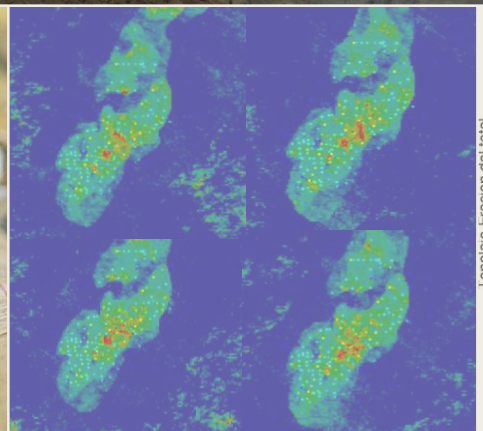
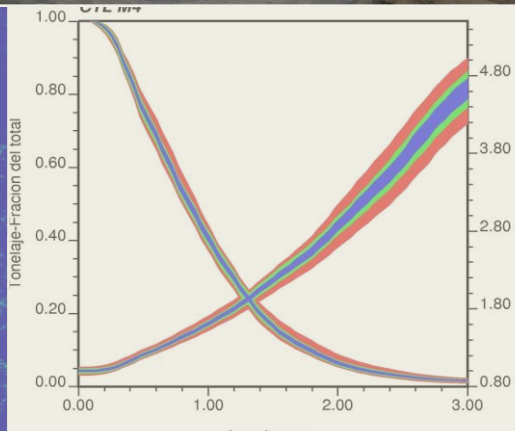
GeoInnova®

Evaluación del Impacto de la calidad de la información de leyes y geología en Recursos Minerales

Alejandro Cáceres, Rodrigo Riquelme, Lucas Contreras, Pablo Carrasco.

Junio 2017



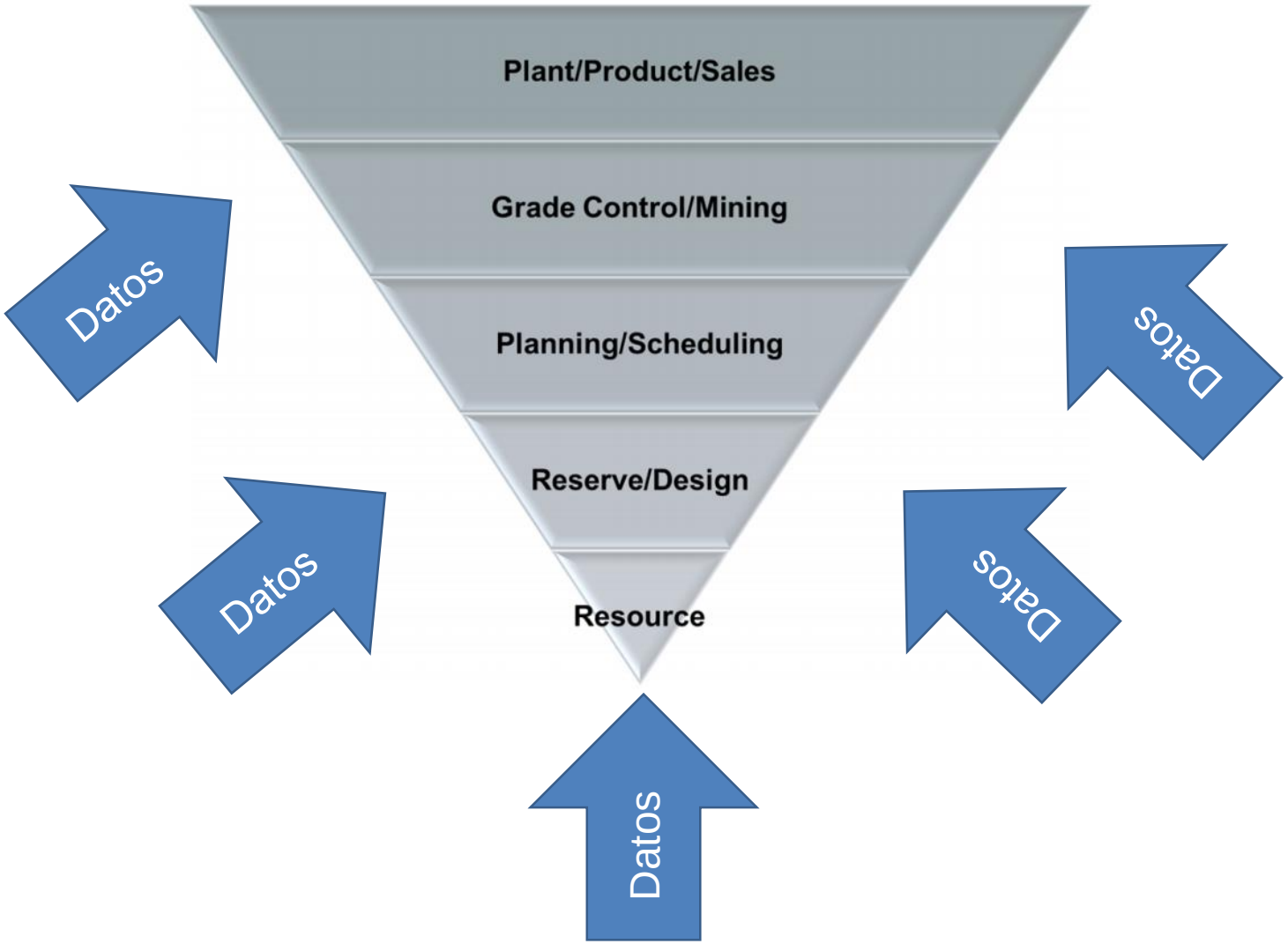


Outline

1. La importancia de la calidad de los datos
2. Qué hacemos hoy frente a temas de calidad
3. Ejemplo de evaluación de Impacto
4. Aprendizajes y Conclusiones

IMPORTANCIA DE LA CALIDAD DE LOS DATOS

Mining Value Chain Pyramid



Problemas de calidad en la información base

- Genera una percepción generalizada de problemas en el Proyecto/compañía
- Genera tomas de decisiones distorsionadas
  - Toma de decisiones mal sustentadas
  - Detiene o paraliza la toma de decisión
  - Genera trade-off Cantidad vs Calidad
- Disminuye moral en equipo y circulo negativo

Pérdida de valor x calidad

Ejemplos Pérdidas ocultas de valor por muestreo y análisis incorrecto

ORIGEN	IMPACTO	PÉRDIDA MU$	OBSERVACIONES
Caso 1 INEXACTITUD ANALÍTICA LEYES CuT	PERCEPCIÓN ERRONEA DEL VALOR DE VENTA DEL PROYECTO	300	ZONA DE ÓXIDOS. RAJO ABIERTO
Caso 2 INEXACTITUD MUESTREO RELAVES	COBRE PERDIDO EN EL RELAVE. SOBRESTIMACIÓN DE LA RECUPERACION	235	ZONA PRIMARIA. BLOCK CAVING
Caso 3 IMPRECISIÓN MUESTREO DE POZOS DE TIRO	SELECCIÓN MINERA ERRONEA.	148	ZONAS SECUNDARIA Y PRIMARIA. RAJO ABIERTO

PÉRDIDA TOTAL = 683

Ejemplos tomados de P. Carrasco

Harvard Business Review

DATA

Bad Data Costs the U.S. $3 Trillion Per Year

by Thomas C. Redman

SEPTEMBER 22, 2016

Principalmente asociado a malas decisiones

QUÉ HACEMOS HOY
ANTE TEMAS DE CALIDAD

Implicancias en código JORC

JORC TABLE 1

Section 1 Sampling Techniques and Data

(Criteria in this section apply to all succeeding sections.)

Criteria	Explanation
Sampling techniques	• *Nature and quality of sampling (eg cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling.* • *Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used.* • *Aspects of the determination of mineralisation that are Material to the Public Report. In cases where 'industry standard' work has been done this would be relatively simple (eg 'reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30 g charge for fire assay'). In other cases more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg submarine nodules) may warrant disclosure of detailed information.*
Drilling techniques	• *Drill type (eg core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).*
Drill sample recovery	• *Method of recording and assessing core and chip sample recoveries and results assessed.* • *Measures taken to maximise sample recovery and ensure representative nature of the samples.* • *Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.*
Logging	• *Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.* • *Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.* • *The total length and percentage of the relevant intersections logged.*
Sub-sampling techniques and sample preparation	• *If core, whether cut or sawn and whether quarter, half or all core taken.* • *If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.* • *For all sample types, the nature, quality and appropriateness of the sample preparation technique.* • *Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.* • *Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/second-half sampling.* • *Whether sample sizes are appropriate to the grain size of the material being sampled.*
Quality of assay data and laboratory tests	• *The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.* • *For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, etc.* • *Nature of quality control procedures adopted (eg standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie lack of bias) and precision have been established.*
Verification of sampling and assaying	• *The verification of significant intersections by either independent or alternative company personnel.* • *The use of twinned holes.* • *Documentation of primary data, data entry procedures, data verification, data storage (physical and electronic) protocols.* • *Discuss any adjustment to assay data.*
Location of data points	• *Accuracy and quality of surveys used to locate drill holes (collar and down-hole surveys), trenches, mine workings and other locations used in Mineral Resource estimation.* • *Specification of the grid system used.* • *Quality and adequacy of topographic control.*
Data spacing and distribution	• *Data spacing for reporting of Exploration Results.* • *Whether the data spacing and distribution is sufficient to establish the degree of geological and grade continuity appropriate for the Mineral Resource and Ore Reserve estimation procedure(s) and classifications applied.* • *Whether sample compositing has been applied.*
Orientation of data in relation to geological structure	• *Whether the orientation of sampling achieves unbiased sampling of possible structures and the extent to which this is known, considering the deposit type.* • *If the relationship between the drilling orientation and the orientation of key mineralised structures is considered to have introduced a sampling bias, this should be assessed and reported if material.*
Sample security	• *The measures taken to ensure sample security.*
Audits or reviews	• *The results of any audits or reviews of sampling techniques and data.*

Section 2 Reporting of Exploration Results

(Criteria listed in the preceding section also apply to this section.)

Criteria	Explanation
Mineral tenement and land tenure status	• *Type, reference name/number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings.* • *The security of the tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area.*
Exploration done by other parties	• *Acknowledgment and appraisal of exploration by other parties.*
Geology	• *Deposit type, geological setting and style of mineralisation.*

Drill hole Information	• *A summary of all information material to the understanding of the exploration results including a tabulation of the following information for all Material drill holes:*
	  ◦ *easting and northing of the drill hole collar*
	  ◦ *elevation or RL (Reduced Level – elevation above sea level in metres) of the drill hole collar*
	  ◦ *dip and azimuth of the hole*
	  ◦ *down hole length and interception depth*
	  ◦ *hole length.*
	• *If the exclusion of this information is justified on the basis that the information is not Material and this exclusion does not detract from the understanding of the report, the Competent Person should clearly explain why this is the case.*

Data aggregation methods	• *In reporting Exploration Results, weighting averaging techniques, maximum and/or minimum grade truncations (eg cutting of high grades) and cut-off grades are usually Material and should be stated.* • *Where aggregate intercepts incorporate short lengths of high grade results and longer lengths of low grade results, the procedure used for such aggregation should be stated and some typical examples of such aggregations should be shown in detail.* • *The assumptions used for any reporting of metal equivalent values should be clearly stated.*
Relationship between mineralisation widths and intercept lengths	• *These relationships are particularly important in the reporting of Exploration Results.* • *If the geometry of the mineralisation with respect to the drill hole angle is known, its nature should be reported.* • *If it is not known and only the down hole lengths are reported, there should be a clear statement to this effect (eg 'down hole length, true width not known').*
Diagrams	• *Appropriate maps and sections (with scales) and tabulations of intercepts should be included for any significant discovery being reported These should include, but not be limited to a plan view of drill hole collar locations and appropriate sectional views.*
Balanced reporting	• *Where comprehensive reporting of all Exploration Results is not practicable, representative reporting of both low and high grades and/or widths should be practiced to avoid misleading reporting of Exploration Results.*
Other substantive exploration data	• *Other exploration data, if meaningful and material, should be reported including (but not limited to): geological observations; geophysical survey results; geochemical survey results; bulk samples – size and method of treatment; metallurgical test results; bulk density, groundwater, geotechnical and rock characteristics; potential deleterious or contaminating substances.*
Further work	• *The nature and scale of planned further work (eg tests for lateral extensions or depth extensions or large-scale step-out drilling).* • *Diagrams clearly highlighting the areas of possible extensions, including the main geological interpretations and future drilling areas, provided this information is not commercially sensitive.*

Section 3 Estimation and Reporting of Mineral Resources

(Criteria listed in section 1, and where relevant in section 2, also apply to this section.)

Criteria	Explanation
Database integrity	• *Measures taken to ensure that data has not been corrupted by, for example, transcription or keying errors, between its initial collection and its use for Mineral Resource estimation purposes.* • *Data validation procedures used.*
Site visits	• *Comment on any site visits undertaken by the Competent Person and the outcome of those visits.* • *If no site visits have been undertaken indicate why this is the case.*
Geological interpretation	• *Confidence in (or conversely, the uncertainty of) the geological interpretation of the mineral deposit.* • *Nature of the data used and of any assumptions made.* • *The effect, if any, of alternative interpretations on Mineral Resource estimation.* • *The use of geology in guiding and controlling Mineral Resource estimation.* • *The factors affecting continuity both of grade and geology.*
Dimensions	• *The extent and variability of the Mineral Resource expressed as length (along strike or otherwise), plan width, and depth below surface to the upper and lower limits of the Mineral Resource.*
Estimation and modelling techniques	• *The nature and appropriateness of the estimation technique(s) applied and key assumptions, including treatment of extreme grade values, domaining, interpolation parameters and maximum distance of extrapolation from data points. If a computer assisted estimation method was chosen include a description of computer software and parameters used.* • *The availability of check estimates, previous estimates and/or mine production records and whether the Mineral Resource estimate takes appropriate account of such data.* • *The assumptions made regarding recovery of by-products.* • *Estimation of deleterious elements or other non-grade variables of economic significance (eg sulphur for acid mine drainage characterisation).* • *In the case of block model interpolation, the block size in relation to the average sample spacing and the search employed.* • *Any assumptions behind modelling of selective mining units.*
Estimation and modelling techniques (continued)	• *Any assumptions about correlation between variables.* • *Description of how the geological interpretation was used to control the resource estimates.* • *Discussion of basis for using or not using grade cutting or capping.* • *The process of validation, the checking process used, the comparison of model data to drill hole data, and use of reconciliation data if available.*
Moisture	• *Whether the tonnages are estimated on a dry basis or with natural moisture, and the method of determination of the moisture content.*
Cut-off parameters	• *The basis of the adopted cut-off grade(s) or quality parameters applied.*
Mining factors or assumptions	• *Assumptions made regarding possible mining methods, minimum mining dimensions and internal (or, if applicable, external) mining dilution. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential mining methods, but the assumptions made regarding mining methods and parameters when estimating Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the mining assumptions made.*
Metallurgical factors or assumptions	• *The basis for assumptions or predictions regarding metallurgical amenability. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential metallurgical methods, but the assumptions regarding metallurgical treatment processes and parameters made when reporting Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the metallurgical assumptions made.*
Environmental factors or assumptions	• *Assumptions made regarding possible waste and process residue disposal options. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider the potential environmental impacts of the mining and processing operation. While at this stage the determination of potential environmental impacts, particularly for a greenfields project, may not always be well advanced, the status of early consideration of these potential environmental impacts should be reported. Where these aspects have not been considered this should be reported with an explanation of the environmental assumptions made.*
Bulk density	• *Whether assumed or determined. If assumed, the basis for the assumptions. If determined, the method used, whether wet or dry, the frequency of the measurements, the nature, size and representativeness of the samples.* • *The bulk density for bulk material must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the deposit.* • *Discuss assumptions for bulk density estimates used in the evaluation process of the different materials.*

Implicancias en código JORC

JORC TABLE 1

Section 1 Sampling Techniques and Data

(Criteria in this section apply to all succeeding sections.)

Criteria	Explanation
Sampling techniques	• *Nature and quality of sampling (eg cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling.* • *Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used.* • *Aspects of the determination of mineralisation that are Material to the Public Report. In cases where 'industry standard' work has been done this would be relatively simple (eg 'reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30 g charge for fire assay'). In other cases more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg submarine nodules) may warrant disclosure of detailed information.*
Drilling techniques	• *Drill type (eg core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).*
Drill sample recovery	• *Method of recording and assessing core and chip sample recoveries and results assessed.* • *Measures taken to maximise sample recovery and ensure representative nature of the samples.* • *Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.*
Logging	• *Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.* • *Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.* • *The total length and percentage of the relevant intersections logged.*
Sub-sampling techniques and sample preparation	• *If core, whether cut or sawn and whether quarter, half or all core taken.* • *If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.* • *For all sample types, the nature, quality and appropriateness of the sample preparation technique.* • *Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.* • *Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/second-half sampling.* • *Whether sample sizes are appropriate to the grain size of the material being sampled.*
Quality of assay data and laboratory tests	• *The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.* • *For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, etc.* • *Nature of quality control procedures adopted (eg standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie lack of bias) and precision have been established.*
Verification of sampling and assaying	• *The verification of significant intersections by either independent or alternative company personnel.* • *The use of twinned holes.* • *Documentation of primary data, data entry procedures, data verification, data storage (physical and electronic) protocols.* • *Discuss any adjustment to assay data.*
Location of data points	• *Accuracy and quality of surveys used to locate drill holes (collar and down-hole surveys), trenches, mine workings and other locations used in Mineral Resource estimation.* • *Specification of the grid system used.* • *Quality and adequacy of topographic control.*
Data spacing and distribution	• *Data spacing for reporting of Exploration Results.* • *Whether the data spacing and distribution is sufficient to establish the degree of geological and grade continuity appropriate for the Mineral Resource and Ore Reserve estimation procedure(s) and classifications applied.* • *Whether sample compositing has been applied.*
Orientation of data in relation to geological structure	• *Whether the orientation of sampling achieves unbiased sampling of possible structures and the extent to which this is known, considering the deposit type.* • *If the relationship between the drilling orientation and the orientation of key mineralised structures is considered to have introduced a sampling bias, this should be assessed and reported if material.*
Sample security	• *The measures taken to ensure sample security.*
Audits or reviews	• *The results of any audits or reviews of sampling techniques and data.*

Section 2 Reporting of Exploration Results

(Criteria listed in the preceding section also apply to this section.)

Criteria	Explanation
Mineral tenement and land tenure status	• *Type, reference name/number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings.* • *The security of the tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area.*
Exploration done by other parties	• *Acknowledgment and appraisal of exploration by other parties.*
Geology	• *Deposit type, geological setting and style of mineralisation.*

Drill hole Information	• *A summary of all information material to the understanding of the exploration results including a tabulation of the following information for all Material drill holes:*
	  ◦ *easting and northing of the drill hole collar*
	  ◦ *elevation or RL (Reduced Level – elevation above sea level in metres) of the drill hole collar*
	  ◦ *dip and azimuth of the hole*
	  ◦ *down hole length and interception depth*
	  ◦ *hole length.*
	• *If the exclusion of this information is justified on the basis that the information is not Material and this exclusion does not detract from the understanding of the report, the Competent Person should clearly explain why this is the case.*

Data aggregation methods	• *In reporting Exploration Results, weighting averaging techniques, maximum and/or minimum grade truncations (eg cutting of high grades) and cut-off grades are usually Material and should be stated.* • *Where aggregate intercepts incorporate short lengths of high grade results and longer lengths of low grade results, the procedure used for such aggregation should be stated and some typical examples of such aggregations should be shown in detail.* • *The assumptions used for any reporting of metal equivalent values should be clearly stated.*
Relationship between mineralisation widths and intercept lengths	• *These relationships are particularly important in the reporting of Exploration Results.* • *If the geometry of the mineralisation with respect to the drill hole angle is known, its nature should be reported.* • *If it is not known and only the down hole lengths are reported, there should be a clear statement to this effect (eg 'down hole length, true width not known').*

Section 3 Estimation and Reporting of Mineral Resources

(Criteria listed in section 1, and where relevant in section 2, also apply to this section.)

Criteria	Explanation
Database integrity	• *Measures taken to ensure that data has not been corrupted by, for example, transcription or keying errors, between its initial collection and its use for Mineral Resource estimation purposes.* • *Data validation procedures used.*
Site visits	• *Comment on any site visits undertaken by the Competent Person and the outcome of those visits.* • *If no site visits have been undertaken indicate why this is the case.*
Geological interpretation	• *Confidence in (or conversely, the uncertainty of) the geological interpretation of the mineral deposit.* • *Nature of the data used and of any assumptions made.* • *The effect, if any, of alternative interpretations on Mineral Resource estimation.* • *The use of geology in guiding and controlling Mineral Resource estimation.* • *The factors affecting continuity both of grade and geology.*
Dimensions	• *The extent and variability of the Mineral Resource expressed as length (along strike or otherwise), plan width, and depth below surface to the upper and lower limits of the Mineral Resource.*
Estimation and modelling techniques	• *The nature and appropriateness of the estimation technique(s) applied and key assumptions, including treatment of extreme grade values, domaining, interpolation parameters and maximum distance of extrapolation from data points. If a computer assisted estimation method was chosen include a description of computer software and parameters used.* • *The availability of check estimates, previous estimates and/or mine production records and whether the Mineral Resource estimate takes appropriate account of such data.* • *The assumptions made regarding recovery of by-products.* • *Estimation of deleterious elements or other non-grade variables of economic significance (eg sulphur for acid mine drainage characterisation).* • *In the case of block model interpolation, the block size in relation to the average sample spacing and the search employed.* • *Any assumptions behind modelling of selective mining units.*
Estimation	• *Any assumptions about correlation between variables.*
	• *The bulk density for bulk material must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the deposit.* • *Discuss assumptions for bulk density estimates used in the evaluation process of the different materials.*

- Código exige un control de calidad en mapeos y leyes
- Aseguramiento de ubicaciones de sondajes
- Integridad de base de datos

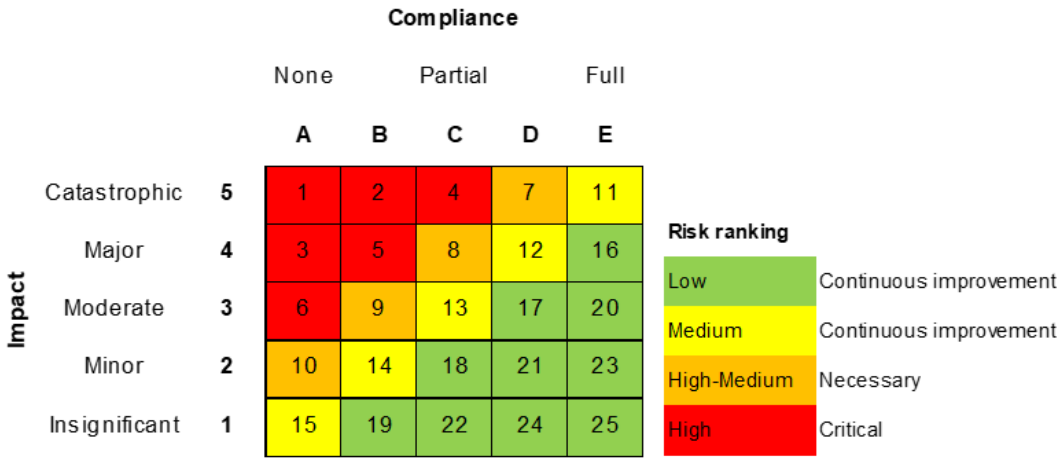
Cumplimiento de temas planteados en códigos internacionales

Cumplimiento

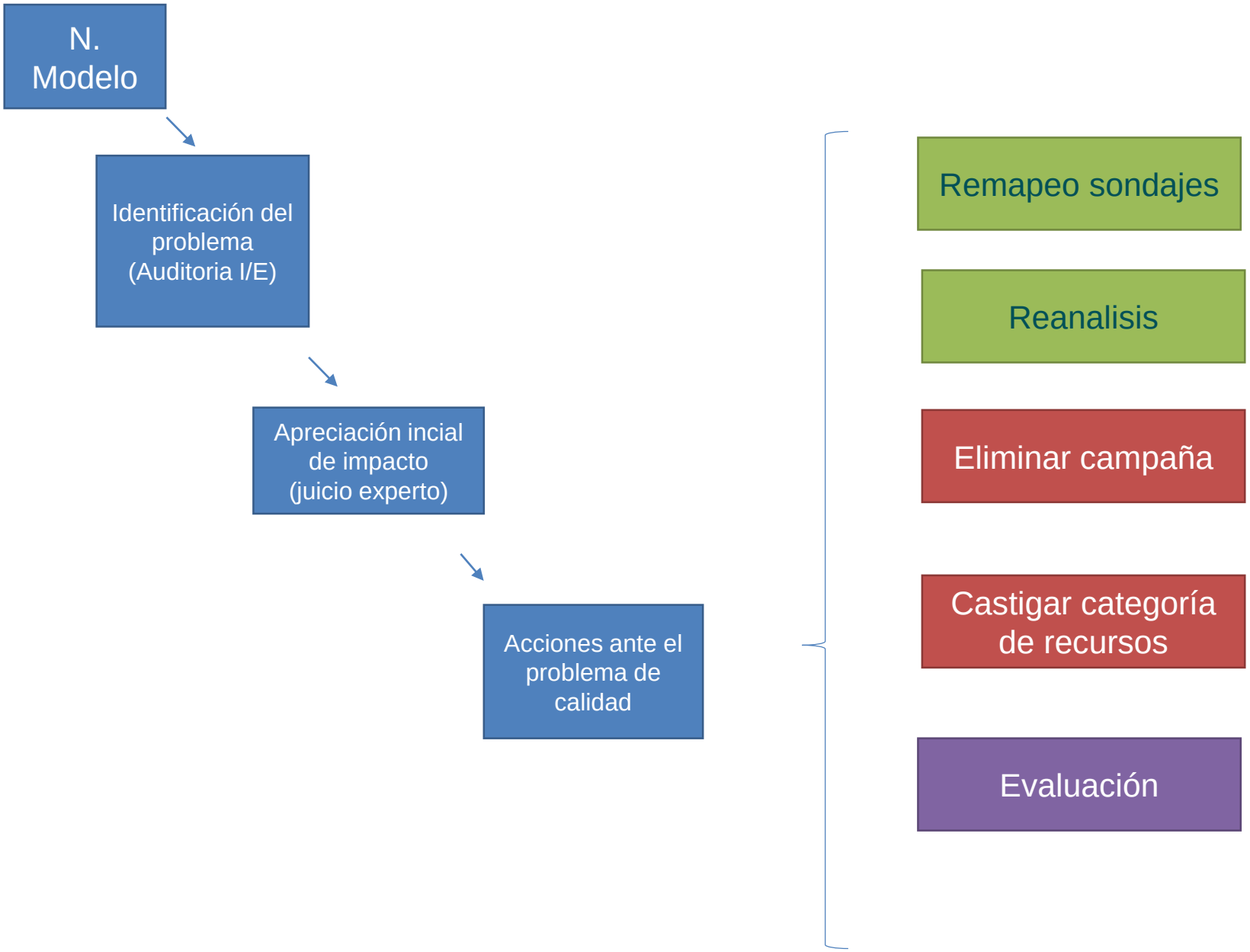
Level	Descriptor	Description
A	Non-compliance	Major compliance issues
B	Partial compliance	Significant improvement required
C	Partial compliance	Room for improvement
D	Partial compliance	Minor improvement possible
E	Full compliance	Industry best-practice

Impacto

Level	Descriptor	Value
1	Insignificant	Non-material change
2	Minor	Non-material change
3	Moderate	Material change – some adjustments
4	Major	Material change – significant adjustments
5	Catastrophic	Material change – mine closure



Se identificaron XXX% sondajes localizados al interior del pit Caso Base cuyos certificados de coordenadas de collar, trayectoria y leyes no están disponibles. Se recomienda eliminar estos sondajes de las etapas de modelamiento y estimación.


N. Modelo
Identificación del problema (Auditoria I/E)
Apreciación incial de impacto (juicio experto)
Acciones ante el problema de calidad
Remapeo sondajes
Reanalisis
Eliminar campaña
Castigar categoría de recursos
Evaluación

Evaluación

Remapeo sondajes

Reanalisis

Gemelos

OK

No OK

Eliminar campaña

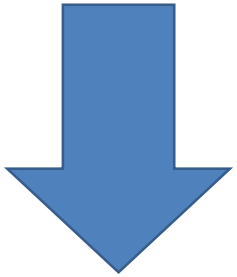
Castigar categoría de recursos

Evaluar impacto de situacion actual en recursos

EJEMPLO EVALUACION DE IMPACTO

Impacto de Cantidad y Calidad en Proyecto

- 61% sondajes sin trayectorias
- Mapeos de geología históricos
- Análisis químicos históricos



Incertidumbre en los recursos

→ **Incertidumbre en el proyecto**

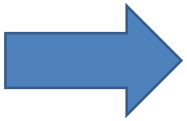
Metodología global

- ***Cuantificar el impacto de las problemáticas en los recursos del proyecto***
  - **Trayectorias**:
    - Análisis de potenciales desviaciones
  - **Mapeos históricos**:
    - Remapeo de X% de base de datos
  - **Análisis químicos históricos**:
    - Reanálisis de X% de muestras de Cut y Cus

- Cuantificación de incertidumbre asociados a la cantidad y calidad de información por medio de simulaciones de recursos.

