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MAZAR - 2026

**APPLICATION OF THE LREM METHOD TO THE LOW-FLOW SEASON
AND POWER OUTAGES IN ECUADOR**

THEK-LREM-MAZAR 2026

Estimation of low-flow severity, minimum reservoir elevation, risk zones, and calculated power-outage hours.

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Version 11 (V11) · October 2026

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ABSTRACT

This paper presents a specific 2026 application of the LREM (Low-Flow Reservoir Evolution Model) method to the Mazar–Power Outages problem, organized through the FGET–VRR–NFF methodological sequence developed by Moncayo Theurer [11–13].

This method does not constitute a deterministic prediction of the phenomenon; its purpose is to model the phenomenon so that its output can be used as a reference value by society, local governments, and the central Government to project response plans and investments aimed at mitigating the costs of the phenomenon. The model is a prospective reference that can be used each year to assess how the phenomenon could develop.

It is recommended that this first model be calibrated with a broader number of years and with future behavior. The same methodology is also recommended for all reservoirs in the system and even for the complete system, following the same methodology; it can also be applied in other countries with similar phenomena.

Mathematical models do not represent reality itself, but rather an abstraction that provides mathematical support for values and quantities used in calculations required for risk and damage estimation. Researchers using the method are asked to apply it safely and with high technical standards; it should not be used for sensationalism or to create fear among the population.

THEK Research Institute supports open science used responsibly. The sole purpose of these models is to provide a method that advances resilience in Ecuador and worldwide, helping countries and societies prepare more effectively for these hazards.

The procedure uses the loss of Mazar reservoir elevation during September to construct the dimensionless Invernal Type index (I_T), calculates a time-dependent elevation trajectory, and transforms that elevation into an estimate of potential daily rationing hours.

Using the data adopted for 2026, $I_T = 1.8831$ is obtained.

The central trajectory places the minimum at approximately 2114.08 m around November 9; the 2115 m elevation is crossed approximately between October 25–26 and November 24, defining a period of about 29–30 days below that threshold.

At the minimum, the power-outage-hours expression yields approximately 5.16 h/day. The paper explicitly distinguishes between the mathematical result of the model and the operational update based on actual observations.

Keywords: Mazar; Ecuador; low-flow season; electricity rationing; power outages; Internal Type; FGET; VRR; NFF; energy modeling.

1. INTRODUCTION

Mazar plays a strategic role in Ecuador's hydropower system by regulating water resources that feed the Paute Integral Hydroelectric Complex. CELEC technical information establishes 2153 m a.s.l. as the maximum operating elevation and 2098 m a.s.l. as the minimum technical elevation [6].

For the 2026 operational analysis, the 2115 m level is also incorporated, as cited in public reports as a critical safety reference for recent operation [3]. These thresholds have different meanings: 2098 m corresponds to the technical design limit published by CELEC, whereas 2115 m is used here as a precautionary operating reference.

The reduction in Mazar reservoir elevation was evident from the first days of September 2026. PRIMICIAS reported approximately 2147 m on September 1, 2146.3 m on September 5, and 2144.69 m on September 8 [1].

Near the end of the month, the closest published value was 2132.94 m at 18:00 on September 29 [2]. On October 2, the observed level was 2131.01 m [3]. This sequence allows the actual evolution of the reservoir to be compared with the trajectory calculated by the model.

The purpose of this study is to document, through reproducible calculations, the behavior of the THEK formulation when applied to Ecuador's 2026 low-flow season. For clarity, the analysis is organized into three levels: the mathematical output of the equations, comparison with observed reservoir elevations, and an updated operational scenario based on the most recent available measurement.

The 2026 application incorporates two complementary trajectories within LREM. The first is the original model curve, calibrated with the years 2022, 2023, and 2024. The second is the adjusted 2026 curve, constructed from the available actual reservoir measurements during September and early October. Comparing the two trajectories makes it possible to present, within a single analysis, the minimum elevation, risk zones, and evolution of

potential power-outage hours for both the original model and the model adjusted to the behavior observed in 2026.

