Application of a new Mean Velocity equation of Flow in a natural stream of 8.5 m3/s, Its Verification and extrapolation: Copper Creck river, Virginia (USA).

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Abstract: - The application of a new equation for average flow velocity in turbulence has already been done in a calibrated channel with precise results [1], so it is interesting to apply it now to a larger natural channel, of 8.9 m3/s, with tracer measurements that They were made in the USA in 1959 and were very well documented [2][3][4]. This condition of abundance of information, the same as in the Caltech Canal, allows the reliability of the new equations to be verified in detail, and to achieve substantial improvements in river hydrometry techniques

Key-Words: - Hydraulics; Fick, Chezy-Manning; Models; turbulence, state functions.

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1. Introduction

Environmental and Hydraulic Impact studies currently depend critically on a certain set of data from water bodies that generally depend, in their quantity and quality, on the measurement methods used. Thus, although there are very advanced and powerful computer programs, and there is refinement in many equipment and techniques, a great drawback remains in that there is no direct link between Hydraulics, geomorphology and dispersive transport, only at the level of semi-empirical equations, that do not ensure a necessary generality.

The author has presented a definition of a State function, involving the mean velocity of flow, as follows. [5][6]

$$\Phi \approx \frac{/vd/}{U} \quad (1)$$

Here the "dispersion velocity", $\pm \boldsymbol{vd}$, acts in both longitudinal directions from the center of the Gaussian distribution, and whose module is:

$$/vd/ \approx \frac{\Delta}{\tau} \approx \frac{\sqrt{2*D*\tau}}{\tau} \quad (2)$$

With, $\boldsymbol{\Delta}$ equal to a characteristic Brownian displacement, and $\boldsymbol{\tau}$ equal to the characteristic time of that displacement, with $\boldsymbol{D}$ as Longitudinal Dispersion Coefficient.

The definition of the characteristic time, $\boldsymbol{\tau}$, corresponds to the Brownian mechanism of self-similarity at all scales established by M. Feigenbaum, with its fractal constant, $\boldsymbol{\delta}$. [7]

$$\frac{t}{\tau} \approx \delta \approx 4.6692 \quad (3)$$

In the formulation of the mean velocity of flow, $\boldsymbol{U}$, the interactions that are considered are the Coulomb forces of the Van der Waals type.[8].

$$U \approx \frac{1}{\Phi}\sqrt{\frac{2D}{\tau}} \quad (4)$$

Of course, the average velocity corresponds to that defined in mechanical terms, according to Chezy-Manning, considering mechanical, Newtonian, forces [9].

$$U \approx \frac{R^{\frac{2}{3}}}{n}\sqrt{S} \quad (5)$$

Where $\boldsymbol{R}$ is the hydraulic radius, $\boldsymbol{n}$ is the Manning roughness, and $\boldsymbol{S}$ is the energy slope of the flow.

An important characteristic of the new equation is that it depends on a thermodynamic potential, such that:

$$\oint d\Phi = 0 \quad (6)$$

This is important for several reasons, since this type of function is sensitive to the thermodynamic conditions of the process, and also depends on few variables, which allows defining a statistical coupling of the tracer with the flow, since basically the evolution of ***Φ***, reflects the phase transition of the solute from solid to gaseous, when the tracer plume is so diluted (osmotically) that it is almost virtually a set of water particles, with the particularity that it can be traced with instruments. [10]

Historically an important link, between Hydraulics, geomorphology and dispersive transport, was the proposal by W. Elder [11], who early related the slope, ***S***, and the depth of flow, ***h***, with the longitudinal dispersion coefficient, ***D***.

$$D \approx 5.93 * h * \sqrt{h * g * S} \tag{7}$$

This equation did not gain sufficient audience, since at the time it was proposed, it was thought that since it was based on the vertical distribution of flow velocity, it did not also represent the lateral distributions.
In this way, current techniques for studying river advection and dispersion have lacked tools that reestablish this link. This is the aim of presenting this new flow velocity equation.

2. Problem Formulation.

2.1 The evolution of State function: How to define and apply it.

Based on the above concepts, the state function can be approximately defined as: [12].

$$\Phi \approx \frac{M}{Q*\gamma*1.16} * \frac{1}{\sqrt[3]{tp}} \tag{8}$$

Here, ***M*** is the mass of tracer injected, ***tp*** is the peak time of tracer curve, and ***γ*** is a characteristic parameter of each solute used, and which must be calculated experimentally:

$$\gamma \approx \frac{Cp(tp)}{tp^{-\frac{2}{3}}} \tag{9}$$

Then, it can be established that ***Φ(t)*** evolves as shown in Figure 1.

