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THREE DECADES OF DEVELOPMENT AND APPLICATION OF NUMERICAL SIMULATION TOOLS AT INA HYDRAULICS LAB

Angel N. Menéndez

Laboratorio de Hidráulica
INA (Instituto Nacional del Agua)
Autop. Ezeiza-Cañuelas, Tramo J. Newbery, Ezeiza, Argentina
e-mail: menendez@satlink.com, web page: http://www.ina.gov.ar

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Abstract. *The main lines of work on numerical simulation at INA Hydraulics Lab during its three decades of existence are briefly reviewed. They are rooted in four main subjects: hydrodynamics, sediment dynamics, pollutant dynamics and heat dynamics. Software development and applications are also mentioned. It is emphasized that these lines of work are problem-driven, i.e. they are defined by the practical requirements of the social media. This policy has led to participation in a variety of studies of significant social impact, which are briefly mentioned. The present lines of work are not only directed to the use of more sophisticated techniques, but also to exploit existing tools in order to provide results ready to be used for long-range planning by decision-makers.*

1 INTRODUCTION

Numerical simulation has been a technique used at INA Hydraulics Lab (HL) since its creation, back in 1969. Within the working group named the "Computational Hydraulics Program", originally the "Departament of Mathematical Models", a variety of numerical models have been developed and applied during these three decades.

At INA-HL development has been always problem-driven, i.e., it has been the practical problems posed to the institution the ones that have triggered the subject of work. Until the 80's the source of problems was specifically Hydraulic Engineering. During the 90's the field of interest expanded to incorporate requirements from Environmental Engineering.

Four lines of work have been pursued: hydrodynamics, sediment dynamics, pollutant dynamics and heat dynamics. The following are the main problems treated within each of these lines:

a) *Hydrodynamics:* flood routing, water currents in shallow waters, wave transformation in the coastal zone
b) *Sediment dynamics:* river, estuarine and reservoir bottom morphology, sedimentation in navigation channels, turbidity plumes
c) *Pollutant dynamics:* contamination by point sources, pollutant balance
d) *Heat dynamics:* thermal contamination, thermal stratification

In the following, for each one of the identified problems the numerical technique, its implementation in software and results of its application to specific problems are briefly described.

At the end, the new problems undertaken at the present decade are briefly introduced.

2 HYDRODYNAMICS

Flood routing

Flood routing has been one of the problems triggering numerical modeling in Hydraulics Engineering during the 60´s. The aim is to determine the maximum water level attained along a river stretch during the propagation of a flood wave. This information is used for:

- Establishment of flood risk due to natural or anthropogenic causes
- Hydraulic design of flood control structures
- Providence of flood warning

Flood routing through numerical techniques was the first problem faced at INA-HL. Due to the long flood wave extension relative to the transversal dimensions of the river, the problem is mathematically represented by a one-dimensional hydrodynamic model based on the well known Saint Venant equations[1,2]:

$$\begin{aligned} &\frac{\partial \Omega}{\partial t} + \frac{\partial Q}{\partial x} = q \\ &\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + g\frac{\partial z}{\partial x} + gI_f = -\frac{q}{\Omega}(U - u_L) \end{aligned} \tag{1}$$

where t is time, x the longitudinal coordinate, Q the discharge, Ω the area of the cross-section, U the mean velocity, g gravity, z the water surface level, I_f the friction slope, q the lateral discharge per unit length and u_L the x component of its velocity. These equations were numerically solved using Preissmann scheme[3], an implicit finite difference method. The first fully operative version was software EZEIZA III[4]. This was upgraded to EZEIZA IV[5], which included treatment of floodplains, flow transitions (convergence, divergence, curves) and hydraulic structures (bridges, culverts, gates). The most advanced version, EZEIZA V[6], allows treatment of an arbitrary flow net.

One of the earliest applications of EZEIZA V was for the systematization study of the Reconquista River Basin, in the Province of Buenos Aires[7]. The hydrodynamic model, driven through inputs of hydrological models for the tributaries, was used to design the channelization and the minimum cross-sectional transparency at the bridge sites.

The main application of EZEIZA V has been for the Hydrological Warning System of the Rio de la Plata Basin, a service provided by INA. Specifically, the Paraná River has been modeled from Yacyretá dam down to Rosario city, including part of the Paraguay River[8], for a total of about 1,500 km. Figure 1 shows a comparison between recorded and calculated water levels at Esquina Station for the calibration run, showing an average error of about 10 cm.