2. LREM METHOD - MAZAR 2026 APPLICATION

The mathematical architecture derives from three developments by the author. FGET is used as a framework for exploring families of candidate expressions and relationships [11]; THEK-VRR organizes variable reduction, comparison, and prioritization [13]; and NFF compacts successive relationships through coefficient nesting and reorganization [12].

In this application, these three layers lead to a simple chain: September elevation loss $\rightarrow I_T \rightarrow$ elevation $Z(d) \rightarrow$ power-outage hours H . The current formulation is specific to the Mazar-Power Outages problem, while its construction logic belongs to the THEK methodological ecosystem and is related to other modeling work developed by the author [8–29].

2.1. Invernal Type Index

$$I_T = 1 + \frac{\Delta Z_{sep}}{16}$$

Equation (1a). Invernal Type Index

$$\Delta Z_{sep} = Z_{1sep} - Z_{30sep} \quad (1b)$$

Where:

ΔZ_{sep} = reservoir elevation loss between September 1 and September 30;

Z_{1sep} = Mazar reservoir elevation on September 1;

Z_{30sep} = Mazar reservoir elevation on September 30.

I_T is dimensionless. Its function is to represent the relative severity of the September decline: when the loss is small, the index remains close to 1; as the decline increases, I_T also increases. In this paper, it is an internal scale of the model.

2.2. Time-Dependent Reservoir Elevation Formula

$$Z(d) = \frac{-b_0}{2200} \left[\frac{I_T d^2}{141} - I_T d + 6663.51 \right]$$

Equation (2). Time-dependent reservoir elevation projection

Where:

$Z(d)$ = projected Mazar reservoir elevation;

d = day counted from September 1;

I_T = Invernal Type factor for the year analyzed;

b_0 = empirical coefficient of the time-dependent formulation.

The timing of the minimum is obtained directly from the geometry of the quadratic expression. The d -dependent part contains the term $d^2/141 - d$; differentiating it and setting the derivative equal to zero gives $d = 70.5$. Since $d = 1$ represents September 1, the vertex occurs approximately at midday on November 9, 2026.

2.3. Final Formula for Potential Power-Outage Hours

$$H = \frac{10620 I_T^{3.7} - 5 I_T^{3.7} Z}{100}$$

Equation (3). Potential rationing hours

Where:

H = potential rationing hours per day;

I_T = Invernal Type factor for the year analyzed;

Z = Mazar reservoir elevation.

The factored expression allows 2124 m to be interpreted as the mathematical activation point of the hours formula. Above that level, the algebraic value is negative and $H = 0$ is imposed on physical grounds. Below 2124 m, the number of hours increases as Z decreases and as I_T increases.

Table 1. Main model variables.

Symbol	Definition	Unit
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Symbol	Definition	Unit
d	Day number counted from September 1	day
Z	Mazar reservoir elevation	m a.s.l.
ΔZ_{sep}	Reservoir elevation loss between September 1 and 30	m
I_T	Invernal Type Index	dimensionless
H	Potential rationing hours	h/day

3. INPUT DATA FOR ECUADOR 2026

The 2026 application retains the data used during development of the model. For September 1, $Z_{1\text{sep}} = 2147.03$ m is adopted, consistent with the approximate public value of 2147 m [1]. For September 30, $Z_{30\text{sep}} = 2132.90$ m is used as the working value of the THEK series; the closest cited public record is 2132.94 m at 18:00 on September 29 [2].

Table 2. Data used in the 2026 application.

Data	Value used	Reference / condition
$Z_{1\text{sep}}$	2147.03 m	THEK series; public report ≈ 2147 m [1]
$Z_{30\text{sep}}$	2132.90 m	Working closing value; Sep 29 = 2132.94 m [2]
$Z_{20\text{Oct}}$ observed	2131.01 m	Oct 2, 2026, 10:00 [3]
Reported recent decline	0.8-0.9 m/day	Rate cited by technical experts on Oct 2 [5]
Critical operating elevation	2115 m	Critical level reported for shutdown [3]
Minimum technical elevation	2098 m	CELEC technical specification [6]

4. STEP-BY-STEP CALCULATION

4.1. Reservoir Elevation Loss During September

$$\Delta Z_{\text{sep}} = 2147.03 - 2132.90 = 14.13 \text{ m}$$

Calculation (1). Adopted decline during September 2026

Using these two levels, the monthly loss used by the model is 14.13 m. The decline exceeds the value used for 2023 and is smaller than the value corresponding to the 2024 scenario, placing 2026 in an intermediate range of relative severity.

