

ORIGINAL ARTICLE

Technical aspects and consequences of establishing the shoreline in Poland

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Abstract

The shifting of the shoreline is a natural phenomenon closely related to the existence of watercourses. One of its consequences is the need to periodically update the real estate cadastre with regard to parcel boundaries and their owners. Land use types use are also subject to updates, which bears particular significance in this context. This article presents the most essential practical aspects of establishing the shoreline in Poland, including the identification of property boundaries located in the immediate vicinity of watercourses. The main problems associated with conducting the process of demarcating land under water are discussed using selected technical reports as examples. Attention is drawn to the numbering of parcels resulting from the implementation of the analyzed procedure, as well as the precision of recording surface areas. Moreover, the consequences of changing the natural watercourse shoreline and the limitations imposed on property ownership rights are presented, along with the issue of compensation claims.

Key words: cadastre, parcel, boundary, shoreline, flowing waters

1 Introduction

Property boundaries should generally remain permanent over time. Changes to these boundaries can result from administrative and judicial proceedings, including procedures for subdivision of parcels, demarcation, or adverse possession of properties. A particular case of the property boundary is the boundary of natural watercourses, referred to as the shoreline, which, due to the forces of nature, exhibits temporal and spatial variability, especially in the case of unregulated watercourses. This issue has been the subject of research in the literature both in Poland and worldwide (Kucharzak and Kowalski, 2009; Donaldson, 2011; Kowalski, 2011; Dragičević et al., 2013; Hanus et al., 2014; García-Rubio et al., 2015; Geleynse et al., 2015; Thompson, 2015; Mika et al., 2016; Mączyńska and Kwartnik-Pruc, 2016; Hanus and Pęska, 2016; Dragičević et al., 2017; Pietrzak, 2017; Felcenloben, 2017; Siejka et al., 2018; Wassie et al., 2018; Alden Wily et al., 2017; Felcenloben, 2018; Mika et al., 2018; Srebro, 2018; Bazan-Krzywoszańska et al., 2019; Ghosh and Sahu, 2019; Jasińska, 2019; Selamat et al., 2019; Xu et al., 2019; Raj et al.,

2019; Alberdi and Erba, 2020; Bitner et al., 2020; Pęska-Siwik, 2020; Cienciała et al., 2021; Kwartnik-Pruc et al., 2022; Kwartnik-Pruc and Mączyńska, 2023; Singh et al., 2023; Wadowska et al., 2023).

This article discusses the technical aspects of establishing the shoreline in the context of Polish legal regulations. It also considers the issue of identifying boundaries of properties located in the immediate vicinity of watercourses. An important part of the article is the analysis of selected cases of shoreline determination and the limitations imposed on property owners by the changes in the position of such a line.

2 Shoreline – technical aspect

The land beneath flowing surface waters, which is owned by the State Treasury, is designated in the cadastre as a land use with the "Wp" symbol (Regulation, 2021). The spatial extent of this land use generally corresponds to the boundary of a parcel resulting from the demarcation of land under the waters. From a practical standpoint,

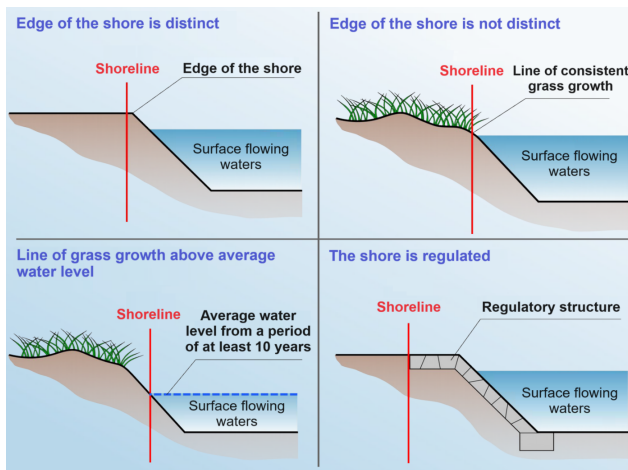


Figure 1. Different variants of the location of the shoreline (Source: own elaboration based on Kowalski (2015))

this procedure leads to the division of the property. An important issue in this context is the identification of the shoreline directly in the field by a licensed surveyor (see Figure 1).

Article 220 of the Water Law Act (Act, 2017) specifies the principles under which the shoreline should be identified:

- The shoreline for natural watercourses, lakes, and other natural water bodies is defined as the edge of the shore, the line of permanent grass cover, or the line determined based on the average water level from at least the past 10 years.
- If the edge of the shore is distinct, the shoreline runs along that edge.
- If the edge of the shore is not distinct, the shoreline runs along the border of the permanent grass cover. If the border of the permanent grass cover lies above the average water level from at least the past 10 years, the shoreline runs along the line of intersection between the water surface at that level and the adjacent land.
- If the water edges are regulated, the shoreline runs along a line connecting the outer edges of regulatory structures, or in the case of willow plantations on land acquired through regulation, the boundary of the plantation from the land side.

The above-mentioned regulations are general and require knowledge and experience in both geodesy and hydrology. Therefore, it happens that surveyors conducting demarcation of land beneath flowing surface waters rely on studies prepared by authorized hydrologists. This is a practical solution. The method of establishing the shoreline depends primarily on the morphology of the watercourse channel: whether it is regulated or unregulated, the distinctness of the shore edge, the position of the grass cover line as compared to the average water level, etc.