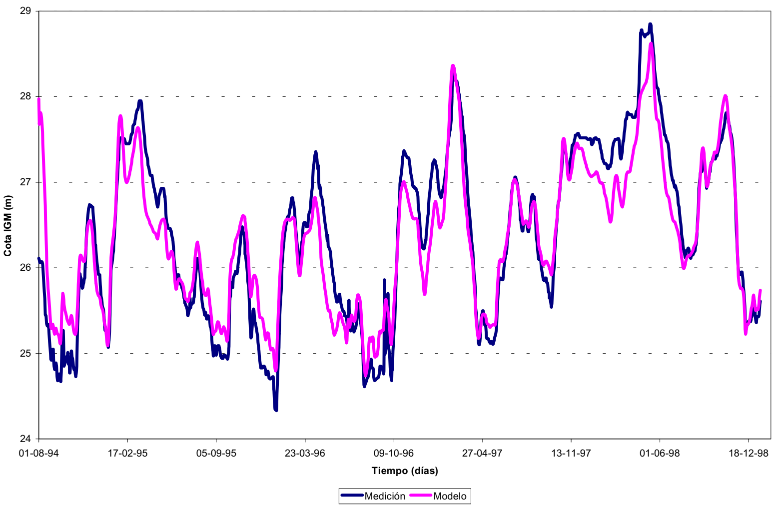

Figure 1: Comparison between calculated and recorded levels at Rosario Station.

Water currents in shallow waters

In shallow waters currents are driven by flow discharge, tidal waves and/or wind action. Its determination is needed for:

- Evaluation of water action on bottom sediments and margins
- Hydraulic design of hydraulic structures
- Dimensioning of bottom or margin protection works
- Input for maintenance dredging calculations of engineering works (harbours, navigation channels)

Due to the shallow water condition, the problem is mathematically represented by a two-dimensional horizontal hydrodynamic model based on the well known shallow water equations[9]:

$$\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}(hu)+\frac{\partial}{\partial y}(hv)=0$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-f_g v+g\frac{\partial(h+z_0)}{\partial x}+\frac{\tau_{fx}}{\rho\,h}-\frac{\tau_{sx}}{\rho\,h}-\frac{1}{\rho\,h}\frac{\partial}{\partial x}(hT_{xx})-\frac{1}{\rho\,h}\frac{\partial}{\partial y}(hT_{xy})=0 \qquad (2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+f_g u+g\frac{\partial(h+z_0)}{\partial y}+\frac{\tau_{fy}}{\rho\,h}-\frac{\tau_{sy}}{\rho\,h}-\frac{1}{\rho\,h}\frac{\partial}{\partial x}(hT_{xy})-\frac{1}{\rho\,h}\frac{\partial}{\partial y}(hT_{yy})=0$$

where x and y are the spatial coordinates, u and v the vertically-averaged velocities in those directions, respectively, f_g the geotrophic factor, τ_{sx} and τ_{sy} the components of the shear stress on the surface due to wind, τ_{fx} and τ_{fy} the components of the shear stress on the bottom and T the effective stresses tensor. These equations were numerically solved using an implicit alternating direction finite difference method of the Leenderste type. The algorithm was implemented in software HIDROBID II[10]. It has the capacity to represent a variety of boundary conditions (inflow, outflow, non-reflecting, level-driven, velocity-driven) and model a wide range of hydraulic structures (impermeable and permeable walls, bridges, culverts, gates).

One of the earliest applications of HIDROBID II was for the construction of Yacyretá dam on the Paraná River, located at the boundary between Argentina and Paraguay. The hydrodynamic model was used to design the strategy for closure of the secondary branch, which indicated a priori a risk of uncontrolled bottom erosion[11].

The use of the shallow water model to determine the hydraulic impact of physical connections across the river valley has been discussed by the author in a recent paper[12].

The main application of HIDROBID II has been for studies of the Rio de la Plata. The first hydrodynamic model of the whole river was implemented back in 1985[13], considering both the tidal currents generated by the incoming oceanic wave and the drift current induced by the tributaries. Through posteriori work wind action was introduced[14]. In 1999 un updated model was implemented, with a much finer numerical grid and an improved calibration[15]. Figure 2 presents instantaneous views of the free surface elevation and the velocity field. Model outputs were used, for example, to determine the water current along the navigation channels of the Río de la Plata, through which the oceanic vessels proceeds, in order to evaluate their maintenance dredging in view of the bid for concession of the dredging works[16].

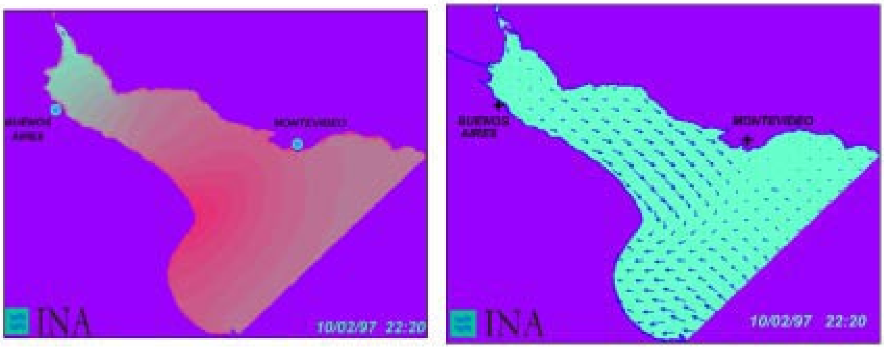

Figure 2: Instantaneous maps of free surface elevation and velocity field according to model

