# Reformulation of engineering Education at Undergraudate Level in the Faculdad de Ingenieria y Ciencias Hidricas Universidad Nacional del Litoral - Water Resources and Engineering Degrees

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## Summary

For the last twenty years the *Facultad de Ingeniería y Ciencias Hídricas (FICH),* from the *Universidad Nacional del Litoral (Santa Fe, Argentina - UNL),* is offering the ***"Water Resources Engineering"*** (university degree). This has contributed to form specialized professionals with an important technical-scientific knowledge base in the field of the water resources. In order to provide answers to the changing social needs, the Study Program has been modified during this period. Nowadays, a new change in the structure of the engineering careers is proposed. It includes:

- less length of the career,
- periods structured design and knowledge integration.

These are the new paradigms that a modern engineering curriculum should consider.

In a context of great transformations of the social system, where the concepts of development and sustainability reach their equilibrium through scientific and technical contributions, the FICH clearly faces the need of modernizing the engineering teaching process. Thus, the Study Program of the ***Water Resources Engineering*** career has been reformed.

From 1990's, the need of incorporate both the environmental component and the sustainability concept in the engineering projects that are directly or indirectly related to the natural resources, was increased. This led to implement two branches in the *Water Resources Engineering* career:

- Environmental.
- Hydraulic Constructions, Ports and Inland Waterways.

At the present time, the ***Environmental Engineering*** career has been created on the basis of the *Water Resources Engineering* career (with its two branches), plus the significant contribution that other Departments of the UNL could provide. Consequently, it was necessary to reform the Study Program of the *Water Resources Engineering* (Environmental and Hydraulic Constructions, Ports and Inland Waterways). In this sense, it should be taken into account the special collaboration of the *Instituto de Desarrollo Tecnológico para la Industria Química (INTEC)* and the *Facultad de Ingeniería Química (FIQ),* both belonging to the UNL. Therefore, at the twenty-first century's door , particularly in the Litoral region - where an important number of industrial and agronomical activities takes place - the ***Environmental Engineer*** would fill an empty field in the argentine engineering. The framework of the career is supported by a set of common courses, a set of specific courses of each engineering career (*Water Resources Engineering and Environmental Engineering careers*) and an another set of optional courses. They are articulated in the curricula of five years in length (i.e. 3750 hours), with modifications such as: flexible correlative courses and a thesis as a linking final work.

## Water Resources Engineering at the Universidad Nacional del Litoral

For over twenty years, the career of Water Resources Engineering, held at the Department of Engineering and Water Sciences (FICH), Universidad Nacional del Litoral, at Santa Fe city, Argentina, has become an essential factor in the process of specializing human resources in that field.

In a country where the water resources strongly influence the development and well-being of the people, and because of the severe inequality in their distribution, with a considerable "wet region" (approx. 1/3 of the country) which suffers from frequent excesses, and a vast arid region (the remaining 2/3) with chronic deficit, the work of professionals specialized in the study, use and conservation of water resources becomes vital.

Through the Department of Engineering and Water Sciences, created in 1974, the Universidad Nacional del Litoral has been able to satisfy, to a great extent, the Argentinean demand as for professionals specialized in the subject. During the last two decades, the graduates of this Department have been working throughout the country, both in the private sector (consultant companies, private affairs) and for the public sector (Water Administration Offices, Sanitary Services, Research

Organisms, Universities). Nowadays, FICH is still the only university institution that trains professionals specialists in water resources.

## The need to update the study programs of the engineering careers

In 1997, FICH in agreement with a general conception of the Argentinean university institutions connected to the teaching of engineering, decided to undertake a Project of Reformulation of the Teaching of Engineering at university degree level. This project was created within a scheme of profound social transformations where concepts such as development and sustainability meet a balance whose answer must be given on the basis of technical and scientific knowledge.

Previous modifications introduced in the study programs have tried to meet the changing demands of the social context in which the career develops. In this permanent evaluation process, the present situation puts forward a new challenge from the point of view of the organization of engineering degrees: shortening of their duration, a design structured in cycles, integration of knowledge, and articulation with the post-graduate courses, are some of the new paradigms that the modern curriculum of engineering must necessarily take into account.