In addition to the proposed shoreline, elements relevant to the chosen method of determining that line should also be indicated on the map of the land demarcation project for land under the waters. Research in the literature shows that the shoreline is most commonly treated as a line that intersects with a distinct riverbank edge. In such cases, there is usually no problem in achieving the accuracy required by applicable laws and regulations during the measurement process. However, it should be considered whether the shoreline should indeed be determined with an accuracy of 0.10 meters, which is appropriate for Group I of terrain details, according to § 16 (1) of the Regulation of the Minister of Development on the technical standards for performing cadastral surveys and height measurements (Regulation, 2020). In other words, it is worth considering whether the shoreline should be directly treated as a property boundary. The answer to this question should be affirmative, but it is key to distinguish between the technical activity of measurement and the proper identification of the shoreline directly

in the field.

The mentioned implementing act (Regulation, 2020) provides for the following accuracy groups for determining the position of a terrain detail as compared to geodetic or measurement control points:

- 0.10 meters – for Group I of terrain details (terrain details uniquely identifiable in the field, maintaining long-term shape and position stability, especially boundary marks, geodetic marks, above-ground objects, and construction devices).
- 0.30 meters – for Group II of terrain details (terrain details with less distinct contours or underground objects, especially structures and earthworks such as embankments, excavations, dikes, earth dams, ditches, canals, as well as artificial water reservoirs, underground construction objects, and devices).
- 0.50 meters – for Group III of terrain details (terrain details whose unambiguous identification in the field is difficult and dependent on the assessment of the person performing the measurement, especially boundaries of land use, soil excavations for soil classification purposes, natural watercourses and reservoirs with natural shorelines, as well as forest compartments in forest and national parks).

In the case of watercourses with unregulated channels, a common practice is to assume the shoreline along the upper edge of the slope, dam, or flood protection embankment. If this is not possible and it is necessary to establish the shoreline based on the average water level from at least the past 10 years, an additional hydrological opinion is generally required. The issue of generalizing the shoreline to avoid an excessive number of boundary points of the designated parcel still remains ambiguous. On the one hand, there is a question of the accuracy detail of Group I, which is the property boundary, and on the other hand, the identification of the shoreline as the edge of the slope, which is a detail of Group III.

An important aspect of determining the shoreline is the occurrence of impounding structures, covered watercourse channels, or lands that were submerged before the construction of water management facilities. These are special cases that will not be further discussed in this article.

3 The shoreline and possible consequences for adjacent landowners

In addition to the risk of losing property rights, landowners located near flowing waters must also consider other legal and economic consequences, such as:

- The possibility of not obtaining a building permit if, according to the cadastral data, the land had a minimum permissible area for construction under local laws, which has been reduced due to river erosion activities.
- Restrictions on the construction of buildings within a certain distance from the shoreline. In Poland, this issue is regulated not only by the Water Law (Act, 2017) but also by separate regulations, such as the Act of April 16, 2004, on nature protection (Act, 2004), which introduced the possibility of prohibiting the construction of new buildings within a 100-meter strip from the river and lake shorelines within landscape parks and protected landscape areas, which together account for about 30% of the country's area. Local spatial development plans prepared by individual municipalities also contain significant provisions regarding this matter.
- Prohibition of fencing within a distance of less than 1.5 meters from the shoreline, as well as the inability to impose a ban or prevent passage through this area, as stipulated in Article 232(1) of the Water Law (Act, 2017).
- The possibility of establishing a protective zone by the voivode (regional governor) upon the request of the State Water Holding Polish Waters, in accordance with Article 141 of the Water Law

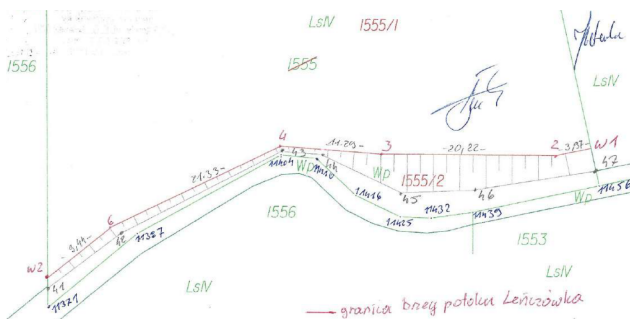


Figure 2. Part of the border sketch showing the shoreline (parcel No. 1555) (Source: technical report P.1206.2022.11235)

(Act, 2017), resulting in restrictions or even prohibitions on land use or water utilization.

- Limitations on the sale of land adjacent to a river when the property being sold has been partially covered by flowing water and the shoreline has not been determined and registered in the cadastre. In such cases, the sale transaction should be preceded by the procedure of dividing the land under water, known as "land delimitation."

The above circumstances indicate that properties located in the immediate vicinity of watercourses are exposed to the risk of decreasing market value due to the shoreline determination process. All the aforementioned aspects effectively reduce the investment attractiveness of the property from the perspective of a potential buyer. This issue would have less significance if the land was primarily used for recreational purposes. However, compensatory claims defined in the Water Law (Act, 2017) only cover compensation for land permanently covered by flowing water as a result of determining the shoreline. The law does not provide for the possibility of seeking compensation for the decrease in market value of the remaining part of the property still owned by the current owner. However, such cases have been identified in the course of analyzing available materials and are described further in this article.

