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WATER SECURITY AND THE DEVELOPMENT OF KEDAH RUBBER CITY IN PADANG TERAP, KEDAH, MALAYSIA

(Keselamatan Air dan Perkembangan Kedah Rubber City di Padang Terap, Kedah, Malaysia)

[1]Mohd Firdaus Abdullah & [2]Mohd Jailani Ibrahim

[1]Center for Research in History, Politics and International Affairs,
Faculty of Social Sciences and Humanities,
Universiti Kebangsaan Malaysia, Malaysia
[2]Independent Researcher, H-G-1 Pangsapuri Seri Tulip,
Jalan Tulip, Seksyen BS 2, Bukit Sentosa,
Rawang, Selangor

[1]Corresponding author: mfa@ukm.edu.my

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ABSTRACT

This article examines Padang Terap, Kedah, as an emerging site of zero-reserve industrialisation: the pursuit of resource-intensive industrial development within a state water system reported to have no secure treated-water reserve margin. Focusing on Kedah Rubber City (KRC), the article analyses how a largely rural and upstream district is being repositioned as an industrial water frontier, where new demands for water, energy and infrastructure intersect with unresolved questions of domestic water security. Based on qualitative analysis of policy documents, investment materials, infrastructure reports and public statements, the article argues that KRC's projected industrial water demand cannot be treated as a neutral

utility requirement. Rather, it must be understood within Kedah's wider development trajectory, in which rubber-based industrialisation, border economic zones and AI-ready digital infrastructure are expanding alongside fragile water-system capacity. The article actively bridges this Malaysian case with wider global debates on the political ecology of infrastructure, water security, resource frontiers and the hidden material costs of industrial and digital capitalism. Although Padang Terap is not itself a data-centre site, its transformation reveals how the pressures of digital-industrial expansion are redistributed across wider hydrological and infrastructural systems. The article contributes the concept of zero-reserve industrialisation to explain how states pursue investment-led growth in contexts where domestic water systems lack sufficient operational buffers. It shows that industrial development in water-constrained regions cannot be evaluated solely through investment value, land availability or employment creation, but must also be assessed through treated-water reserves, treatment capacity, distribution resilience and the prioritisation of household users. By foregrounding Padang Terap, the article demonstrates how peripheral upstream districts are increasingly enrolled into global circuits of industrial and digital expansion.

Keywords: Kedah Rubber City, AI Data Center, Border Economic Zone, Zero Water Reserve Margin, Padang Terap, Kedah, Malaysia, Southeast Asian

INTRODUCTION

Today, industrial development is increasingly presented as a symbol of regional competitiveness, economic diversification and technological readiness. Underneath the dominant narrative that stresses investment attraction, job creation, infrastructure expansion and participation in global value chains, there is an often-neglected ecological dimension: the pressure placed on domestic water systems by new forms of industrial demand (Daly, 1992: Li, Yang & Xu, 2019). Industrial parks, data centres, logistics hubs and border economic zones are frequently discussed through the language of growth, connectivity and productivity (Kollar & Stokols, 2026). However, these infrastructures are also material systems that require land, energy, treated water, raw-water security, distribution networks and long-term operational resilience (Carse, 2012: Larkin, 2013). In the context of climate uncertainty, ageing water infrastructure and uneven regional development, industrialisation can no longer be treated merely as an economic or spatial planning issue. Instead, it must also be positioned as part of the wider political ecology of water, infrastructure and resource allocation (Swyngedouw, 2004: Bakker, 2010; Peet, Robbins & Watts, 2011).

At the global level, the relationship between industrial expansion and water security has become increasingly critical. Contemporary economic growth is no longer driven only by traditional manufacturing, but also by resource-intensive digital infrastructure, semiconductor production, logistics systems, food processing, energy facilities and high-value industrial parks (Larkin, 2013: Bridge, 2014). These sectors require reliable water supply not only as a direct production input, but also as a condition for cooling, cleaning, processing, sanitation, worker accommodation and environmental compliance. This situation is especially significant in developing and postcolonial economies where industrial investment is often promoted as a route toward national upgrading, while the ecological costs of such development are displaced onto rivers, aquifers, reservoirs and public utilities (Peet, Robbins & Watts, 2011: Anand, 2017). In this context, water becomes more than a natural resource. It becomes an infrastructural condition for development, a political object of allocation and a measure of whether industrialisation is compatible with domestic water security.