Fuentes de incertidumbre

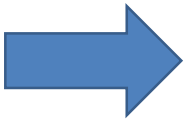
Cantidad de sondajes + variabilidad geológica y de leyes



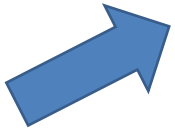
Incertidumbre asociada a cantidad de información y variabilidad

Incertidumbre total del proyecto

Trayectoria + Mapeos+ Leyes



Incertidumbre asociada a calidad de información base

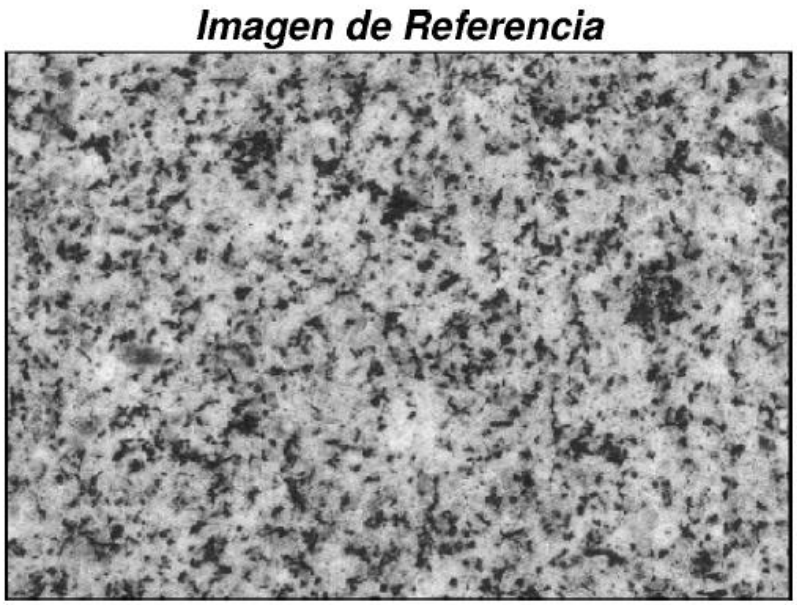


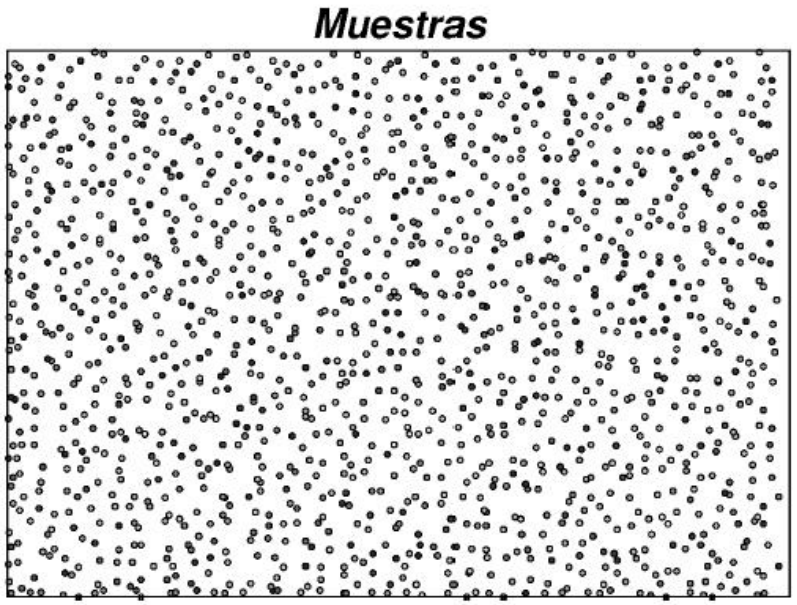
INCERTIDUMBRE ASOCIADA A CANTIDAD DE INFORMACIÓN

Ejemplo simulación

Fenómeno desconocido (depósito)

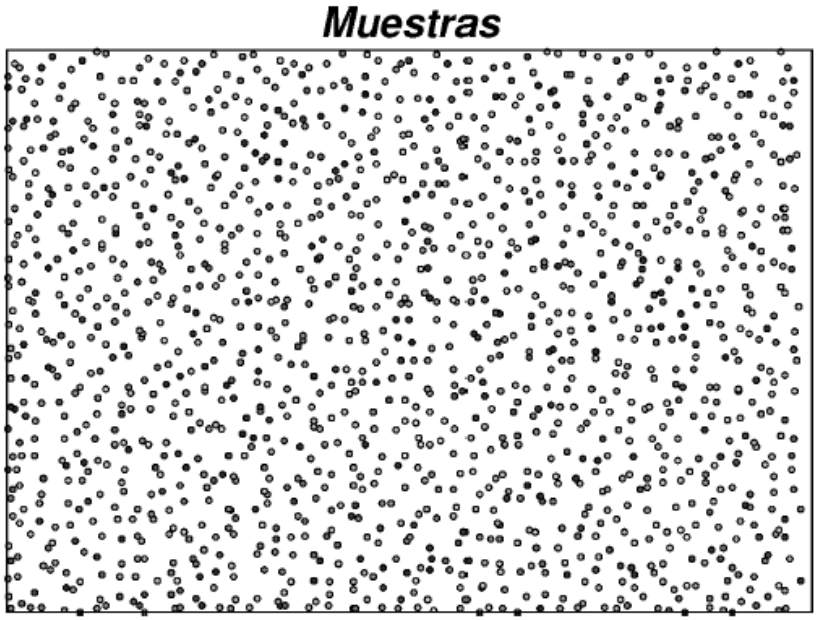
Información (muestras/sondajes)

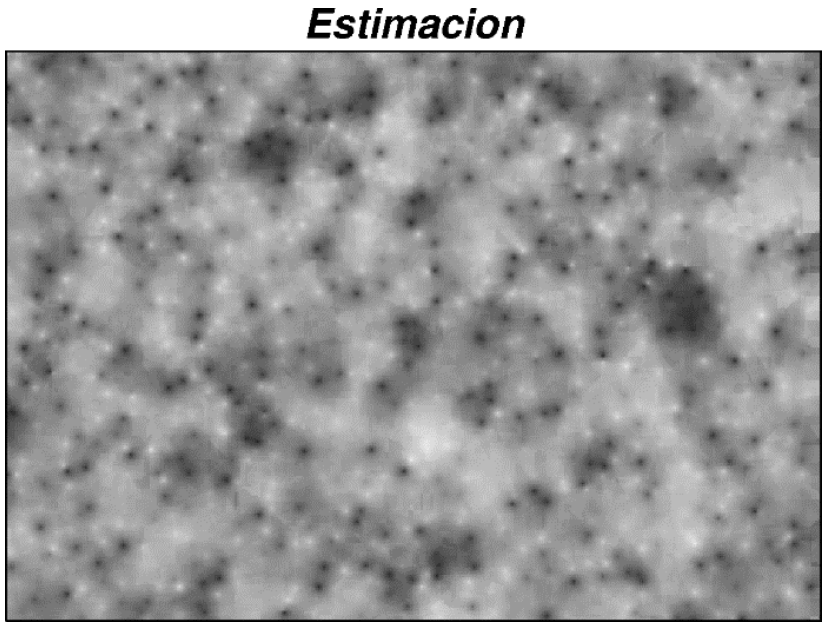




- No conocemos el depósito completamente, usamos muestras ***para predecir*** la geología, leyes y variables de procesos, construir planes y proyectos.

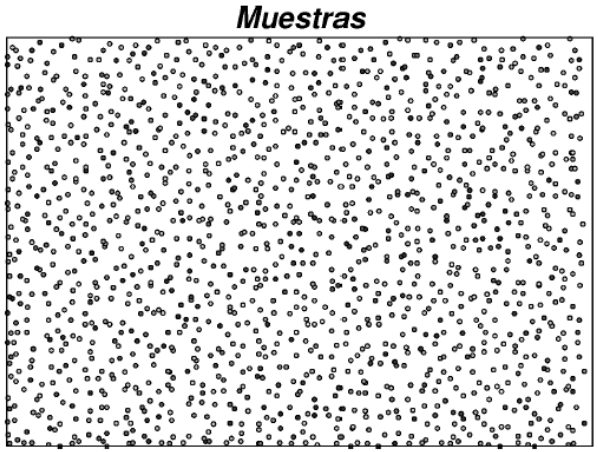
Estimación

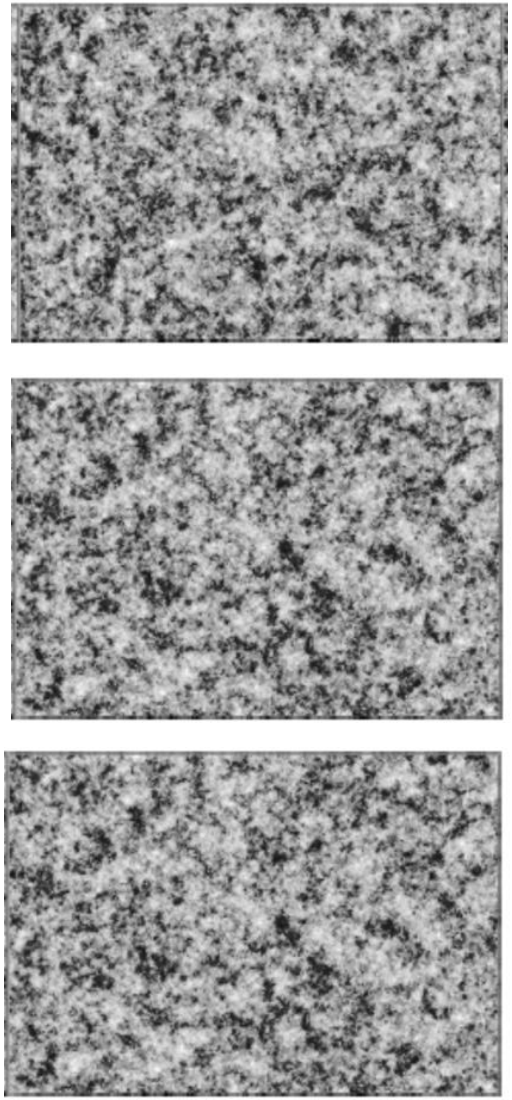


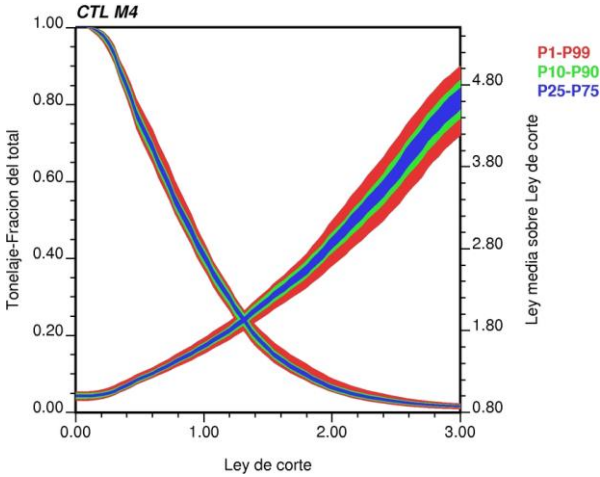


- Usando las muestras estimamos o interpolamos sus valores
- Es menos variable que los datos y el fenómeno→ No luce como la realidad!