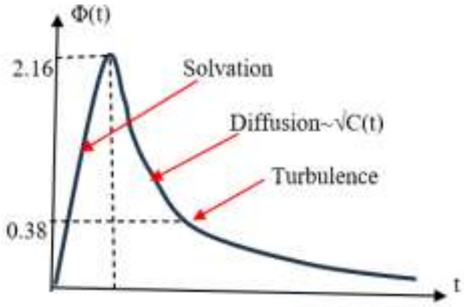

Figure 1.- Evolution of State function Φ(t).

The steep segment (up to ***Φ≈ 2.16***) corresponds to the "solvation" process of the solute. The smooth decaying segment corresponds to the evolution of the ions, which diffuse until at ***Φ≈ 0.38***, almost all of them are in the gas phase, and ***Φ(t)*** is considered to describe the turbulent evolution of the flow.[13] Figure 2.

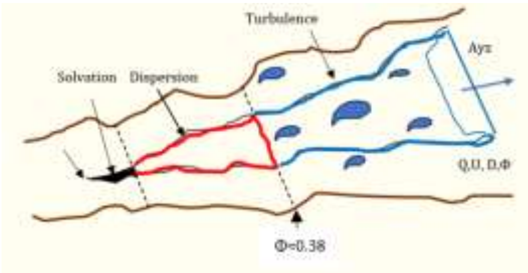

Figure 2.- Turbulence described locally by a State function Φ(t).

The blue "patches" seen in this figure correspond to linearity fluctuations related with discontinuities of the homogeneity on the "Coarse grained" representation, that the "dynamic equilibrium", ideally would impose on the Probability Distribution of the channel.[14][15]
This effect arises from the fact that water flows do not ideally comply with the "linearity" of non-equilibrium thermodynamics, deviating somewhat from "statistical sufficiency". [16][17][18] This fact means that the variances of the magnitudes in the fluvial processes are small but not zero (Principle of minimum entropy production).

2.2 Efficient planning of Advection-Dispersion measurements using tracers.

These considerations allow planning measurements in turbulent channels of a certain large size, in which other methodologies fail due to not having precise extrapolation mechanics, such as being able to know where the "Complete Mixing" condition occurs, as the transition is called. to "ideal gas" of the tracer ***(Φ≈ 0.38)*** where the area in which the channel already meets its "assimilation" condition is conventionally

delimited, and where the location of physical, chemical and biological monitoring equipment is located by the eventual homogeneity of their readings.
This feature of the State Function is very useful as it allows practical calculations of turbulent flow, at convenient distances, and using minimum amounts of tracer, since it is not required to "saturate" the flow (as in conventional methods). All this is possible without entering into conventional discussions about the non-linear nature of the process [19]. Figure 3.

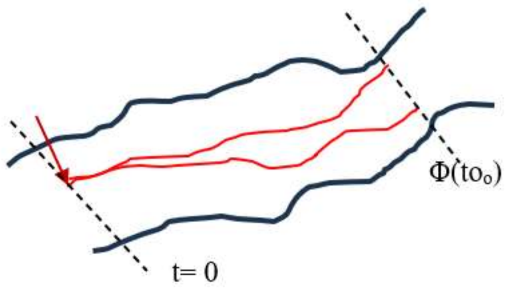

Figure 3.- Extrapolation by means of State function Φ(t).

With these criteria and techniques, it is feasible to plan an efficient measurement campaign in which a series of Advection, Dispersion and geomorphology data can be provided, which guarantee very precise modeling procedures.

2.3 Modified Fick equation: realistic representation of asymmetric tracer curves.

The classical theory of one-dimensional transport for conservative solutes is expressed in the Fick equation, with M the mass suddenly injected into the flow, ***Ayz*** the cross-sectional area of the tracer flow, ***U*** the average velocity and ***D*** the dispersion coefficient.

$$C(X,t) \approx \frac{M}{Ayz*\sqrt{4\pi*D*t}} e^{-\frac{(Xo-U*t)^2}{4*D*t}} \qquad (10)$$

This definition considers that ***D*** does not depend on time (constant value), so the shape of the theoretical curve does not represent the experimental bias that appears.
To restore the faithful representation of reality, the Coefficient ***D*** must be cleared from equation (4), and replaced in equation (10), where ***τ≈0.214*tp***, using Feigenbaum's development [20][21]:

$$D(t) \approx \frac{\Phi^2*U^2*\tau}{2} \qquad (11)$$

In this expression Φ(t) fulfills the function of "form factor" while the degree of asymmetry is determined by it, and the irreversible losses are represented by U2. This means that the Longitudinal Dispersion Coefficient is a non-linear function of time since the factors that define it are in turn a function of time.
From this we obtain "modified" Fick equation, with Q as the flow rate:

$$C(X,t) \approx \frac{M}{Q*\Phi*t*1.16} e^{-\frac{(to-t)^2}{2*0.214*(\Phi*t)^2}} \qquad (12)$$

When the mass of the tracer is in milligrams or micrograms per liter, the flow rate is in Liters per second.