Malaysia is also part of this wider transformation. The country has positioned itself as a competitive investment destination in Southeast Asia through the expansion of industrial corridors, special economic zones, data centres and sector-specific industrial parks (MIDA, 2025). Recent debates on Malaysia's digital economy have focused strongly on Johor, Kuala Lumpur and Selangor, especially because of the rapid expansion of data centres and AI-ready infrastructure (RimbaWatch, 2025). However, such debates risk overlooking the northern region, where Kedah is also experiencing a significant shift in its development geography. Kedah is not merely an agricultural state associated with rice production and rural water landscapes. It is increasingly being drawn into new industrial and digital circuits through projects such as Kedah Rubber City in Padang Terap and the D8-1 Data Centre in the Delapan Special Border Economic Zone, Bukit Kayu Hitam (NCIA, n.d: Open DC, n.d). This transformation is important because it occurs in a state already marked by a fragile treated-water reserve condition.

In Kedah, the issue of industrial development cannot be separated from the state's water reserve problem. Reports in 2024 indicated that Kedah had a zero treated-water reserve margin due to water pressure issues and infrastructure deficiencies (New Straits Times, 2024a). The National Water Services Commission has set a treated-water reserve margin of 15 per cent as an important operational benchmark, while the Kedah state government has targeted a minimum treated-water reserve of 15 per cent by 2030 after the completion of several key water supply projects (New Straits Times, 2024a: New Straits Times, 2024b). This means that Kedah's present development trajectory is taking place within a water system that has limited operational buffer. A zero or extremely low treated-water reserve does not necessarily mean that water supply has collapsed. Rather, it indicates that existing treatment and distribution capacity is almost fully absorbed by current demand, leaving limited flexibility to respond to new industrial consumption, drought, treatment plant disruption, pressure loss or rapid population growth (SPAN, 2020). In such a context, every new industrial water demand becomes politically and ecologically significant.

Table 1

Kedah Recorded A 0.0% Treated-Water Reserve Margin From 2020 To 2024.

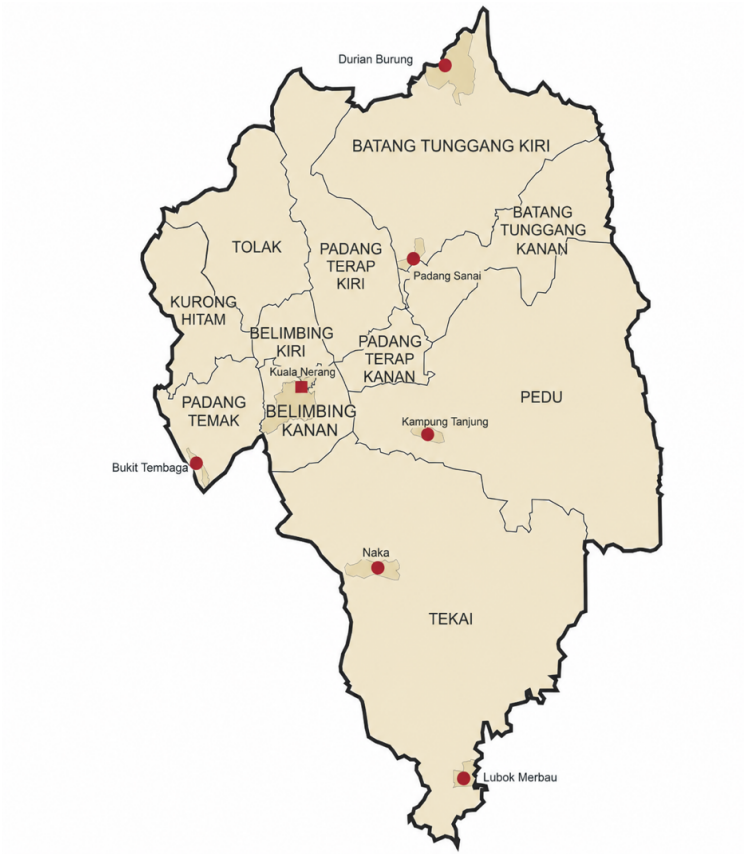
Unit (%)	2020	2021	2022	2023	2024
Johor	9.7%	14.3%	11.5%	16.8%	15.7%
Kedah	0.0%	0.0%	0.0%	0.0%	0.0%
Kelantan	0.0%	0.0%	0.0%	4.6%[r]	4.4%
F.T. Labuan	18.7%	17.1%	20.3%	22.6%	21.2%
Melaka	11.2%	7.5%	4.7%	6.1%	5.2%
N.Sembilan	20.0%	18.4%	19.1%	16.8%	16.2%
Pulau Pinang	30.7%	29.6%	26.4%	25.6%	29.9%
Pahang	14.2%	20.6%	17.3%	17.9%	19.1%
Perak	26.2%	26.7%	27.3%	28.4%	25.7%
Perlis	1.9%	4.5%	8.4%	1.3%	5.0%
Selangor	0.0%	17.4%	15.2%	13.4%	12.1%
Terengganu	23.6%	25.7%	31.8%	27.5%	24.8%
Pen. Malaysia & F.T. Labuan	16.3%	16.9%	15.7%	15.4%[r]	14.9%