Simulación







GeoInnova

Flujo incertidumbre asociado a cantidad de información Dsal

Información
+
Variabilidad geológica

Información
+
Variabilidad leyes

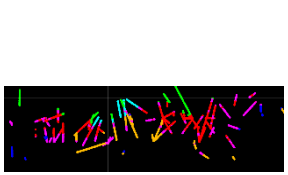
Cuantificación de incertidumbre

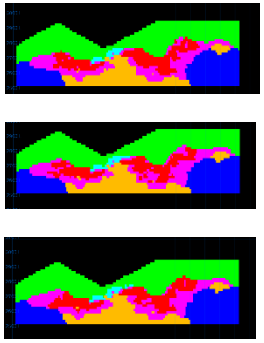
BD Mapeo

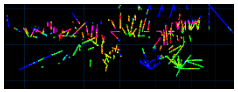
Simular Geología

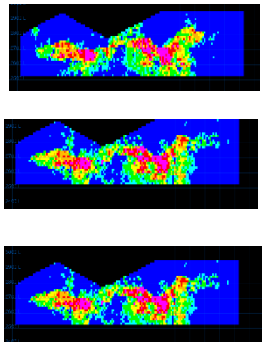
BD CuT

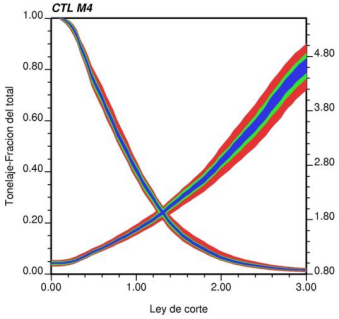
Simular Leyes



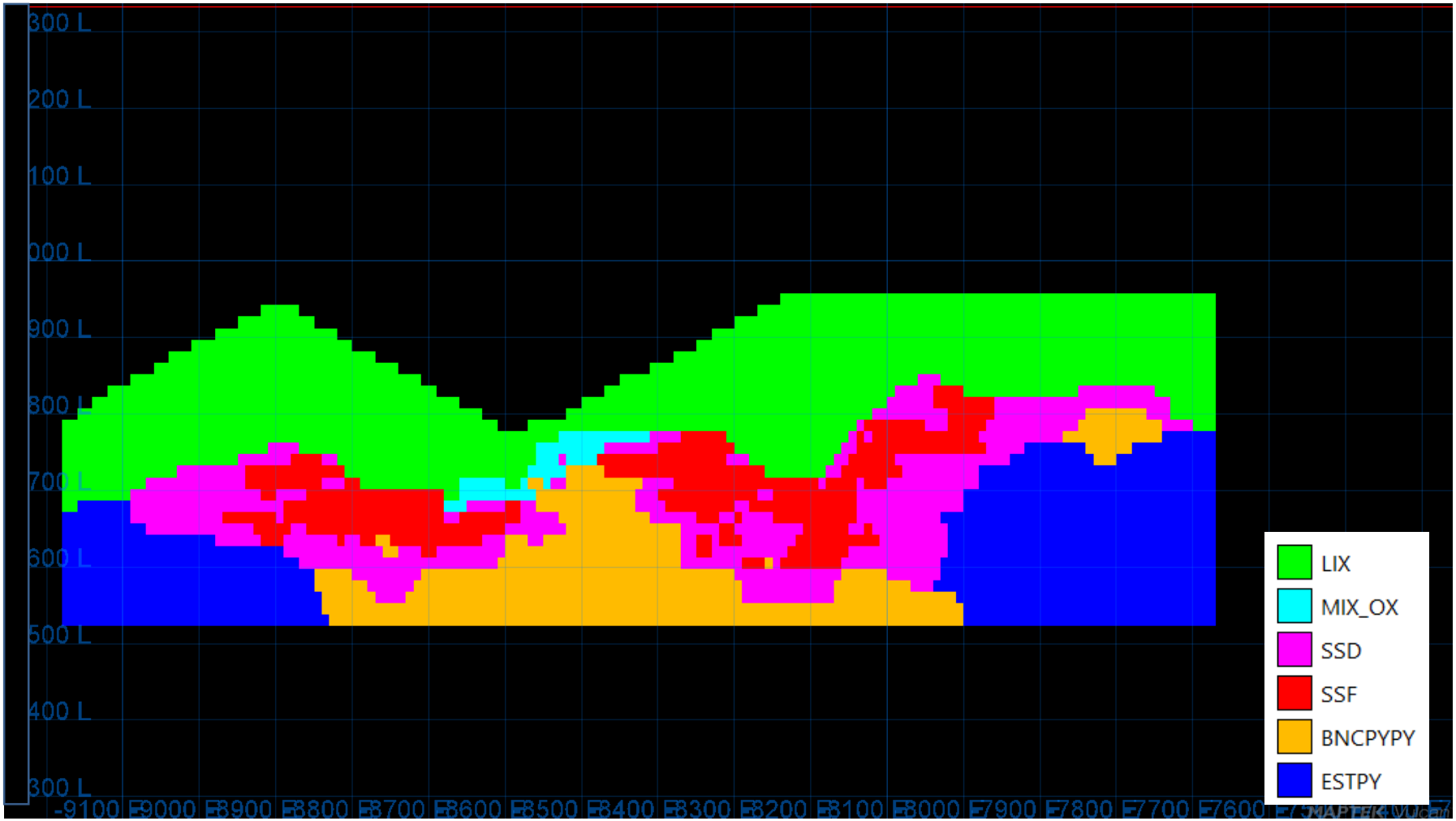




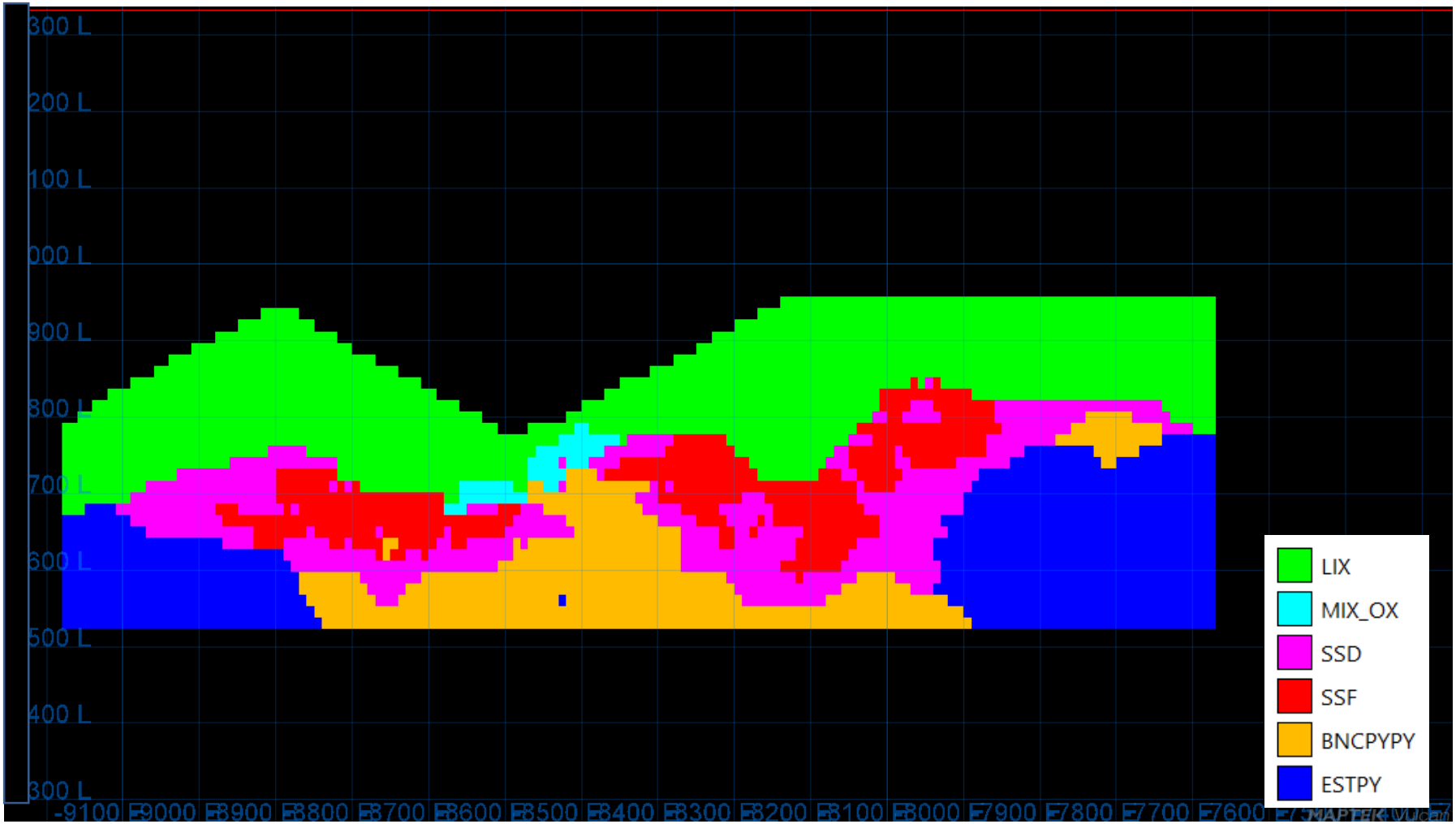




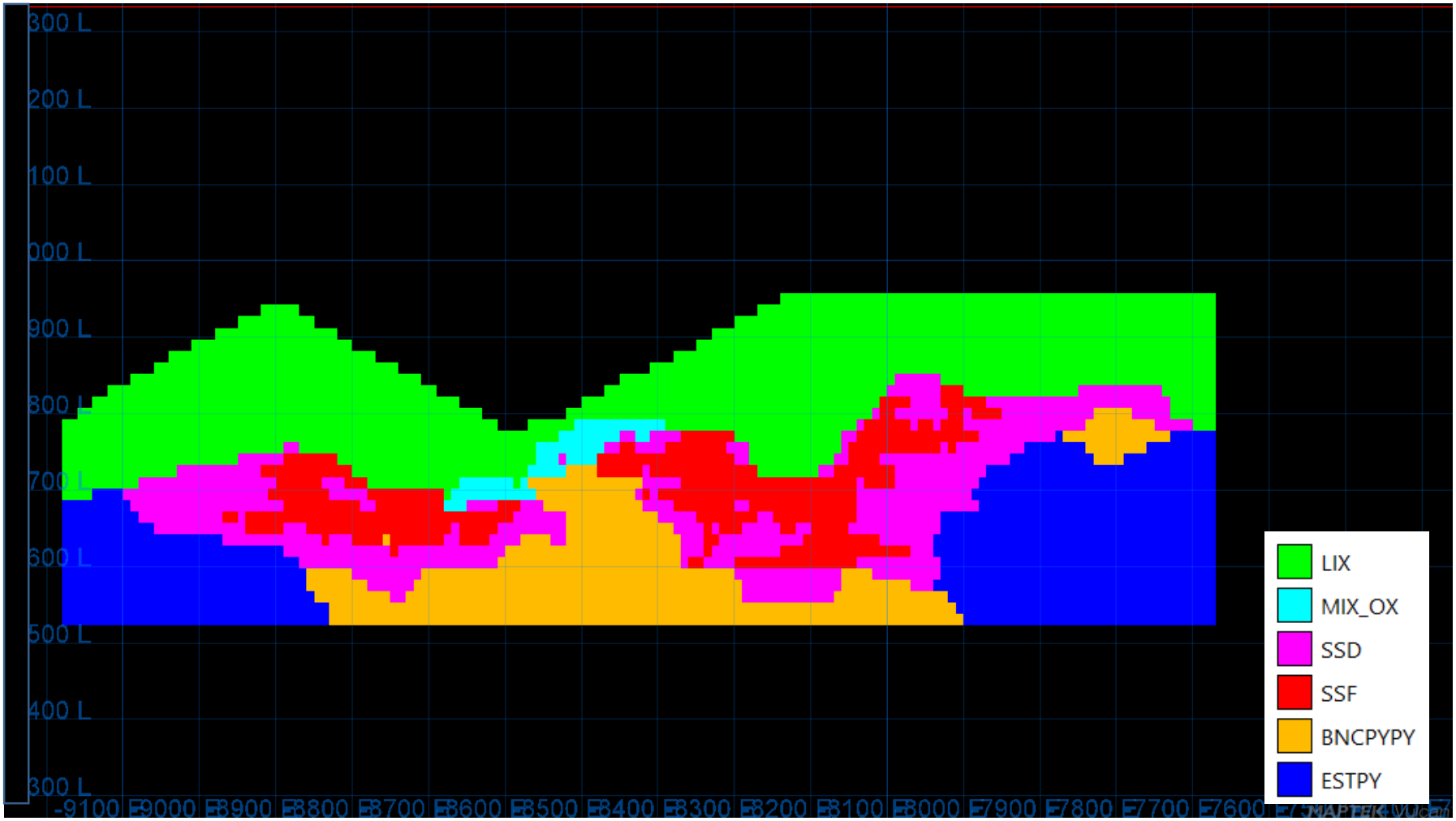
Simulaciones de geología



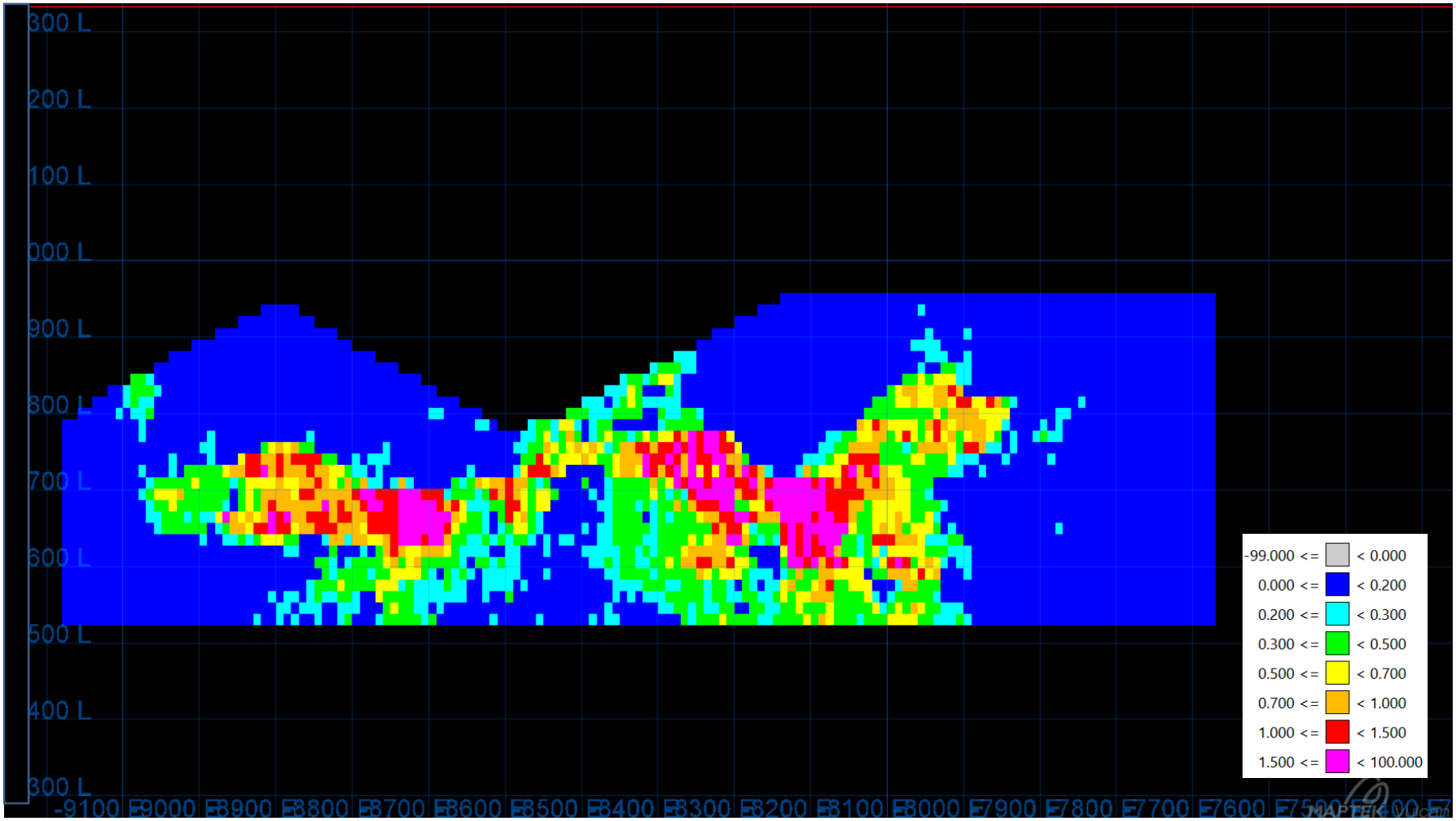
Simulaciones de geología



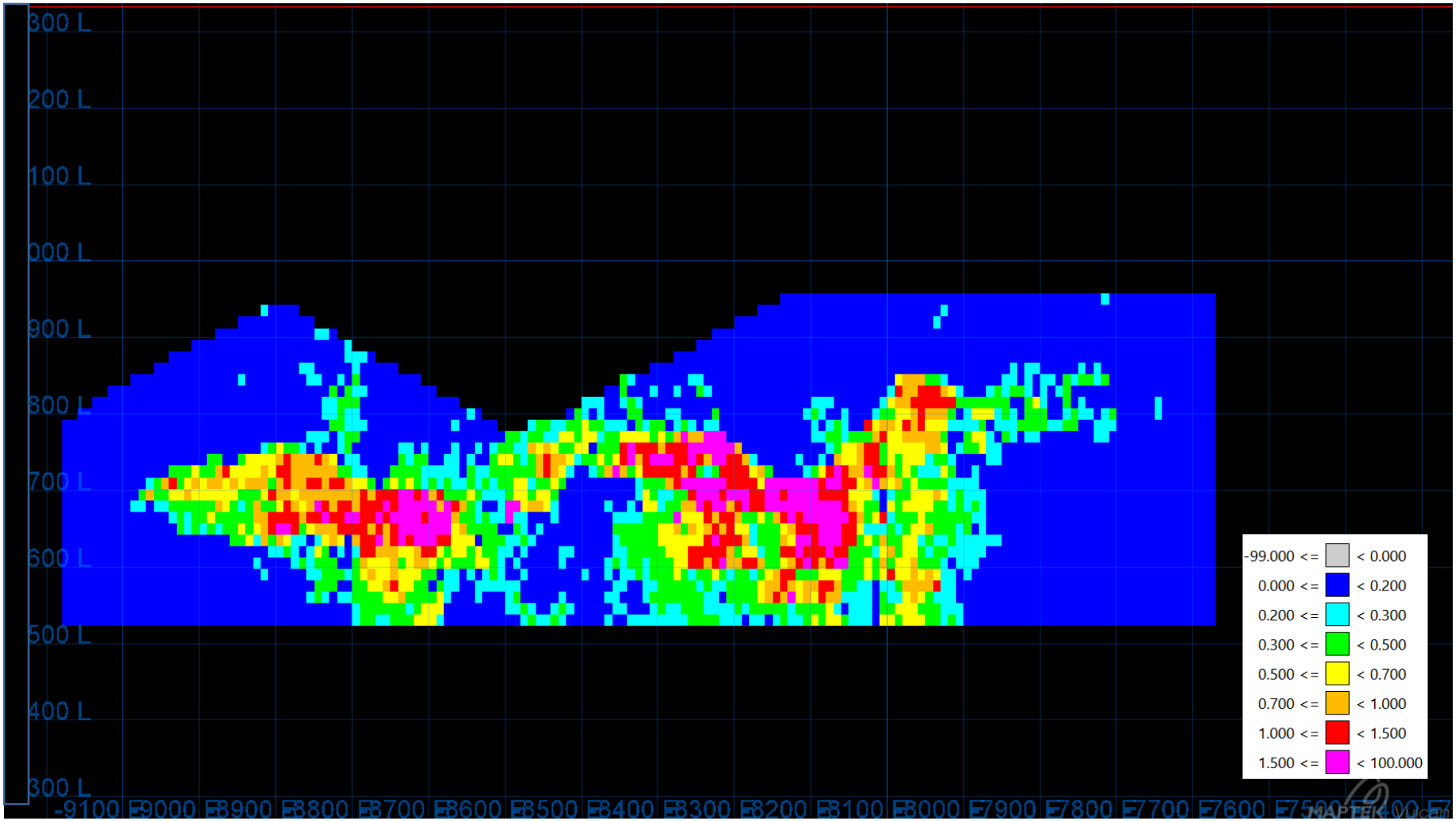
Simulaciones de geología



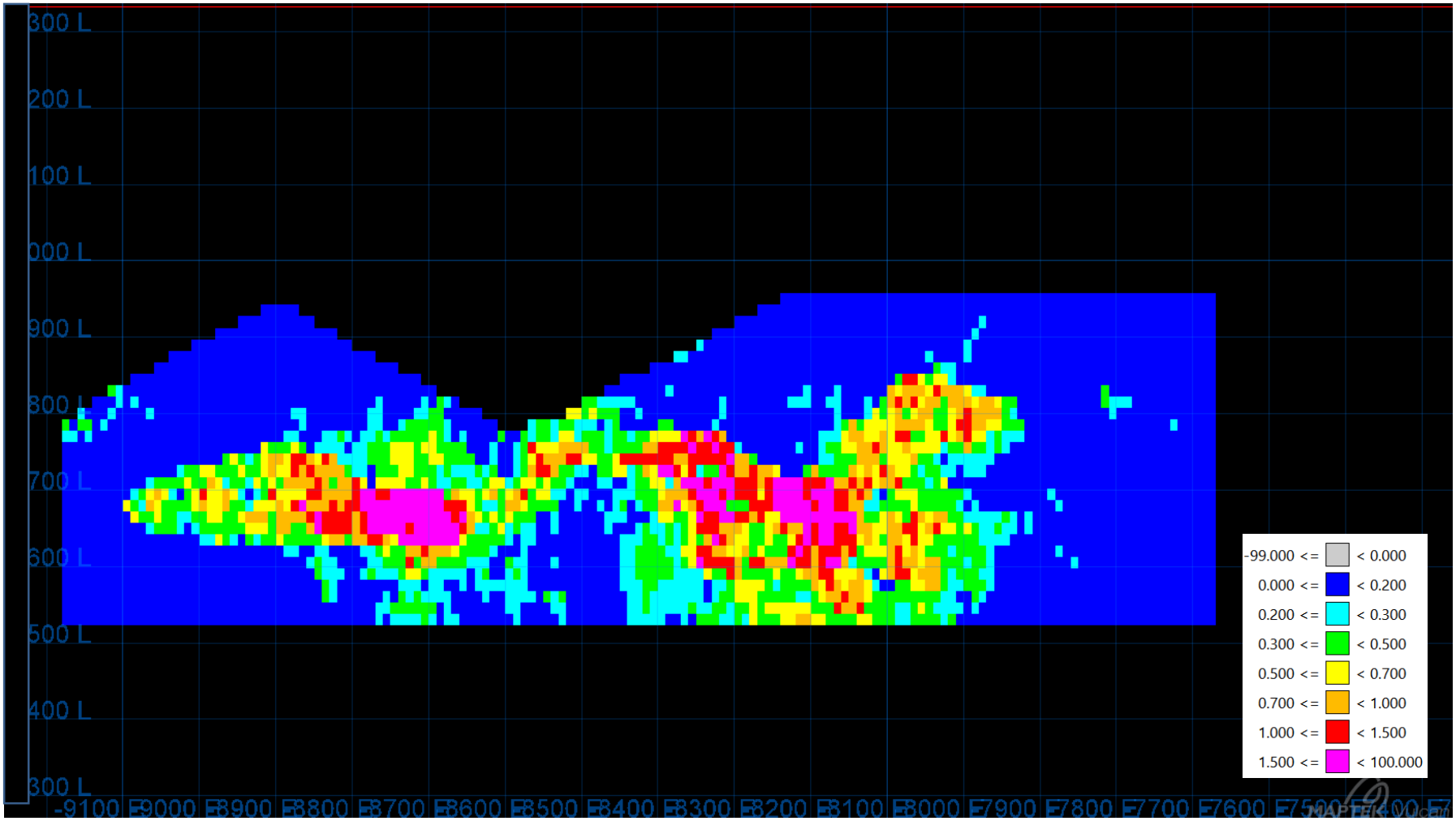
Simulaciones de leyes



Simulaciones de leyes



Simulaciones de leyes



INCERTIDUMBRE ASOCIADA A CALIDAD DE INFORMACIÓN

INCERTIDUMBRE ASOCIADA A CALIDAD DE INFORMACIÓN

TRAYECTORIAS

Problema

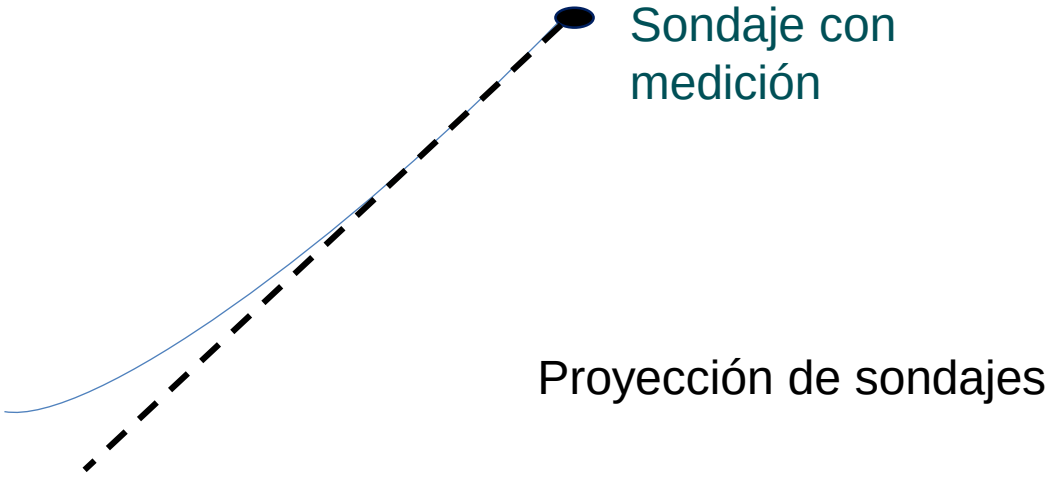
- Existe una importante cantidad de sondajes antiguos que no cuenta con desviación histórica

	Largo				
1_1_medicion	Means	N	Porcentaje	Sum	Std.Dev.
N mediciones >1	194.9	1157	39	225,538	106.1
Solo una medición	152.2	1778	61	270,556	98.1
All Grps	169.0	2935	100	496,094	103.4

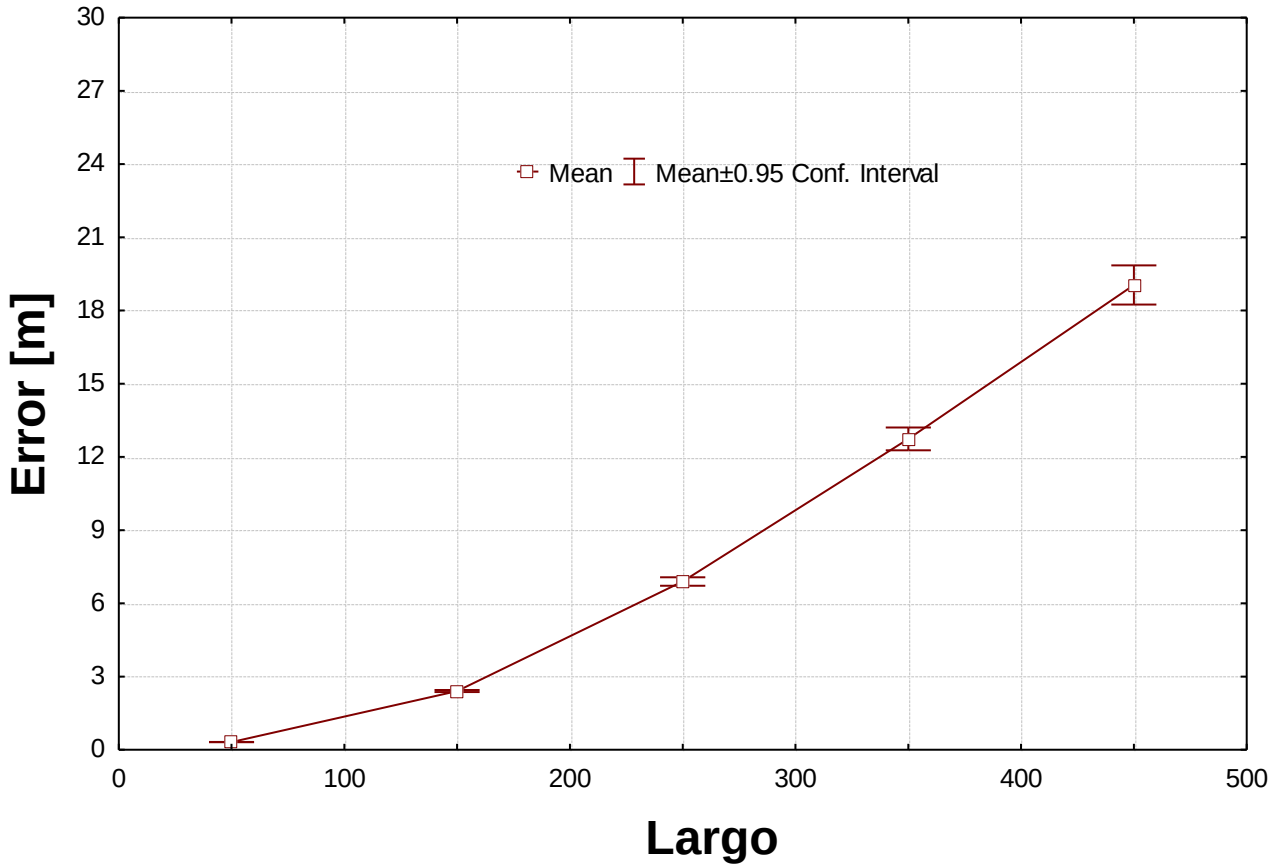
- El 60% de los sondajes solo cuenta con medición de trayectoria en el collar, el largo promedio de estos es de 152 metros

Aproximación

- Se compararon sondajes con mediciones de trayectoria con respecto a una proyección desde el collar



Errores en metros vs largo de sondajes



- Errores mayores a 6 metros → sobre 250 metros
- Hay que considerar que modelo de bloques es 10x10x15m

Sondajes > 250 m y cantidad de mediciones de trayectoria

% de sondajes

	N mediciones >1	Solo una medició	Row Totals
<250 m	30.2	53.2	83.4
>250 m	9.2	**7.4**	16.6
All Grps	39.4	60.6	100.0

- **Solo el 7.4% podría tener una desviación mayor a 6 metros**

Implicancias trayectorias

- La falta de trayectoria es un riesgo menor ya que la mayoría de los sondajes son cortos < 200 m
- Los sondajes potenciales con errores mayores a 6 metros son del orden del 7% del total
- Principales controles de zonas minerales subhorizontales

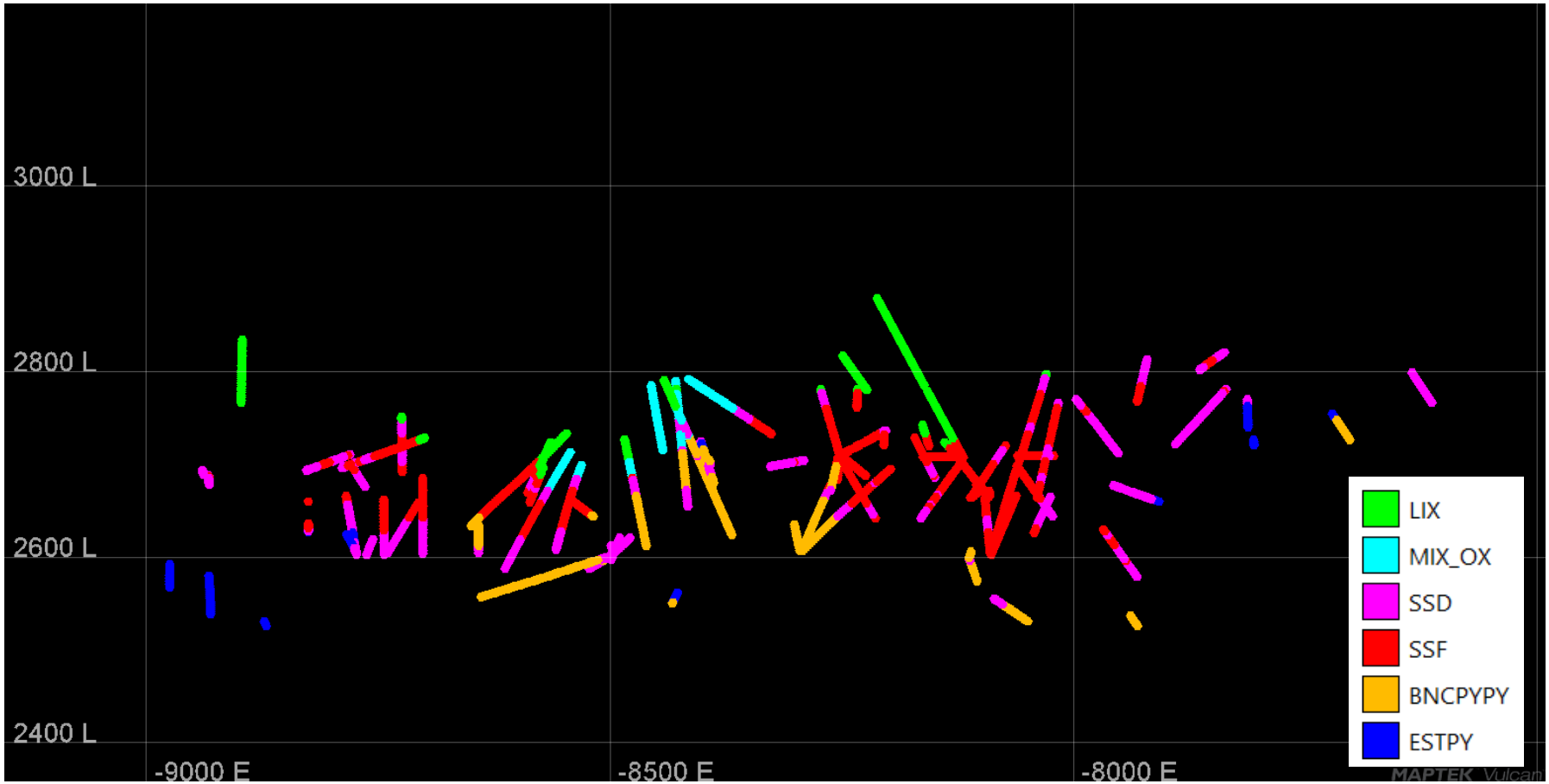
INCERTIDUMBRE ASOCIADA A CALIDAD DE INFORMACIÓN

MAPEOS HISTORICOS

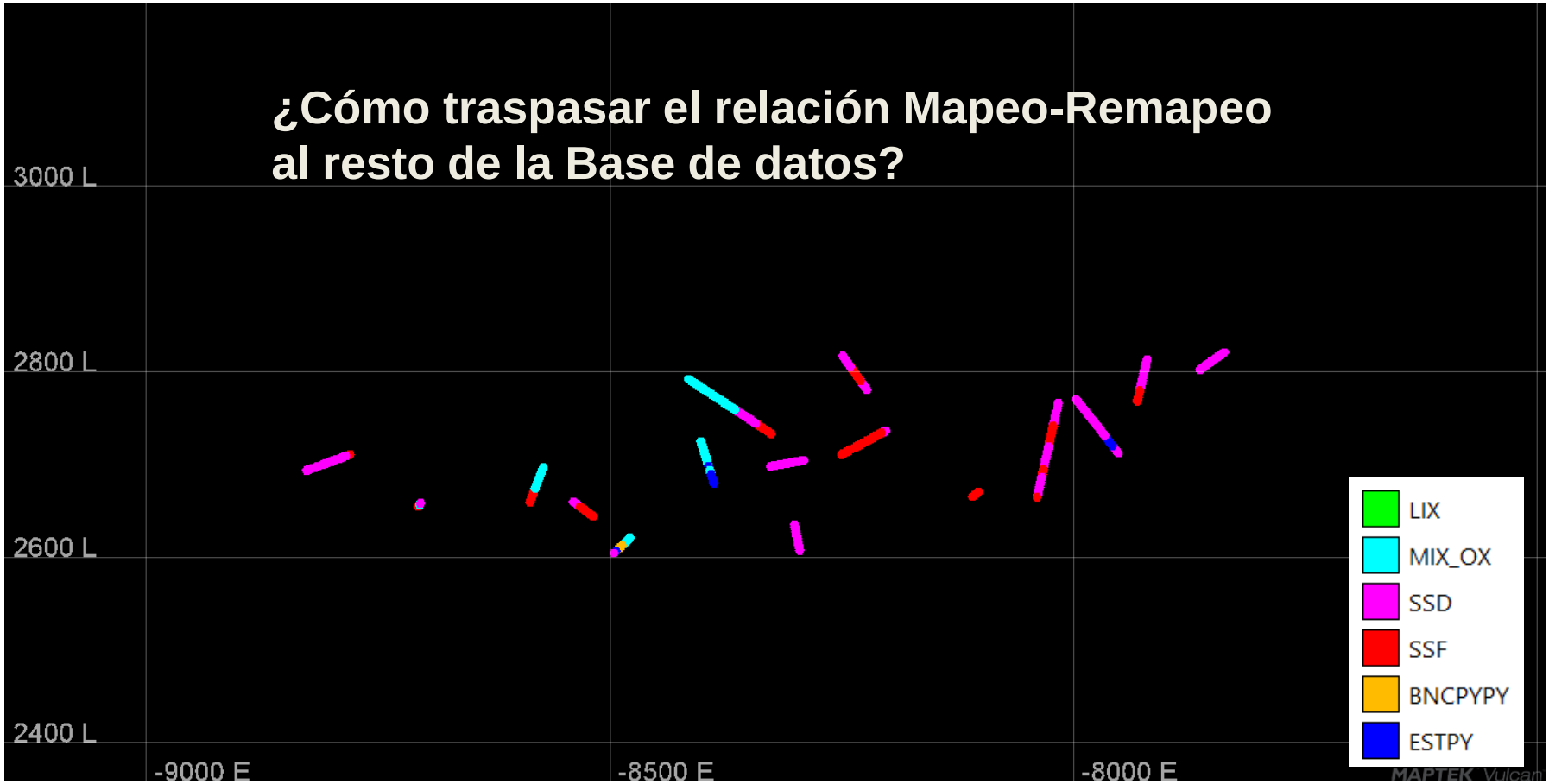
Problemática mapeo y remapeo

- Mapeos: 432,000 metros
- Remapeos: 16,000 metros (3.7 %)

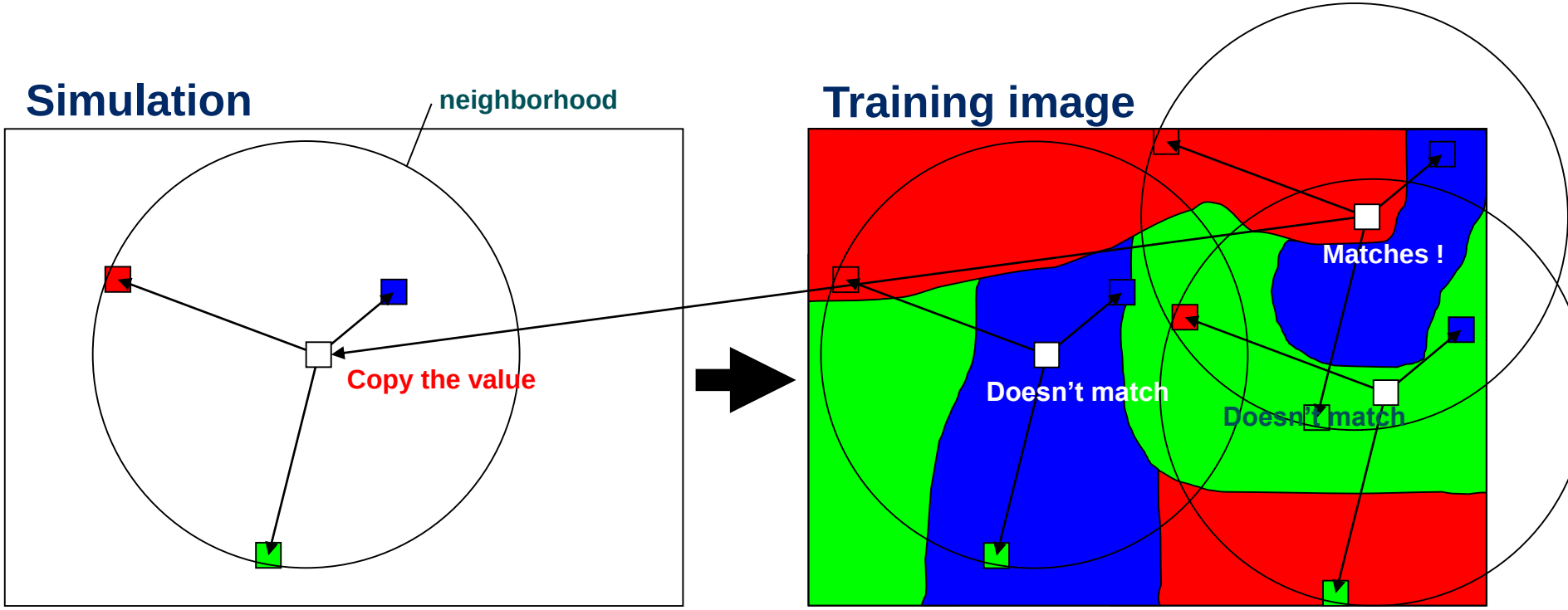
Mapeos Originales



Remapeos


¿Cómo traspasar el relación Mapeo-Remapeo
al resto de la Base de datos?
3000 L
2800 L
2600 L
2400 L
-9000 E
-8500 E
-8000 E
LIX
MIX_OX
SSD
SSF
BNCPYPY
ESTPY
MAPTEK Vulcan

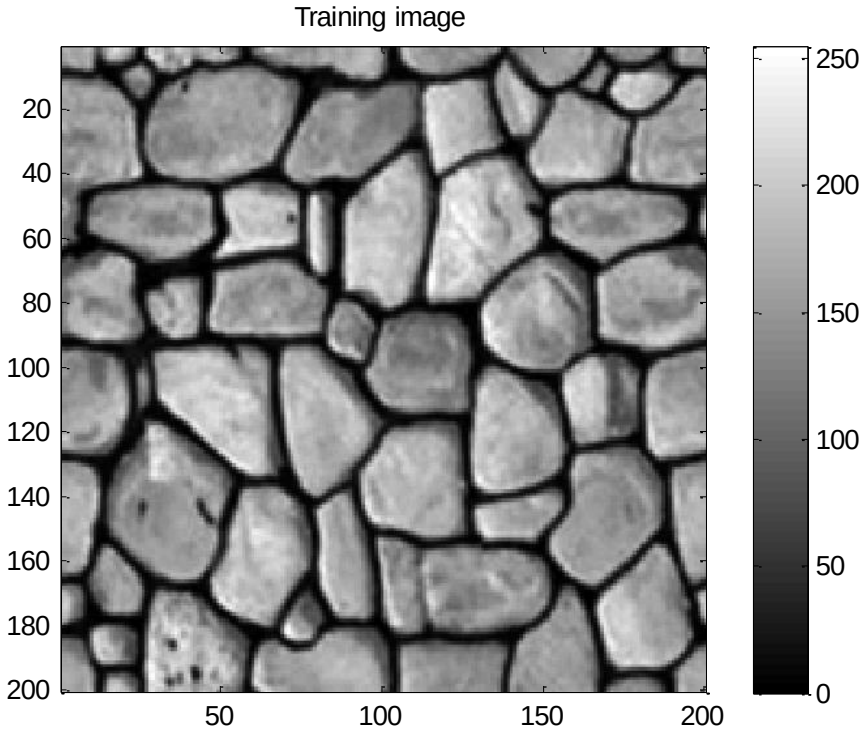
Simulación por muestreo directo (Mariethoz, 2009)

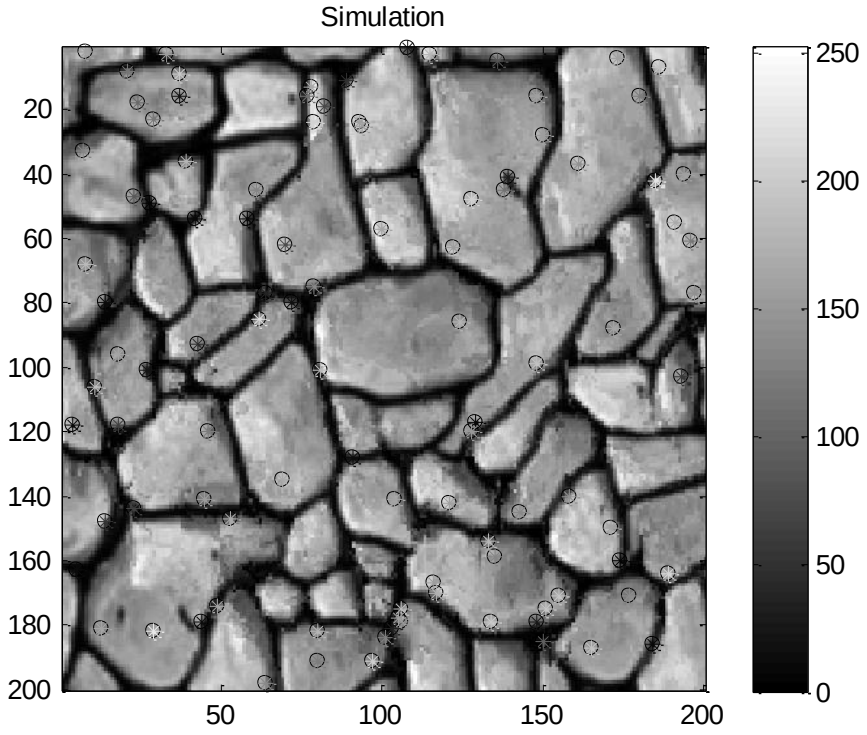


As soon as one good configuration is found,

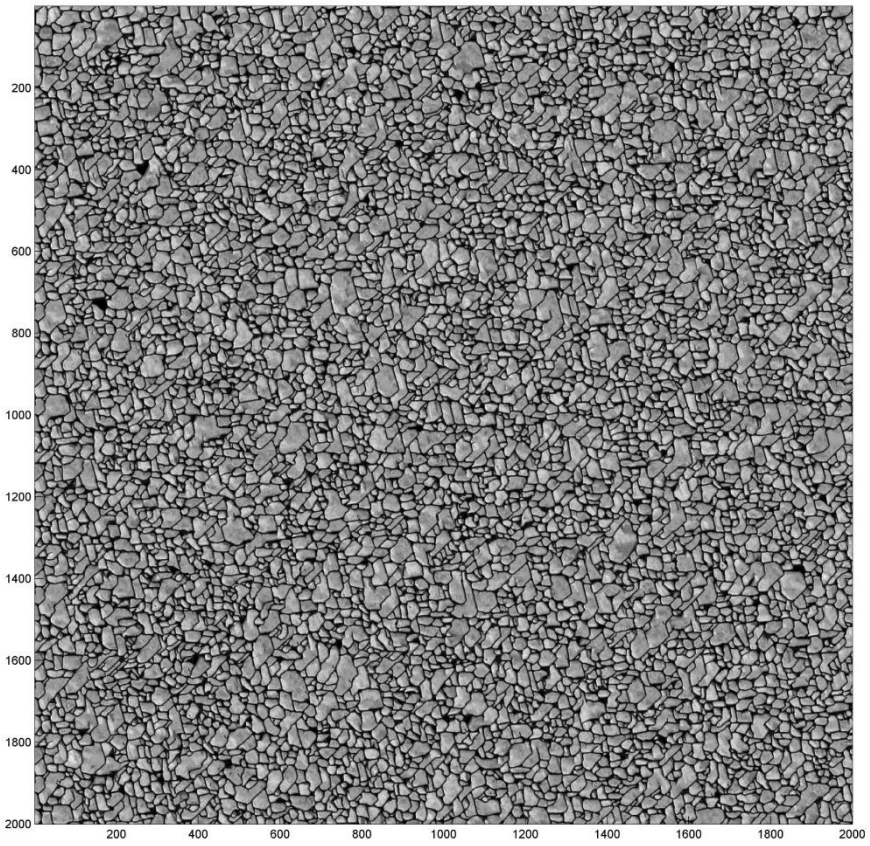
the value at the central pixel is assigned to the simulated node.