2.3 Flow velocity and tracer centroid velocity.

The question usually arises about what velocity data to use when describing the movement of the flow: If it is related to the peak of the distribution, ***tp***, or if it is related to the time of centroid of it, ***ts***, which is greater than ***tp***. Figure 4.

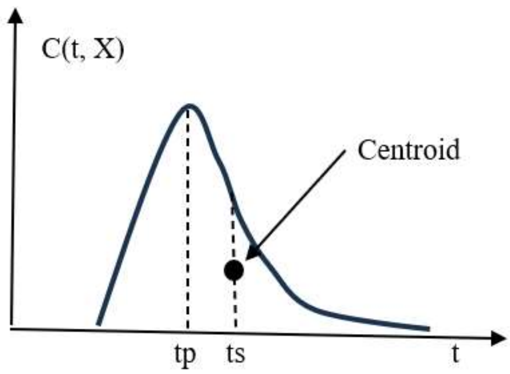

Figure 4.- Center and centroid of the distribution.

When the solute is injected into the flow, the dipolar water molecules attract the tracer particles, destroying its crystalline structure (solvation or ion-dipole interaction). From there, you will have a set of ions that increasingly separate from each other more and more, which leads to a decrease in concentration as a function of time. This concentration produces a braking effect on the tracer ions themselves, which can be modeled as a mechanism of ion-ion interaction.[22]
For this reason, you must distinguish the velocity of the "mass centroid" of the tracer plume from the velocity of the flow itself.

$$v(flujo) \approx \frac{Xo}{tp} \qquad (13)$$

And

$$v(soluto) \approx \frac{Xo}{ts} \quad (14)$$

As the braking effect of the ions on each other depends on the concentration, and this decreases with time, the two velocities tend towards a common value. Figure 5.

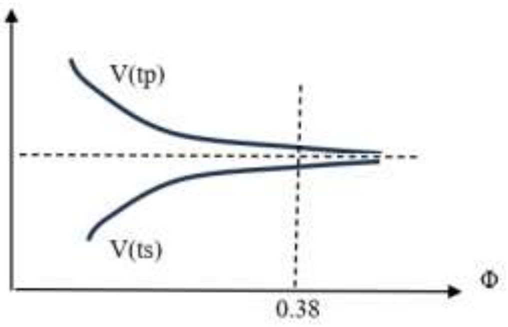

Figure 5.- Behavior of v(ts) and v(tp)

For the "Complete Mix" condition, the difference between them is approximately 13%.

2.4 The kinematics of the tracer plume: Source of symmetry for a Lagrangian observer and of asymmetry for a Eulerian observer.

For a moving (Lagrangian) observer who goes over the peak of the distribution, with velocity ***U***, as there is no displacement of the mass centroid, consequent to the fact that there is no composition of velocities between ***U*** and ±***vd***, where ***vd*** is the modulus of the velocities of dispersion, side by side on the X axis. Figure 6.

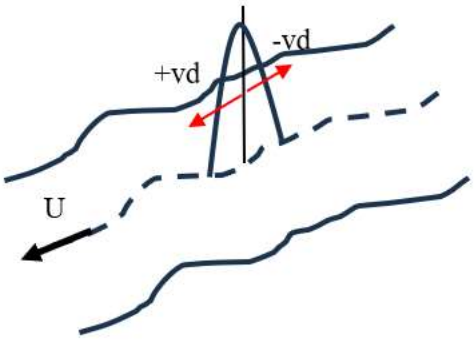

Figure 6.- Symmetric tracer curve measured by an Lagrangian observer.

For this observer, the distribution equation that is valid is one that does not consider the kinematic composition analyzed, i.e. the distribution has not bias (Φ function is not present) but does consider the effect of irreversible losses.

$$C(t, X) \approx \frac{M}{Ayz*(4\pi*D(t)*t*1.16)} * e^{-\frac{X^2}{4D(t)t}} \quad (15)$$

For an observer fixed on the shore (Eulerian), who watches the passage of the plume, this does make the composition of velocities ***U*** and ±***vd***, in such a way that the front of the plume advances with greater speed than the rear part, which It goes at a lower speed, hence the asymmetry of the curve. Figure 7.