4 Determination of the shoreline and cadastral update – selected cases

Based on the technical reports obtained from the District Center of Geodetic and Cartographic Documentation in Kraków, the individual problematic cases of shoreline determination under the provisions of the Water Law Act (Act, 2017) were analyzed. Additionally, it is worth mentioning that between May 2022 and the end of June 2023, a total of 21 surveying works within this scope were conducted in Kraków County.

4.1 Municipality of Świątyniki Górne, Świątyniki Górne cadastral district, registered parcels No. 1555, 1558

The shoreline was determined in accordance with Article 220(1) of the Water Law (Act, 2017); it was stated that it runs along a distinct edge of the shore, which was defined in the field by the licensed surveyor. Although the documentation lacks clear evidence of how the shore edge was identified during fieldwork, based on the sketch, it can be concluded that the escarpment edge was recognized as the defined line.

The result of the performed work was the demarcation of the land under the waters, where parcel No. 1555 was divided into parcels No. 1555/1 and 1555/2 (see Figure 2), while parcel No. 1558 was divided into parcels No. 1558/1 and 1558/2 (see Figure 3), respectively. In the analyzed case, due to the lack of established boundaries for all sections of the parcels, the area of the parcels that were

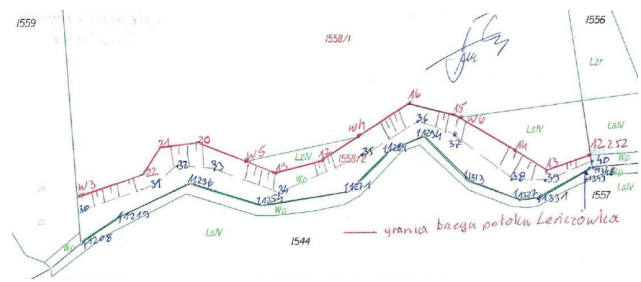


Figure 3. Part of the border sketch showing the shoreline (parcel No. 1558) (Source: technical report P.1206.2022.11235)

demarcated and left in the possession of the current owner was recorded in the cadastre with a precision of up to 1 are. However, in the case of parcels that were designated as land under surface water flow, indicated by the "Wp" symbol, an analytical calculation of the surface area was conducted based on the coordinates of the boundary points, and as a result, they were registered with a precision of up to 1 are (see Figures 4 and 5).

4.2 Municipality of Liszki, Rączna cadastral district, registered parcels No. 1321/1

Analyzing this case, it is worth emphasizing that within the boundaries of the parcel resulting from the division of land under the surface flowing waters, only land designated as "Wp", i.e. under flowing waters, should be located. However, this principle was not followed in this case. The contractor responsible for the subdivision project identified a parcel within its new state boundaries that contained both "Wp" and "Ł" (permanent meadows) land use categories (see Figure 6). The survey report was accepted and included in the geodetic and cartographic resources but could not be used as a basis for issuing an administrative decision establishing the shoreline under Article 220 of the Water Law (Act, 2017). The geodetic contractor was requested to rectify the deficiencies. As a result of the actions taken, within the boundaries of the divided parcel numbered 2274, only land designated as "Wp" was registered (see Figure 7). Due to the described situation, the entire procedure for issuing a decision establishing the shoreline was prolonged by approximately six months.

It is also worth noting that, unlike the case described in subsection 4.1, the division of land under the waters resulted in the establishment of separate cadastral parcel numbers that are not linked to the number of the original parcel from which they were separated. This is legally permissible, although the lack of clear regulations in the considered scope leads to a situation where the determination of the shoreline becomes a procedure that yields heterogeneous results.

5 Determining the shoreline and limiting the usability of real estate – selected cases

Analyzing individual technical reports, cases were also identified where the shoreline determination resulted in a limitation of the usability of the property. This may lead to a deterioration in the investment potential of the property, and, consequently, to a decreased market value.

LIST OF CHANGES IN CADASTRAL DATA

Old state						New state				
Number				Land use and class	Area ha	Owner	Acquirer	Parcel number	Land use and class	Area ha
Land register	Map sheet	Register unit	Parcel							
31198/8		580	1555	LsIV	0,22	[REDACTED]		1555/1	LsIV	0,21
				Wp	0,01					
				Total	0,23			1555/2	Wp	0,0237
									Total	0,2337

Figure 4. List of changes in cadastral data after determining the shoreline (parcel No. 1555) (Source: own elaboration based on technical report P.1206.2022.11235)

LIST OF CHANGES IN CADASTRAL DATA

Old state						New state				
Number				Land use and class	Area ha	Owner	Acquirer	Parcel number	Land use and class	Area ha
Land register	Map sheet	Register unit	Parcel							
31198/8		580	1558	PsIV	0,75	[REDACTED]		1558/1	PsIV	0,74
				LsIV	0,07				LsIV	0,06
				LzIV	0,02				LzIV	0,00
				Wp	0,02				Total	0,80
				Total	0,86			1558/2	Wp	0,0608