4.2. Calculation of I_T and Relative Low-Flow Type

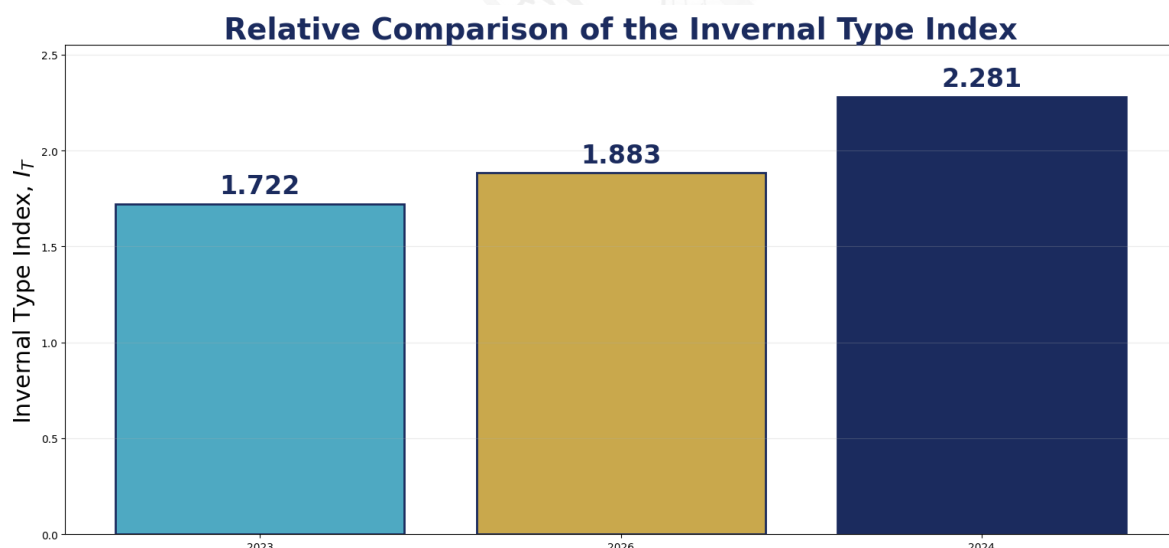
$$I_T = 1 + 14.13 / 16 = 1.8831$$

Calculation (2). 2026 Invernal Type

Previous calibration yielded approximately $I_T = 1.7219$ for 2023 and $I_T = 2.2806$ for 2024. The 2026 value, $I_T = 1.8831$, lies between the two: it is about 9.4% higher than 2023 and approximately 17.4% lower than 2024.

Within the 2023–2024 interval, 2026 is positioned closer to the 2023 case. It is therefore described here as an intermediate-to-strong low-flow season within the THEK relative scale, without assigning it an official category.

RELATIVE CLASSIFICATION 2026 Defined here as an intermediate-to-strong low-flow season, but closer to the 2023 pattern than to 2024.



2026 lies between 2023 and 2024 and is closer to the 2023 case.

Figure 1. Comparison of I_T for 2023, 2026, and 2024. The 2026 value lies between the two calibration cases and is closer to 2023.

4.3. Date and Value of the Minimum Reservoir Elevation

The date of the minimum is determined by setting the derivative of Equation (2) equal to zero. The condition $2d/141 - 1 = 0$ yields $d = 70.5$. With the time origin set at September 1, this value corresponds approximately to November 9, 2026 at 12:00.

$$d_{\min} = 70.5 \rightarrow \text{November 9, 2026 (approx.)}$$

Calculation (3). Geometric date of the minimum

$$Z_{\min} = Z(70.5) = 2114.08 \text{ m}$$

Calculation (4). Minimum reservoir elevation projected by Formula 1

The resulting minimum value, 2114.08 m, lies 0.92 m below the 2115 m operating reference and, at the same time, remains 16.08 m above the 2098 m technical minimum published by CELEC [6]. Consequently, the central scenario enters the Red Alert for Maximum Power-Outage Risk, while remaining well above the technical design limit.