Continuous variable (Mariethoz, 2009)

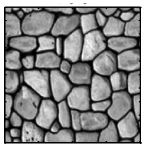




Simulación en imagen de tamaño mayor (Mariethoz, 2009)



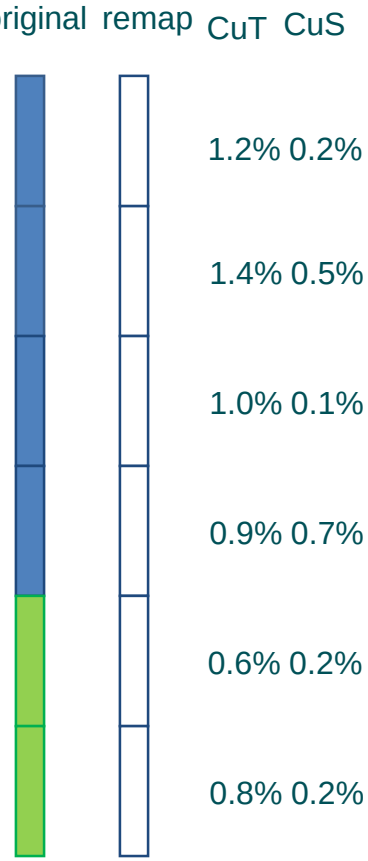
Training image



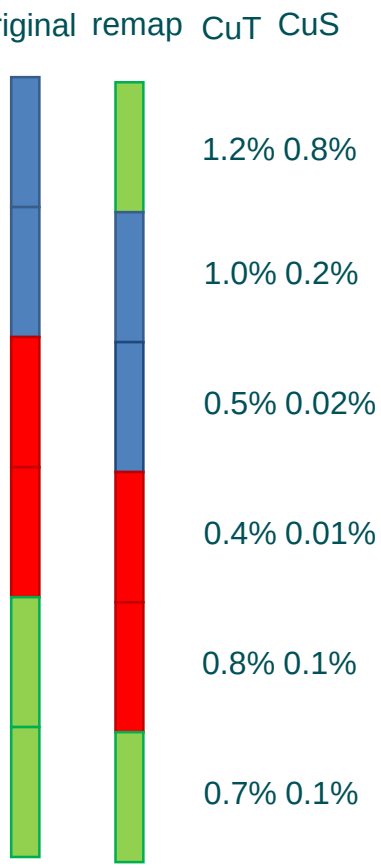
200 x 200

Metodología Incorporación de remapeos

Sondajes sin remapeo

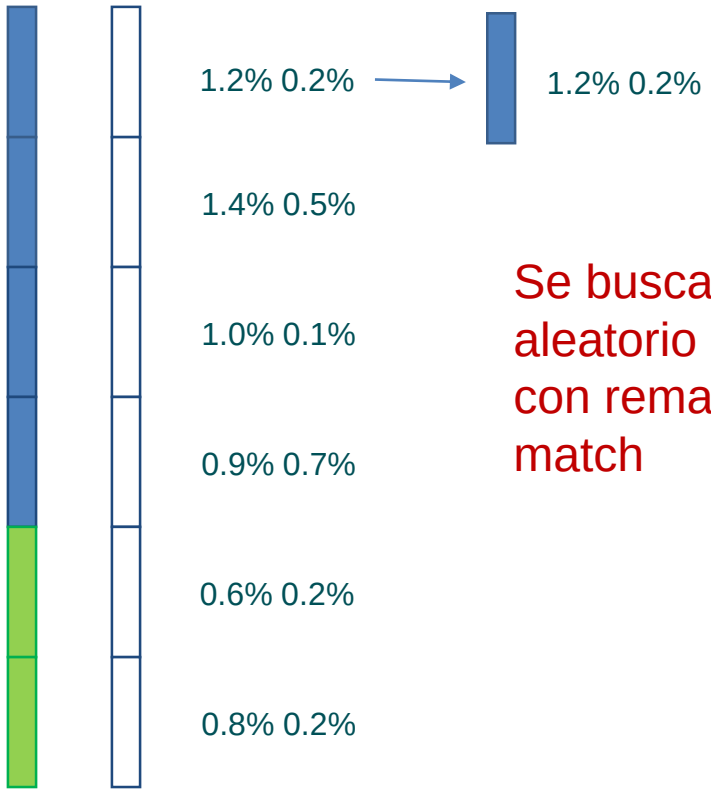


Sondajes con remapeo



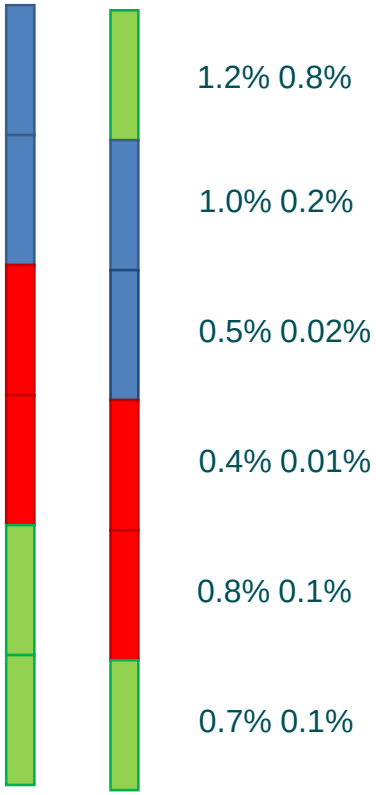
Metodología inclusión remapeos

Sondajes sin remapeo

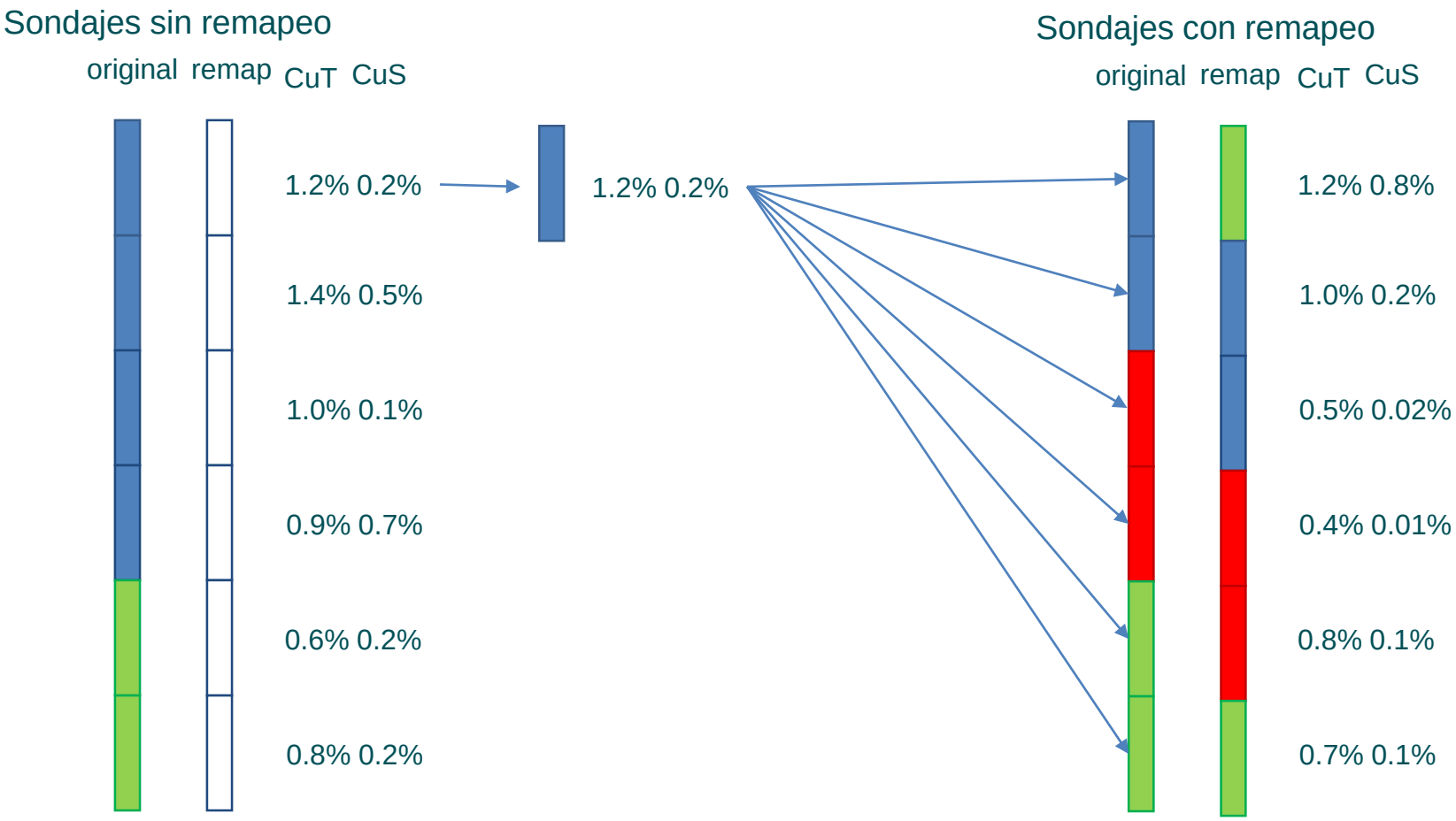


Se busca en orden aleatorio en los sondajes con remapeo el mejor match

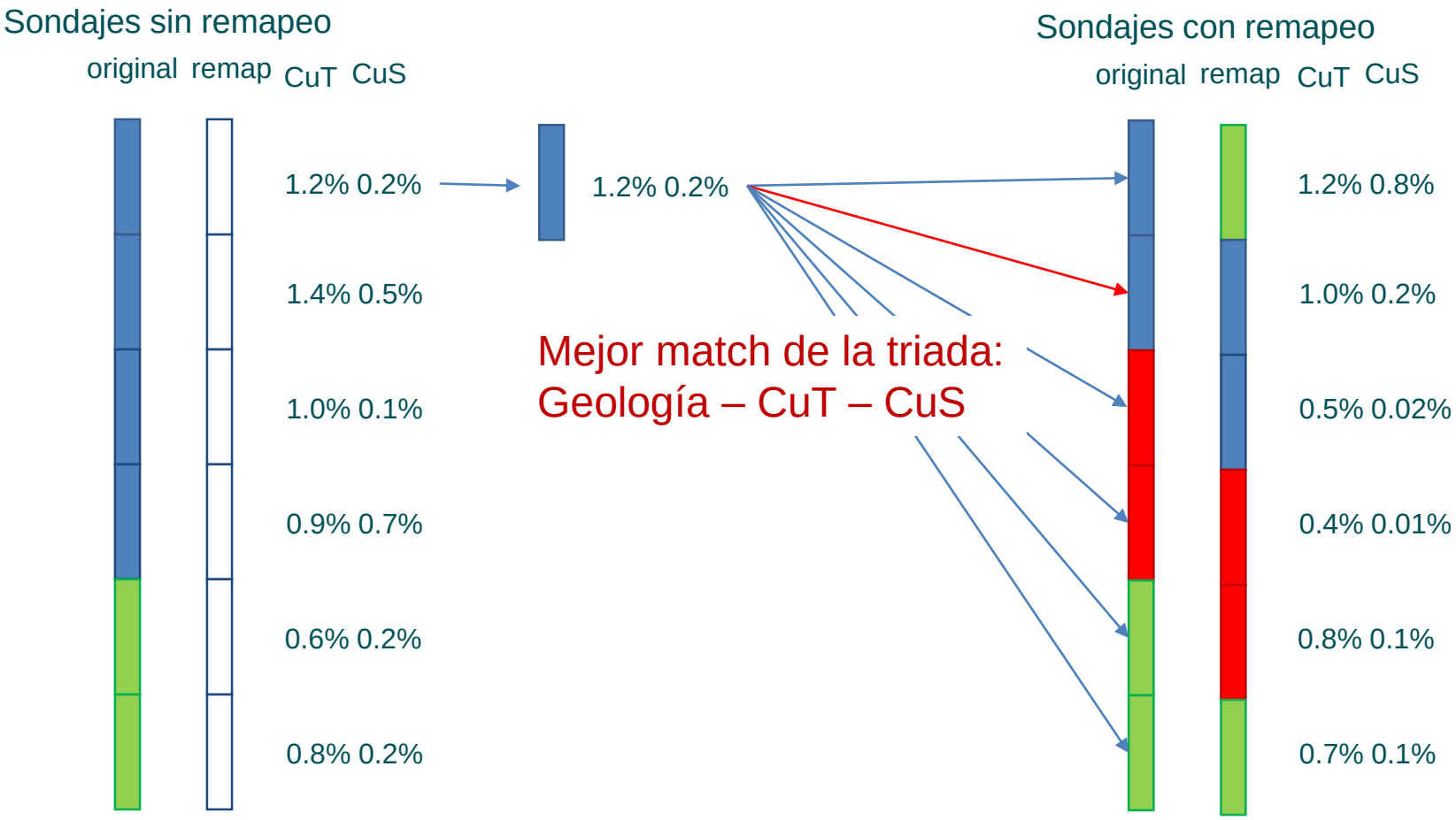
Sondajes con remapeo



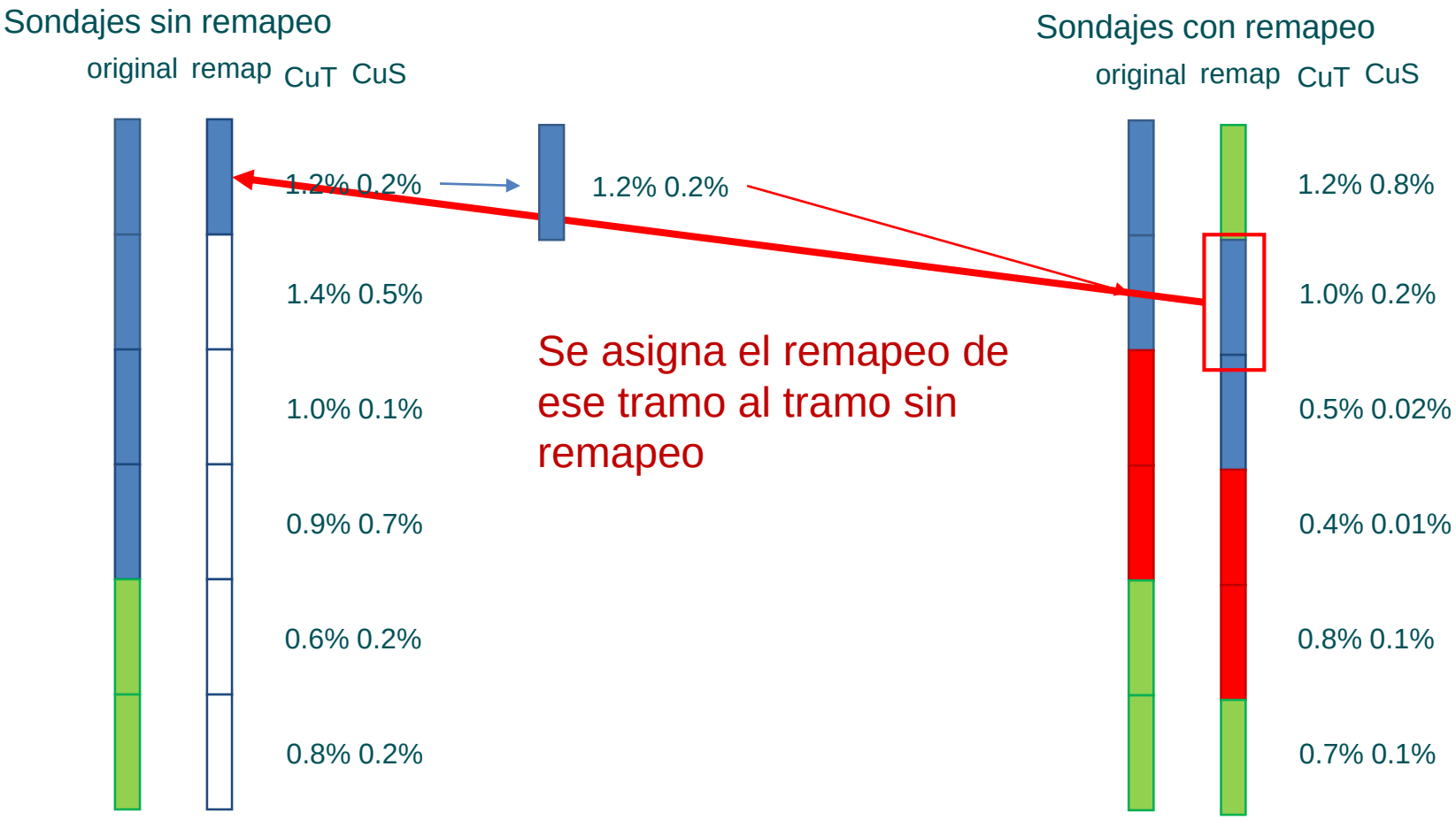
Metodología inclusión remapeos



Metodología inclusión remapeos

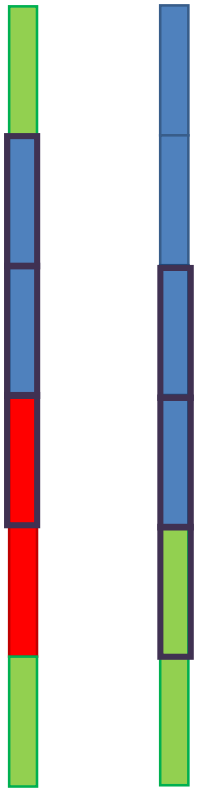


Metodología icorporación de remapeos



Métricas disimilitud

E(x) E(x')



$$DIF\big(E(x,w),E(x',w)\big) = \sum_{i}^{2w+1} \left(D^{i}_{zmin} + D^{i}_{CUT} + D^{j}_{CUS}\right) \Big/$$

ZMIN	LIX	MIX_OX	SSD	SSF	ESTPYCPY	BNCPY
LIX	0	8	8	8	8	8
MIX_OX	7	0	4	4	8	8
SSD	6	3	0	4	8	8
SSF	6	6	4	0	8	8
ESTPYCPY	5	8	8	8	0	8
BNCPY	8	8	6	6	5	0

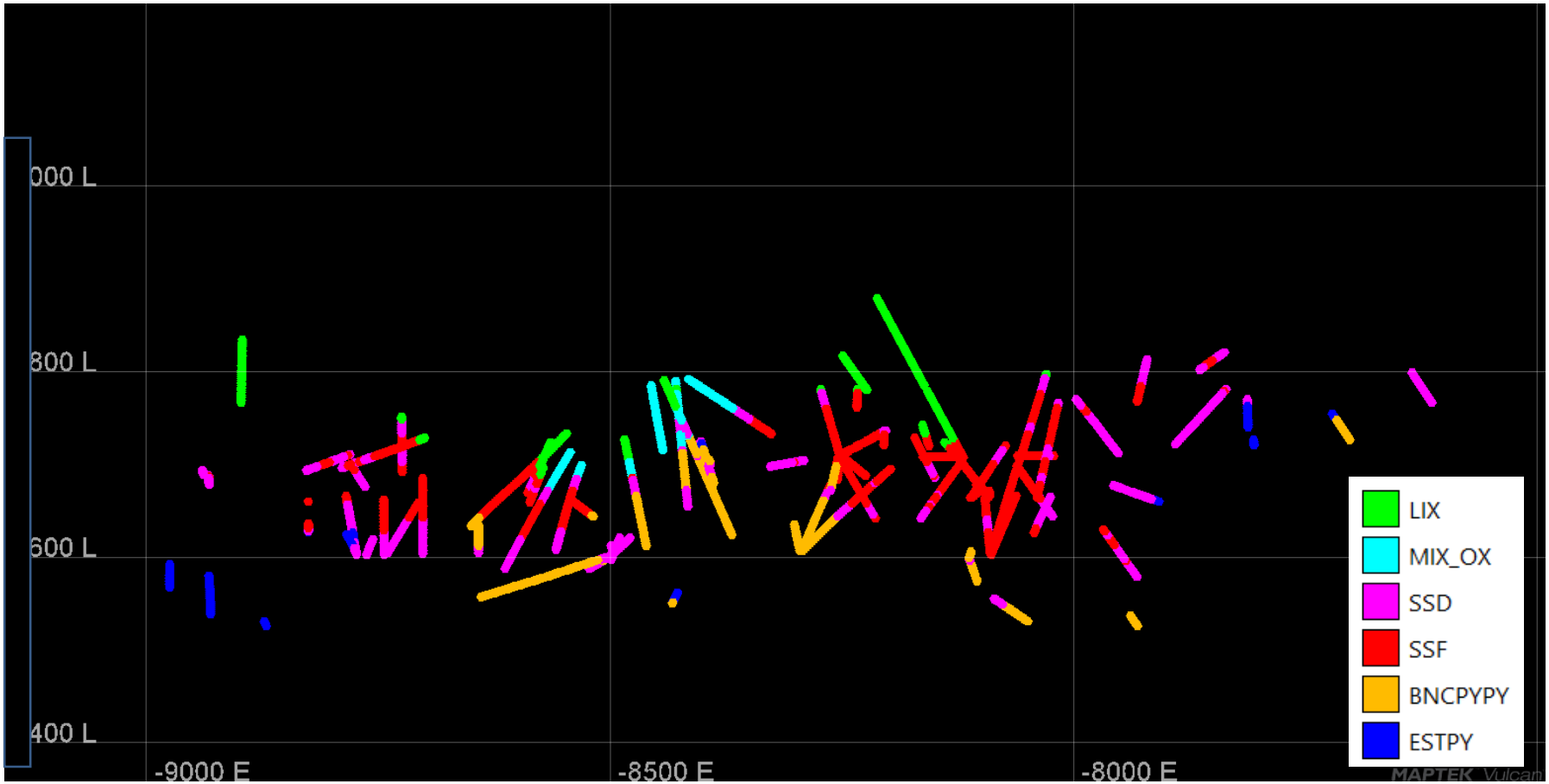
CUT		0	0.05	0.1	0.19	0.3	0.4	0.52	0.67	0.9	1.43
		1	2	3	4	5	6	7	8	9	10
0	1	0	1	1	10	10	10	10	10	10	10
0.05	2		0	1	10	10	10	10	10	10	10
0.1	3			0	10	10	10	10	10	10	10
0.19	4				0	1	2	3	5	6	7
0.3	5					0	1	2	3	5	6
0.4	6						0	1	2	3	5
0.52	7							0	1	2	3
0.67	8								0	1	2
0.9	9									0	1
1.43	10										0

GeoInnova

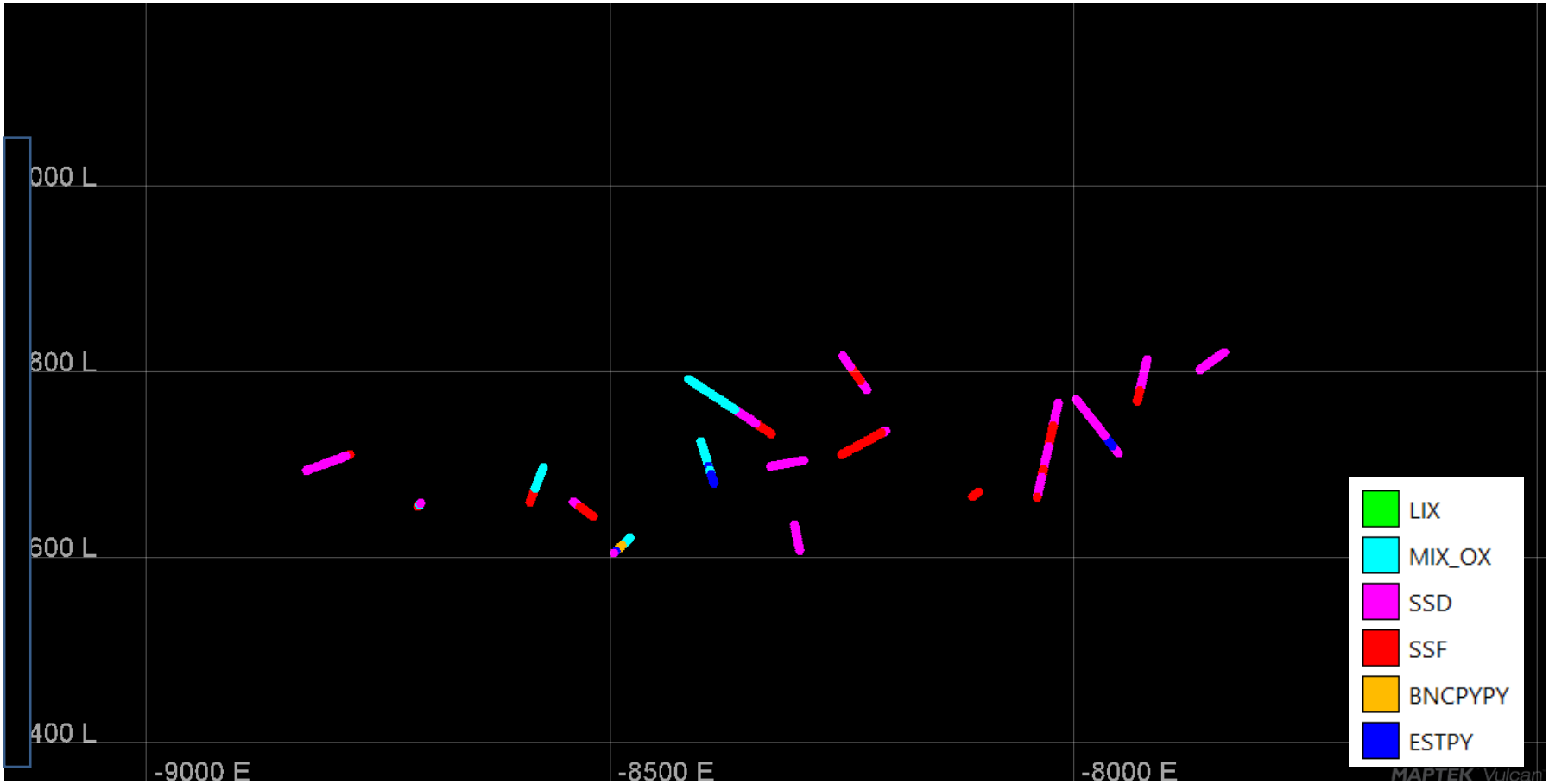
Workflow Direct sampling heterotópico

1. Dos bases de datos
   - Entrenamiento (donde existe mapeo y remapeo)
   - Aplicación (donde solo existe mapeo original)
2. Definir métrica de Similitud de zonas minerales y leyes de cut
3. Definir tamaño del plantilla de búsqueda en sondajes
4. Visitar aleatoreamente una ubicación (x) de BD. App .
   1. Seleccionar evento EA(x) Mapeo-Cut-Cus
5. Visitar aleatoreamente la BD de entrenamiento, hasta cierto número de iteraciones
   1. Calcular métrica de similitud entre EA(x) y la base de dato de entrenamiento
   2. Seleccionar el evento más similar en BD. Entrenamiento EE(x')
   3. Asignar el remapeo del evento EE(x') a la ubicación X en BD. App.
6. Volver a 4 hasta simular toda la base de datos con remapeos