It is worth insisting on the necessity of an adequate articulation of the different levels of education. Higher education must be conceived as a whole, that is: undergraduate degrees, post-graduate courses and continuous training. It is evident that the technological advances by the end of the 20th century confirm, as never before, the need for professionals permanently updated, thus making the relationship University-graduate-professional , a permanent one. Within this context, it is worth mentioning the recent creation of the graduate program within FICH (Master Course in Water Resources Engineering and Doctorate in Engineering) which reinforces the need of a curricular adaptation of the degree of Water Resources Engineering.

## New Curriculum Fundamentals. Creation of the Environmental Engineering degree

Undoubtedly, society has been increasingly valuing the aspects that determine its quality of life, thus giving a greater significance to the surrounding environment. This awareness is shown in the permanent and sustained claims to the private and public sectors for deep actions which will lead to the preservation of the environment. On the other hand, the increase in population and the rising standard of life demand an intense use of the natural resources of our planet. To make these two factors compatible, and to reach a sustainable development, engineers with a global vision and trained specifically in the management of such resources, of productive processes and in the treatment and disposal of waste, are required.

The public sector must meet this demand, either local or foreign, complying with regulations and control systems, monitoring and follow-up of environmental aspects of existing civil and industrial constructions or of those yet to be built.

The need to incorporate the environmental component to engineering, as well as the concept of sustainability which should be included in every project linked directly or indirectly to natural resources, and to the works derived from their development, led to the implementation of the Environmental Orientation in the Water Resources Engineering degree at FICH in 1992.

Although the timely modification of the curriculum, which consisted basically in the incorporation of structural calculus and environmental training, resulted in a curriculum which permitted primarily to satisfy the needs of an environmental training without neglecting the basic engineering training, it also involved some negative aspects such as:

- Too extended a curriculum, with 42 courses, four of which took two semesters.
- High nominal duration and amount of hours (5 years and a half- 4200 hours ).
- Lack of integration of knowledge through a Final Project in which the received training could be materialized.

To the above mentioned situation, it must be added the absence of coordination and complementation of the different Departments of the Universidad Nacional del Litoral, where there was no integration among the professors/researchers with training and experience in the different disciplines related to the environmental issue.

These failures resulted in some adverse consequences such as : a decrease in enrollment and in the number of undergraduates; a reduction in the number of graduates; an increase in graduation times, leading to an average of 9 years, sensibly higher than the nominal duration of the career (5.5 years).

On the other hand, it is worth noticing that the causes for this situation cannot be attributed to external factors, since it can be stated that, taking into account the follow-up of graduate Water Resources Engineers, there are no serious problems in the job market. Moreover, and especially after the privatization process of public services in Argentina, a steady increase in the demand for our graduates has been perceived, to such an extent that many of them work part-time in the last years of the career, undertaking semi-professional tasks.

As regards the request for professionals trained in Environmental Engineering, and despite there is no expressed demand (due to the lack of a concrete offer in our market), an increasing request for engineers trained in

that field is predictable, as a consequence of recurrent and more and more serious environmental problems of different sorts, mainly derived from population growth and industrial development. The creation of an engineering community such as it has been proposed, will not only help to attend to the demand, but also its mere existence will boost the awareness within the community towards the need to take care of the environment on the basis of a solid technical and scientific background**.**

The topicality of the subject, reflected in dissatisfied social demands, the important starting point constituted by the environmental orientation of the Water Resources Engineering degree and the significant contribution that other Departments of the Universidad Nacional del Litoral can make, provide a favorable framework for the creation of the Environmental Engineering degree at FICH. This effort is a reformulation of the Study Program , 1992- (Water Resources Engineering degree with two orientations: Environmental and Hydraulic Works, Ports and Waterways). In this sense, it is worth emphasizing the academic contribution of the Institute of Technological Development for Chemical Industry (INTEC), where renowned researchers work on environmental subjects, and the Department of Chemical Engineering (FIQ), another University Department with professors and researchers with a vast experience in specific topics such as the relationship between industrial processes and the environment. In brief, the cooperative work of teachers and researchers of these institutions will contribute to optimize the use of human and material resources. Within this framework, the Environmental engineer would fill a vacant space in the field of engineering in Argentina, particularly in the wet region where major industrial and agricultural activities- which make a great use of natural resources- are concentrated.