Figure 5. List of changes in cadastral data after determining the shoreline (parcel No. 1558) (Source: own elaboration based on technical report P.1206.2022.11235)

LIST OF CHANGES IN CADASTRAL DATA

No.	OLD STATE						NEW STATE								
	Register unit	Land register	Parcel number	Land use and class	Area		Parcel number	Land use and class	Area		Register unit	Land register			
1	2	3	5	6	7	7	9	10	11	11	12	13			
1	G1025	Kw KR1K/000045429	120607_2.0012.1321/1	Ł-ŁIII	0	04	56	120607_2.0012.2273	Ł-ŁIII	0	04	38	G1025	Kw KR1K/000045429	
				Wp	0	00	24	Total:		0	04	38			
				Total:		0	04	80							
								120607_2.0012.2274	Ł-ŁIII	0	00	18			
									Wp	0	00	24			
								Total:		0	00	42			
			Overall:		0	04	80	Overall:		0	04	80			

Figure 6. Incorrect list of changes in cadastral data after determining the shoreline (parcel No. 2274) (Source: own elaboration based on technical report P.1206.2022.11976)

LIST OF CHANGES IN CADASTRAL DATA

No.	OLD STATE						NEW STATE								
	Register unit	Land register	Parcel number	Land use and class	Area		Parcel number	Land use and class	Area		Register unit	Land register			
1	2	3	5	6	7	7	9	10	11	11	12	13			
1	G1025	Kw KR1K/000045429	120607_2.0012.1321/1	Ł-ŁIII	0	04	38	120607_2.0012.2273	Ł-ŁIII	0	04	38	G1025	Kw KR1K/000045429	
				Wp	0	00	42	Total:		0	04	38			
				Total:		0	04	80							
								120607_2.0012.2274	Wp	0	00	42			
								Total:		0	00	42			
				Overall:		0	04	80	Overall:		0	04	80		

Figure 7. The correct list of changes in cadastral data after determining the shoreline (parcel No. 2274) (Source: own elaboration based on technical report P.1206.2023.642)

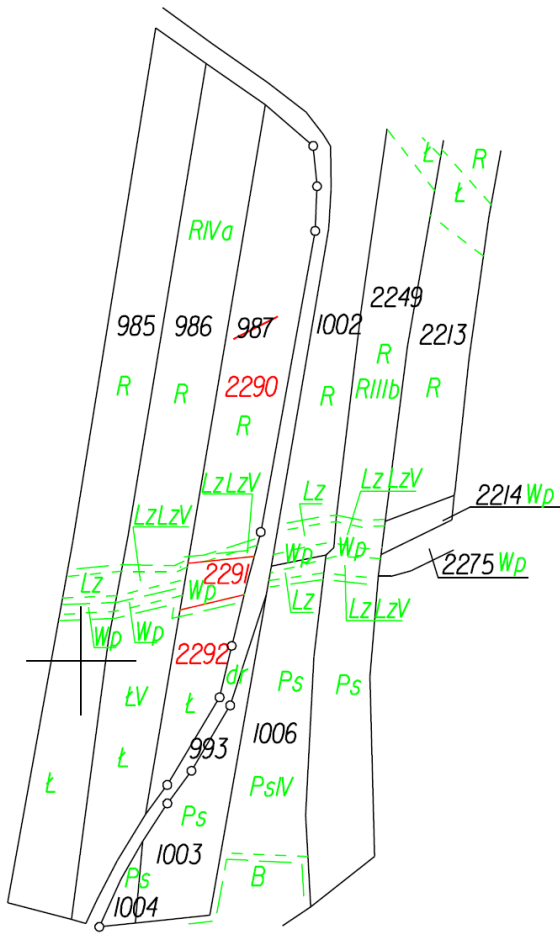


Figure 8. An example of the lack of significant deterioration of the real estate condition after separating the land under water (parcel No. 987, Rączna cadastral district) (Source: technical report P.1206.2023.1825)

5.1 Municipality of Liszki, Rączna cadastral district, registered parcel No. 987, and Municipality of Mogilany, Konary cadastral district, registered parcel No. 442/16

In the previously discussed cases, as a result of determining the shoreline and delineating the land under water, the property undergoing the procedure was practically divided into two new cadastral parcels. However, there are situations where flowing water divides a parcel into three or more parts. In such cases, the geodetic and legal status after the conducted actions may vary.

In the case of parcel No. 987, located in the Rączna cadastral district, Liszki Municipality, the division did not result in a significant deterioration of the property condition. This is due to the fact that the parcels created after the process of demarcating land under water still had access to a public road (see Figure 8). The developmental potential of the property did not change significantly, except for the deterioration in the geometry of the parcel resulting from the division.

