs water uses entail (for example, minimum acceptable flow for aquatic life), and to point out situations and trends of unsuitability to select priorities among alternative uses.

8)-*Drinking water supplies*. This subproject has different objectives, ranging from the qualitative and quantitative determination of drinking water supplies to efficiency analysis, with reference to infrastructures (canalization), as well as to the identification of measures and cost analysis.

9)-*Control of large alpine lakes*. The objective is to identify lake discharge monitoring systems, which can satisfy the needs for protection against floods in the areas around and downstream the lakes, as well as the requirements for agricultural and industrial activities, for power plants, and for the conservation of environmental characteristics (minimum acceptable flow, etc.).

10)-*Meteorological, hydrologic and quality monitoring*. All the processes characteristics of the hydrologic cycle should be monitored, after definition of the variables, spatial density, and measurement frequency for descriptive and predictive models. Furthermore, this subproject provides for an analysis of the possibilities of performing instrumental data surveys as well as for cost estimation.

11)-*Coordination of projects*. This subproject is designed to coordinate not only the 10 subprojects for which the Authority is responsible, but also all the subprojects and regional plans. It also provides for hardware and software suitable for a data bank.

The subprojects briefly described above, should help, in the long run, develop a Project preparatory to the Plan. Many have been already approved and are being entrusted.

It is interesting to note that, before implementing the Plan, the Authority has adopted a "Predictive and Programmatic Model" through which it tackles the most pressing problems.

A total expenditure of 425 billion liras (240 for 1991, 52 for 1992, and 133 for 1993-1995) has been approved for short-term measures to be taken on problems such as pollution, accidents, risk of flooding, and for studies designed to increase the knowledge on the basin, etc. Another expenditure has been approved for total 413 billion liras for urgent measures against eutrophication in the Adriatic sea, which depends, to a great extent, on the contributions by the Po. The funds allocated for these urgent measures are considered inadequate.

As far as the Basin Plan is concerned, no estimate of expenditure can be made at the moment; a provisional estimation of the overall coast for the Basin recovery will be set up after the Project preparatory to the Plan is completed.

TABLE 1

Main characteristic data referring to the Po river basin obtained from different sources. These hydrographic and hydrologic data refer to the closing section of the entire basin, located at about 90 km from the mouth of the river.

Area of the basin	71,057 km^2
Area of the plain	29,000 km^2
Area of the delta	380 km^2
Average altitude of the basin	740 m a.s.l
Average altitude of the plain	100 m a.s.l
Maximum altitude of the basin	4,807 m a.s.l
Elevation of the original spring	2,020 m a.s.l
Glacial area	0.8 %
Natural lake area	1.3 %
Volume of major lakes	118 x 10^9 m^3
Surface of major lakes	790 km^2
Volume of reservoirs	1.6 x 10^9 m^3
No of lakes and reservoirs with area >2 km^2	108
No of first and second order tributaries	141
Length of the river course	677 km
Maximum width of the average flow bed	2.5 km
Maximum depth of the average flow bed	10-12 m
Maximum width of the high-flow bed	3 km
Maximum depth of the high-flow bed	20-22 m
Mean velocity of average flow	0.5-1.5 m/s
Mean velocity of high flow	2.5 m/s
Annual average precipitation	1,107 mm
Annual average runoff	668 mm
Apparent loss	439 mm
Runoff coefficient	0.6
Mean annual flow rate	1,470 m^3/s
Maximum daily flow rate	11,580 m^3/s
Minimum daily flow rate	275 m^3/s
Duration of flow rate, 10 days	3,710 m^3/s
Duration of flow rate, 91 days	1,820 m^3/s
Duration of flow rate, 182 days	1,180 m^3/s
Duration of flow rate, 274 days	865 m^3/s
Duration of flow rate, 355 days	420 m^3/s

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