Wave transformation in the coastal zone

Waves arriving at the coast undergo transformation processes due to depth variations and the presence of obstacles. Knowledge of the resulting wave at the coast, once the wave conditions at the open sea are determined, is needed for:

- Evaluation of coastal erosion
- Design of coastal protection works
- Design of harbour layout in order to minimize wave energy

On a long scale the main processes of wave transformation are refraction and shoaling. They can be modeled with a simple ray theory (Snell law). On a short scale, usually very close to the coast, diffraction effects cannot be neglected. Working in the frequency domain, through Fourier decomposition, the problem is mathematically represented by a two-dimensional horizontal hydrodynamic model based on the mild slope equation[17]:

$$\nabla.(cc_g \nabla\phi) + \frac{c_g}{c}\omega^2\phi = 0 \qquad (3)$$

where ϕ is the reduced plane potential, c the phase velocity, c_g the group velocity and ω the angular frequency. This equation was numerically solved using a hybrid finite element-boundary element method. The algorithm was implemented in software DIFRAC[18]. It has the capacity to represent a variety of boundary conditions (wave-driven, radiation, non-reflecting).

The main application of DIFRAC has been for the design, optimization and, once built, analysis of response of Caleta Paula harbour, at Province of Santa Cruz[19]. A similar, more recent, study was done for the reconfiguration of Rawson harbour, at Province of Río Negro. Figure 3 shows a prediction of wave height distribution for the chosen design under northeastern wave action.

One of the most interesting applications of DIFRAC was for the analysis of protection works against ship waves at the Yatch Club Argentino marina, located within Buenos Aires harbour[21].

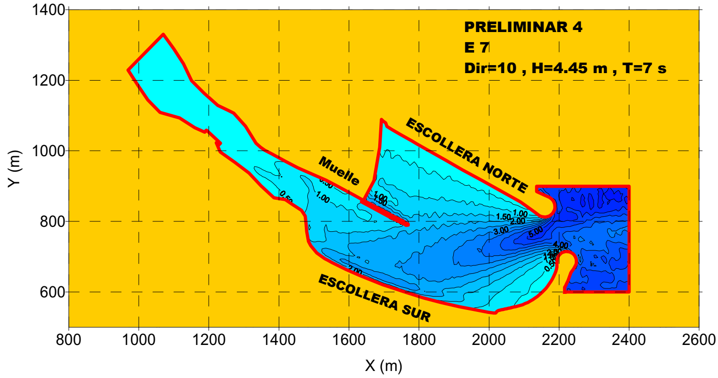

Figure 3: Wave height distribution for waves coming from NE

3 SEDIMENT DYNAMICS

River, estuarine and reservoir bottom morphology

The bottom of a natural water course evolves continuously due to sediment transport, both in suspension and as bed load, driven by the water currents. Evaluation of this evolution is needed for:

- Diagnosis of observed erosion or sedimentation problems
- Prognosis of future bottom evolution due to new hydraulic works
- Design of bottom protection works

For changes taking place on a long spatial scale relative to the transversal dimensions of the water course, a one-dimensional analysis is sufficient. Such an approach was used to make predictions on the generalized erosion of the Paraná River bottom that would occur if the Paraná Medio Dam project were implemented[22].

The width of a river or estuary is usually much larger than its depth. Hence, for bottom changes with spatial scales of the order of the width a two-dimensional horizontal sedimentologic model can be used[23]:

$$\frac{\partial (hC)}{\partial t}+\frac{\partial (q_{sx})}{\partial x}+\frac{\partial (q_{sy})}{\partial y}$$
$$=\frac{\partial}{\partial x}\left(hK_{11}\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial x}\left(hK_{12}\frac{\partial C}{\partial y}\right)+\frac{\partial}{\partial y}\left(hK_{21}\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(hK_{22}\frac{\partial C}{\partial y}\right)-D+E \tag{4}$$

where C is the vertically-averaged suspended sediment concentration, q_{sx} and q_{sy} the specific solid discharge (including suspended and bed load) in the x and y directions, respectively, h

the water depth, *K* the diffusion-dispersion tensor, *D* the deposition rate and *E* the erosion rate. This equation was numerically solved using a finite difference method compatible with the 2D hydrodynamic software HIDROBID II. The algorithm was implemented in software SEDIMBID[24]. It has the capacity to represent both suspended and bottom load and to treat adequately the boundary conditions for both coarse (sand) and fine (silt and clay) suspended sediments.

The main application of SEDIMBID for a fluvial water course has been for the diagnosis of the observed erosion at the Paraná River bottom around the section where the Mesopotamic Gasoduct crosses the river, threatening with provoking its failure[24]. The model adequately predicted the general trend of the phenomenon: a continuation of the erosion process at a slower rate. Figure 4 presents the bottom morphology evolution as predicted by the model after 3 months.