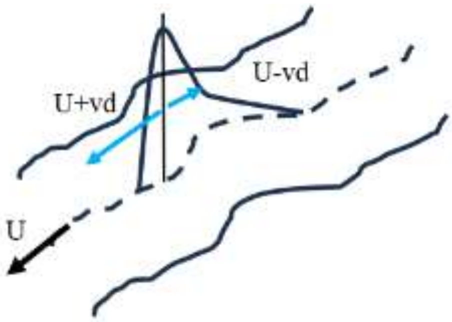

Figure 7.- Asymmetric tracer curve measured by an Eulerian observer.

In this case, the modified equation of Fick (12) is valid, showing the bias.

2.5 Extrapolation of measurements through the State Function and the new equations.

Although software systems have made great progress and efficiently support modeling in engineering and environmental studies, a serious problem remains in this field, which is the absence of efficient measurement methods to provide timely, homogeneous and precise data. In particular the methods of obtaining advection and dispersion data are archaic to say the least. Modern current meters and Doppler profilers, although digital, are essentially based on the principle of conservation of momentum, and provide "local" data, without connection to the flow as such.
Tracers, on the other hand, are based on the principle of energy conservation, and can provide "general" flow data, given their thermodynamic foundation. However, the current methods and equipment of this technique do not have theoretical tools that expand their field of action, and the technologies are coupled to this way of understanding measurement processes. Function the evolution of the plume as such, there is a basic uncertainty that is attenuated with the application of multiple equations and empirical values, which, without detracting from their value, reflect conditions. "local" that are often not applicable.[23][24]

On the contrary, the methodology based on the State Function and the average flow velocity equation based on Coulomb interactions, allow efficient planning of monitoring campaigns, promoting the obtaining of a series of coherent and precise data for feed the models.

2.6 Extrapolation procedures.

A.- Advection, Dispersion, geometric and geomorphology parameters interconnected.

A main objective in the detailed study of a channel is to have the State Function, which allows the calculation of parameters such as the Solute Concentration at a given distance, and others dispersive and advective parameters as will be analyzed below.
Apart from having the equation of the State Function itself, equation (7), a first step is to be able to use it to make an interpretation that relates it to the basic Geometry and geomorphology data. To do this, the following operations are carried out on the identity of the two one-dimensional mean velocity equations (4) and (5):

$$U \approx \frac{R^{\frac{2}{3}}}{n}\sqrt{S} \approx \frac{1}{\Phi}\sqrt{\frac{2D}{\tau}} \tag{16}$$

To make a coherent development, "*n*", the Manning Roughness, must be replaced by its dimensional equivalent dependent on the hydraulic radius and time, with "***k***" a constant that allows solving numerical proportionality. [25]

$$n \approx k * t * R^{-\frac{1}{3}} \tag{17}$$

Therefore, we can solve for Φ:

$$\Phi \approx \left(\frac{R^{\frac{1}{3}} * \sqrt{\frac{2D}{\tau}}}{k * \sqrt{S}}\right) * \frac{1}{\sqrt[3]{t}} \tag{18}$$

As you can see, this equation is equivalent to equation (8) that defines the evolution of the state function. From here it can be established that:

$$\left(\frac{R^{\frac{1}{3}} * \sqrt{\frac{2D}{\tau}}}{k * \sqrt{S}}\right) \approx \frac{M}{Q * \gamma * 1.16} \tag{19}$$

From this it follows that knowing all the data of the tracer (dispersion and advection factors), one can solve for a hydraulic and geomorphological variable based on the other.
Normally the easiest thing is to establish the Hydraulic Radius (by bathymetry), and clear the slope, which is more difficult to establish.

B.- Calculating the area of cross section of flow by means of C(X) distribution.

Apart from this evident improvement in the ability to interconnect parameters that are measured by the tracer curve and "external" parameters such as slope or hydraulic radius, which are measured or estimated by other means, the state function and its related equations, allow determining other parameters such as the area of the cross section through the area under the curve of tracer concentration as a function of distance, which will also have bias since it is another version (spatial and not temporal) of the curve seen by the Eulerian observer on the shore. Figure 8.