Source: Suruhanjaya Perkhidmatan Air Negara. (2024). Water & sewerage fact book 2024. SPAN. https://www.span.gov.my/document/upload/KASixe2qy0sqnqNLWvBFVxgffGbQBDyR.pdf

Padang Terap provides a particularly important empirical site for examining this issue. Historically, Padang Terap has been understood largely as a rural, upstream and relatively peripheral district in Kedah's development geography. Its name originates from the terap tree (Artocarpus elasticus), which once grew widely in open field areas, while its modern local authority was established in 1976 following the reorganisation of the Padang Terap Town Board. Its identity has therefore been shaped more by settlement, agriculture, forested catchments and its relationship to the hinterland than by large-scale industrialisation (Majlis Daerah Padang Terap, 2022). However, the development of Kedah Rubber City has begun to reposition Padang Terap as a strategic industrial district. KRC is promoted as Malaysia's first dedicated rubber industrial park and is designed to strengthen the rubber value chain through upstream, midstream and downstream industrial activities (NCIA, 2024). More importantly for this article, KRC is not only an investment project. It is also a water-dependent industrial infrastructure. The project's utility profile includes industrial water demand of approximately 20 million litres per day (NCER, 2024). This figure may appear modest when compared with major metropolitan water systems, but it becomes highly significant when placed within Kedah's wider zero-reserve water condition.

Figure 1

Map of Padang Terap District, Kedah



Source: Author's Own Work

The significance of KRC therefore lies not only in its potential economic benefits, but also in the new water politics it introduces into Padang Terap. Once an upstream district is repositioned as an industrial water frontier, water is no longer understood primarily as a domestic, agricultural or rural resource (NCIA, 2024). It is transformed into a strategic input for industrial competitiveness (Bakker, 2010; Swyngedouw, 2004). This transformation raises important questions. Can new industrial water demand be supplied without weakening domestic water reliability? Will new infrastructure expansion strengthen local water systems or prioritise industrial users? How should treated-water reserve margins, distribution resilience and household water security be evaluated when industrial development is justified through investment value and employment creation? These questions are especially important because local communities are often promised employment opportunities, road upgrading, public amenities and regional development benefits, while the long-term ecological and infrastructural implications of industrial water demand receive less critical attention (Anand, 2017: Larkin, 2013).

The issue becomes more complex when Padang Terap is situated within Kedah's broader industrial and digital turn. Although Padang Terap is not presently identified as the location of an AI data centre, it is indirectly connected to the same state-wide development logic that seeks to reposition Kedah as a modern industrial and digital economy. Open DC's D8-1 Data Centre, located in the Delapan Special Border Economic Zone in Bukit Kayu Hitam, has been promoted as Kedah's Tier III data centre and as a facility capable of supporting AI, cloud, telecommunications and power-intensive workloads (Open DC, n.d; Open DC, 2024). Its official profile also notes the use of chilled water systems, a target power usage effectiveness and upgradable power capacity (Open DC, 2024). This indicates that Kedah's development geography is no longer limited to agriculture and conventional industry. It is being reconfigured through multiple resource-intensive projects, including rubber-based industrialisation in Padang Terap and digital infrastructure in the northern border corridor (NCER, n.d; Open DC, 2024). The absence of a data centre in Padang Terap therefore does not make the district irrelevant to debates on digital-industrial development. Rather, Padang Terap must be understood as part of a wider hydrological and infrastructural system in which cumulative water demand is generated across districts.