## The new curricular structure of engineering degrees at FICH. Purposes for the change

The new functional structure of the two engineering degrees possesses a group of core courses common to both careers, a group of courses specific to each engineering and a group of elective courses, all of them distributed in 5 years. The program is flexible in terms of prerequisites, and it incorporates a Final Project. The main goals of the curricular change and the mechanisms for its implementation are:

- To diversify the present academic offer, turning the only engineering degree offered since 1997 into two degrees, Water Resources Engineering and Environmental Engineering, thus allowing a more efficient development of the process of training at university level.
- To satisfy social demands in the best possible way, by the introduction of innovations in the educational offer, ensuring proper graduating times, and graduates more in tune with the new social requirements and compatible with the major international academic centers. In this way, a more efficient insertion in the job market is pursued.
- To tend to reverse the reduction in the enrollment in engineering degrees, based on an offer not only attractive from the point of view of the graduate insertion in the job market, but also from the academic level itself.
- To implement a curricular design which will sensibly shorten graduation times, reducing the number of courses from 42 to 34, and the required number of class hours from 4200 to 3750. This in turn will make the demands of prerequisites more flexible and will incorporate a Final Project (300 hours) as an integrating practice.
- To put an end to a tradition of isolation among the Departments of the Universidad Nacional del Litoral, in pursue of the execution of university projects facing an integration process based in common goals.

## Environmental Engineering

### Scope of the environmental engineer degree

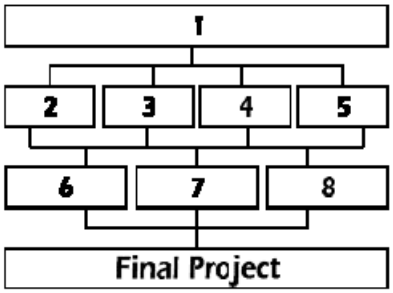
The scope of the environmental engineer degree, approved by the Ministry of Culture and Education in Argentina, is as follows:

1. To carry out studies, to evaluate, project, conduct and supervise the construction, operation and maintenance; to audit and monitor:
    - Works intended to avoid environmental pollution produced by any type of effluent originated by industries and/or services derived from them
    - Works intended to avoid environmental pollution produced by urban settlements as a consequence of solid, liquid and gaseous waste
    - Urban or rural drainage works.
    - Works for the regulation, reception and supplying of water for human or industrial use.
    - Remedial solutions to soil, water and air pollution.
2. To carry out studies and consulting services about pollution of surface and ground water , of soil and air, derived from productive processes, engineering works and other anthropic actions.
3. To formulate and integrally ( socially, economically and environmentally) assess projects which involve soil, water and air integrity.
4. To organize and conduct assessment studies of environmental impact.
5. To design, conduct and audit systems of management for the rational use of soil, water and air in production and service companies and in public organizations.

6. To perform studies and consulting services about the legal and economic aspects related to the incidence of works of engineering, industries and urban areas upon the environment.
7. To carry out arbitration, expert reports and valuations related to the incidence of works of engineering, industries and urban areas upon the environment.
8. To evaluate and report on the hygienic, security and pollution conditions of urban and industrial work places, and of ecosystems in general.
9. To participate in the elaboration of rules and policies intended to preserve the environment.

**Curriculum**

The curriculum of Environmental Engineering comprises a group of core basic courses (1), four groups (2 to 5) of core integrated and specialized courses, and three groups (6 to 8) of elective specialized courses. It also includes two courses of general training. In most cases the courses take one 15 weeks "semester". Only three courses take a whole year. The courses demand a variable amount of hours per week - between 5 and 8 and 8 hours - which means between 75 and 120 hours per semester. The groups of core integrated and specialized courses are the following: Water Resources (2); Environment (3); Environmental Management (4); Sanitary Engineering and Treatment (5). The groups of elective specialized courses are as follows: Management and Planning (6); Structures and Hydraulics (7); Natural Resources (8). The Study Program includes an integrating Final Project, which demands approximately 300 hours.