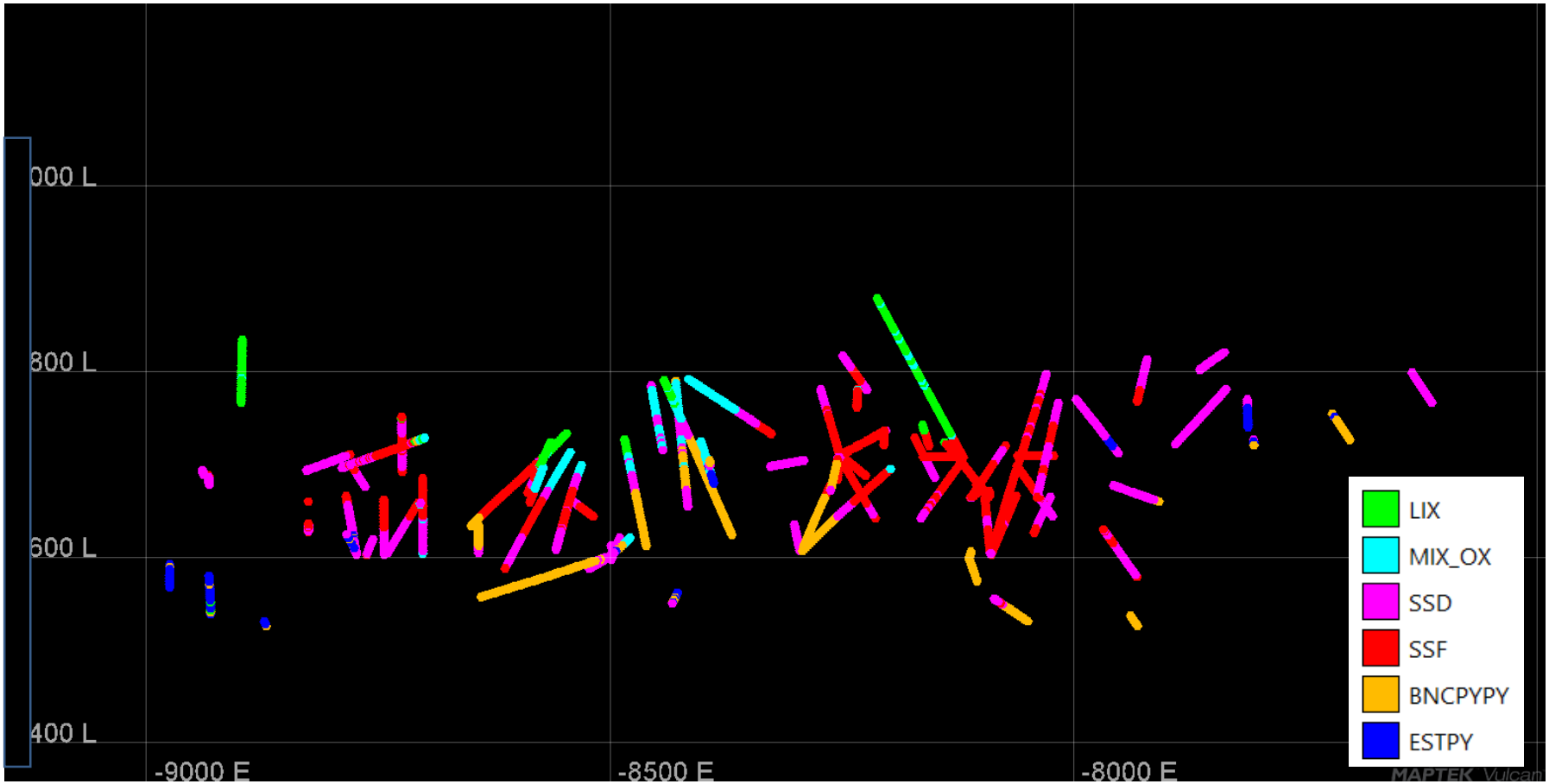
Mapeos Originales



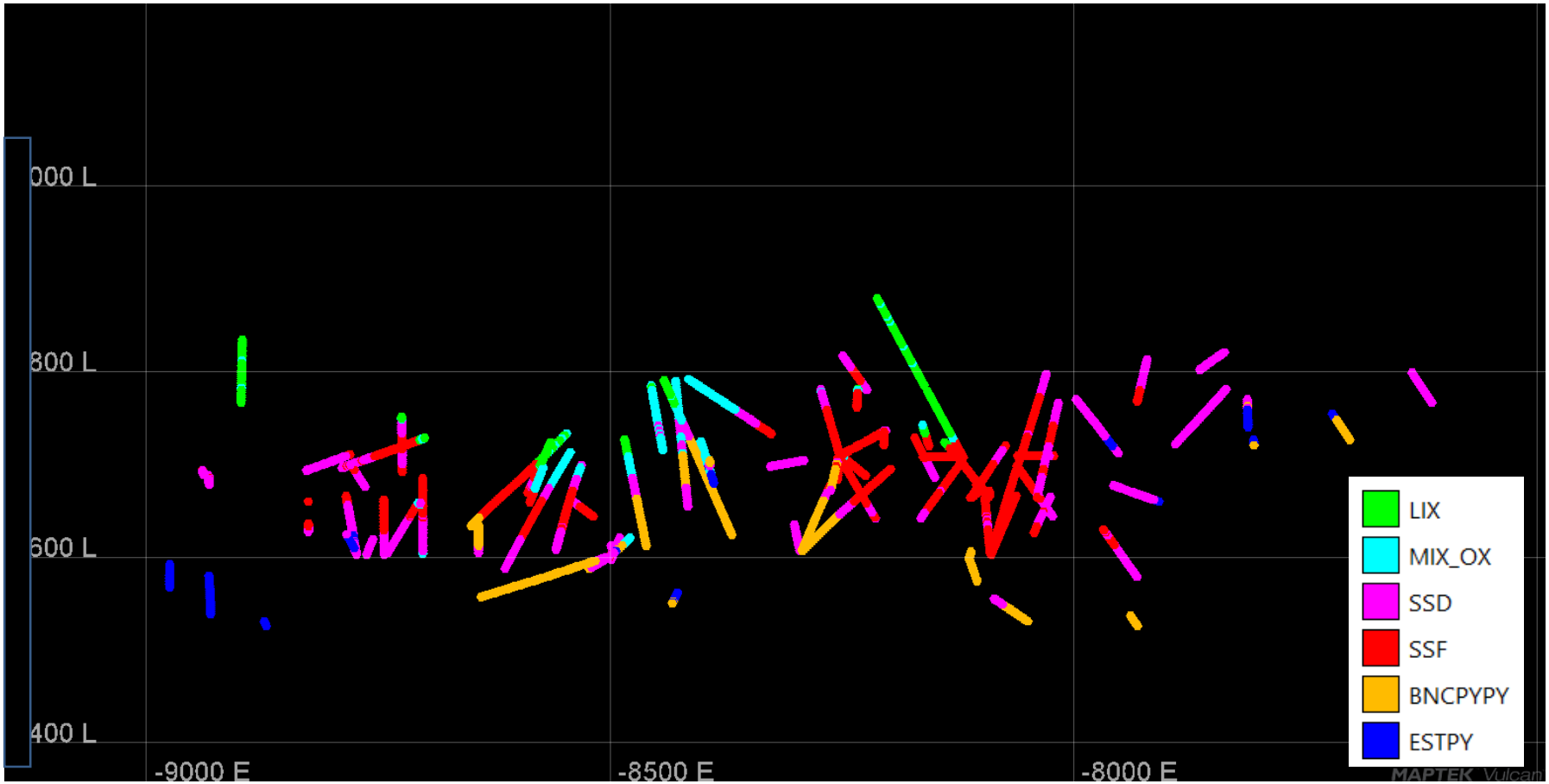
Bases de datos remapeadas



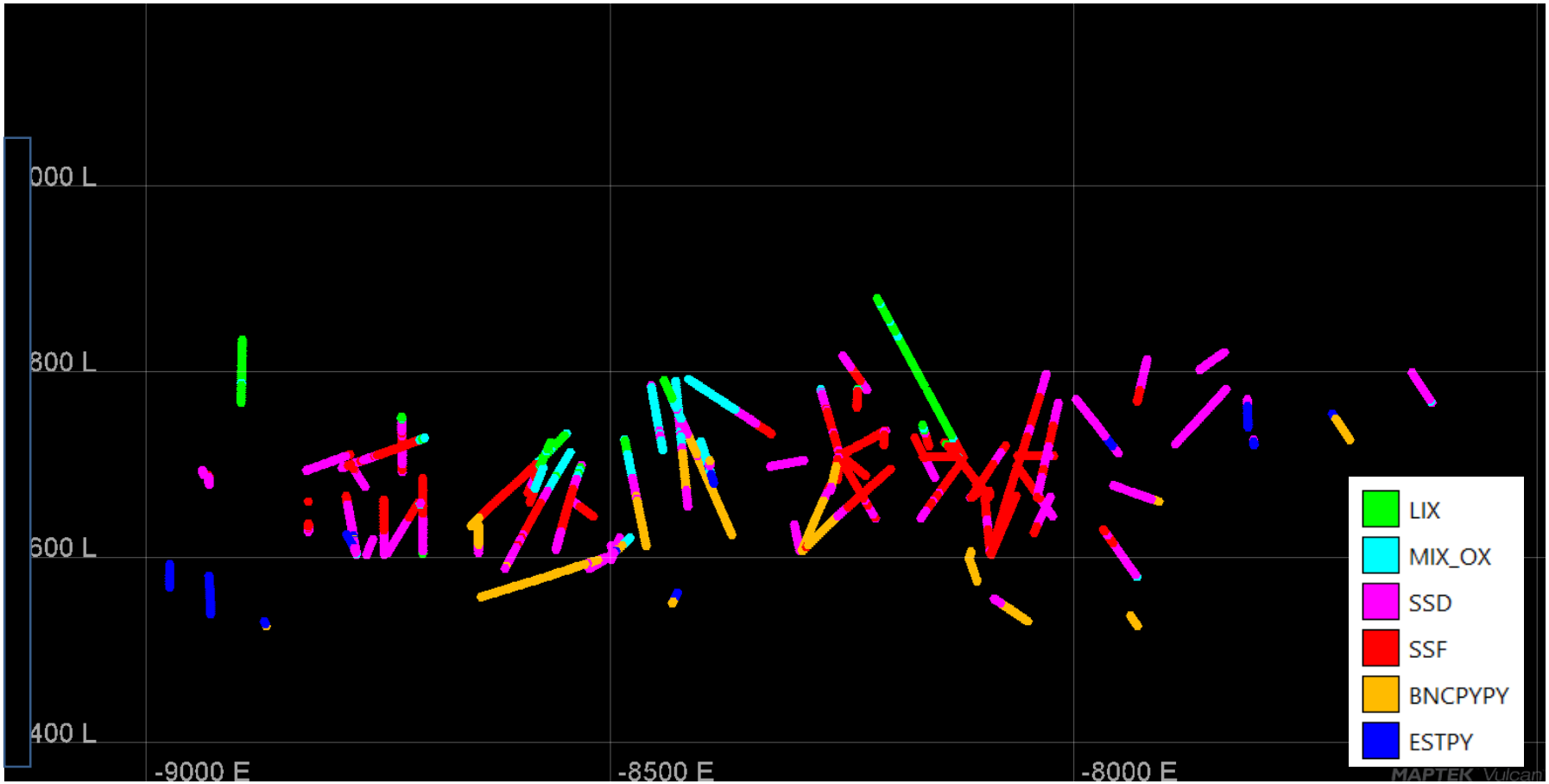
Re-Mapeos Simulados N°1

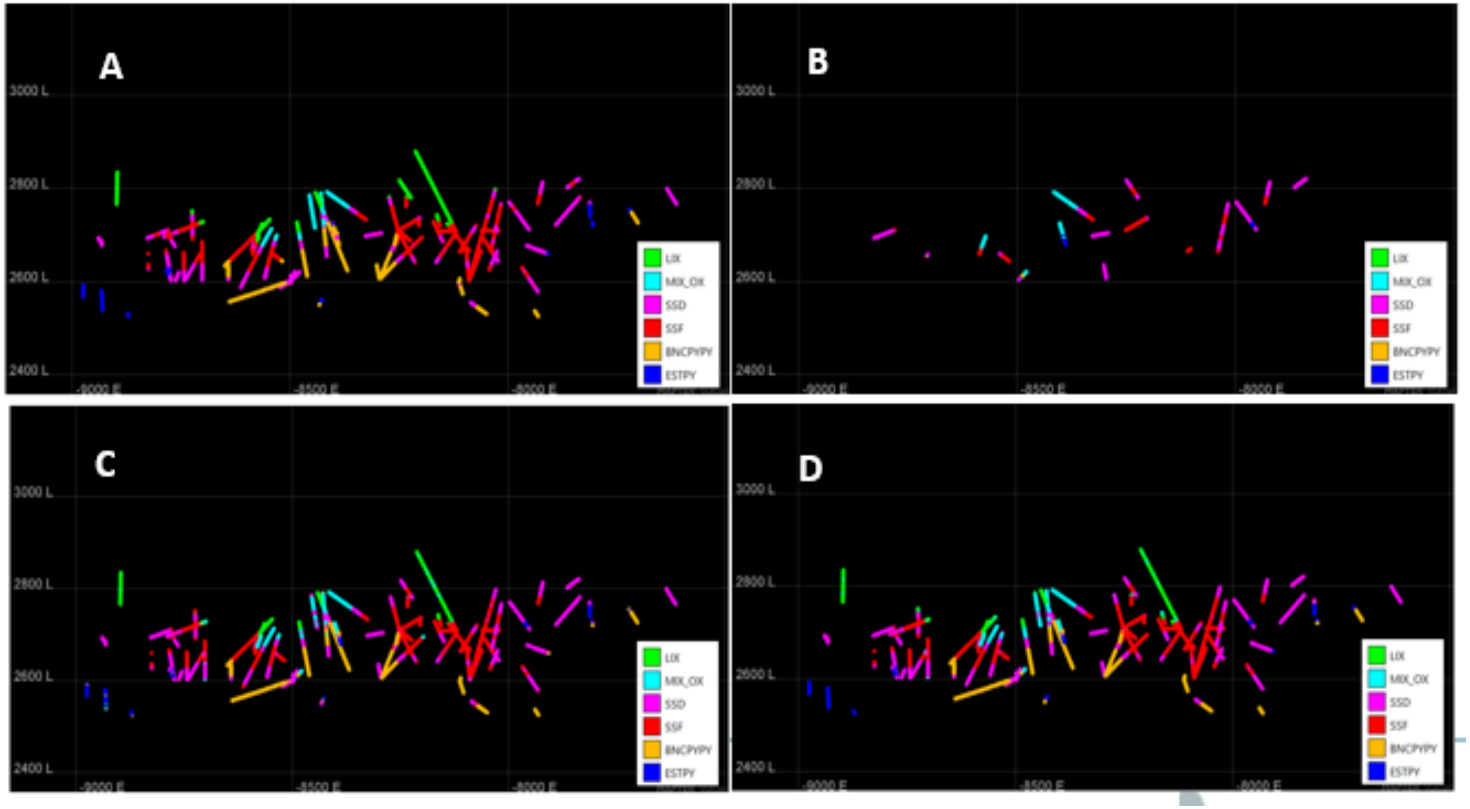


Re-Mapeos Simulados N°2



Re-Mapeos Simulados N°3




A
B
C
D
3000 L
2800 L
2600 L
2400 L
LIX
MIX_OIX
SSD
SSF
BNCPYPY
ESTPY

Flujo incertidumbre asociado a cantidad de información y calidad mapeos

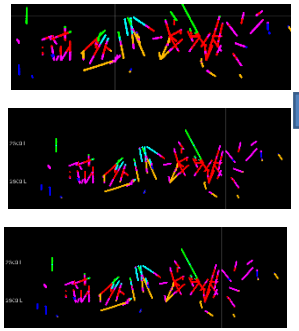
Calidad información
Mapeos

Información
+
Variabilidad geológica

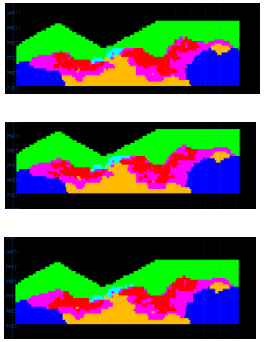
Información
+
Variabilidad leyes

Cuantificación de incertidumbre

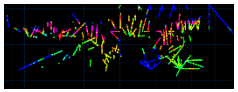
BD Mapeo



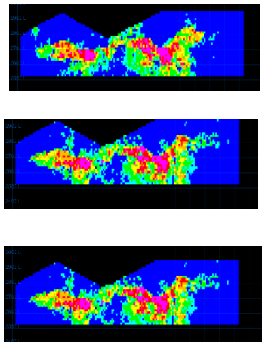
Simular Geología

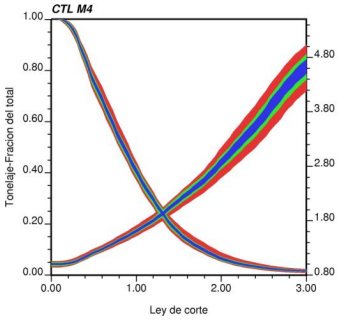


BD CuT



Simular Leyes





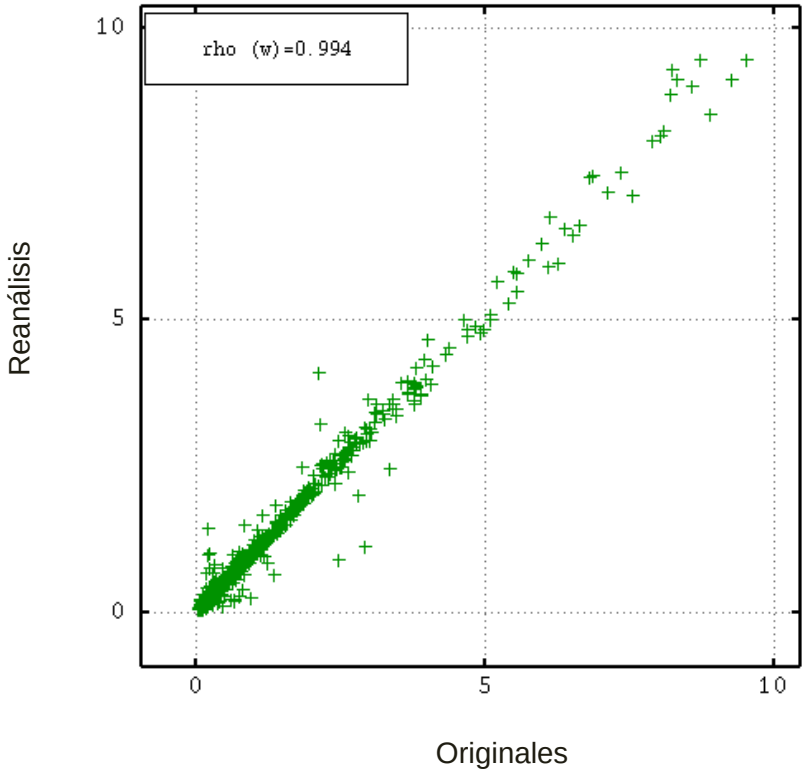
GeoInnova

INCERTIDUMBRE ASOCIADA A CALIDAD DE INFORMACIÓN

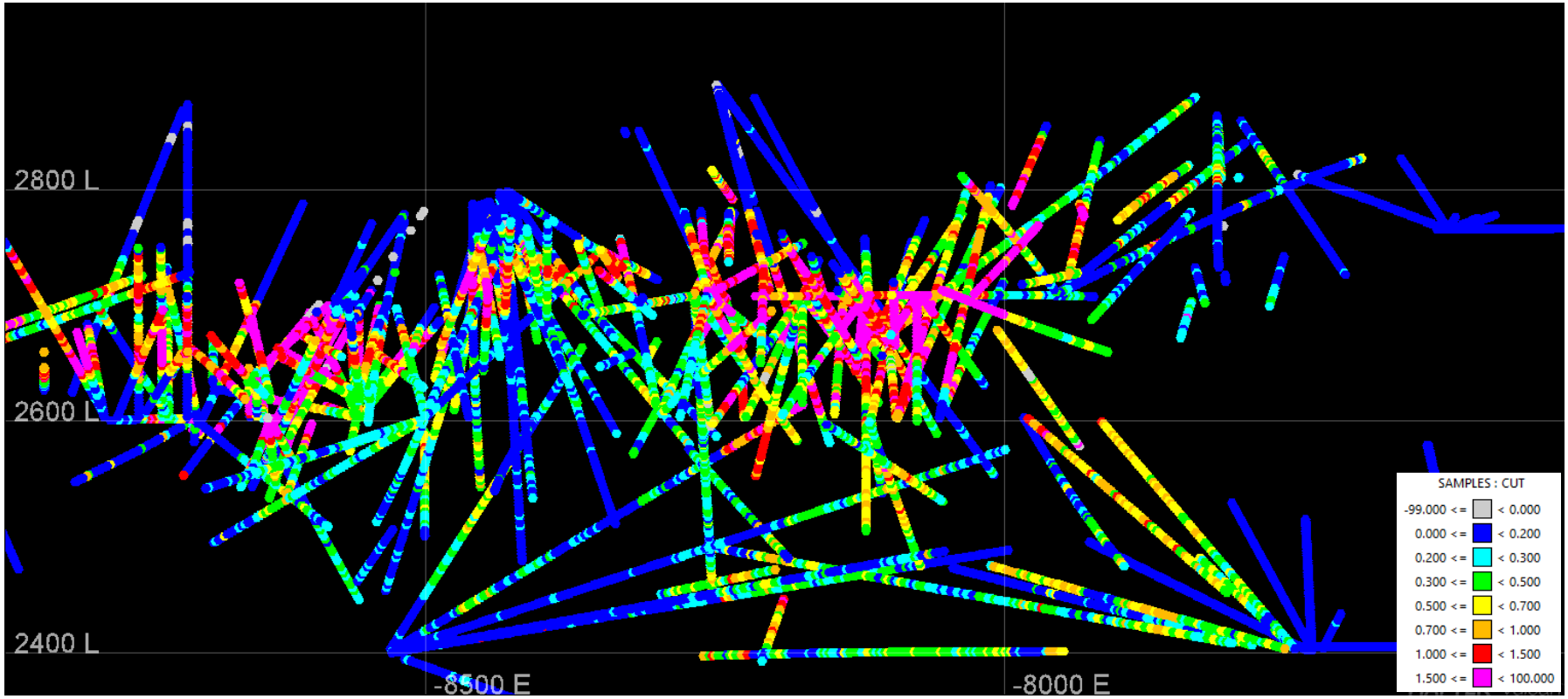
ANALISIS QUIMICOS

Información Disponible

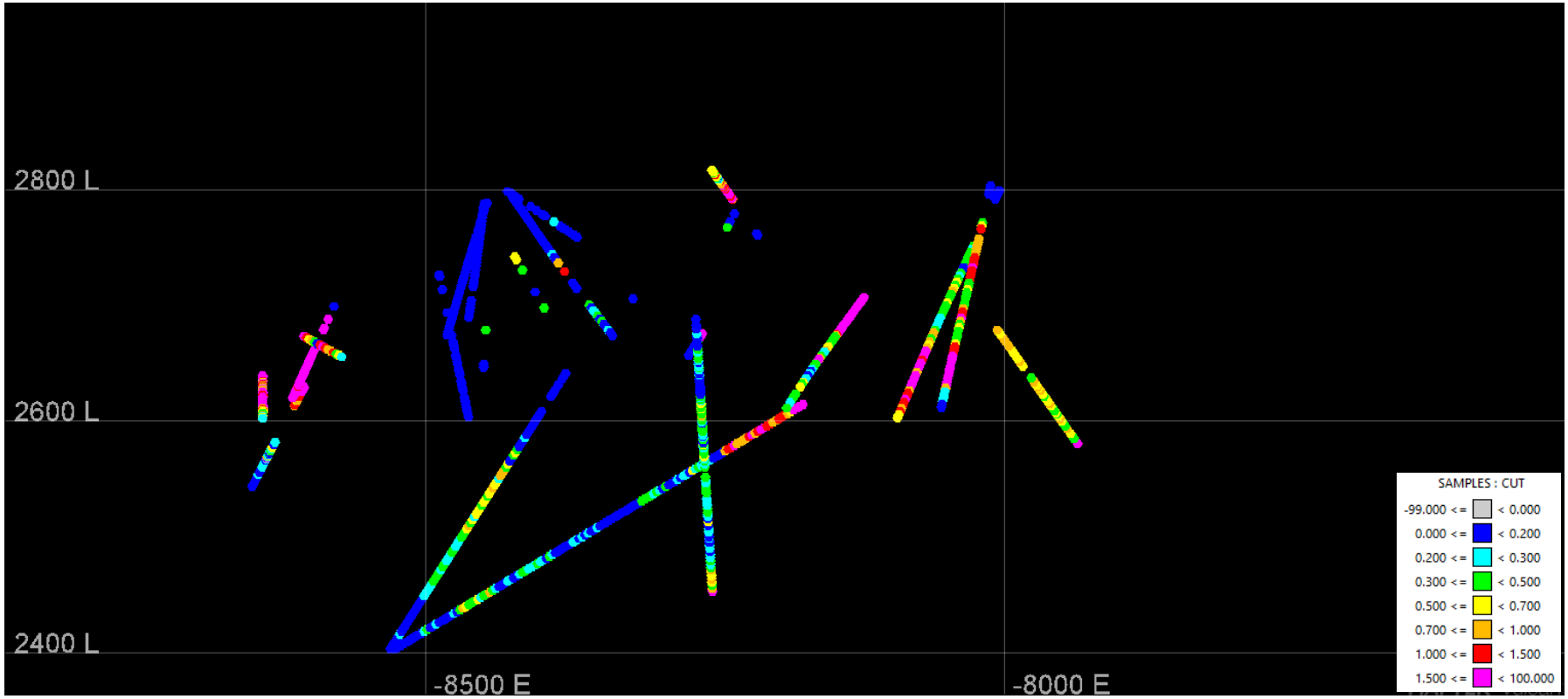
- Leyes de Cut: 145,000 muestras
- Re análisis de Cut: 2,352 (1.6%)