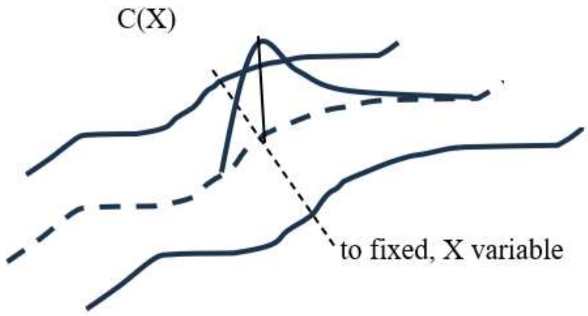

Figure 8.- Calculating Area of cross section by using C(X) distribution.

La distribución requerida, C(X), se escribe como:

$$C(X) \approx As * e^{-\frac{(Xo-X)^2}{2*0.214*(\Phi*X)^2}} \tag{20}$$

Y el area de la sección transversal es expresa como:

$$Ayz \approx \frac{A}{\int_{x1}^{x2} As(X)dX} \tag{21}$$

3. Application of new method: A case of study.

3.1 The Copper Creck stream experiment in USA, in 1959. [26]

between 1959 and 1961. This channel in the studied section is not small to the extent that it has 8.5 m3/s and an average width of 18.0 m, and an average depth

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of 0.84 m. Curves of the 1-60 experiment, with radioactive isotope as tracer is shown as in Figure 9.

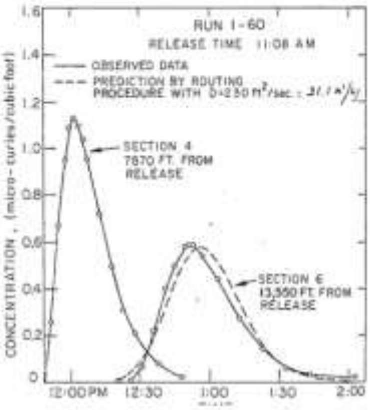

Figure 9.- tracer curves at 4 and 6 sites.

A radioactive isotope was used as a tracer, gold trichloride -198 ($AuCl_3$) which has the following advantages over other isotopes: A: allowing a maximum manageable concentration, B. - shorter half-life time (decay rate) which reduces the risk of contamination. C.- Reasonable cost.

Radioactive tracers are chemical species that emit particles in a way that are detected by "Geiger counters", and are measured, in each species by: A.- The decay constant, λ, specific for each species, which measures the % of atoms that disintegrate in the unit of time, B.- Half-life, T, which is the reciprocal of λ. C.- Activity, A, is the number of atoms disintegrated per second, which is measured in Curios (***Cui***), referred to a unit of $3.7*10^{10}$ disintegrations per second.

Unlike mass, when an "Activity" is injected in flow, (measured in ***Cui***) the active ingredient already has the condition "per second", that is, only "Cui/volume" (Specific Activity) is required at the measurement points. [27]

For the experiment (Series) 1.60 at Copper Creck, 6 measurement sections are located, of which sections 4 and 6 are chosen for measurements with instrumentation, whose photographs from the time are shown. Figure 10.

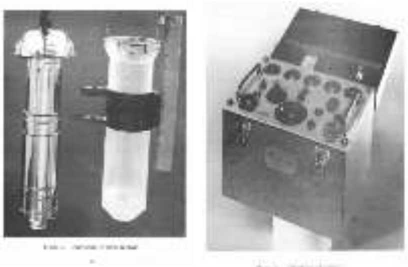

Figure 10.- Probe and data logger for signals.

Using the Second tracer curve in Figure 9, the "Activity" injected at the beginning of the experiment is initially calculated, through graphical integration, which is data that does not appear in the documentation, and which is important for the calculations. Figure 11.

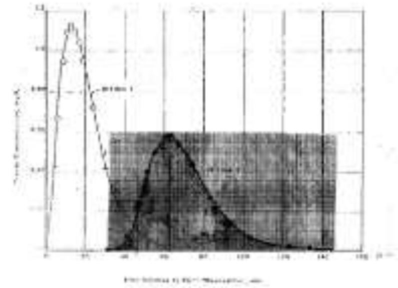

Figure 11.- Graphic integration for injected Activity.

$$A(injected) \approx Q * \int_{t1}^{t2} As(t)dt \approx 378600\ (\mu Ci) \qquad (20)$$

Series 1-60 was documented in great detail regarding its geometric and geomorphological characteristics. In English system. Table 1.