4.4. RED ALERT FOR MAXIMUM POWER-OUTAGE RISK: ELEVATION BELOW 2115 m

To estimate how long the trajectory remains below 2115 m, $Z(d) = 2115$ is solved. The quadratic equation produces two intersections, one during the decline and one during recovery: $d = 55.84$ and $d = 85.16$.

Table 3. Red Alert window for Maximum Power-Outage Risk according to Formula 1.

Event	D	Approximate date	Elevation
Descending crossing	55.84	Oct 25-26, 2026	2115 m
Minimum	70.50	Nov 9, 2026	2114.08 m
Ascending crossing	85.16	Nov 24, 2026	2115 m

$$85.16 - 55.84 = 29.32 \text{ days}$$

Calculation (5). Mathematical duration below 2115 m

The separation between the two roots is 29.32 days. This interval is interpreted as mathematical persistence below 2115 m, not as guaranteed total plant unavailability. Actual operation depends on flow management, dispatch, unit availability, and operator decisions, variables that are not explicitly included in this formulation.

The multi-year validation of LREM shows a high-precision fit in the recent reference years, especially 2022, 2023, and 2024. In 2026, the available public observations lie above the baseline curve, describing a higher and more favorable reservoir behavior. Therefore, alongside the original model trajectory, an adjusted 2026 curve connected to the measured points is proposed so that both results can be presented within the same methodological framework.

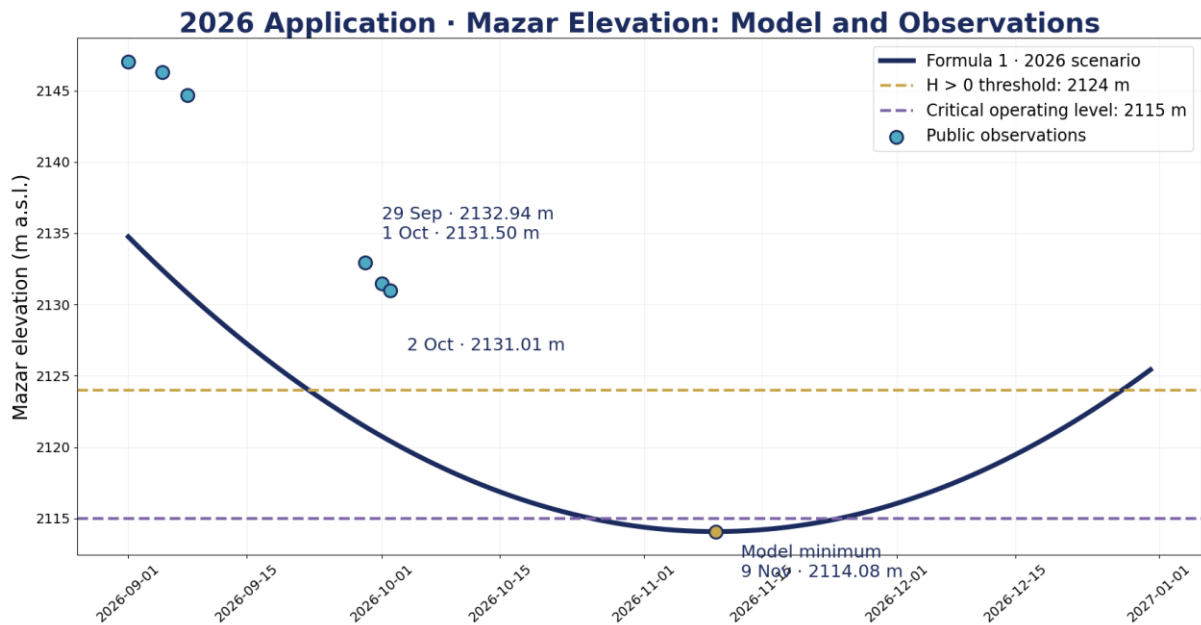


Figure 2. Reservoir-elevation trajectory calculated by Formula 1 and public observations available in 2026. The combined interpretation of the baseline model and the observed data supports the construction of an adjusted 2026 curve.