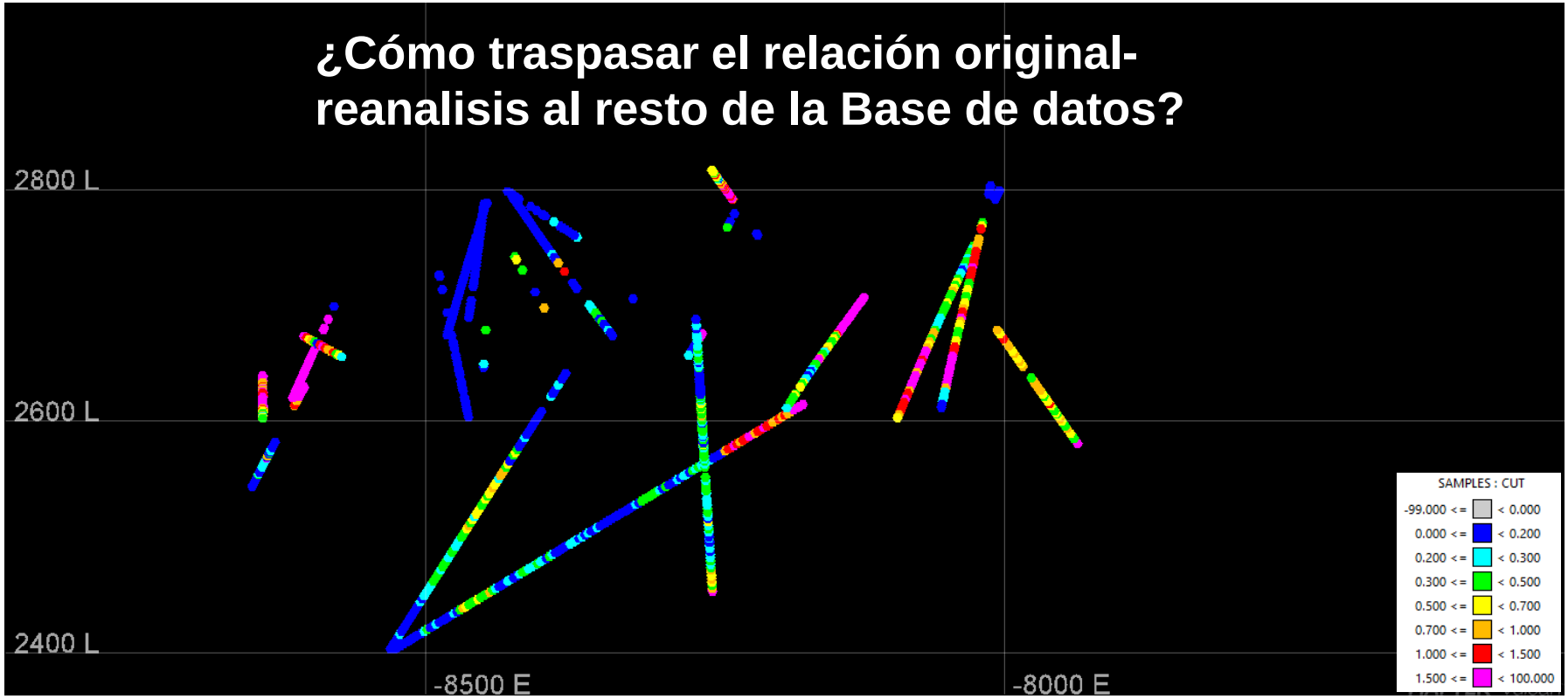
Cut original completo



Cut original

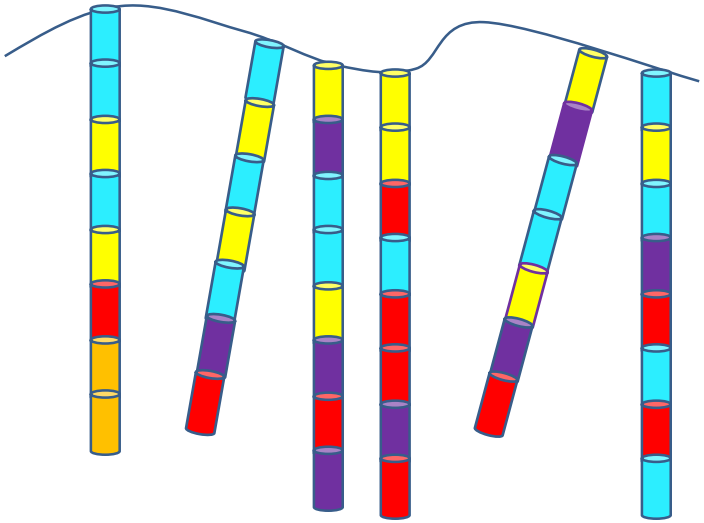


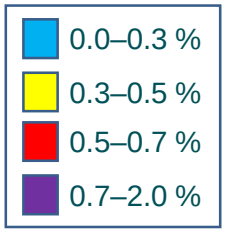
Cut re analizado



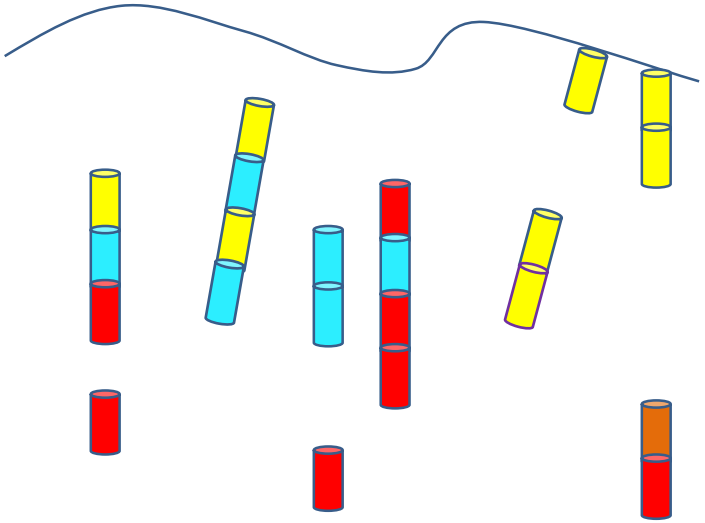
Metodología simulación mapeos

Leyes Cut originales



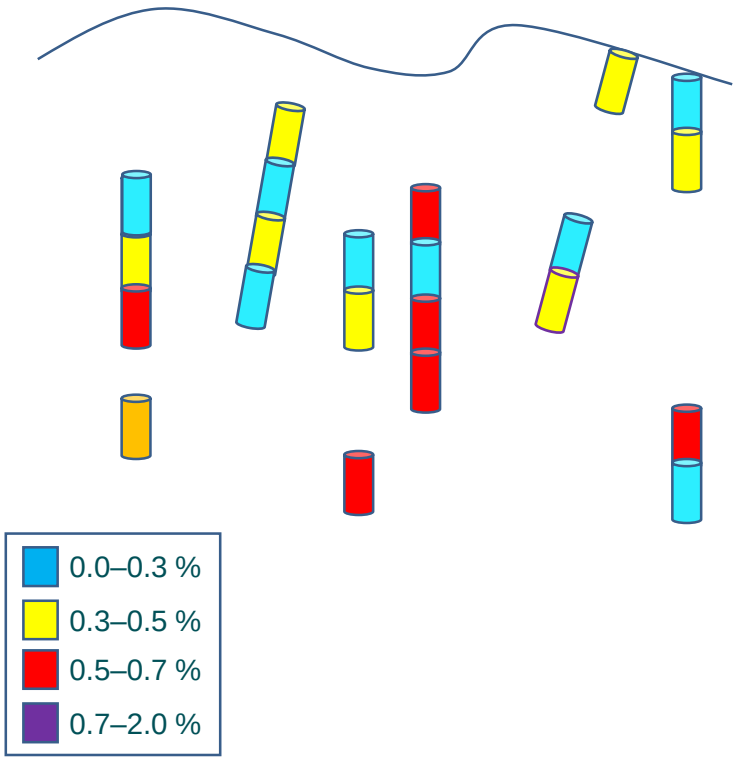


BD Reanálisis Cut

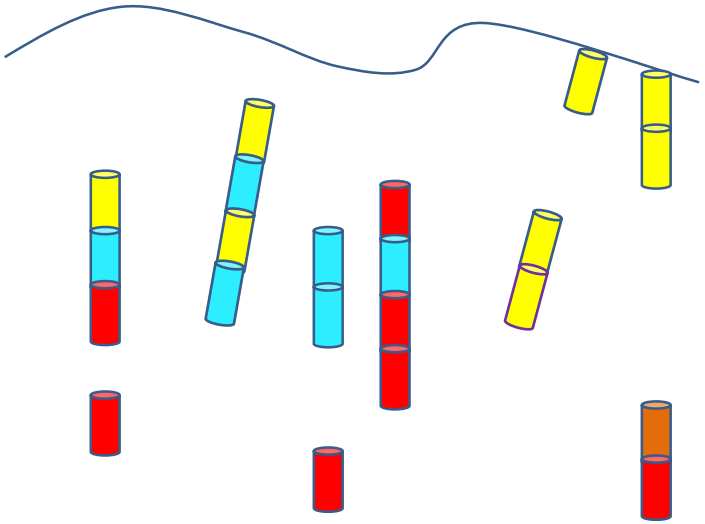


Metodología simulación mapeos

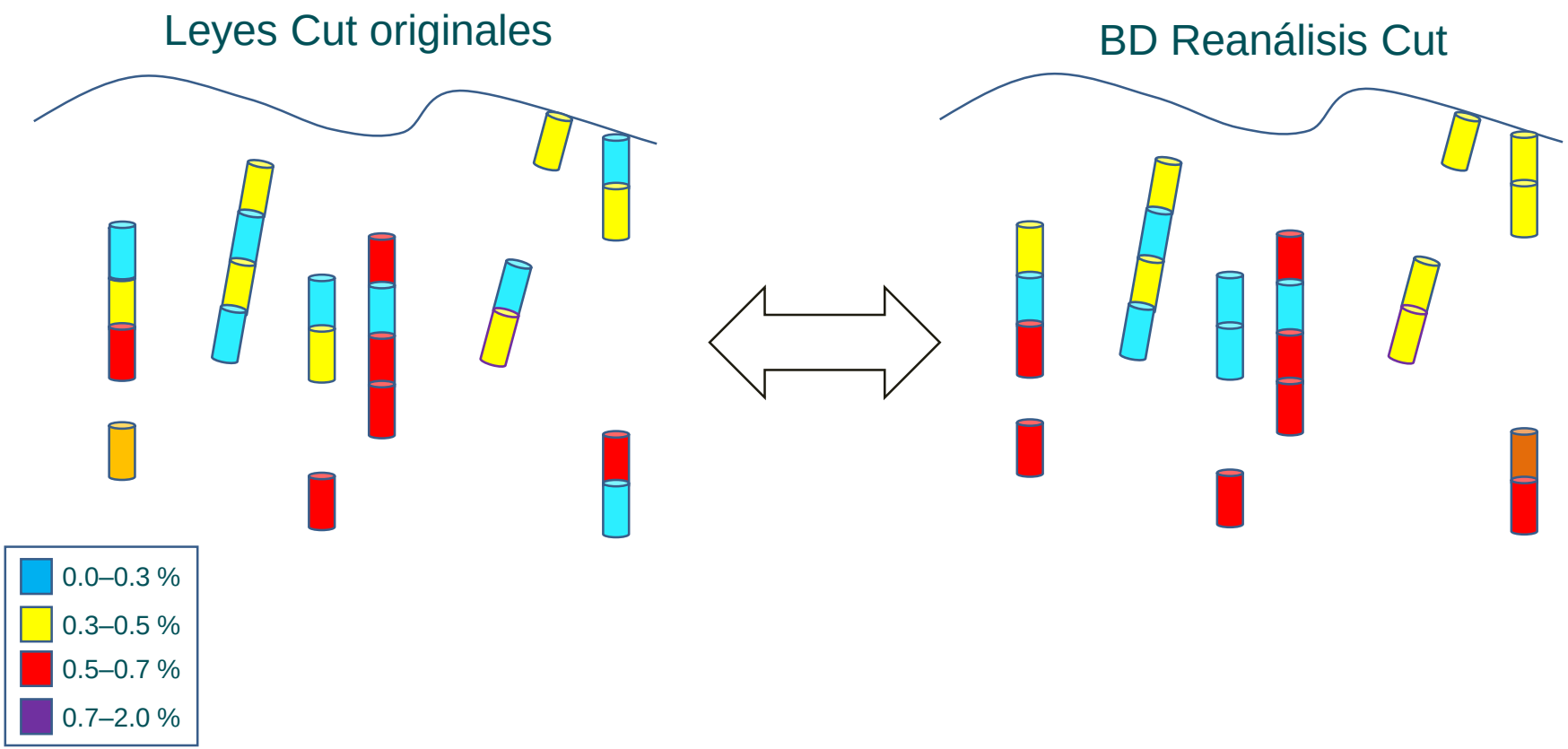
Leyes Cut originales



BD Reanálisis Cut



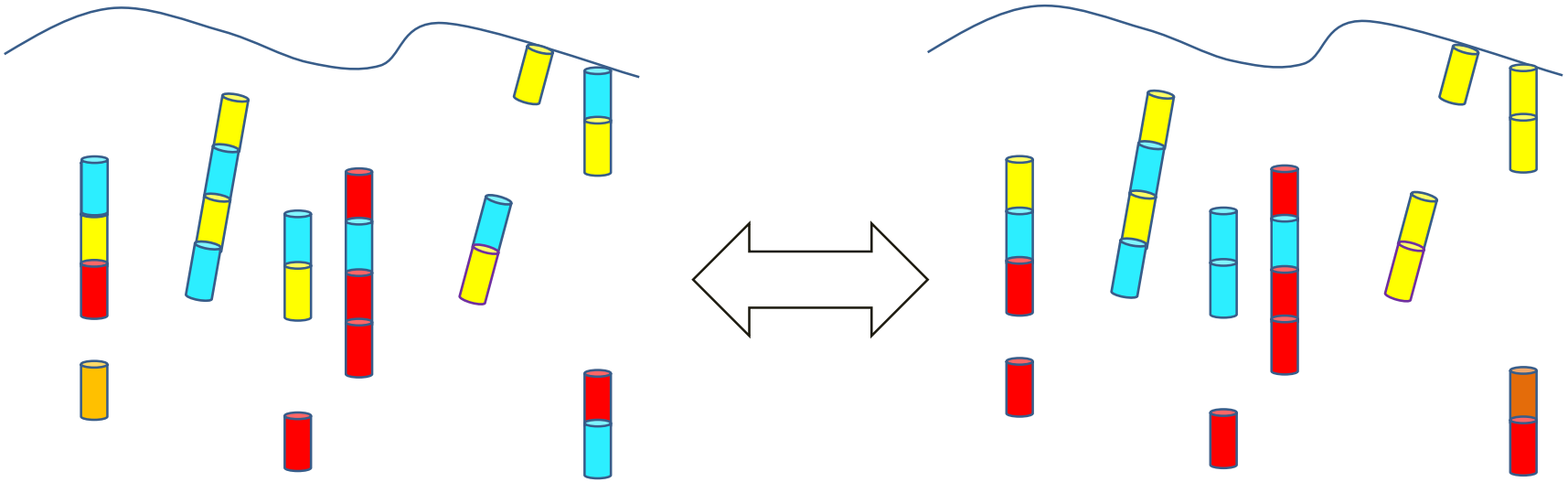
Metodología simulación mapeos

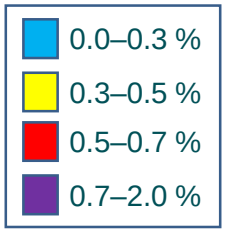


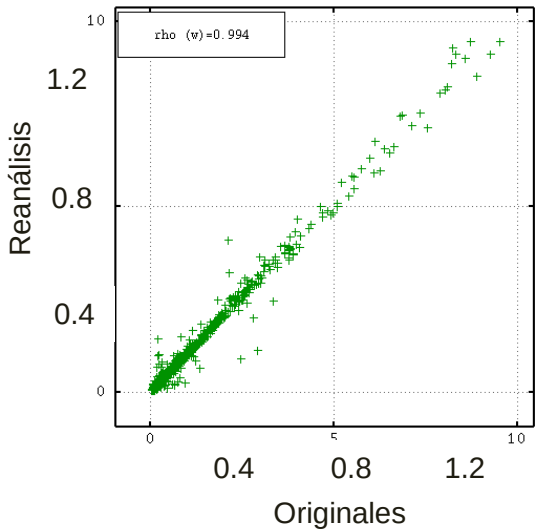
Metodología simulación mapeos

Leyes Cut originales

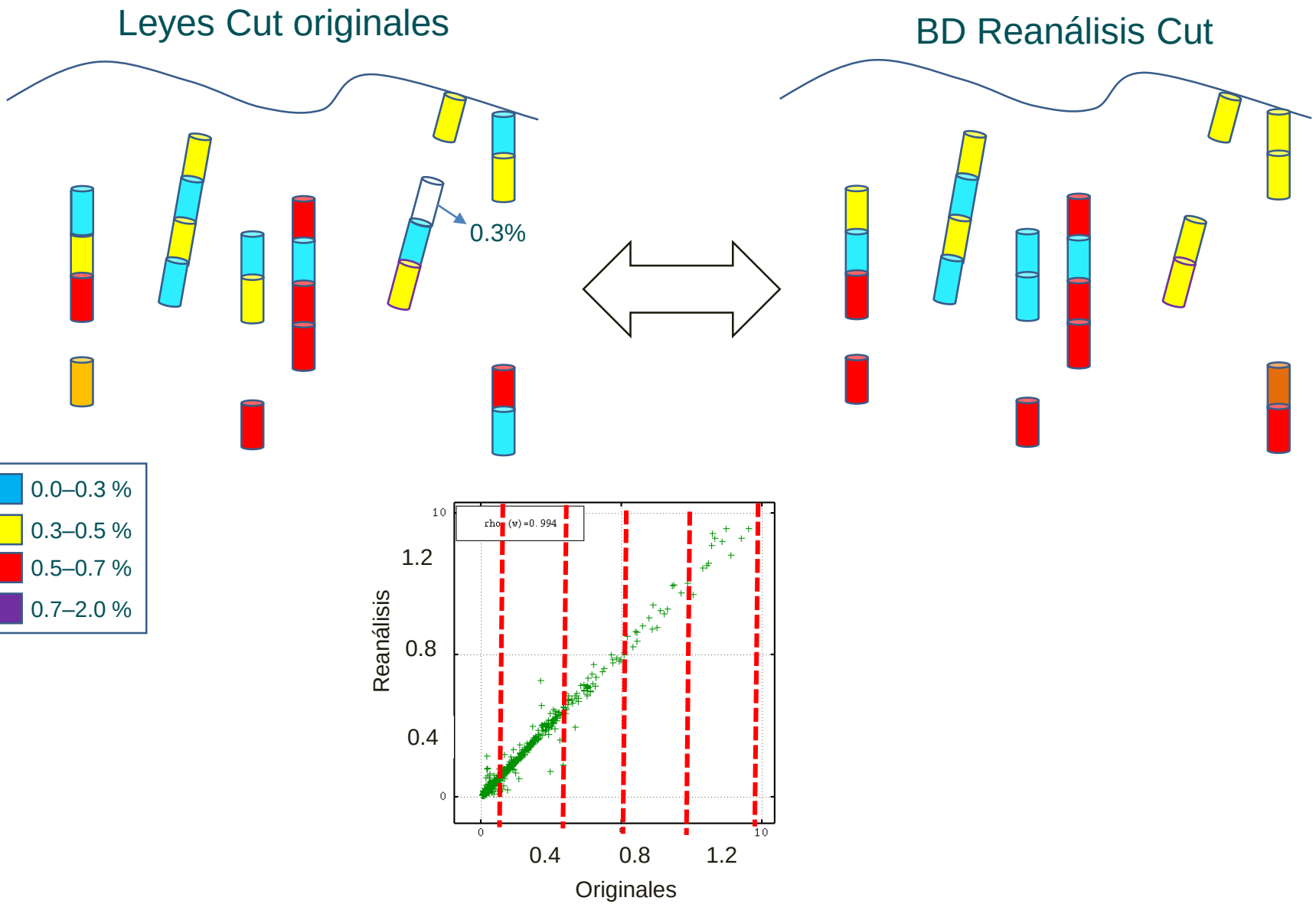
BD Reanálisis Cut





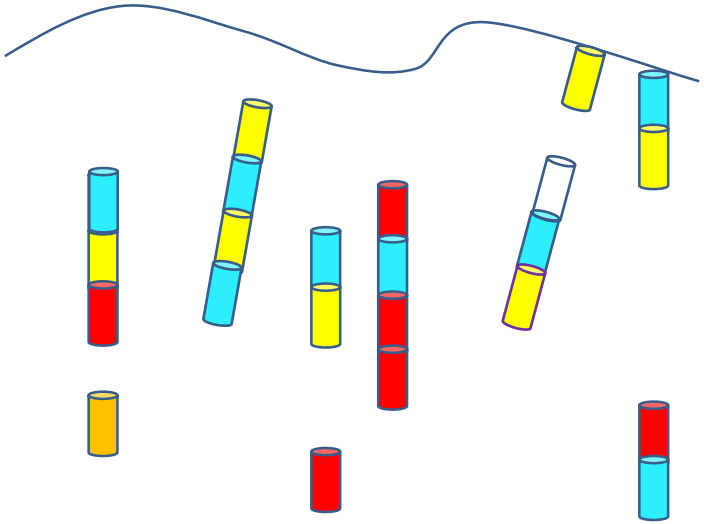


Metodología simulación mapeos

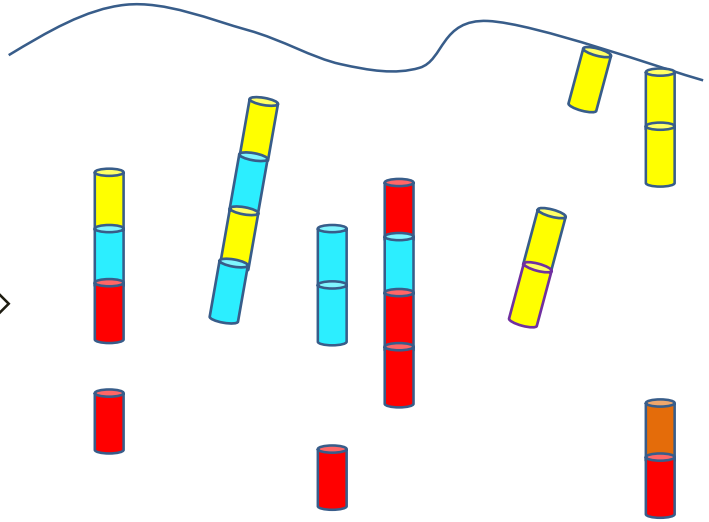


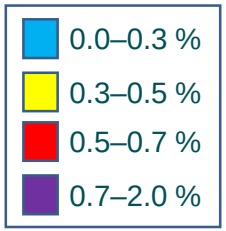
Metodología simulación mapeos

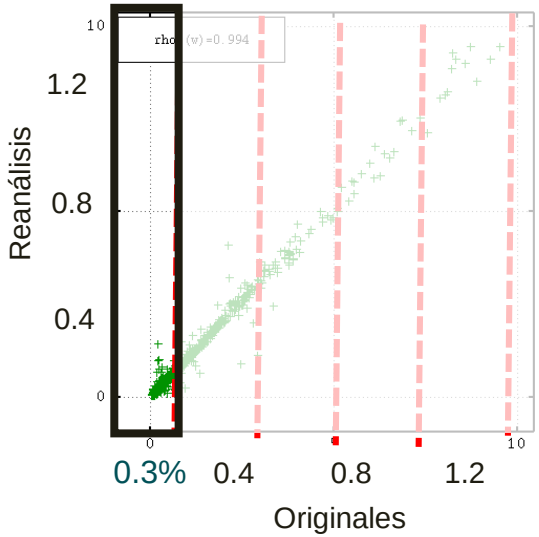
Leyes Cut originales



BD Reanálisis Cut



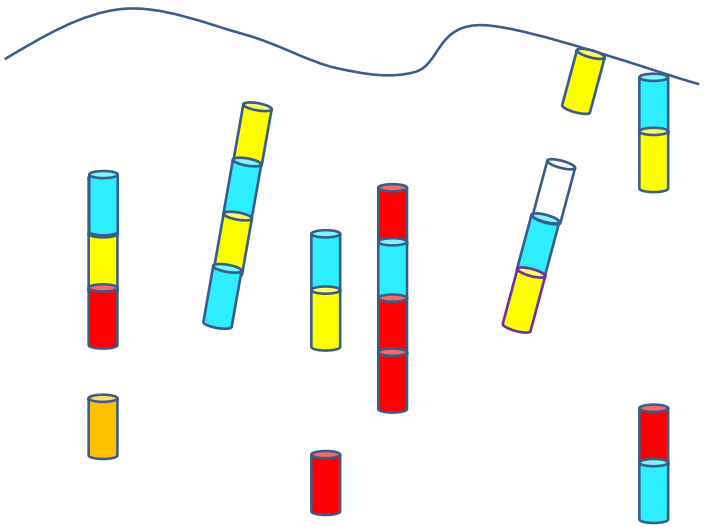


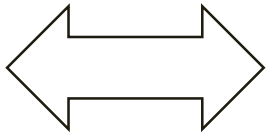


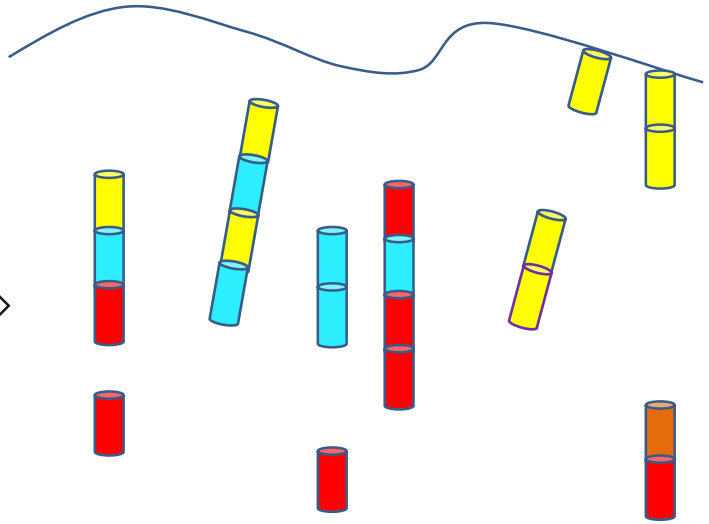
Metodología simulación mapeos

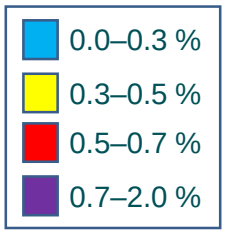
Leyes Cut originales

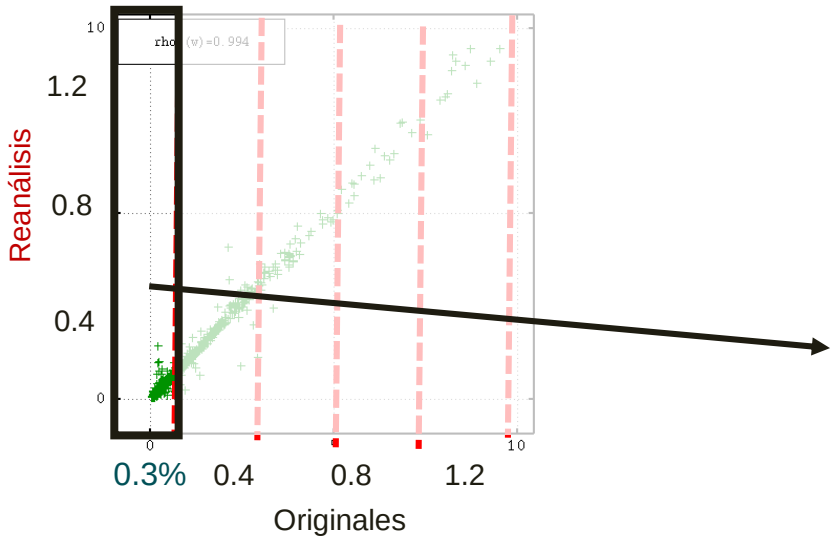
BD Reanálisis Cut