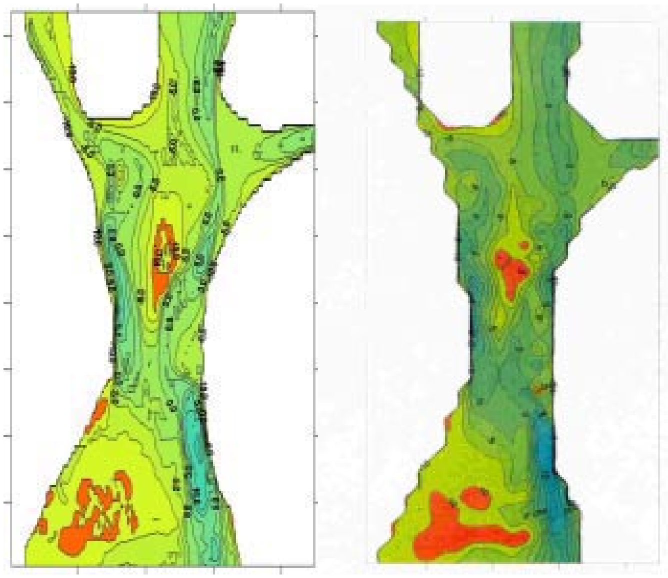

Figure 4: Evolution of bottom morphology according to model. Initial pattern and 3 months later, respectively.

The application of the model to an estuary was done on the Río de la Plata, in relation to the sedimentation problem that would trigger the construction of protection islands around the main piers of the main bridge of Punta Lara-Colonia physical connection project. The evolution of the sedimentation bars was predicted[25]. Figure 5 shows the final form, attained after around 1½ centuries.

In the case of a reservoir, the width can be much smaller than the depth, in which case the bottom changes with spatial scales of the order of the depth can be represented with a two-dimensional vertical sedimentologic model[26]:

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}+(w-w_s)\frac{\partial C}{\partial z}=\frac{\partial}{\partial z}\left(\varepsilon_z\frac{\partial C}{\partial z}\right) \tag{5}$$

where C is the laterally-averaged suspended sediment concentration, u and w the laterally-averaged velocities in the x and z directions, respectively, w_s the fall velocity of the suspended sediment and ε_z the laterally-averaged turbulent diffusion in the vertical direction. This equation was numerically solved using a finite element method. The corresponding 2D vertical hydrodynamic model was also solved. The algorithm was implemented in software SEDIMRES[26]. It has the capacity to represent both suspended and bottom load and to treat adequately the boundary conditions for both coarse (sand) and fine (silt and clay) suspended sediments.

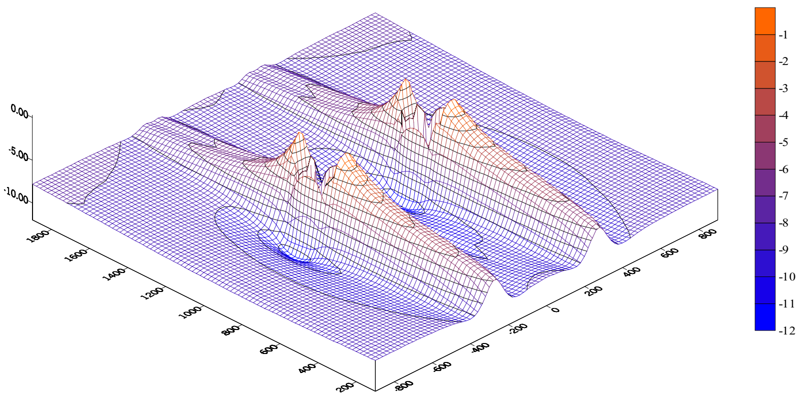

Figure 5: Final form of the longitudinal bars around the protection islands

SEDIMRES, which formulation constituted a Ph.D. thesis, has been validated through its application to Lake Mead reservoir, on the Colorado River (USA)[26]. Figure 6 presents the comparison between the measured and simulated bottom profiles after 30 years.

Sedimentation in navigation channels

Navigation channels, constructed through dredging operations, usually needs a continuous maintenance dredging due to the tendency of the channel to fill again with sediments. Estimation of maintenance dredging is needed for:

- Evaluation of alternative alignments of channels to be built
- Design of dredging operations in order to optimize them
- Prognosis of future maintenance dredging for deepening projects

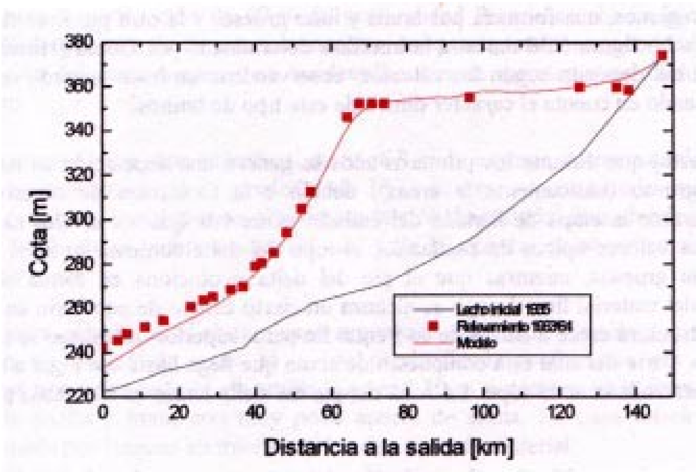

Figure 6: Comparison between model prediction and measurement for bottom form after 30 years.