Such a situation has a critical implication for domestic water security. In a water system with sufficient treated-water reserve, additional industrial demand can be planned, absorbed and buffered through spare capacity. In a zero-reserve system, however, industrial demand becomes more politically sensitive because the margin between supply and demand is already narrow (SPAN, 2024). This does not mean that KRC will automatically reduce household water supply in Padang Terap. Such a claim would require site-level operational evidence. However, it does mean that KRC's 20 MLD industrial water requirement cannot be treated as a neutral technical figure (NCER, n.d). It must be analysed in relation to treatment capacity, raw-water availability, non-revenue water, distribution pressure, drought resilience and the state's ability to protect household users during periods of stress (Anand, 2017). Domestic water security is not only about whether taps run under normal conditions. It is also about whether the system has enough reserve capacity to protect households when industrial demand, climatic variability and infrastructure weaknesses converge.

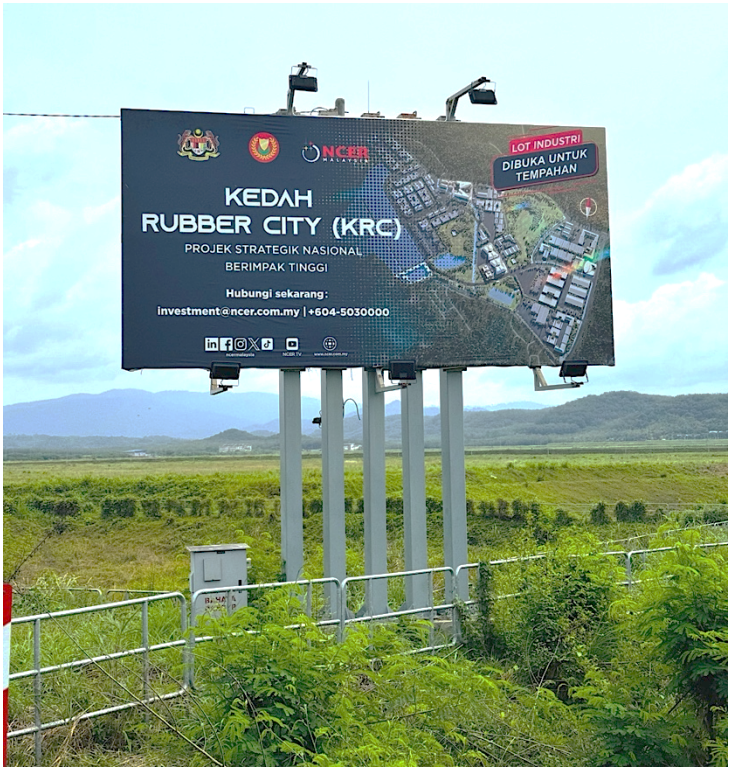
This predicament must be understood from a wider framework of political ecology and infrastructure studies. Political ecology highlights that environmental problems are never purely natural or technical. They are shaped by power relations, development priorities, institutional arrangements and the unequal distribution of ecological risks (Peet, Robbins & Watts, 2011: Robbins, 2012). Infrastructure studies similarly show that roads, pipes, treatment plants, industrial parks and data centres are not passive technical systems. They organise social life, redistribute resources and produce new forms of dependency (Carse, 2012: Larkin, 2013). In the case of Padang Terap, KRC demonstrates how a rural district can be enrolled into wider circuits of industrial capitalism through the provision of land, utilities and logistical connectivity (NCER, n.d: Bernama, 2026). At the same time, Kedah's zero treated-water reserve reveals the limits of

development strategies that assume water infrastructure can expand smoothly in response to investment demand (SPAN, 2024). The politics of water is therefore not external to industrialisation. It is embedded within the very conditions that make industrialisation possible.