Table 1.- Geometric, hydraulic and geomorphological information in English System.[28]

Table II Channel Geometry and Flow Data, Test 1-60

Section	1	2	3	4	5	6
X (ft)	630	3,310	5,670	7,870	11,000	13,550
Q (cfs)[1]	249	276	280	269	286	308
V (ft/sec)[1]	1.65	1.82	1.88	1.74	1.64	1.49
A (sq ft)[1]	151	153	149	155	174	207
b (ft)[1]	46	63	57	58	65	70
d (ft)[1]	3.28	2.43	2.61	2.67	2.68	2.96
R (ft)[1]	3.07	2.41	2.56	2.61	2.62	2.91
T (°F)	50	50	50	50	51	50
F (ft)	0.62	4.42	7.51	10.70	13.36	17.34
$S^{1/2}$	0.031	0.037	0.036	0.037	0.036	0.036
n	0.05	0.05	0.05	0.05	0.05	0.06

[1] Based on discharge measurements made one day before tracer injection. Other data obtained from observations made during tracer test.

This data is converted into I.S in Table 2.

Table 2.- Geometric, hydraulic and geomorphological information in I.S. System.

Parameter	Section 4	Section 6
Distance from injection	X1≈2400.0 m	X2≈4100.0 m
Discharge	Q1≈ 7.62 m3/s	Q2≈ 8.72 m3/5
Mean Velocity	U1≈ 0.53 m/s	U2≈ 0.45 m/s
Area of Cross section	Ayz1≈14.4 m^2	Ayz2≈19.3 m^2
Hydraulic Radius	R1≈0.80 m	R2≈0.89 m
Mean depth	H1≈0.814 m	H2≈ 0.902 m
Mean width	W1≈ 17.7 m	W2≈ 21.4 m
Slope	S1≈0.00137	S2≈0.00130

The tracer injection characteristics are shown in Table 3.

Table 3.- Tracer information in I.S. System.

Parameter	Section 4	Section 6
Injected Activity	378600 µCi	378600 µCi
Specific Activity	As≈ 1.13 (µCi/pie^3) ≈35.3 (µCi/m3)	As≈ 0.59 (µCi/pie^3) ≈ 20.9 (µCi/m3)
Φ (t)	0.257	0.210
tp	4727 s	8596 s
τ	1016 s	1848 s
D	9.42 (m^2/s)	8.79 (m^2/s)

3.2.- Calculations of some parameters related with tracer.

A.- Calculation of "γ" for tracer $AuCl_3$-198, using equation (9), changing Concentration for specific Activity on experiment in 4 th section:

$$\gamma 4 \approx \frac{As4}{tp4^{-\frac{2}{3}}} \approx \frac{35.3}{0.0036} \approx 9937 \quad (22)$$

B.- Calculation of "γ" on experiment in 6 th section:

$$\gamma 6 \approx \frac{As6}{tp6^{-\frac{2}{3}}} \approx \frac{20.9}{0.0023} \approx 8765 \quad (23)$$

Using the values corresponding to Section 4, the factor that affects the State Function as time dependent can be initially found, according to the modified equation (8):

$$\frac{A}{Q*\gamma*1.16} \approx \frac{378600(\mu Ci)}{7.62\left(\frac{m3}{s}\right)*9937*1.16} \approx 4.31 \quad (24)$$

Therefore, Φ(t) remains:

$$\Phi(t) \approx 4.31 * \frac{1}{\sqrt[3]{tp}} \quad (25)$$

The next step is to check the values for t4 and t6:

$$\Phi(t4) \approx 4.31 * \frac{1}{\sqrt[3]{4727}} \approx 0.257 \quad (26)$$

And.

$$\Phi(t4) \approx 4.31 * \frac{1}{\sqrt[3]{8596}} \approx 0.210 \quad (27)$$

These calculated values correspond well to Table 3. Therefore, it is accepted that the State Function for the analyzed experiment is correct as:

$$\Phi(tp) \approx 4.31 * \frac{1}{\sqrt[3]{tp}} \quad (28)$$

3.3 Extrapolation of calculations using Φ(tp4) in 6 th section.

A.- Specific Activity in 6 th section.

It is interesting to verify the specific Activity in Section 6, using equation (9), but using the parameter γ4:

$$As\ 6 \approx \gamma_4 * tp4^{0.666} \approx 9937 * 0.0023 \approx 22.9 \left(\frac{\mu Ci}{m3}\right) \quad (29)$$

This is an acceptable result for hydraulic calculations, with an error of 9%, which could be improved by using an average of the "γ" constants.