4.5. Potential Rationing Hours in the Central Scenario

Substituting $I_T = 1.8831$ and $Z = 2114.08$ m into the final hours expression gives the maximum of the original method's central scenario, approximately 5.16 h/day. Applying the same equation to the adjusted 2026 curve reduces the associated maximum to approximately 1.00 h/day.

$$H_{\max} = 0.05 (1.8831) 3.7 (2124 - 2114.08) = 5.16 \text{ h/day}$$

Calculation (6). Maximum potential rationing hours

Table 4. Sensitivity of hours to reservoir elevation for $I_T = 1.8831$.

Elevation Z	Interpretation	Estimated H
2124 m	Mathematical threshold	0.00 h/day
2120 m	Moderate decline below the threshold	2.08 h/day
2115 m	Critical operating elevation	4.68 h/day
2114.08 m	Projected 2026 minimum	5.16 h/day

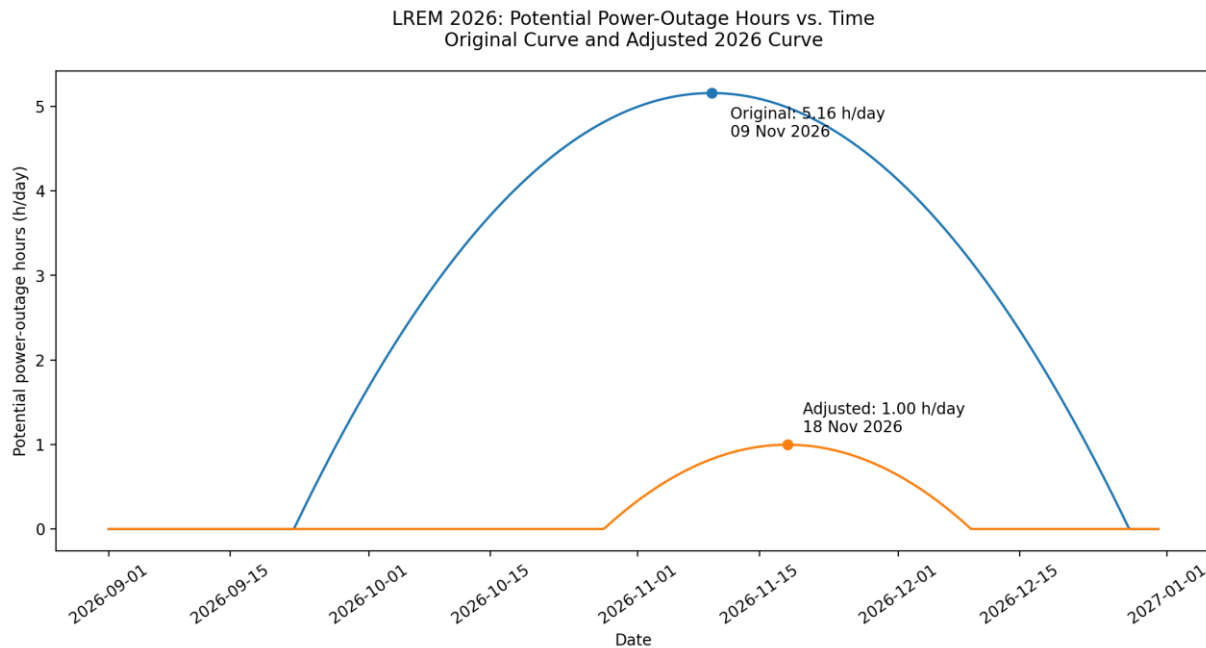


Figure 3. Potential power-outage hours obtained by applying Formula 2 to the original trajectory $Z(d)$ and to the adjusted 2026 curve. The original curve reaches approximately 5.16 h/day, while the adjusted 2026 curve reaches approximately 1.00 h/day.