However, there are relatively frequent situations in which, as a result of land division under the water bodies, the created small parcels of land lack legal access to a public road (see Figure 9). Unlike provisions regulating the acquisition of land by the State Treasury to construct public roads, the legislator has not provided property owners subject to the procedure of shoreline determining with the opportunity to apply for the purchase of parcels of land resulting from the division (the so-called remnants) that are not suitable for rational use. Compensation claims in this scope are literally granted

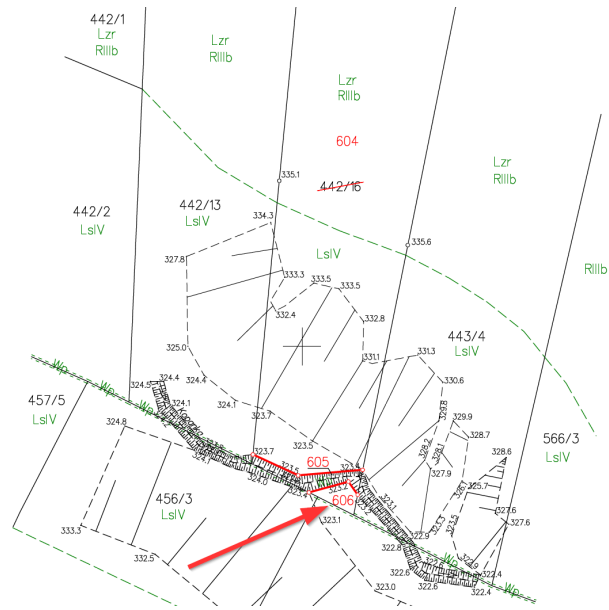


Figure 9. An example of a significant deterioration of the condition of a part of the real estate after the division of land under water (parcel No. 442/16, Konary cadastral district) (Source: own elaboration based on technical report P.1206.2023.6126)

only for land taken over by the State Treasury in connection with permanent occupation by inland flowing waters.

5.2 Municipality of Liszki, Choleryn cadastral district, registered parcel No. 302/2

In the context of compensation claims, it is also worth noting the problem of property devaluation due to permanent coverage of land by inland flowing waters. Such a situation has already been mentioned in this article. In the case presented in Figure 10, the subdivision of land under the waters resulted in a reduction of the surface area of parcel No. 302/2 by approximately 40%. As a result, the property in question lost its value as a building parcel. Although the actual utilization indicated the impossibility of investing in the western part of the parcel covered by flowing water (see Figure 11), there was a legal possibility of development in the eastern part of the property. However, after the reduction of the parcel surface area from 769 m² to only 450 m², any construction investment would be inconsistent with the provisions of the applicable local spatial development plan, particularly regarding the minimum size of a parcel for building purposes (often ranging from 600–700 m²), biologically active area, and building intensity coefficient. Due to the lack of formal compensation regulations in the Water Law (Act, 2017) in the discussed scope, parcel owners are left to pursue their rights and claims under the Civil Code (Act, 1964).

It is worth noting that the issue of permanent water encroachment on real estate is not addressed in the legal regulations concerning property valuation in Poland. It is not clear what type of land should be considered for comparison in order to determine the market value of property seized by the State Treasury. It is emphasized that since land under surface waters is excluded from civil law transactions, there is no possibility of gathering appropriate transactional data for a comparative approach to valuation. It seems that it would be appropriate to consider the purpose of the land from which a given parcel was separated or the prevailing purpose among the adjacent lands. Similar regulations apply in certain cases of valuing lands separated or taken over for transportation purposes.

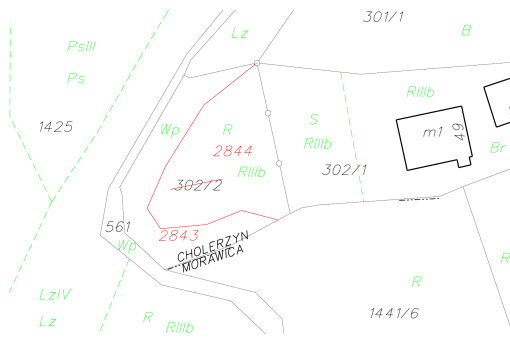


Figure 10. Decrease in the value of the property due to the reduction of the parcel area as a result of the delimitation of land under water (parcel No. 302/2, Cholerzyn cadastral district) (Source: technical report P.1206.2022.15149)

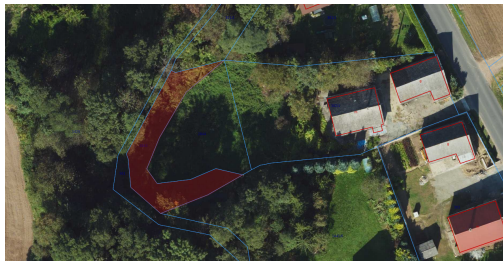


Figure 11. Visualization of the terrain situation against the background of an orthophotomap (parcel No. 2843 marked in red, taken over by the State Treasury, created from the division of parcel No. 302/2 as a result of the delimitation of land under water – Cholerzyn) (Source: own elaboration based on mapy.geoportal.gov.pl)

5.3 Municipality of Liszki, Cholerzyn cadastral district, registered parcel No. 558/2

In the last of the presented cases (see Figures 12 and 13), the delimitation of land under water has led to a situation where there is the accumulation of negative consequences of the entire procedure from the owner’s point of view. The resulting parcel No. 2847 does not have access to a public road, and at the same time, its rational development seems impossible. Therefore, it should be considered whether it could be purchased by the State Treasury, although, as already mentioned, such procedures are not currently regulated by the Water Law (Act, 2017). The second aspect concerns parcel No. 2845, which was formed as a result of the delimitation of land under water and, due to its area (356 m²), could not be developed due to existing planning restrictions.