B.- **Verification of mean velocity at 4th and 6th Sections, using new equation.**

$$U4 \approx \frac{1}{\Phi 4}\sqrt{\frac{2D4}{\tau 4}} \approx \frac{1}{0.257}\sqrt{\frac{2*9.42}{1016}} \approx 0.53\ m/s \quad (30)$$

And

$$U6 \approx \frac{1}{\Phi 6}\sqrt{\frac{2D6}{\tau 6}} \approx \frac{1}{0.210}\sqrt{\frac{2*8.79}{1848}} \approx 0.46\ m/s \quad (31)$$

These average velocity data at the two measurement points are accurate with respect to the experimental data in Table 2.

3.4 Calculation of the cross-sectional area, Ayz, in Section 6.

To calculate this area, based on the distribution ***C(X),*** we use the equation (19, calculated in a fixed time and varying the distance, as shown in Figure 8. It should be considered that this calculation is simply a spatial description of what the observer sees. He is Eulerian at a fixed time, and therefore maintains its own bias.
Using the equation (19) Its model in EXCEL for ***X6≈4130 m*** is shown in Figure 12.

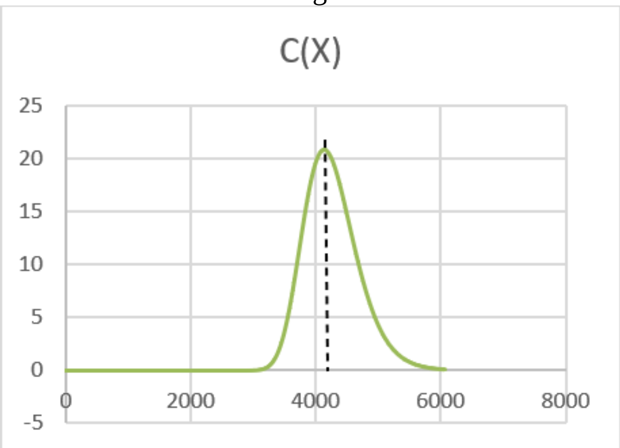

Figure 12.- Eulerian Distribution C(X).
Using Excel, the Area under the Curve of this curve is calculated.

$$\int_{X1}^{X2} C(X)dX \approx 21630 \ \ (Ci*m) \quad (32)$$

The area ***Ayz*** itself is then calculated with equation (20).

$$Ayz \approx \frac{A}{\int_{x1}^{x2} As(X)dX} \approx \frac{378600}{21630} \approx 17.5\ m^2 \quad (33)$$

This approximate value is of the same order as the data that appears in Table 2, ***Ayz≈19.3 m2.***

This means that the channel has assimilated 91% of the tracer (or pollutant) when the transport has been carried out in a time of 8596 s, at the measurement point in section 6. Figure 13.

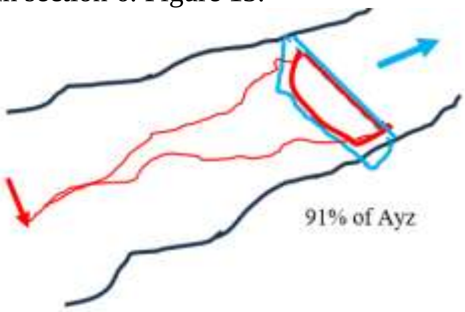

Figure 13.- Assimilation capacity of 91% in section 6th.

This figure can be a practical criterion to measure the pollution assimilation capacity of a natural channel at a given site with respect to a remote discharge.

3.5 Calculation of centroid time, "*ts*", for tracer curve.

It is important to know the centroid time, ***ts***, of the tracer curves and compare them with the peak times, ***tp***, in order to estimate the velocity of the tracer cloud and compare it with the flow's own velocity, according to what is stated in 2.3.
To do this, the tracer curve must be established in Excel, using equation (34) at first site, where ts and tp will have their maximum difference. And with the corresponding dispersion and advection parameters in tables, , applying to the new Fick equation (12). Figure 14.
It can be seen that ***ts4*** is almost equal to ***tp4***, being 3% larger. It is evident that there is already a "statistical coupling" of the plume with the flow.

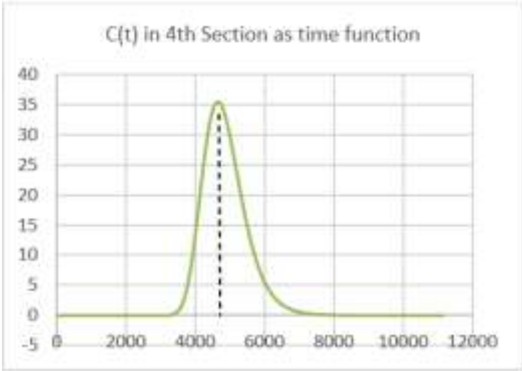

Figure 14.- New Fick distribution for 4th section.

$$ts4 \approx \frac{\sum_{t1}^{t2} Asj*\Delta tj*tj}{\sum_{t1}^{t2} Asj*\Delta tj} \approx 4871\ (s) \quad (34)$$

It can be seen that ***ts4*** is almost equal to ***tp4***, being 3% larger. It is evident that there is already a "statistical coupling" of the plume with the flow, ensuring that the calculated data is correct, describing the complete flow.