4.6. LREM RISK ZONES FOR 2026

MEDIUM-RISK ZONE. In the central scenario of the original method, this zone occurs when $H > 0$ and the Mazar reservoir elevation remains above 2115 m. In this zone, LREM calculates possible power-outage hours greater than 0 and up to 4.68 h/day. In the adjusted 2026 curve, the Medium-Risk Zone also appears, with a higher and more favorable reservoir trajectory and maximum hours close to 1.00 h/day.

RED ALERT FOR MAXIMUM POWER-OUTAGE RISK. In the central scenario of the original method, this stage occurs when the Mazar reservoir elevation falls below 2115 m. For 2026, LREM calculates this stage from October 25 to November 24, with 4.68 to 5.16 h/day and a maximum of 5.16 h/day on November 9. In the adjusted 2026 curve, the trajectory remains above 2115 m and the entire analysis is concentrated within the Medium-Risk Zone.

5. UPDATED 2026 SCENARIO: ORIGINAL CURVE AND ADJUSTED CURVE

The 2026 application is represented through two complementary interpretations. The first corresponds to the original LREM curve, constructed with $I_T = 1.8831$ from the September loss and fitted to the low-flow behavior observed in 2022, 2023, and 2024. The second corresponds to a curve adjusted to the 2026 measurements recorded at Mazar Reservoir, obtained by connecting the general LREM form to the measured points published during September and on October 2, 2026.

To construct the adjusted curve, the difference between the original curve and the available actual observations from September 1, 5, and 8, September 29, and October 2 is evaluated. This difference is represented by a linear residual correction $R(d) = -0.0749 d + 13.6073$, and the new trajectory is expressed as $Z_{adj}(d) = Z(d) + R(d)$. In expanded form, the adjusted curve is: $Z_{adj}(d) = 0.00427983 d^2 - 0.67831929 d + 2148.95941$.

5.1. Result of the Adjusted 2026 Curve

The adjusted curve yields a minimum reservoir elevation of 2122.08 m, occurring around November 18, 2026. This updated trajectory places the 2026 behavior in a higher and more favorable reservoir condition than the central scenario of the original model.

$$7.01 / 0.9 = 7.8 \text{ days} \quad | \quad 7.01 / 0.8 = 8.8 \text{ days}$$

Calculation (7). Time from the Oct 2 observation to 2124 m

With the adjusted curve, the 2124 m threshold is crossed approximately on October 28, 2026 and recovered around December 9, 2026, producing 42.34 days below 2124 m. The adjusted trajectory remains entirely above 2115 m throughout the period and concentrates the analysis within the Medium-Risk Zone. Applying the hours equation at the adjusted minimum elevation gives an associated maximum of approximately 1.00 h/day. In operational terms, this reading represents a regime without widespread power outages, because a requirement of that magnitude can be absorbed through different energy-management measures adopted by the Government.