Groups 1 to 5: core courses
Groups 6 to 8: elective courses

The curricular structure of the degree is as follows (courses common to the Water Resources Engineering degree and Environmental Engineering degree are in bold type. The required amount of hours for each course appears in parenthesis):

| 1st semester | 2nd semester |
|---|---|
| **Basic Mathematics (90)** | **Linear Algebra (75)** |
| **General and Inorganic Chemistry (90)** | **Calculus (1st part) (75)** |
| **Representations Systems (90)** | **Technology, Environment & Society (75)** |
| **English (1st part) (60)** | **English (2nd part) (60)** |
| | Organic Chemistry (105) |
| **Hours per week: 22** | **Hours per week: 26** |

| 3rd Semester | 4th Semester |
|---|---|
| **Calculus (2nd part) (90)** | **Numerical Analysis and Computing(120)** |
| **Statistics (90)** | **Geology, Geomorphology and Soils (90)** |
| **Physics (1st part) (75)** | **Physics (2nd part) (75)** |
| **Topography (90)** | |
| **Hours per week: 23** | **Hours per week: 19** |

| 5th Semester | 6th Semester |
|---|---|
| **Fluid Mechanics (120)** | Soil, water and air pollution (105) |
| Physics-Chemistry (120) | Applied Hydraulics (120) |
| **Hydrometeorology (120)** | Environmental analytical chemistry (120) |
| | **Ecology (90)** |
| **Hours per week: 24** | **Hours per week: 29** |

| 7th Semester | 8th Semester |
|---|---|
| Environmental Microbiology (120) | **Sanitary Engineering (120)** |
| **Environmental hygiene, safety and legislation (90)** | Environmental management and planning(90) |
| Operation and treatment processes(120) | Analysis of environmental systems (105) |
| **Economic-environmental formulation and assessment of projects (90)** | Elective 1 (90) |
| **Hours per week: 28** | **Hours per week: 27** |

| 9th Semester | 10th Semester |
|---|---|
| Elective 2 (90) | Elective 5 (90) |
| Elective 3 (90) | Final Project (300) |
| Elective 4 (90) | |
| Water and Effluents Systems (120) | |
| **Hours per week (min.): 26** | **Hours per week (min.): 26** |

| | |
|---|---|
| **Average amount of hours per week: 25** | **Total amount of hours : 3750** |

The elective specialized courses have been grouped in three thematic areas as follows:

| Courses | Management and Planning | Structures and Hydraulics | Natural Resources |
|---|---|---|---|
| Groundwater Hydrology | | | • |
| Hydraulic Works I | | • | |
| Soil Mechanics and Geotechnical Engineering | | • | |
| Groundwater resources management | • | | |
| Groundwater Engineering | | • | |
| Water quality models | | | • |
| Hydrologic impacts of climate change | | | • |
| Basins and ecosystems management | • | | |
| Geographic Information Systems (GIS) | • | | |
| Construction Technology | | • | |
| Hydraulic Reclamation Projects | | • | |
| Hydrometeorological and Environmental Data Surveying | | | • |
| Materials Technology | | • | |
| Air pollution- monitoring and treatment | | | • |
| Environmental economy | • | | |
| Urban and special solid waste management | | | • |
| Structure Elements | | • | |

## Water Resources Engineering

**Scope of the Water Resources Engineer degree**

The scope of the water resources engineer degree, approved by the Ministry of Culture and Education of Argentina is as follows:

1- To carry out studies, to project, conduct and supervise the construction, operation and maintenance of:
   - groundwater engineering works
   - works of regulation, storage, intake and supplying of water
   - works of evacuation of effluents to water courses, and works of treatment of . sewage
   - works of drainage, irrigation and elimination of urban and rural hydric surplus
   - works of fluvial correction and regulation, including banks protection and stabilization of rivers and works of flood control and mountain stream correction.
   - works of protection against general and local erosion.
   - dams and dikes of loose material and of other hydraulic works which may be built upon the base of standard hydraulic structures and machines.

2- To carry out studies and to project the hydraulic aspect of:
   - port, fluvial and maritime works, of concrete dams and other hydraulic works.
   - fluvial waterways

3- To plan and evaluate the use and administration of water resources

4- To plan, conduct and execute hydrometric and topographic studies intended to evaluate water resources.