As navigation channels are usually long as compared to their width, a truly two-dimensional vertical sedimentologic model can be used[27], i.e., equation (5) with the quantities being now the punctual values instead of the laterally-averaged ones.

This equation was numerically solved using a finite element method. A parametric two-dimensional vertical hydrodynamic model was also considered to provide the driving mechanism. The algorithm was implemented in software AGRADA[28]. It has the capacity to represent both suspended and bottom load and to treat adequately the boundary conditions for both coarse (sand) and fine (silt and clay) suspended sediments.

The main application of AGRADA has been for the prognosis of the maintenance dredging for the deepening of the oceanic vessels navigation route from Santa Fe to the ocean, along the Paraná River and the Río de la Plata. The model results were used as a base for the concession bid for dredging activities, at the beginning of the 90's. Figure 7 shows predictions for the maintenance dredging of the navigation channels of the Río de la Plata for various depths and two alternative routes.

Turbidity plumes

One of the main environmental impacts of dredging operations is the generation of "turbidity plumes", as are termed the zones around the points where the dredged material is dumped, in which a strong over-concentration of suspended sediments develops. Knowledge of the region affected by turbidity plumes is needed for:

- Evaluation of alternative sites for sediment dumping in order to minimize the environmental impact and/or the backfilling
- Establishment of "mixing zones" where water quality standards are not met, at least intermittently

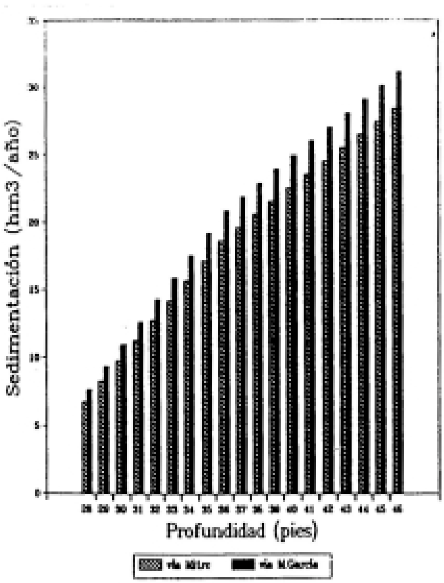

Figure 7: Maintenance dredging for various depths and two alternative routes along the Río de la Plata.

After the initial dilution takes place (in the so called “near field”, where the way in which the dumping is performed is determinant and where three-dimensional effects are significant), a “far field” zone develops, where the sediment is passively transported by the ambient water current. As complete vertical mixing is usually achieved at this zone, the mathematical representation of the transport phenomenon can be made by a two-dimensional horizontal sedimentologic model, i.e., by means of equation (4). However, a special approach can be undertaken taking into consideration the plume characteristics of the transport zone arising from the point discharge. In fact, representing this discharge as a succession of instantaneous pulses, each one gives rise to a 2D cloud with a gaussian distribution, which later develops by translation (through advection), rotation (through diffusion-dispersion), deformation (through diffusion-dispersion) and attenuation (through deposition). The parametric representation for the clouds is the following[29]:

$$C(x,y,t)=\frac{M\sqrt{D}}{\pi h}\exp\left[-a_{11}(x-x_o)^2-2a_{12}(x-x_o)(y-y_o)-a_{22}(y-y_o)^2\right] \tag{6}$$

where M is the mass of the cloud (the product of the rate of mass dumping and the time step), a_{ij} and D form parameters and x_o and y_o the coordinates of the cloud center. Ordinary differential equations are readily obtained for the position and form parameters, which were numerically treated using an splitting technique: the advective part was solved by integrating along the characteristics (the fluid trajectory); for the rotation and deformation parts, standard techniques for ordinary differential equations were used; for the attenuation part a straight integration is possible. The algorithm was implemented in software MANCHAS[30]. It has the capacity to represent multiple sources acting instantaneously or continuously in a time-varying hydrodynamic field. It uses the hydrodynamic conditions provided by HIDROBID II.

MANCHAS has been applied to determine the affectation zone of plumes arising during the dumping of sediments for the deepening of the navigation channels from Santa Fe to the Ocean[31]. Figure 8 presents instantaneous plumes originating in the pumping discharge of sediments dredged from the Mitre Channel (Río de la Plata).

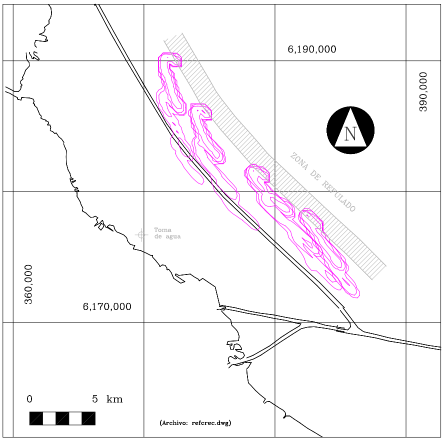

Figure 8: Turbidity plumes arising from dumping of sediment dredged from Mitre channel.