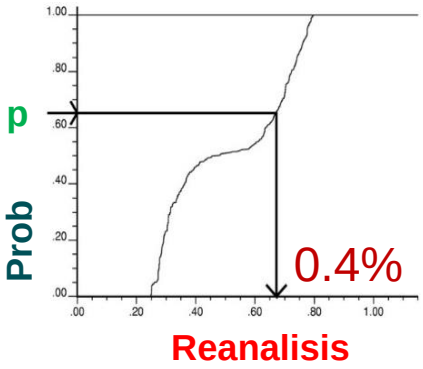






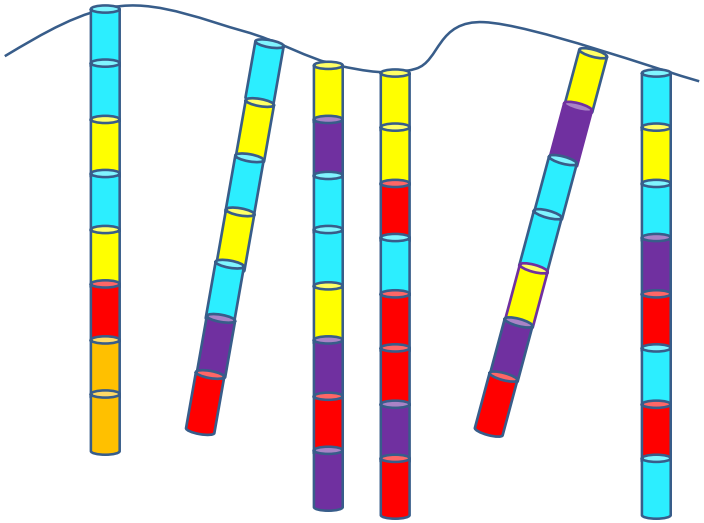


$P(reanalisis|Original = x)$

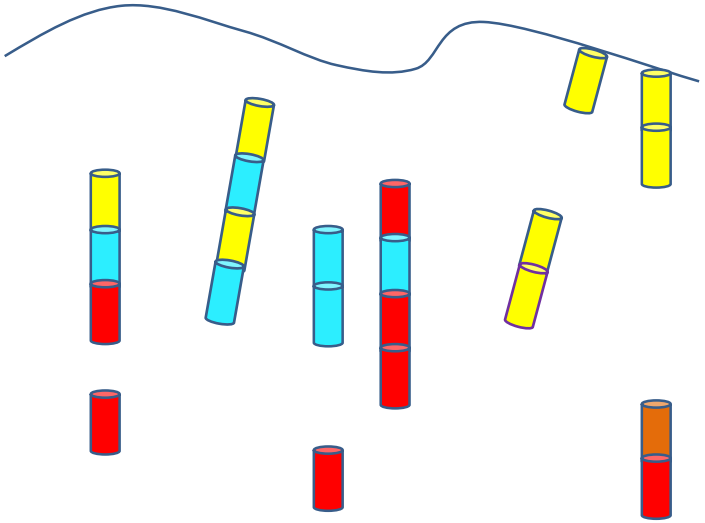


Metodología simulación mapeos

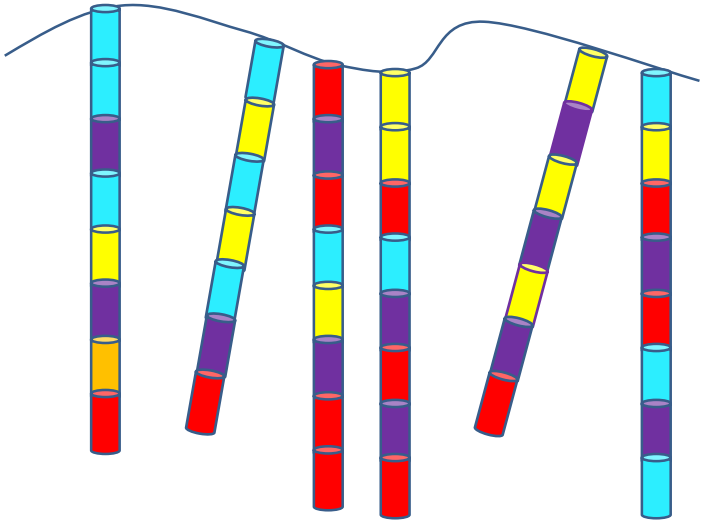
Leyes Cut originales

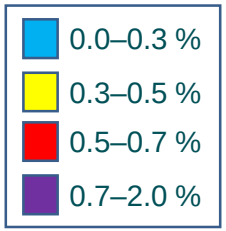


BD Reanálisis Cut



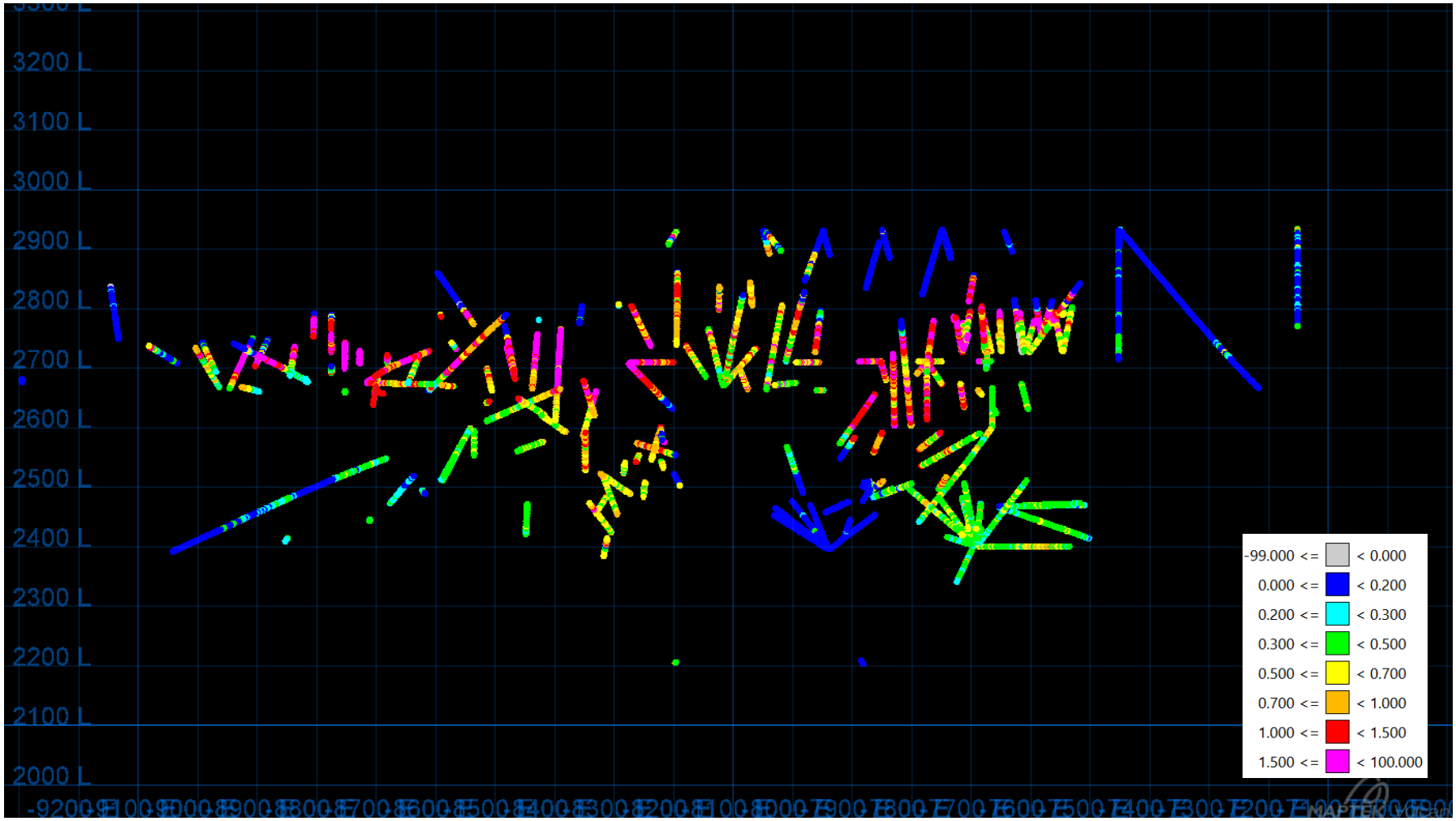
Leyes Cut Sim Cloud



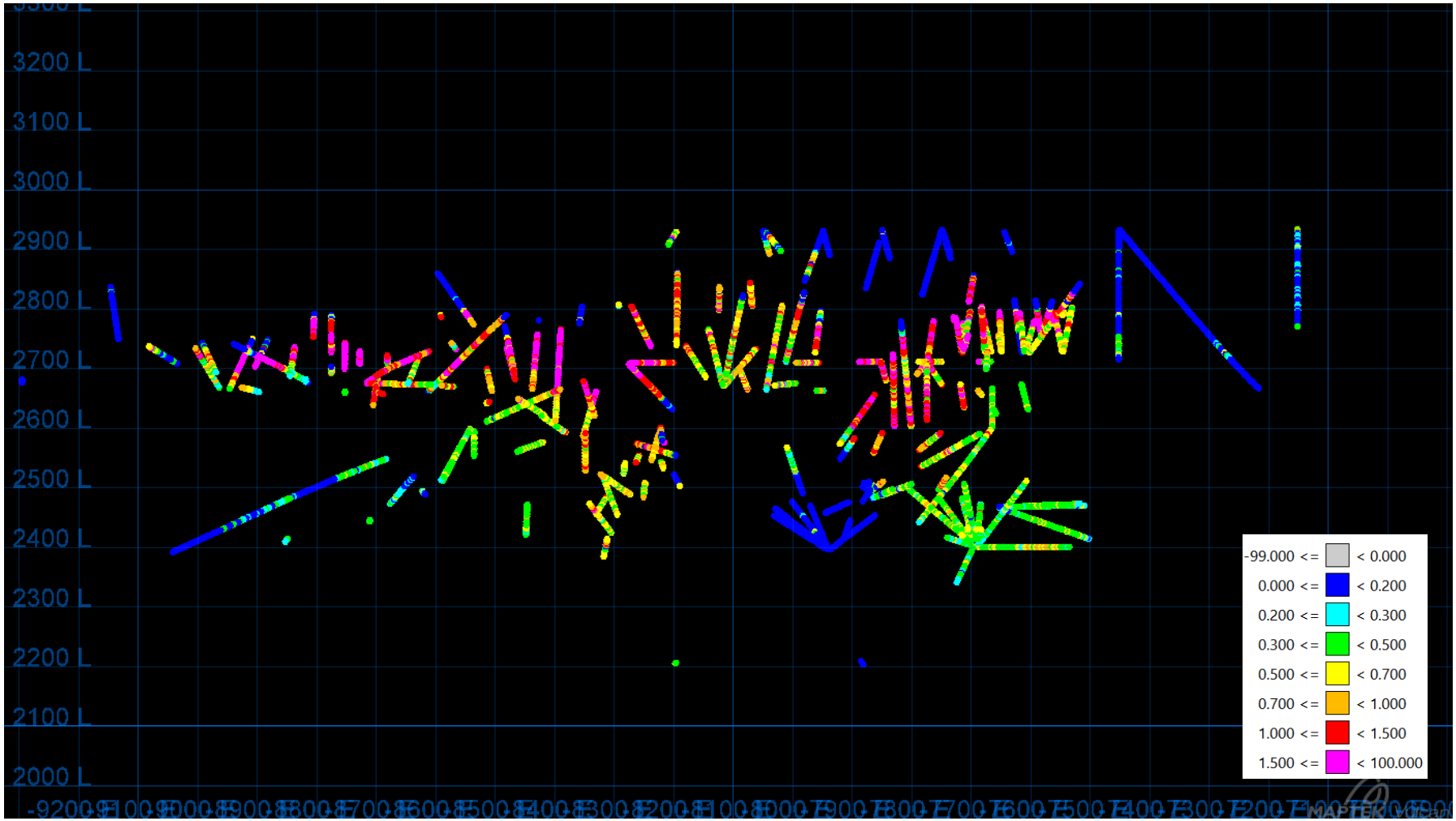


GeoInnova

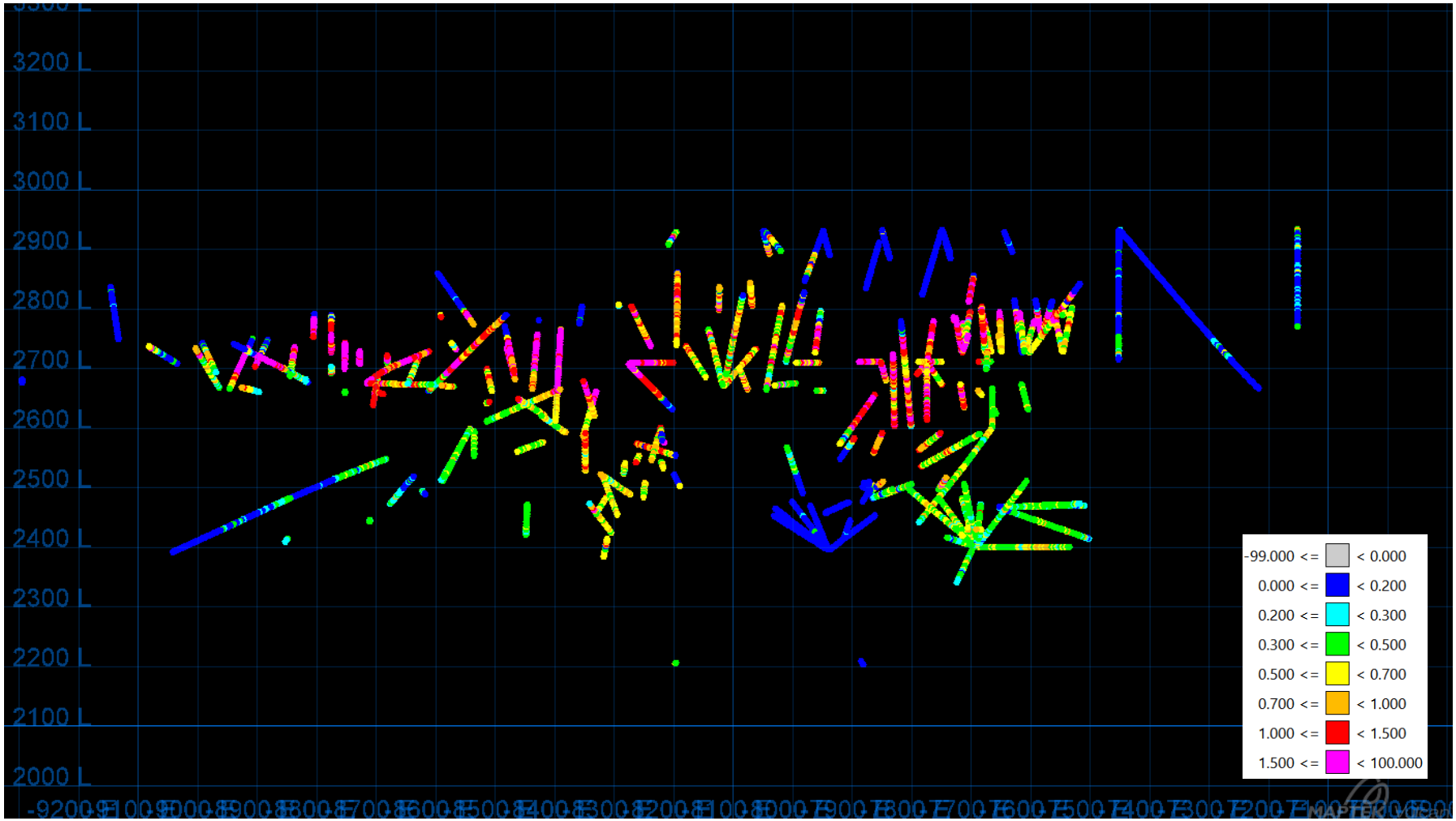
Leyes de cut originales



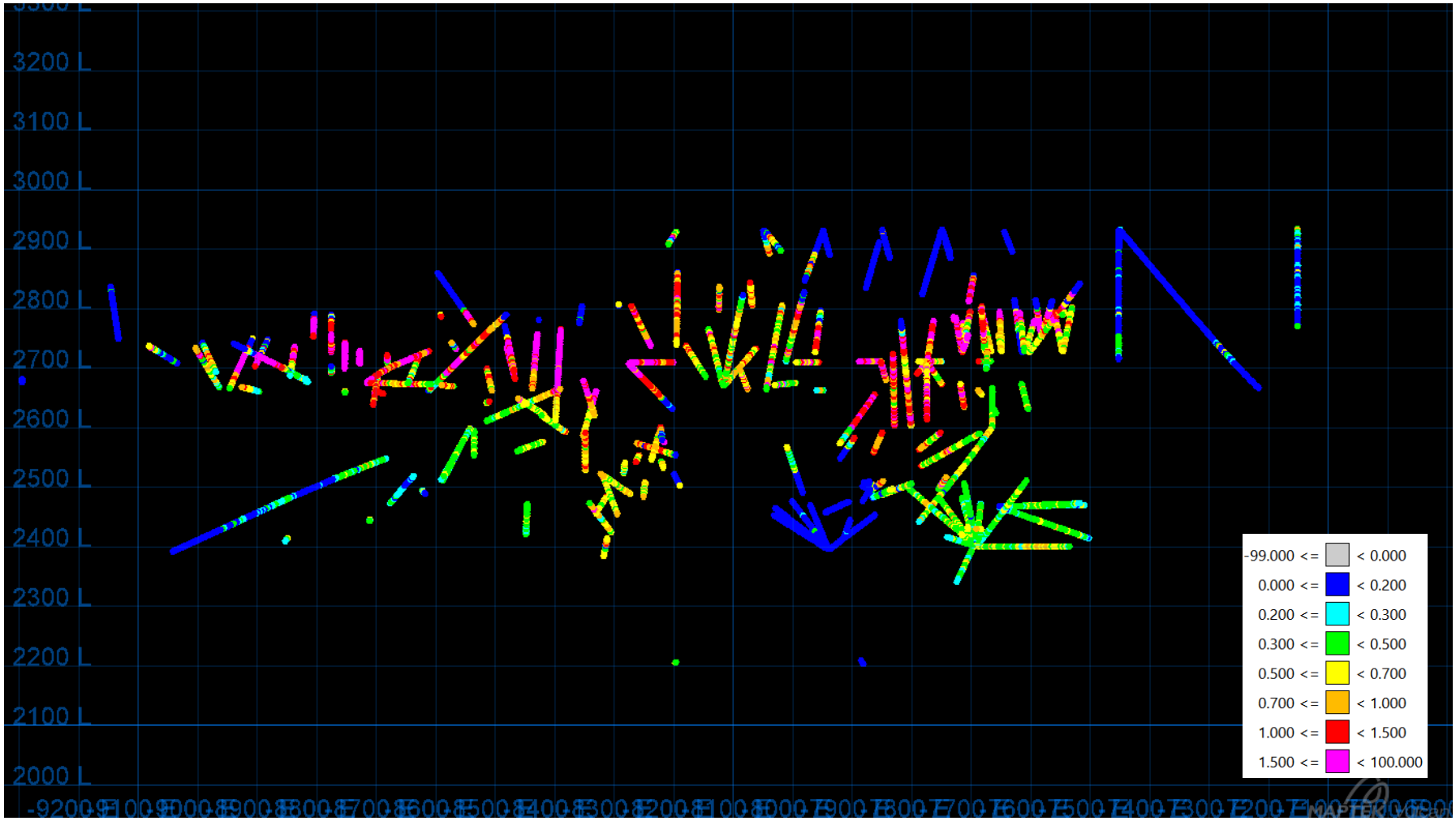
Leyes de Cut simuladas - reanalizadas



Leyes de Cut simuladas - reanalizadas



Leyes de Cut simuladas - reanalizadas



Flujo incertidumbre asociado a cantidad + calidad de información (geo-leyes)

Calidad información Mapeos

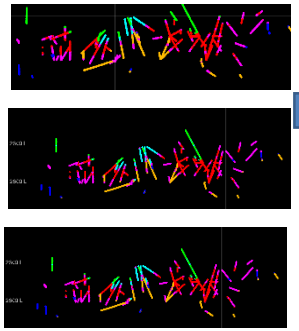
Información + Variabilidad geológica

Calidad información Leyes

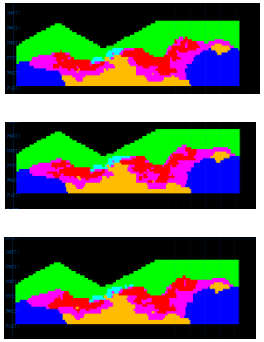
Información + Variabilidad leyes

Cuantificación de incertidumbre

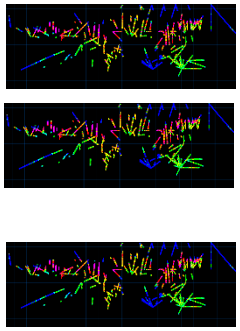
BD Mapeo



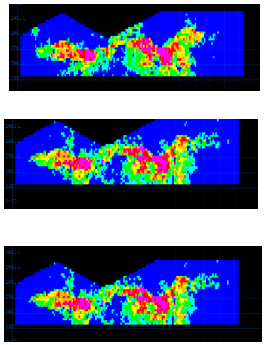
Simular Geología

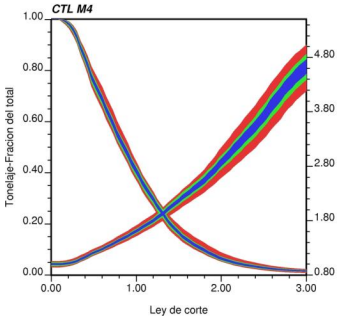


BD CuT



Simular Leyes

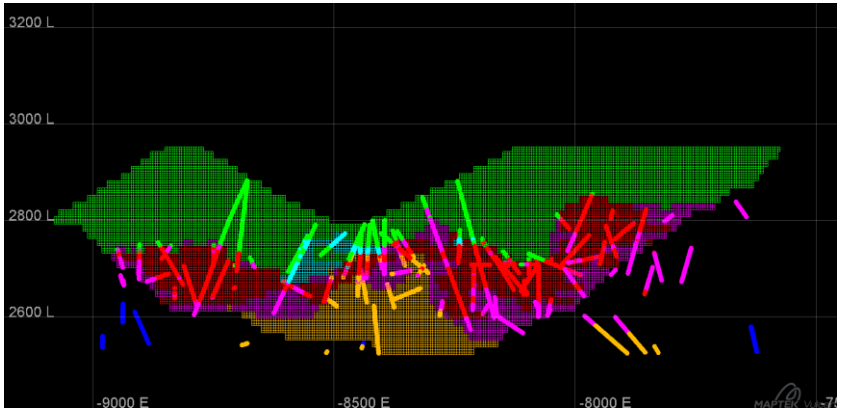




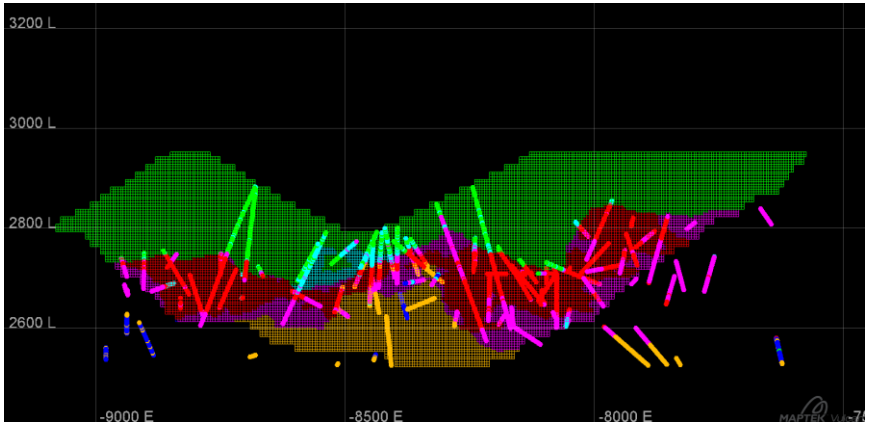
Efecto cantidad de información
+
Efecto calidad mapeo
+
Efecto calidad análisis