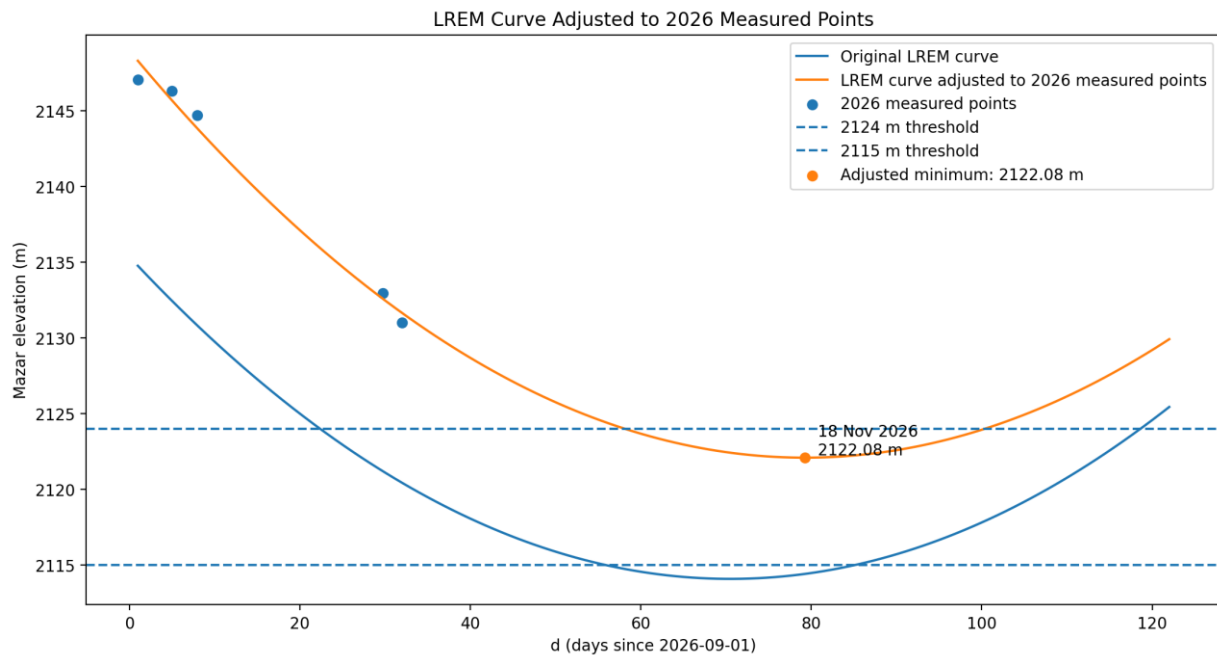


Figure 4. Original LREM curve, adjusted 2026 curve, and measured points in 2026. The adjusted curve preserves the form of the method and connects with the observed data, projecting a minimum elevation of 2122.08 m around November 18, 2026, with persistence below 2124 m between October 28 and December 9 and remaining above 2115 m.

5.2. Combined Interpretation of the Method

The combined interpretation strengthens the 2026 application. The original method preserves the complete LREM structure and provides the central severity scenario; the adjusted curve incorporates the most recent 2026 observations and describes a higher, more positive, and more favorable reservoir evolution. The paper therefore presents both the structural output of the method and the operational update associated with the data measured in 2026. The first curve summarizes the baseline formulation, which fits the recent reference years with high precision, especially 2022, 2023, and 2024; the second curve introduces the 2026 correction from the year's measurements. In conclusion, if 2026 behavior comes to resemble 2023 and 2024, the projection presented at the beginning of this paper should be used; if the 2026 trend is maintained, the prospective values adjusted to 2026 should be considered. Based on the modeler's experience, the 2026-adjusted curve is the most probable; it represents the less severe scenario and indicates that there will be no power outages.

6. CONSOLIDATED RESULTS FOR 2026

Table 5A. Results of the original LREM curve calibrated with 2022, 2023, and 2024.

Indicator	2026 Result	Interpretation
September ΔZ	14.13 m	Decline used to construct I_r
I_r	1.8831	Intermediate-to-strong; closer to 2023
Model minimum elevation	2114.08 m	Original LREM scenario
Date of minimum	Nov 9, 2026	$d = 70.5$
Entry below 2115 m	Oct 25-26, 2026	Entry into Red Alert in the original curve
Exit above 2115 m	Nov 24, 2026	Exit from Red Alert in the original curve
Time below 2115 m	29.32 days	≈ 29 -30 days
H at 2115 m	4.68 h/day	Potential hours
Maximum H	5.16 h/day	At $Z_{\min} = 2114.08$ m
Medium-Risk Zone	$H > 0$ and $Z > 2115$ m	Segment before and after the Red Alert
Red Alert for Maximum Power-Outage Risk	Oct 25 - Nov 24, 2026	$Z < 2115$ m; maximum 5.16 h/day on Nov 9

Table 5B. Results of the model adjusted to actual 2026 measurements.