The aspect of potential synchronization of decisions regarding the shoreline determination with the provisions of the local spatial

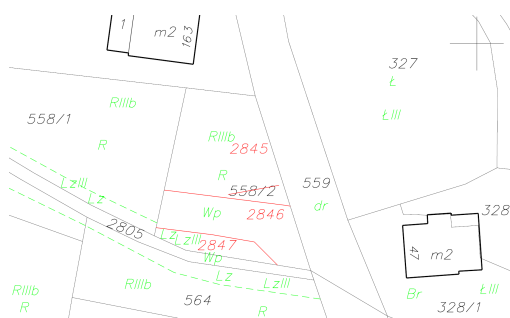


Figure 12. Effects of establishing the shoreline for the owner of the property (parcel No. 558/2, Cholerzyn cadastral district) (Source: technical report P.1206.2022.15160)

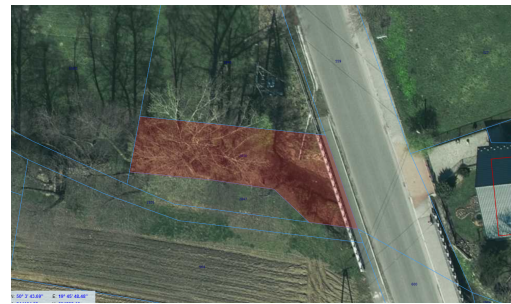


Figure 13. Visualization of the terrain situation against the background of an orthophotomap (red marked parcel No. 2846 taken over by the State Treasury, created from the subdivision of parcel No. 558/2 as a result of the delimitation of land under water – Cholerzyn) (Source: own elaboration based on mapy.geoportal.gov.pl)

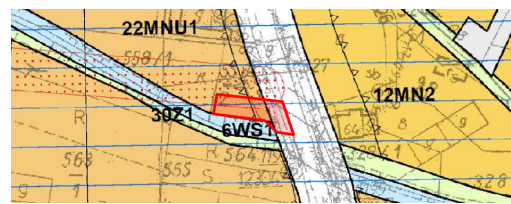


Figure 14. Parcel separated as land occupied by flowing water and provisions of the local spatial development plan (parcel No. 558/2, Cholerzyn cadastral district) (Source: sip.gison.pl/liszki)

development plan is also worth attention. In the discussed case, a situation arises where a parcel of land permanently covered by inland surface waters is designated for residential and service development (see Figure 14), while adjacent parcels of land, where there is no physical presence of a watercourse due to its change in position, remain designated as inland surface water areas. Such discrepancies can lead to a significant prolongation of property exposure in the market and, consequently, to negative financial consequences for the selling party. Unfortunately, synchronization in this regard would require interoperability of real estate cadastre databases maintained by the county authorities with local spatial development plans, the adoption of which is the responsibility of the municipality. Additionally, it should be noted that any change in the graphical part of the plan would have to be approved by an appropriate resolution of the municipal council. This is further evidence that the timeliness of data on the boundaries of properties adjacent to inland surface waters remains a complex issue that affects various branches of real estate management.

6 Conclusions

Maintaining up-to-date data in the real estate cadastre is an important issue. This is particularly evident in the case of lands permanently covered by flowing waters. According to Polish legal regulations, the activities of natural forces lead to changes in the ownership structure of lands adjacent to watercourses. Such changes should be appropriately documented and registered. Otherwise, owners of lands adjacent to rivers may be exposed to various legal and economic consequences.

Although the principles for determining the shoreline in Poland were formulated in Article 220, paragraphs 1–4 of the Water Law (Act, 2017), their implementation poses a number of problems in practice. One of these issues is related to determining the areas of cadastral parcels that arise within the discussed procedure. In practice, the surveyor is forced to determine the area with an accuracy of 1 are or to establish additional boundaries of the parcels (beyond

the shoreline). Another significant drawback is the lack of solutions regarding the method of determining the designation of parcels undergoing the procedure. Treating the demarcation of lands under water as both a quasi-division and a situation where new parcels unrelated to the original parcel are created is permissible, which leads to inconsistencies in the application of regulations.

Finally, the procedure for determining the shoreline can have negative effects on the utility of the property, manifested, for example, by restricting investment opportunities due to a decrease in the surface area of the property and deterioration of its geometry or limiting access to public roads. Importantly, there is currently no provision for seeking compensation claims in connection with the decrease in the market value of the property after the demarcation of lands under water. As a result, recourse to general regulations of the Civil Code is necessary. However, this seems to be an insufficient and unfavorable solution for owners of properties adjacent to flowing waters. There is also a need to introduce provisions into the Water Law (Act, 2017) that would allow for claims to repurchase small, unusable parcels resulting from the division of lands under water.

Efforts should also be made to integrate local spatial development plans with cadastral data updated in connection with the determination of the shoreline. Otherwise, property owners may encounter problems when intending to sell a parcel whose portion remains designated in planning documents as inland surface water areas, although this is not reflected in the actual state or the cadastral database.