4 POLLUTANT DYNAMICS

Contamination by point sources

The discharge of domestic and industrial residual liquids to superficial water bodies through ducts or outfalls constitutes one of the main sources of water contamination. The determination of the zones affected by these point sources is needed for:

- Diagnosis on how existing point discharges affect the receiving water body
- Evaluation of alternative sites for the discharge
- Establishment of “mixing zones” where water quality standards are not met

The problem of point discharges is mathematically equivalent to the already discussed problem of turbidity plumes. Hence, the parametric equations (6) constitute the mathematical model. The main difference is that attenuation due to deposition must be replaced by a more general “reaction” term, that includes chemical, biochemical and biological mechanisms of transformation of the substance, in addition to the physical mechanisms.

The main application of MANCHAS to point source contamination has been to the problem of diagnosing the effect of the submarine outfall at Berazategui, on the Río de la Plata, which discharges the domestic effluents from the metropolitan region of Buenos Aires[30]. A later similar work was done for Bahía Blanca[32]. Figure 9 shows an instantaneous plume representing concentrations of coliforms.

Figure 9: Pollution plume representing coliform distribution in Bahía Blanca.

Pollutant balance

Flowing waters transport a variety of natural and anthropogenic pollutants. Through adequate mass balances, including all the relevant mechanisms acting within the water body, important conclusions can be drawn for:

- Diagnosis on the sources of origin and the magnitude of each contribution
- Evaluation of the impact of each source
- Establishment of management options

For long scales of analysis, relative to the lateral dimensions of the water body, a one-dimensional analysis is possible. For a more detailed analysis of a river or estuarine environment, where the width is much larger than the depth, and for a scale of analysis of the order of the width, a two-dimensional horizontal model is enough, i.e., a mathematical model represented by equation (4), with the deposition-erosion terms replaced by a more general "reaction" term, that includes chemical, biochemical and biological mechanisms of transformation of the substance, in addition to the physical mechanisms.

A recent application of this type of approach has been undertaken using public domain software WASP (from USEPA) to study nutrient balance in the Inner Río de la Plata[33]. Figure 10 presents the comparison between measured and calculated electrical conductivity (the calibration quantity) for the 12 segments in which the study zone was divided.

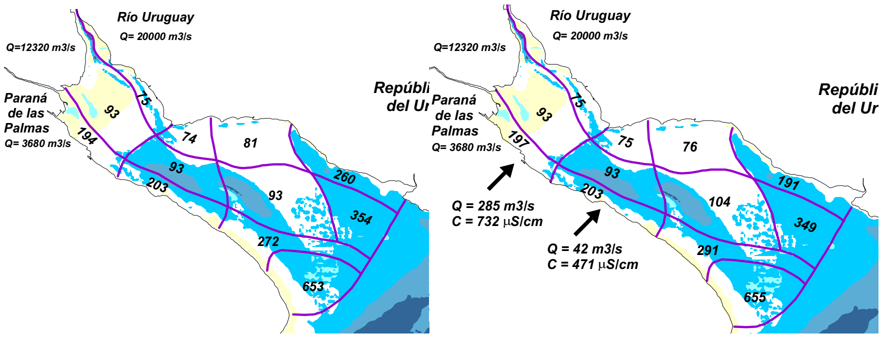

Figure 10: Measured and calculated segment-averaged conductivity.

5 HEAT DYNAMICS

Thermal contamination

If the discharge of heated water towards a water body is weak enough to prevent any significant effect on the hydrodynamics, it can be treated as a passive pollutant transport problem. The determination of the zones affected by these heat point sources is needed for:

- Evaluation of alternative sites for the discharge
- Establishment of "mixing zones" where water quality standards are not met
- Study of possible heat short-cuts in refrigeration systems of power stations

The problem of thermal point discharges behaving as a passive pollutant is, then, mathematically equivalent to the already discussed problem of turbidity plumes and pollutant point sources. Hence, again the parametric equations (6) constitute the mathematical model. This time, the source-sink term must represent the heat exchange rate with the atmosphere, including incoming long and short wave radiation, backwards scattering, black-body radiation, and advective and diffusive heat transfer.

The main application of MANCHAS to heat point source contamination has been to the problem of analyzing the performance of the refrigeration system of the thermal power station "Central Costanera", located at the mouth of the Riachuelo, in order to make a prognosis for the situation with the expansion of the plant[34]. Figure 11 shows an instantaneous thermal plume.