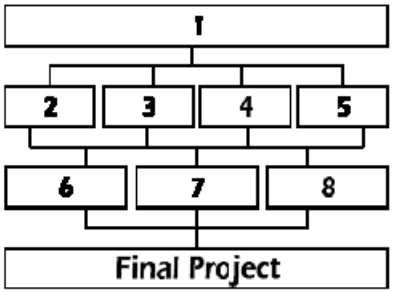
5- To evaluate quantity and quality of water resources-meteoric, surface water and ground water.

6- To perform studies and consulting services about:
   - pollution in water courses
   - modifications produced in water resources as consequence of works of engineering related to them

7- To carry out studies and research work referring to the explanation of hydric phenomena and to methodologies for the evaluation and management of water resources.
8- To advise on the elaboration of rules related to the use and management of water resources.
9- To participate in the elaboration and implementation of policies intended to the use and management of water resources.
10- To carry out arbitration and expert reports referring to the use and management of water resources.

**Curriculum**

The curriculum of Hydric Resources Engineering is formed by a group of core basic courses, four groups of core integrated and specialized courses and three groups of elective specialized courses, distributed within a scheme similar to that of Environmental Engineering as seen in 5.2. It also includes two courses of general training. In most cases the courses take one semester (only three take two semesters), for 15 weeks and with a variable amount of classes per week between 5 and 8 hours, which means between 75 and 120 hours per semester. The groups of core integrated specialized courses are as follows: Hydrology (2); Hydraulics (3); Environmental Management ( 4); Structures (5). The groups of elective specialized courses are: Management and Planning (6); Hydraulics (7); Hydrology (8). The Study Program includes an integrating Final Project which takes approximately 300 hours.




Groups 1 to 5: core courses
Groups 6 to 8: elective courses

The curricular structure of the degree is as follows (courses common to the Water Resources Engineering degree and to the Environmental Engineering degree are in bold type. The required amount of hours for each course appears in parenthesis):

| **1st semester** | **2nd semester** |
|---|---|
| **Basic Mathematics (90)** | **Linear Algebra (75)** |
| **General and Inorganic Chemistry (90)** | **Calculus (1st part) (75)** |
| **Representations Systems (90)** | **Technology, Environment and Society(75)** |
| **English (1st part) (60)** | Hydrochemistry (90) |
| | **English (2nd part) (60)** |
| **Hours per week: 22** | **Hours per week: 25** |

| **3rd Semester** | **4th Semester** |
|---|---|
| **Calculus (2nd part) (90)** | **Numerical Analysis and Computing (120)** |
| **Statistics (90)** | **Geology, Geomorphology and Soils (90)** |
| **Physics (1st part)** | **(75) Physics (2nd part) (75)** |
| **Topography (90)** | Structures Theory I (90) |
| **Hours per week: 23** | **Hours per week: 25** |

| **5th Semester** | **6th Semester** |
|---|---|
| **Fluid Mechanics (120)** | Hydrometry (105) |
| Soil Mechanics and Geotechnical Engineering (90) | Open channel hydraulics (105) |
| **Hydrometeorology (120)** | Structures Theory II (90) |
| | **Ecology (90)** |
| **Hours per week: 22** | **Hours per week: 26** |

| **7th Semester** | **8th Semester** |
|---|---|
| Fluvial Hydraulics (105) | **Sanitary Engineering (120)** |
| Surface water hydrology and hydrologic designs (105) | Hydraulic Reclamation Projects (120) |
| **Environmental hygiene, safety and legislation (90)** | Groundwater Hydrology (105) |
| **Economic-environmental formulation** | Elective 1 (90) |
| **and assessment of projects (90)** | |
| **Hours per week: 26** | **Hours per week: 29** |

| 9th Semester | 10th Semester |
|---|---|
| Reinforced concrete (120) | Elective 5 (90) |
| Elective 2 (90) | |
| Elective 3 (90) | Final Project (300) |
| Elective 4 (90) | |
| **Hours per week (min.): 26** | **Hours per week (min.): 26** |

| | |
|---|---|
| **Average amount of hours per week: 25** | **Total amount of hours : 3750** |