References

- Act (1964). Civil Code Act of April 23, 1964. *Journal of Laws 1964* No. 16, item 93 (as amended), Poland.
- Act (2004). Act of 16 April, 2004 on nature protection. *Journal of Laws of 2004*, No. 92, item 880 (as amended), Poland.
- Act (2017). Water Law Act of July 20, 2017. *Journal of Laws 2017*, item 1566 (as amended), Poland.
- Alberdi, R. and Erba, D. A. (2020). Modeling legal land object for waterbodies in the context of 4D cadastre. *Land Use Policy*, 98:104417, doi:10.1016/j.landusepol.2019.104417.
- Alden Wily, L., Dubertret, F., Veit, P., Reytar, K., and Tagliarino, N. K. (2017). Water rights on community lands: LandMark's findings from 100 countries. *Land*, 6(4):77, doi:10.3390/land6040077.
- Bazan-Krzywoszańska, A., Mrówczyńska, M., and Tront, S. (2019). GIS technology, 3D models and mathematical models as a tool for assessing development capabilities of flood risk land to make arrangements of municipal planning documents. *Journal of Ecological Engineering*, 20(1):25–33, doi:10.12911/22998993/93866.
- Bitner, A., Litwin, U., Bacior, S., Taszakowski, J., Król, K., and Basta, P. (2020). A distinctive shape of cadastral parcels bordering the Młynówka River in Strzelce Wielkie. *Journal of Ecological Engineering*, 21(6):36–41, doi:10.12911/22998993/123119.
- Cienciąła, A., Sobolewska-Mikulska, K., and Sobura, S. (2021). Credibility of the cadastral data on land use and the methodology for their verification and update. *Land Use Policy*, 102:105204, doi:10.1016/j.landusepol.2020.105204.
- Donaldson, J. W. (2011). Paradox of the moving boundary: Legal heredity of river accretion and avulsion. *Water alternatives*, 4(2):155–170.
- Dragičević, S., Pripuzić, M., Živković, N., Novković, I., Kostadinov, S., Langović, M., Milojković, B., and Čvorović, Z. (2017). Spatial and temporal variability of bank erosion during the period 1930–2016: Case study – Kolubara River Basin (Serbia). *Water*, 9(10):748, doi:10.3390/w9100748.
- Dragičević, S., Tošić, R., Stepić, M., Živković, N., and Novković, I. (2013). Consequences of the river bank erosion in the southern part of the Pannonian Basin: Case study – Serbia and the Republic of Srpska. In *Forum geografic*, volume 12, pages 5–15. doi:10.5775/fg.2067-4635.2013.008.i.
- Felcenloben, D. (2017). Aktualizacja baz danych ewidencji gruntów w związku z ustaleniem linii brzegu cieków naturalnych (Updating land registration databases in relation to establishment of shorelines for natural watercourses). *Przegląd Geodezyjny*, 89(7):25–29, doi:10.15199/50.2017.7.3.
- Felcenloben, D. (2018). Pojęcie linii brzegu, kryteria jej ustalania i skutki prawne z tego wynikające (The concept of the shoreline, the criteria for its determination and the legal consequences resulting from it). *Przegląd Geodezyjny*, 90(4):9–15, doi:10.15199/50.2018.4.1.
- García-Rubio, G., Huntley, D., and Russell, P. (2015). Evaluating shoreline identification using optical satellite images. *Marine Geology*, 359:96–105, doi:10.1016/j.margeo.2014.11.002.
- Geleynse, N., Hiatt, M., Sangireddy, H., and Passalacqua, P. (2015). Identifying environmental controls on the shoreline of a natural river delta. *Journal of Geophysical Research: Earth Surface*, 120(5):877–893, doi:10.1002/2014JF003408.
- Ghosh, D. and Sahu, A. S. (2019). Bank line migration and its impact on land use and land cover change: A case study in Jangipur subdivision of Murshidabad District, West Bengal. *Journal of the Indian Society of Remote Sensing*, 47:1969–1988, doi:10.1007/s12524-019-01043-0.
- Hanus, P., Jasińska, E., and Preweda, E. (2014). Analysis of the accuracy of determining the coordinates property borders. In *9th International Conference "Environmental Engineering"*, 22–23 May 2014, Vilnius, Lithuania. doi:10.3846/enviro.2014.209.
- Hanus, P. and Peška, A. (2016). Technical aspects of determining and revealing shore lines in real estate cadaster. In *Geographic Information Systems Conference and Exhibition "GIS ODYSSEY 2016"*, 5th to 9th of September 2016, Perugia, Italy, pages 114–121. GIS Forum, Zagreb.
- Jasińska, E. (2019). The implementation of spatial management as a factor supporting flood protection. In *E3S Web of Conferences, The First International Scientific Conference on Ecological and Environmental Engineering 2018*, volume 86, page 00016. EDP Sciences, doi:10.1051/e3sconf/20198600016.
- Kowalski, K. (2011). Linia brzegu w postępowaniach administracyjnych – wnioski z orzecznictwa (Shoreline in administrative procedures – conclusions from case law). *Gospodarka Wodna*, (12):496–499.
- Kowalski, K. (2015). Ustalenie linii brzegu – materiały szkoleniowe (Delimitation of the coastline – teaching materials).
- Kucharzak, S. and Kowalski, K. (2009). Geodezyjny aspekt ustalania linii brzegu (Geodetic aspect of shoreline determination). *Gospodarka wodna*, (9):357–363.
- Kwartnik-Pruc, A. and Mączyńska, A. (2023). Methodology of assessing quality of spatial data describing course of shoreline as tool supporting water resource management process. *Journal of Water and Land Development*, (57):167–180, doi:10.24425/jwld.2023.145347.
- Kwartnik-Pruc, A., Mączyńska, A., and Gabryś, B. (2022). The problem of the undetermined legal status of land under flowing. Poland – a case study. *Geomatics and Environmental Engineering*, 16(2):177–196, doi:10.7494/geom.2022.16.2.177.
- Mączyńska, A. and Kwartnik-Pruc, A. (2016). Problematyka różnicowania postępowań administracyjnych dotyczących ustalenia linii brzegu (The problem of diversification of administrative proceedings to determine a shoreline). In *Infrastruktura i Ekologia Terenów Wiejskich*, (II/1):233–245, doi:10.14597/infraeco.2016.2.1.016.
- Mika, M., Siejka, M., and Leń, P. (2016). Dynamika linii brzegowej rzeki górskiej w aspekcie aktualizacji mapy ewidencyjnej – studium przypadku (dynamics of the shoreline of a mountainous river in terms of updating the registry map – a case study). *Infrastruktura i Ekologia Terenów Wiejskich*, (II/1):247–260, doi:10.14597/infraeco.2016.2.1.017.
- Mika, M., Siejka, M., Leń, P., and Król, Ż. (2018). The concept of