RESULTADOS

Modelo Determinístico

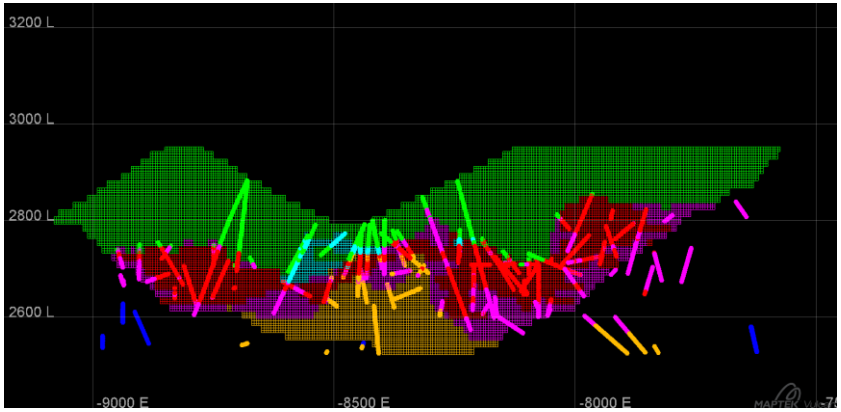


Sim 1

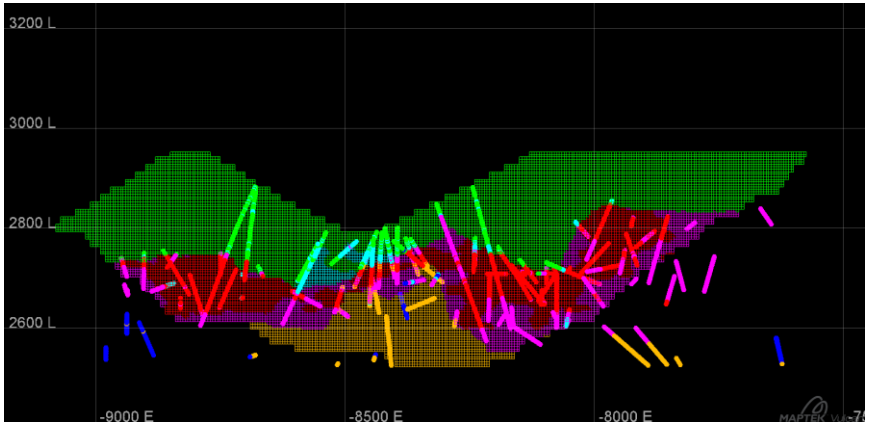


LIX
MIX_OX
SSD
SSF
BNCPYPY
ESTPY

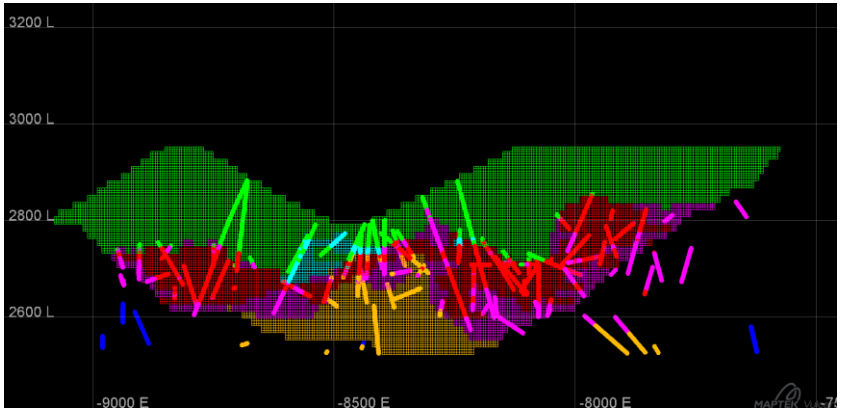
Modelo Determinístico



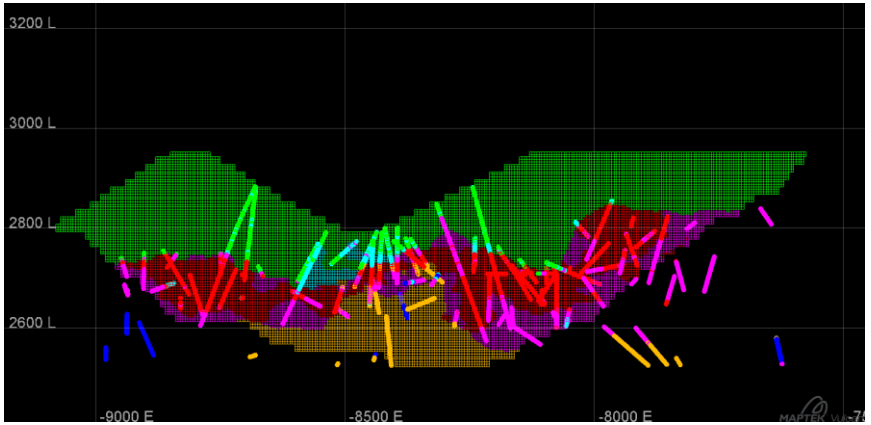
Sim 2



Modelo Determinístico

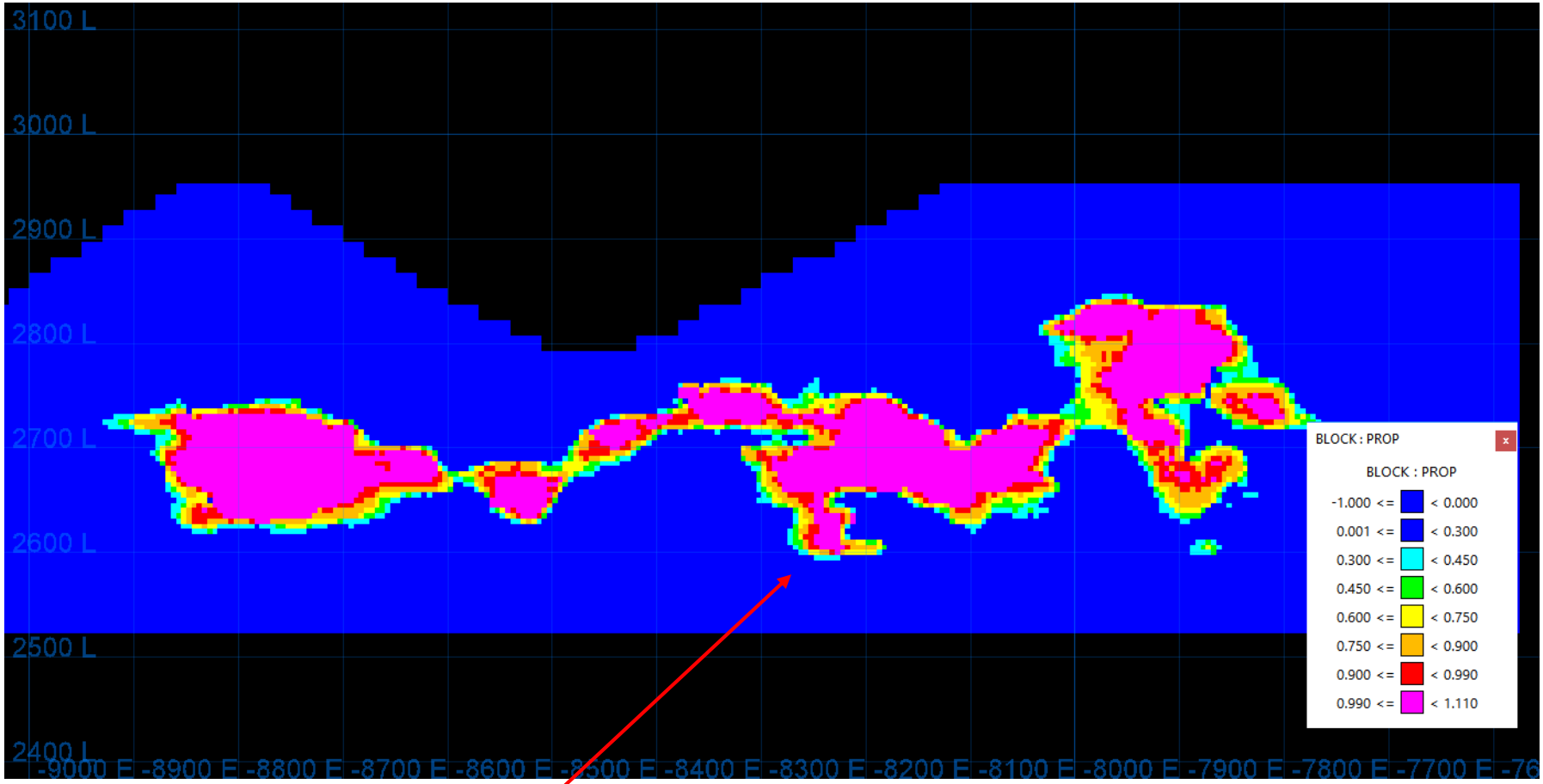


Sim 3



LIX
MIX_OX
SSD
SSF
BNCPYPY
ESTPY

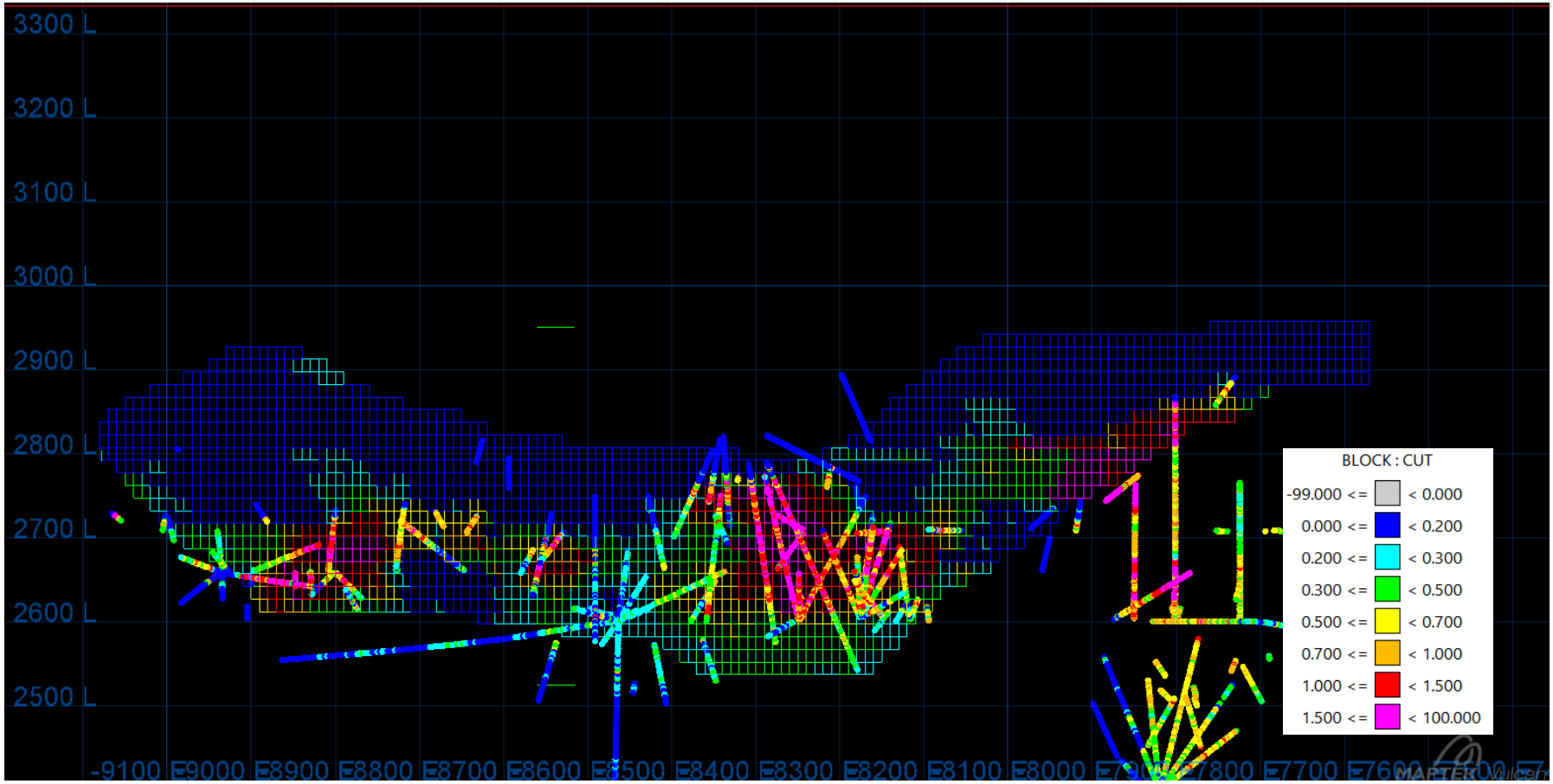
Probabilidad de indicador unidad de mayor aporte al proyecto



Bajo nivel de incertidumbre en tonelaje Unidad de mayor aporte al proyecto

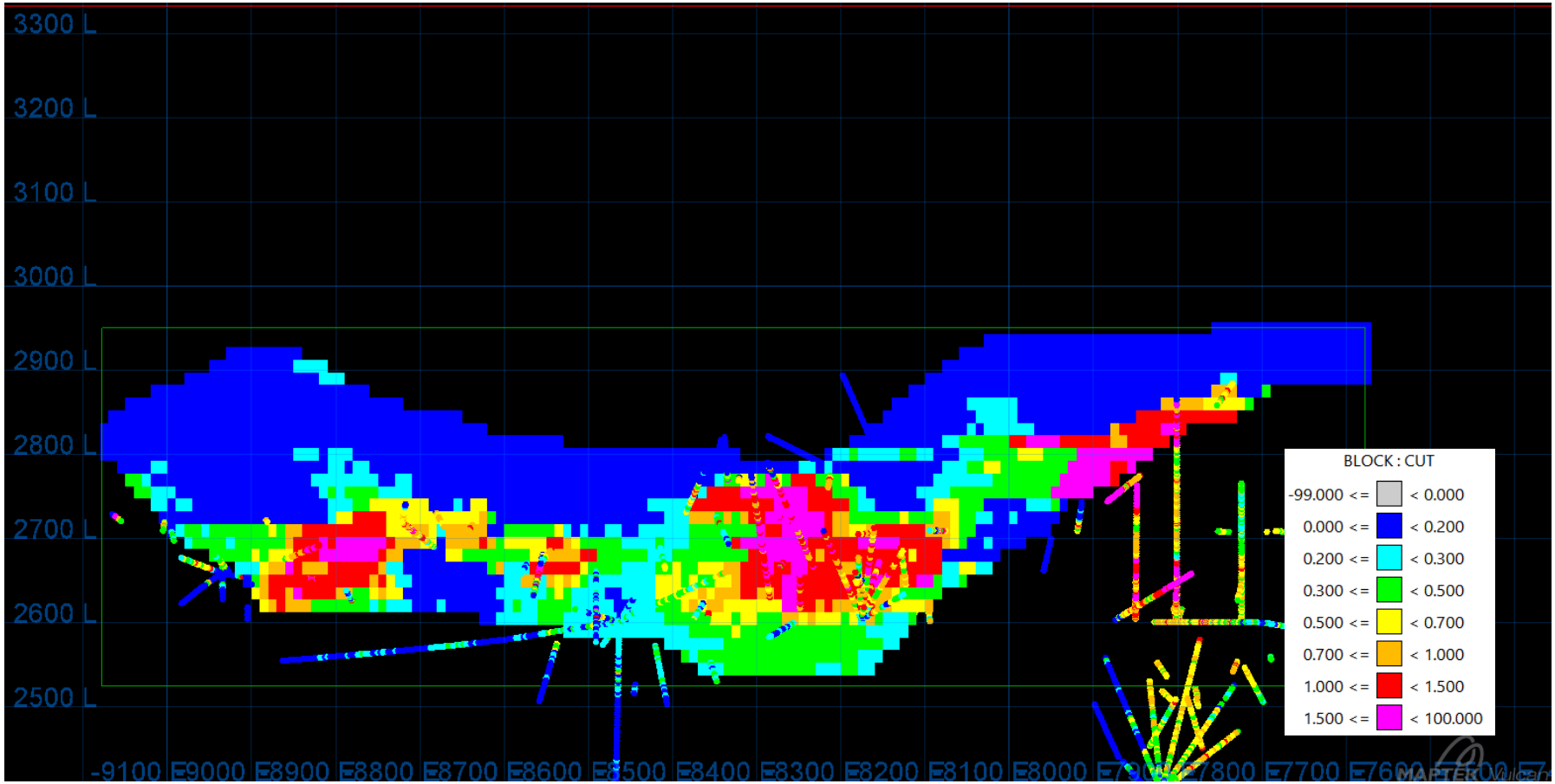
GeoInnova

Cut Determinístico.



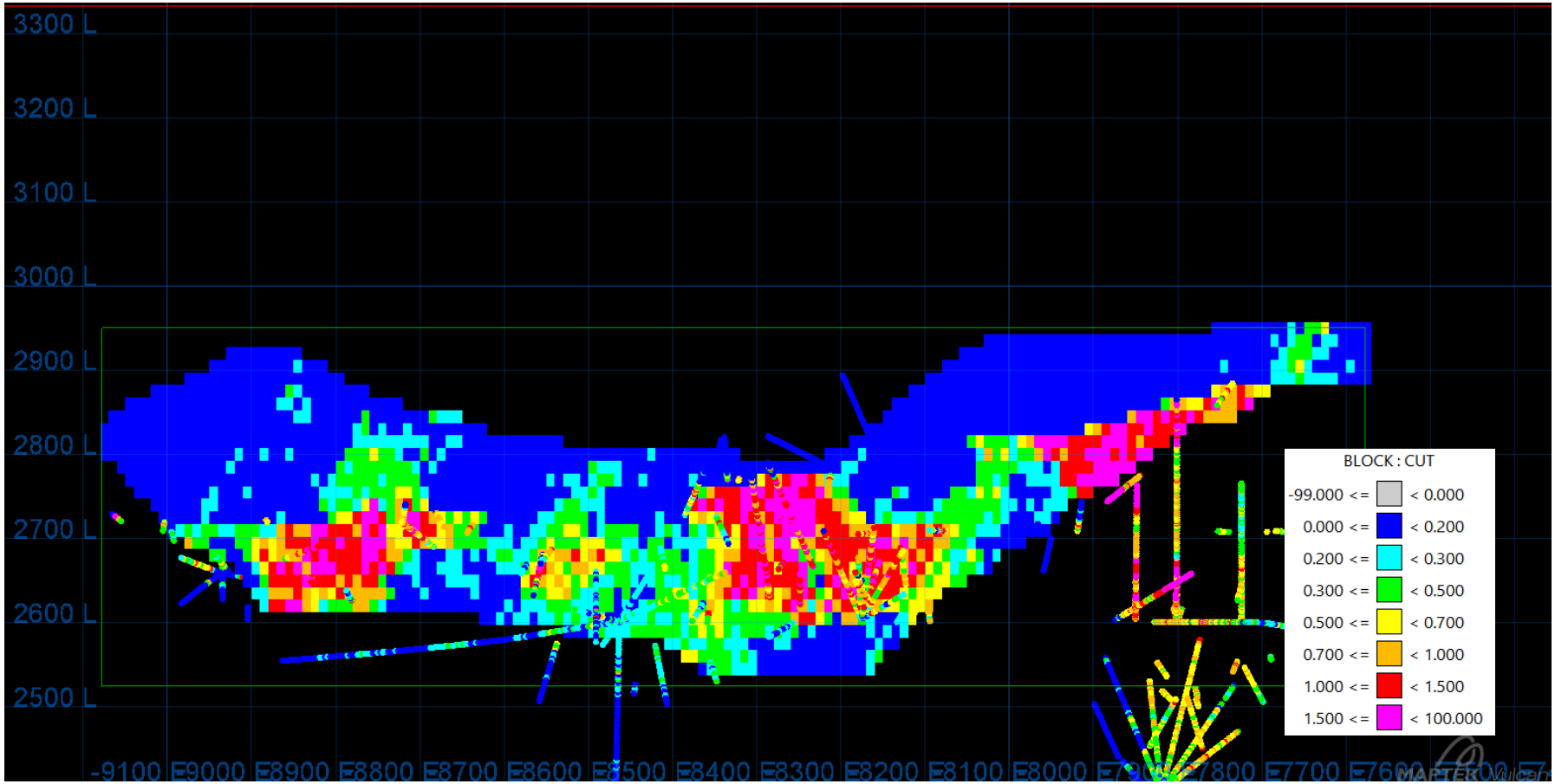
Cut Determinístico.

Periodo 1 -15



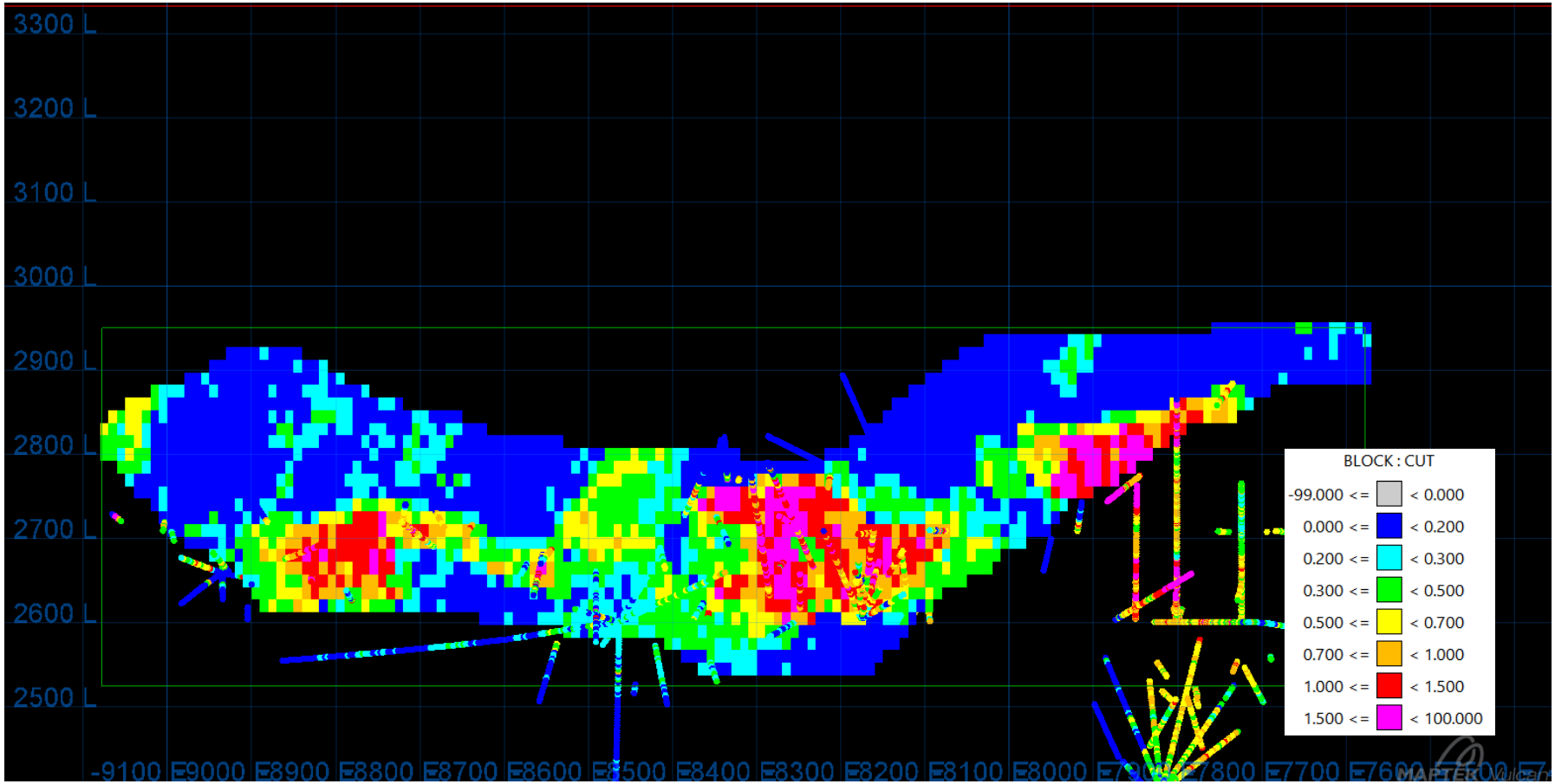
Cut Sim1

Periodo 1 -15



Cut Sim2.

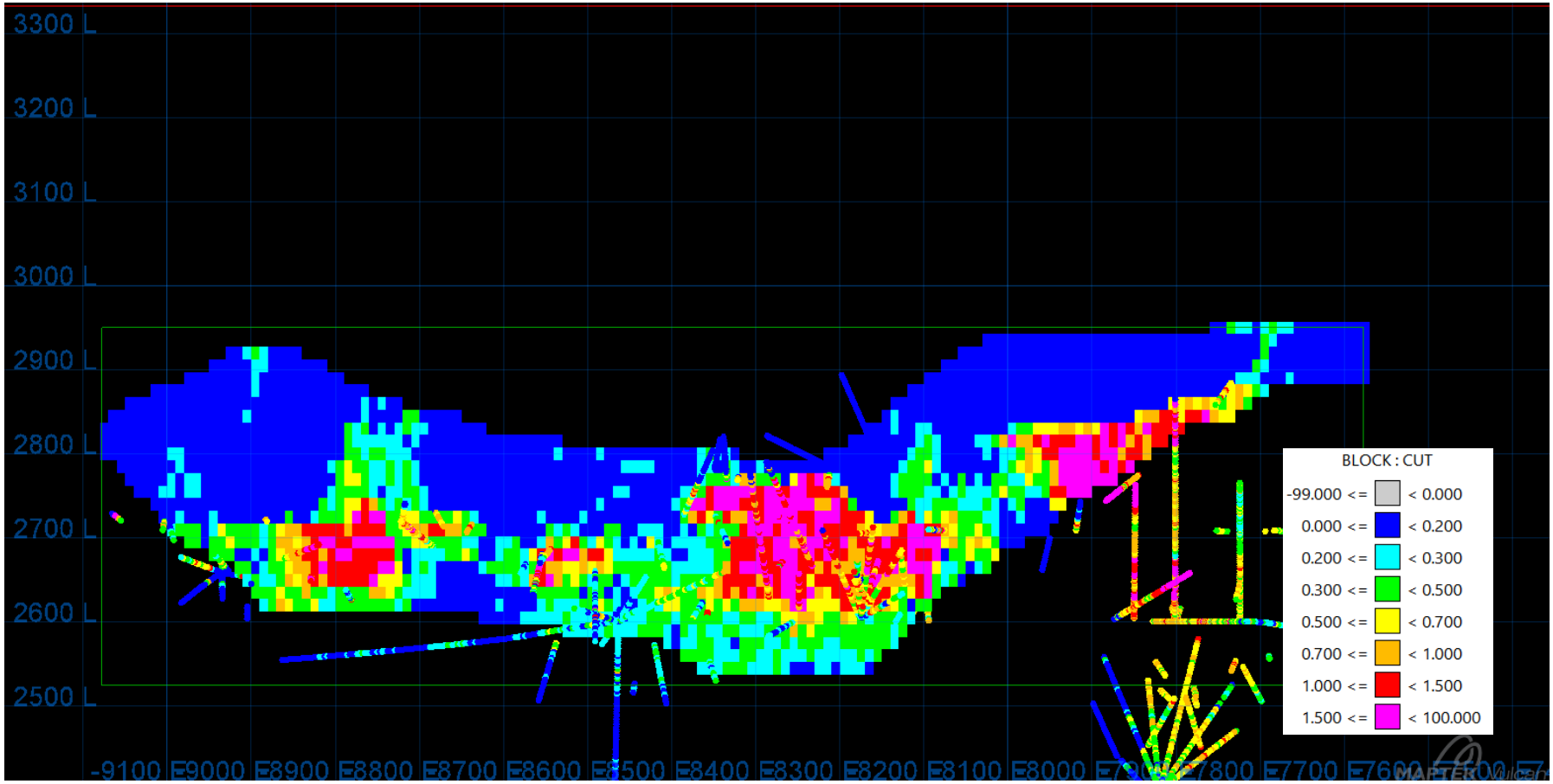
Periodo 1 -15



GeoInnova

Cut Sim3.

Periodo 1 -15



Cubicaciones globales en quinquenio, Ley de corte 0.2%

Cut > 0.2 %

	Mean	p5	p95	i90 %
Ley Cut %	0.69	0.68	0.72	2.95
Tonelaje Mton				1.11
Metal Mton				2.74

- ***En el quinquenio, para una ley de corte de 0.2%, los recursos tienen un nivel de incertidumbre bajo en términos de leyes tonelaje y metal menor a un 3%*** .

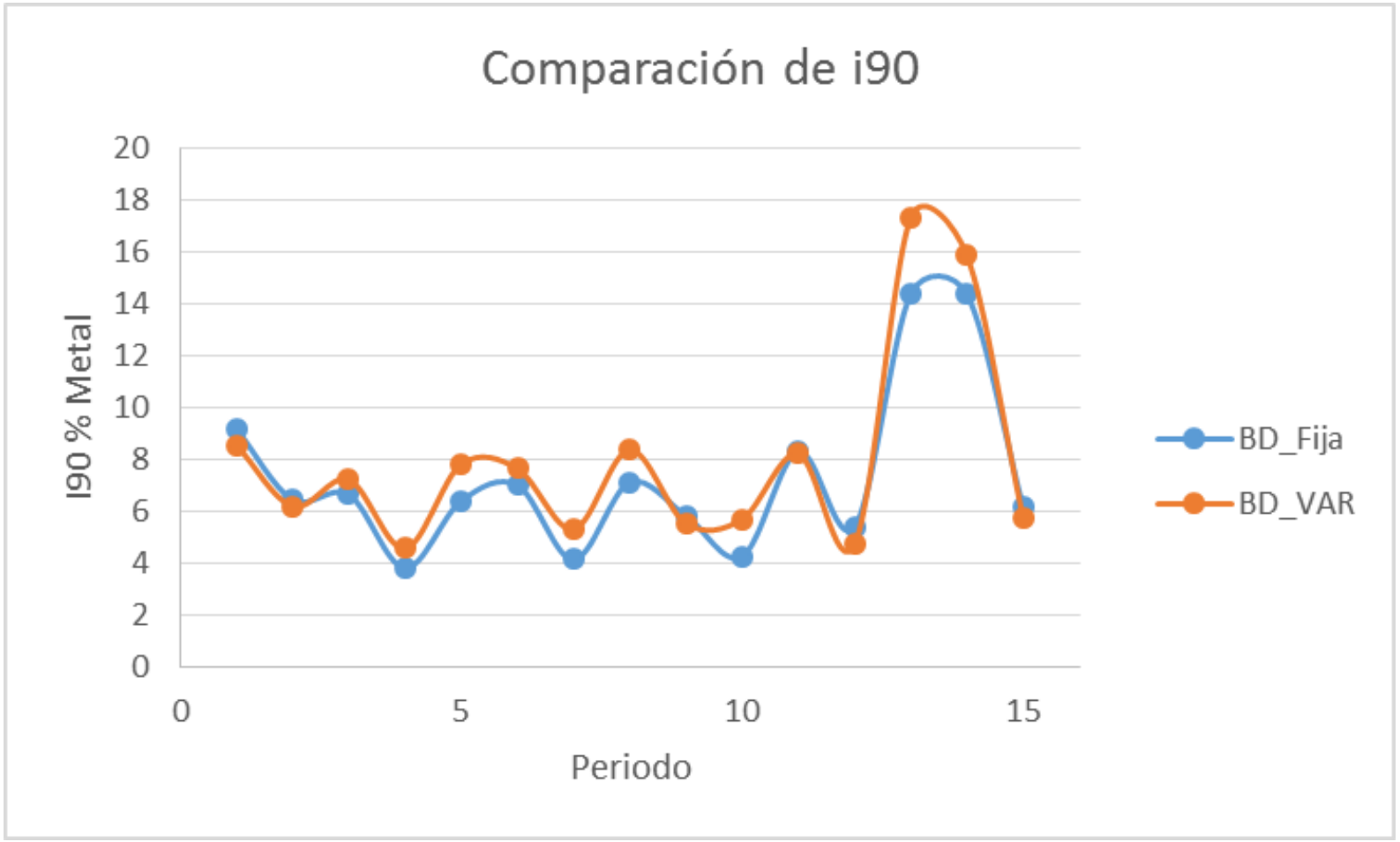
Cubicaciones x periodo (solo sulfuros)

Cut > 0.3 %; Per 1 – 15; In situ

PERIODO	Ley Cut %				Mx Cut Mton				Metal Mton			
	Media	p5	p95	i90	Media	p5	p95	i90	Media	p5	p95	i90
1	0.99	0.90	1.06	**7.85**				**3.21**				**8.59**
2	0.79	0.76	0.83	**4.50**				**3.82**				**6.61**
3	0.74	0.71	0.79	**5.06**				**2.96**				**8.36**
4	0.81	0.77	0.84	**4.20**				**3.89**				**4.89**
5	0.69	0.64	0.75	**7.54**				**3.79**				**9.20**
6	0.69	0.66	0.73	**5.47**				**6.16**				**9.28**
7	0.66	0.62	0.69	**5.10**				**3.59**				**6.06**
8	0.62	0.59	0.64	**3.60**				**9.11**				**10.62**
9	0.69	0.67	0.71	**2.85**				**4.58**				**6.69**
10	0.50	0.49	0.52	**3.05**				**6.00**				**6.96**
11	0.53	0.51	0.55	**3.96**				**12.21**				**9.60**
12	0.74	0.71	0.76	**3.53**				**4.01**				**5.51**
13	0.49	0.44	0.55	**10.97**				**15.88**				**25.54**
14	0.48	0.46	0.52	**6.19**				**17.59**				**21.58**
15	0.67	0.64	0.71	**4.79**				**5.91**				**6.92**

A nivel anual existirá obviamente un aumento de incertidumbre con la disminución de los tonelajes.

Efecto de Calidad de información (Mapeo+QAQC) en incertidumbre



INCERTIDUMBRE POR CANTIDAD DE INFORMACIÓN

INCERTIDUMBRE POR CANTIDAD + CALIDAD DE INFORMACIÓN

GeoInnova

APRENDIZAJES Y CONCLUSIONES

Aprendizajes

- La evaluación del impacto es clave en modelos de recursos.
  - Eliminar datos puede generar más incertidumbre que usar datos inciertos.
  - Castigos de categorías pueden ser excesivos
- La evaluación nos entrega perspectivas del problema más allá del cumplimiento de normas o tradición de la industria.

Quality is everyone's responsibility.

(W. Edwards Deming)