The elective courses (specialized training) have been grouped into three big thematic areas:

| **Courses** | **Hydraulics** | **Hydrology** | **Management and Planning** |
|---|---|---|---|
| Hydraulic Works I | • | | |
| Environmental management and planning | | | • |
| Hydraulic Works II | • | | |
| Urban Drainage | | • | |
| Ports and Waterways | • | | |
| Fluvial Engineering | • | | |
| Groundwater resources management | | | • |
| Groundwater Engineering | | • | |
| Water quality models | • | | |
| Hydrologic systems analysis | | • | |
| Hydrologic impacts of climate change | | • | |
| Basins and ecosystems management | | | • |
| Geographic Information Systems (GIS) | | | • |
| Irrigation and drainage | | • | |
| Construction Technology | • | | |
| Hydrometeorological and Environmental Data Surveying | | • | |
| Water Resources Planning | | | • |

At the end of the 6th semester in both degrees, Water Resources Engineering and Environmental Engineering, students will be required to pass a test to give proof of their knowledge of the English language; and at the beginning of the third semester, students will be expected to pass a test to prove their computing skills in the use of Operating System, Graphic Environment, Spread sheet and Word Processor. The tests are in agreement with the 1st point of the Degree Programs at UNL. For this purpose, the Department must implement extracurricular courses in English (to complement the core courses in the 1st year); and also in Computing Studies, to allow students to acquire the requested knowledge.

With the help of and Advisor, students in both careers must take five (5) elective courses from the available offer according to the following criteria:

1. Three courses in one of the thematic areas.
2. One course in each of the two remaining thematic areas.

The order of the elective courses will be set by the Advisor, in agreement with the professors responsible for the courses.

**Future Actions**

The project of "Reformulation of the teaching of Engineering , at undergraduate level, at the Department of Engineering and Water Sciences of the UNL", was conceived in 1997 by planning two major parallel courses of action. The first was carried out within the academic-institutional field of FICH and UNL, and consisted basically in the reformulation of the Study Program of Water Resources Engineering and the creation of the Environmental Engineering degree, as it is described in points 2 to 6 of the present paper.

The second action line, undertaken the same year, consisted in the presentation and further approval of a project within the framework of "Funds for the Improvement of Education Quality (FOMEC)", which, through the financial support of the World Bank, is carried out by the Ministry of Culture and Education of Argentina. This Project includes training of human resources at post-graduate level in well-reputed university centers, and a workshop intended to optimize the curriculum of the new career through the assistance of international experts in

Environmental Engineering. This workshop will take place at the end of the 1st semester, 1998. Through this project, the proposed curricular designs are to be submitted to the opinion of qualified experts, and the necessary adjustments in the Program of Studies will be made , particularly in the Environmental Engineering degree. Furthermore, the Project will give way to a substantial improvement in the quality of professors at FICH, specialized in environmental topics.

To guarantee the proper achievement of the goals of the Curricular Reform stated in 4, a set of actions characteristic of the implementation process of the Project must be taken. Among them, it is worth noting:

- Horizontal integration of the UNL Departments in order to achieve the teaching and research human resources necessary for the implementation of the reform, without having to appeal to extra material or teaching resources.
- Development of an efficient system of educational management, with the corresponding follow-up of undergraduates through the implementation of the Advising Systems and controlling processes of the application of new curricular designs. At the same time, a permanent self-assessment process of the practice itself will be established, in which the participation of students in the courses and the respective teaching activity will be prioritized, in order to produce the necessary adjustments to the processes and their regulations.
- The structure of the new Study Program will give rise to a graduate with an initial professional experience which will help him in the job market. Within this framework, the incorporation of students in the last year as "fellows" to work in the Technical Assistance Services (SAT), which operate from the Department to the community, have proved to be a successful practice which should be continued. This way, these consulting services provide professional practice to the graduates. Both initiatives have been successfully put into practice at FICH since 1995.
- The contents of the courses that form part of the proposed curriculum must be the necessary minimum and will meet the specific needs of the career as well as those common to the engineering training.
- The pedagogical criteria developed should accompany the undergraduate student in his training process. It is considered of a great importance the creation of the "advisor" role. The advisor will help the student on aspects related to his academic life, his future professional practice, the need to recognize and prioritize the "academic excellence" as a social value during his training process, his complementary training and the selection of courses in terms of his vocational profile. The advisor will also help the student with the selection of his Final Project.
- The need to spread the competences of the graduates in these degrees, specially in Environmental Engineering, which is pioneer at degree level in this field among the state universities in Argentina, the same as Water Resources Engineering was in the '70s.

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