3.6. Calculation of hydraulic data from dispersive data.

From equation (19) in which the mass, ***M***, must be changed by the injected activity, ***A***:

$$\left(\frac{R^{\frac{1}{3}}*\sqrt{\frac{2D}{\tau}}}{k*\sqrt{S}}\right) \approx \frac{A}{Q*\gamma*1.16} \quad (35)$$

First, find the value of "k":

$$k \approx \frac{R^{\frac{1}{3}}*\sqrt{\frac{2D}{\tau*S}}}{\left(\frac{A}{Q*\gamma*1.16}\right)} \quad (36)$$

For section 4th (initial) we have:

$$k \approx \frac{0.8^{\frac{1}{3}}*\sqrt{\frac{2*9.42}{1016*0.00137}}}{\left(\frac{378600}{7.62*9937*1.16}\right)} \approx \frac{3.414}{4.31} \approx 0.8 \quad (37)$$

Now, with this value, equation (34) is completed and applied to the second measurement site (Section 6), to calculate the slope at that subsequent site:

$$S6 \approx \frac{\left(\frac{\sqrt[3]{R}*\sqrt{\frac{2D}{\tau}}}{k}\right)^2}{\left(\frac{A}{Q*\gamma*1.16}\right)^2} \approx 0.00634 \quad (38)$$

This value of slope has the same order of magnitude as the experimental value.

3.7 Calculations in large rivers.

One strategy may be to adjust a sufficient mass of tracer, ***M***, and place two fluorimetry measurement devices, ***E1*** and **E2**, in sequence, so that several state function data can be obtained. With equation (8) and the adjustment of the experimental data, an extrapolation can be made to the required distance, ***D***, in the section of the channel under study. within reasonable limits, which allow the tracer concentration curve to be modeled, and from there the corresponding calculations can be derived, as explained in this article. The variances of the data at the extrapolation point will be minimized if it is considered that in principle, the river is in "Dynamic equilibrium". Figure 15.

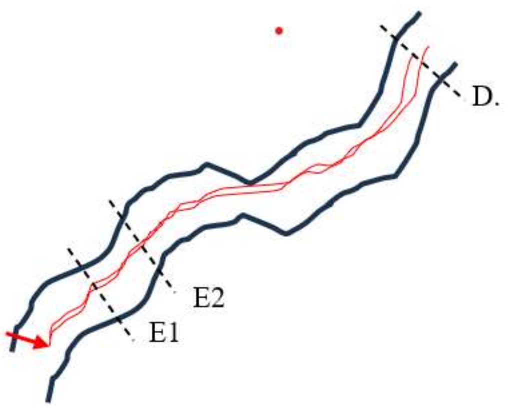

Figure 15.- Extrapolation of measurements by means of State function.

In the case being studied, applying the approximate model for ***Φ(tp),*** from equation (8), the comparison is made with the experimental data as shown below. As you can see, the data is of the same order. Table 4:

Table 4.- Comparison between Φ(tp) calculated with equation (8), and the experimental data in Table 3.

Parameter	Section 4	Section 6
Φ (t) experimental	0.257	0.210
Φ (t) model, equation (8)	0.250	0.205
tp (s), approx..	4730 s	8600 s

4. Conclusions

1.- The key to revealing the values of the hydraulics in a natural cause is to have a state function such as ***Φ(t)*** that allows calculating the various parameters involved, both dispersive and advective, and also making an approximate connection with the geomorphological parameters.

2.- With this theoretical tool it is possible to extrapolate calculations to greater distances to which tracer tests are carried out, which in this way will require less mass of tracer and facilitate the experimental part.

3.- A criterion is developed to know when a natural flow has assimilated (diluted) the mass of contaminant, based on the calculation of the percentage of the cross-sectional area covered by the tracer.

4.-The method presented based on a new equation of the average velocity, allows connecting and calculating the most important parameters of river mechanics, ensuring precise and statistically homogeneous values to successfully feed the models.

5.- The method is applied to examine in detail an experiment documented by the USGS in 1963, with satisfactory results. These results suggest that the presented method can be applied to solve the obtaining of critical data for the modeling of large or medium-sized channels.

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