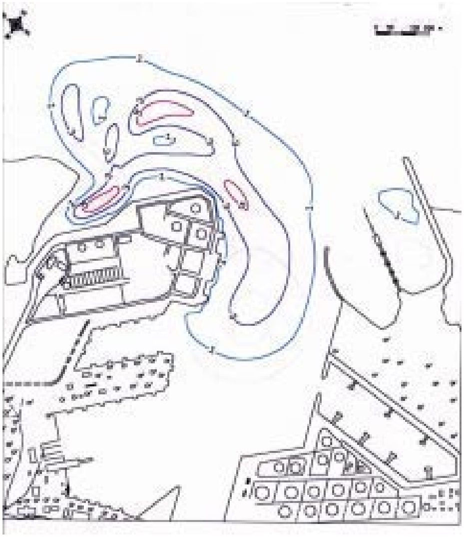

Figure 11: Thermal plume for Central Costanera.

Thermal stratification

If the input of heat to a water body, through heated flow or radiation, is relatively intense, it influences very significantly the hydrodynamics by establishing a thermal stratification. The study of the problem of thermal stratification is needed for:

- Evaluation of performance of cooling ponds for refrigeration systems
- Evaluation of water quality of lakes and reservoirs

The mathematical representation of the problem of thermal stratification requires, at least, the distinction between the upper warm layer and the lower cold layer. The simplest approach consist of a zero-dimensional model in which each of the two layers is treated as a completely mixed reactor. Establishing the conservation of mass and energy for this system, the following set of equations arise[35]

$$\begin{aligned}
\frac{d\forall_h}{dt} &= \alpha Q_i + \beta Q_j - \theta Q_o + e \\
\frac{d\forall_c}{dt} &= (1-\alpha) Q_i - (1-\theta) Q_o - e \\
\frac{d\forall_h T_h}{dt} &= \alpha Q_i T_i + \beta Q_j T_j - \theta Q_o T_h + e T_e + H^*_{fs} - H^*_e \\
\frac{d\forall_c T_c}{dt} &= (1-\alpha) Q_i T_i - (1-\theta) Q_o T_c - e T_e + H^*_e
\end{aligned} \tag{7}$$

where subscripts h and c indicate the hot and cold layer, respectively, V is the layer volume, T the layer temperature, Q_i the water input due to tidal action with temperature T_i, Q_j the water input due to a point source of temperature T_j,, Q_o the water output, α a jet entrainment coefficient, β a partition coefficient, θ a suction coefficient, e a layer entrainment coefficient, T_e the temperature of the donor layer, H_{fs}^* the heat input at the free surface and H_e^* the heat transfer from the hot to the cold layer. This theoretical model was implemented in software ESTRATO. It allows for all types of heat inputs from the atmosphere, heated water inputs, water extraction through outlets and water interchange through tidal action.

The first application of ESTRATO has been to the problem of analyzing the performance of the cooling pond of the thermal power station "Central Puerto", located within Buenos Aires harbour, in order to make a prognosis for the situation with the expansion of the plant[36]. Figure 12 presents the comparison between the predicted and the mean measured location of the thermocline for the situation previous to the expansion.

Another significant application of the model was for the evaluation of stratification at Potrerillos reservoir, in Provincia de Mendoza, within the context of the environmental impact studies[35].

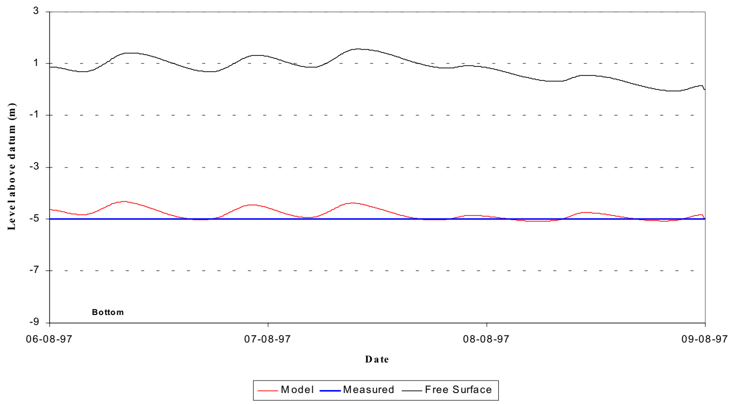

Figure 12: Comparison between predicted thermocline location and its measured position.

6 PRESENT LINES OF WORK

New problems are being posed and more powerful computer technologies are available. They are defining the present lines of work at INA-HL. They are summarized in the following.

Density currents and stratification

Thermal effects or intrusion of saline waters or highly concentrated suspensions can give rise to density currents and, eventually, stratified flow. Resolution of this type of problems is needed for:

- Water quality analysis of lakes and reservoirs
- Sedimentation in reservoirs or in navigation channels due to turbidity currents
- Dynamics of saline fronts in estuaries, with influence in biodiversity

To solve them, truly three-dimensional unsteady fully-coupled models are usually necessary.

A first experience on 3D models application was undertaken using software COHERENS, a public domain software developed by the European Union, to study the saline front dynamics in the Río de la Plata[37].

Pollutant transport

The problem of pollutant transport has a significance strong enough in environmental studies that it deserves the development of more powerful numerical techniques. The lagrangian cloud method used in MANCHAS can now be substituted with the follow up of particles that undergo an stochastic movement.