- using the water cadastre databases components for the construction of multi-dimensional cadastre in Poland. *Survey Review*, 50(360):201–211, doi:10.1080/00396265.2016.1263180.
- Pęska-Siwik, A. (2020). Charakterystyka wybranych prac geodezyjnych związanych z określaniem przebiegu granic działki ewidencyjnej w kontekście atrybutu ZRD (Characteristics of selected geodetic works related to determining the course of cadastral parcel boundaries in the ZRD attribute context). *Przegląd Geodezyjny*, 92(1):16–20, doi:10.15199/50.2020.1.2.
- Pietrzak, L. (2017). Ustalenie linii brzegu i pomiar sytuacyjny linii brzegu w jednostkowych opracowaniach geodezyjnych i w procedurze modernizacji ewidencji gruntów i budynków (Delimitation of the coastline and topographic measurements of the coastline in unique surveying works and in the procedure of modernisation of the lands and buildings registration). *Przegląd Geodezyjny*, 89(3):11–17, doi:10.15199/50.2017.3.3.
- Raj, N., Gurugnanam, B., Sudhakar, V., and Francis, P. G. (2019). Estuarine shoreline change analysis along The Ennore river mouth, south east coast of India, using digital shoreline analysis system. *Geodesy and Geodynamics*, 10(3):205–212, doi:10.1016/j.geog.2019.04.002.
- Regulation (2020). Regulation of the Minister of Development of August 18, 2020, on technical standards for performing cadastral surveys and height measurements, as well as processing and transmitting the results of these surveys to the state geodetic and cartographic resource. *Journal of Laws 2020*, Item 1429 (as amended), Poland.
- Regulation (2021). Regulation of the Minister of Development, Labour and Technology of July 27, 2021, on land and building records. *Journal of Laws 2021*, Item 1390 (as amended), Poland.
- Selamat, S. N., Maulud, K. N. A., Mohd, F. A., Rahman, A., Zainal, M. K., Wahid, M. A. A., and Awang, N. (2019). Multi method analysis for identifying the shoreline erosion during northeast monsoon season. *Journal of Sustainability Science and Management*, 14(3):43–54.
- Siejka, M., Miła, M., Salata, T., and Leń, P. (2018). Algorithm of land cover spatial data processing for the local flood risk mapping. *Survey Review*, 50(362):397–403, doi:10.1080/00396265.2017.1287620.
- Singh, S., Meraj, G., Kumar, P., Singh, S. K., Kanga, S., Johnson, B. A., Prajapat, D. K., Debnath, J., and Sahariah, D. (2023). Decoding Chambal River shoreline transformations: A comprehensive analysis using remote sensing, GIS, and DSAS. *Water*, 15(9):1793, doi:10.3390/w15091793.
- Srebro, H. (2018). Historical cartographic materials as a source for international and cadastral boundary management in rivers. In *Proceedings of the ICA*, volume 1, page 104. Copernicus Publications Göttingen, Germany, doi:10.5194/ica-proc-1-104-2018.
- Thompson, R. J. (2015). A model for the creation and progressive improvement of a digital cadastral data base. *Land Use Policy*, 49:565–576, doi:10.1016/j.landusepol.2014.12.016.
- Wadowska, A., Pęska-Siwik, A., and Maciuk, K. (2023). Problems of collecting, processing and sharing geospatial data. *Acta Scientiarum Polonorum. Formatio Circumiectus*, 21(3–4):5–16, doi:10.15576/ASP.FC/2022.21.3/4.5.
- Wassie, Y., Koeva, M., Bennett, R., and Lemmen, C. (2018). A procedure for semi-automated cadastral boundary feature extraction from high-resolution satellite imagery. *Journal of spatial science*, 63(1):75–92, doi:10.1080/14498596.2017.1345667.
- Xu, Z., Zhuo, Y., Liao, R., Wu, C., Wu, Y., and Li, G. (2019). LADM-based model for natural resource administration in China. *ISPRS International Journal of Geo-Information*, 8(10):456, doi:10.3390/ijgi8100456.