Indicator	Adjusted 2026 Result	Interpretation
Adjusted minimum elevation	2122.08 m	Curve connected to the points measured in 2026
Date of adjusted minimum	Nov 18, 2026	d = 79.25
Period $Z < 2124$ m	Oct 28 - Dec 9, 2026	42.34 days in the Medium-Risk Zone
Condition relative to 2115 m	$Z > 2115$ m	The trajectory remains entirely within the Medium-Risk Zone
Adjusted maximum H	1.00 h/day	Applied at adjusted $Z_{\min} = 2122.08$ m
Risk regime	Medium-Risk Zone	The adjusted curve remains above the Red Alert threshold
Operational reading	No widespread power outages	The approximate maximum requirement of 1.00 h/day can be covered through different energy and management measures

7. DISCUSSION

The comparison between scenarios shows the methodological strength of LREM. The original curve summarizes the structural severity derived from I_T and places the central-scenario minimum at 2114.08 m; the adjusted curve, connected to actual 2026 observations, places the minimum at the higher elevation of 2122.08 m. The two readings complement each other and provide a robust view of reservoir behavior.

The historical performance of the method is especially strong in 2022, 2023, and 2024, years in which the formulation showed high accuracy against actual reservoir elevations. The first curve in the paper is constructed on this basis. Incorporating the actual measurements from September and October 2, 2026 produces the second curve, shifting the trajectory toward higher and more favorable reservoir levels.

The most useful methodological finding of the 2026 test is the coexistence of two complementary technical results: a central scenario generated by the original formulation and an updated scenario that connects the curve to the actual points measured in 2026. Comparing the hours curves shows an equally clear difference: the original curve leads to a maximum of 5.16 h/day, while the adjusted curve leads to approximately 1.00 h/day.

The combination of FGET, VRR, and NFF enables precisely this dual reading: a stable primary structure and an operational update consistent with the

current year. This architecture strengthens the method's usefulness for interpreting low-flow seasons, risk windows, and minimum reservoir elevations on a consistent mathematical basis.

In the 2026 application, this integration leads to a clear conclusion: actual reservoir behavior lies above the baseline curve and defines a more favorable projection, concentrated within a range below 2124 m and entirely above 2115 m in the adjusted curve. The adjusted curve therefore represents a condition in which widespread power outages are not projected, since the maximum requirement of approximately 1.00 h/day can be covered by different operational and energy measures.

8. CONCLUSIONS

1. Using the adopted data, the index is $I_T = 1.8831$. Within the relative scale constructed from 2023 and 2024, the 2026 low-flow season falls within an intermediate-to-strong condition and is closer to 2023.
2. The time-dependent trajectory of the original method calculates a minimum reservoir elevation of approximately 2114.08 m, occurring around November 9, 2026.
3. In the original scenario, the curve remains below 2115 m for approximately 29.32 days, from October 25 to November 24, 2026.
4. At the 2115 m level, the hours equation yields approximately 4.68 h/day, and at the 2114.08 m minimum it reaches approximately 5.16 h/day in the original scenario.
5. The adjusted 2026 curve, connected to the measured points, projects a minimum reservoir elevation of 2122.08 m around November 18, 2026.
6. In the adjusted curve, the period with reservoir elevation below 2124 m extends from October 28 to December 9, 2026, with an approximate duration of 42.34 days.
7. In the adjusted 2026 curve, the trajectory remains above 2115 m throughout the analyzed period and, when the hours equation is applied at the adjusted minimum elevation, the associated maximum is approximately 1.00 h/day.
8. The phase with $H > 0$ and reservoir elevation above 2115 m is called the Medium-Risk Zone. The original method and the adjusted curve make it possible to characterize this zone, and the adjusted curve identifies it as the dominant scenario for 2026.

9. The comparison between the original curve and the adjusted curve presents the two technical results of the 2026 application: a structural trajectory of the method and a trajectory connected to the actual data measured during the year, both integrated within the LREM framework. In operational terms, the adjusted curve describes a condition without widespread power outages, because the approximate maximum requirement of 1.00 h/day can be covered through different system measures.

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Suggested citation

Moncayo Theurer, M. (2026). 2026 Application of the Integrated Mazar–Power Outages Model: Estimation of Low-Flow Severity, Minimum Reservoir Elevation, Critical Window, and Potential Electricity Rationing Hours in Ecuador. THEK Research Institute, Technical Paper, Version 8 (V8).

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