A development is under way using this type of technique. In addition to the already established ways of treating advection and diffusion, research is being made to develop adequate relations for sedimentation and resuspension of sediments.

Evolution of river margins

The topic of river margin evolution is presently one of intensive research. This is due both to its practical significance and to the fact that some maturity has been attained in modeling river bottom evolution, hence creating the basis to undertake this subject. Its practical significance is illustrated by the following problems:

- Margin erosion threatening productive or ecologically valuable lands and properties
- Margin accretion threatening ports activities
- Planning of urban development

The solution of this type of problems requires an integrated approach among hydrodynamic, sediment transport and morphological models. In particular, morphological models must incorporate erosion laws for the margins, taking into account at least both fluvial erosion and bank failure. In turn, sediment transport models must deal with quite different sediment sizes, including bottom sediment and the products of bank erosion.

A first integrated model has been already implemented and validated[38]. It solves the hydrodynamics by a succession of a 1D longitudinal and a 1D lateral model. The margins are assumed as constituted by a coarse material of the same type as the bottom. The erosion mechanism is simulated through an algorithm which continuously monitor the bank slope, producing small slides each time the critical slope is attained. Figure 13 presents a comparison between results of the model and from measurements at a laboratory channel for the width and depth evolution.

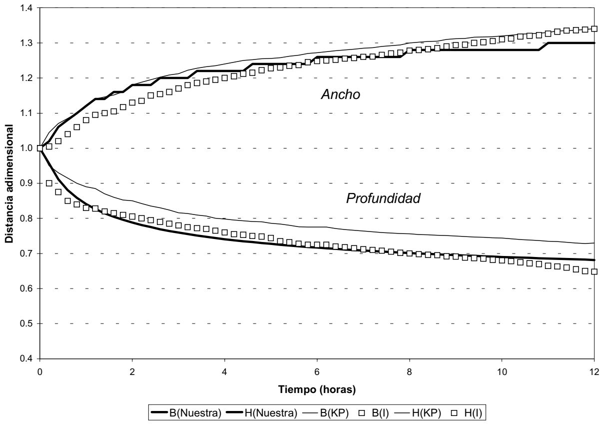

Figure 13: Width and depth evolution according to measurement and model.

Climate change

Climate change is one of the main issues in the present world management agenda. Already accepted the evidence that a natural or anthropogenic change is taking place, efforts are presently directed to:

- Develop future possible scenarios
- Establish the uncertainty of predictions
- Develop remediation and adaptation strategies to deal with unfavorable future scenarios

Dealing with climate change does not necessarily mean undertaking more sophisticated model developments. More important than that is exploiting existing or new tools in a significant way to reach with the results to planning decision makers. This leads to the incorporation of uncertainty and risk analysis.

At present, INA-HL is involved in two interrelated projects. One is a Strategic Project of the University of Buenos Aires named *"Floods: genesis, socio-economical cost, adaptation and prevention"*; the second one is an AIACC project named "*Impact of Global Change on the Coastal Areas of the Río de la Plata: Sea Level Rise and Meteorological Effects*". Both aims at studying the possible effects of climate change on the Río de la Plata coasts. Figure 14 shows results of a hydrodynamic model for the Río de la Plata, implemented on an extended domain in order to make experiments with different storms surges generated in that area.

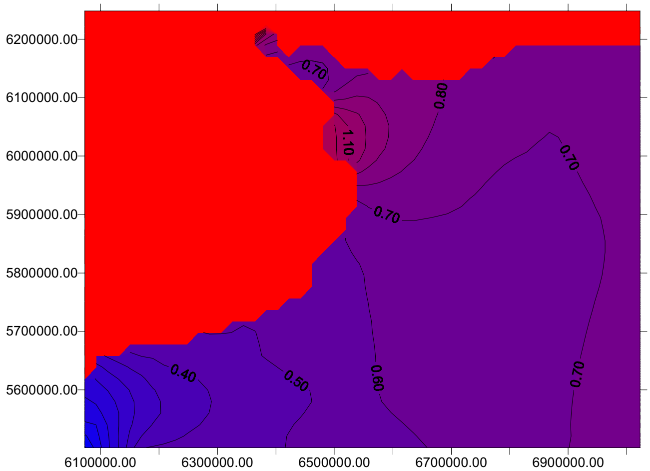

Figure 14: Water surface distribution pattern in the Río de la Plata and it maritime front.

7 CONCLUSIONS

Problem-driven software development has been the policy at INA Hydraulics Lab for three decades. This has allowed participation in a variety of practical studies with significant social impacts using sophisticated numerical tools, meaning that the institutional mission has been fulfilled: research and development at the service of the public needs.

To maintain this policy a continuous follow up of needs from the productive and social media has been performed. Many times, to be consistent with this policy, some research projects had to be abandoned in favor of new lines of work which would attend more directly to the eventual needs.

Present issues, with a high environmental concern and the uncertainties posed by the climatic change, are again reshaping our goals for the near future.

The next example is a multi-line equation:

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