This article introduces the concept of zero-reserve industrialisation to explain this condition. Zero-reserve industrialisation refers to the pursuit of resource-intensive industrial development in a context where treated-water systems lack sufficient operational buffers. The concept does not suggest that industrialisation must be rejected. Rather, it calls for a more critical evaluation of how industrial growth is planned, justified and governed when domestic water systems are already under pressure (Bakker, 2010: Anand, 2017). It also challenges the assumption that industrial parks can be assessed primarily through investment value, employment generation or regional competitiveness. In water-constrained settings, industrial development must also be assessed through treated-water reserve margins, treatment capacity, raw-water security, distribution reliability, household protection and long-term ecological sustainability (Swyngedouw, 2004: Peet, Robbins & Watts, 2011). This is particularly important in postcolonial development contexts where states often compete for investment while environmental infrastructures remain uneven, underfunded or politically fragmented.

Figure 2

Kedah Rubber City (KRC) Billboard in Padang Terap, Kedah



Kedah Rubber City (KRC) billboard in Padang Terap, Kedah, showing the projection of a rural agricultural landscape into a new industrial development frontier. (Source: Author's photograph)

By focusing on Padang Terap, this article actively bridges local empirical realities in Malaysia with wider global debates on water security, infrastructure politics, resource frontiers and the ecological limits of industrial and digital capitalism. The Malaysian case shows that the hidden costs of contemporary

development are not found only at the spectacular sites of data centres, ports or megacities. They may also emerge in upstream and peripheral districts where new industrial projects quietly reorganise water demand and infrastructure priorities (Bridge, 2014; Larkin, 2013). Padang Terap is therefore not important because it hosts AI infrastructure directly. It is important because it reveals how the pressures of industrial and digital transformation can travel through state-wide water systems, development corridors and utility planning. In this sense, the district offers a critical lens for understanding how peripheral regions are increasingly incorporated into global circuits of production and digital growth, even when the most visible technological infrastructure is located elsewhere (Peet, Robbins & Watts, 2010: Bridge, 2014).

Against this background, this article is guided by three interrelated research questions. First, how does the development of Kedah Rubber City reposition Padang Terap from a rural upstream district into an industrial water frontier? Second, to what extent does Kedah's zero treated-water reserve margin reshape the relationship between industrial water demand and domestic water security? Third, how does the wider expansion of industrial and AI-ready infrastructure in Kedah produce cumulative pressure on water governance, even when Padang Terap is not itself a data-centre site? By addressing these questions, this article moves beyond a descriptive account of KRC as an industrial project and positions Padang Terap within broader debates on political ecology, infrastructure, resource sovereignty and the sustainability limits of investment-led development in Southeast Asia.

LITERATURE REVIEW

Recent scholarship on industrial development increasingly challenges the assumption that industrial parks, special economic zones and regional growth corridors should be understood merely as economic spaces. Instead, these infrastructures are now analysed as material, ecological and political systems that depend on extensive networks of land, energy, water, transport, labour, finance and state regulation. Larkin (2013), for example, argues that infrastructure is never a neutral technical object, but a material form that enables circulation, exchange and political imagination. Similarly, Carse (2012) shows that infrastructure is not limited to pipes, roads, canals or treatment plants, but may also include landscapes, watersheds and ecological systems that are actively managed to sustain economic activity. Their work is important because it shifts the study of development away from investment figures and physical facilities towards the wider socio-environmental systems that make industrial growth possible.

Within this broader debate, political ecology provides an important framework for examining the relationship between industrialisation and water. Political ecology argues that environmental problems are not produced by nature alone, but by unequal power relations, uneven development, institutional priorities and political-economic decisions (Peet, Robbins & Watts, 2011: Robbins, 2012). This perspective is especially useful for analysing water because water is frequently presented as a technical matter of supply, demand, treatment and distribution, while the politics of allocation is often concealed. Bakker (2010) shows that urban water crises are deeply connected to governance failure, infrastructure inequality and market-oriented reform. Swyngedouw (2004) further argues that the urbanisation of water is always shaped by relations of social power. These works are significant because they demonstrate that water infrastructure must be understood as both a technical system and a political field.

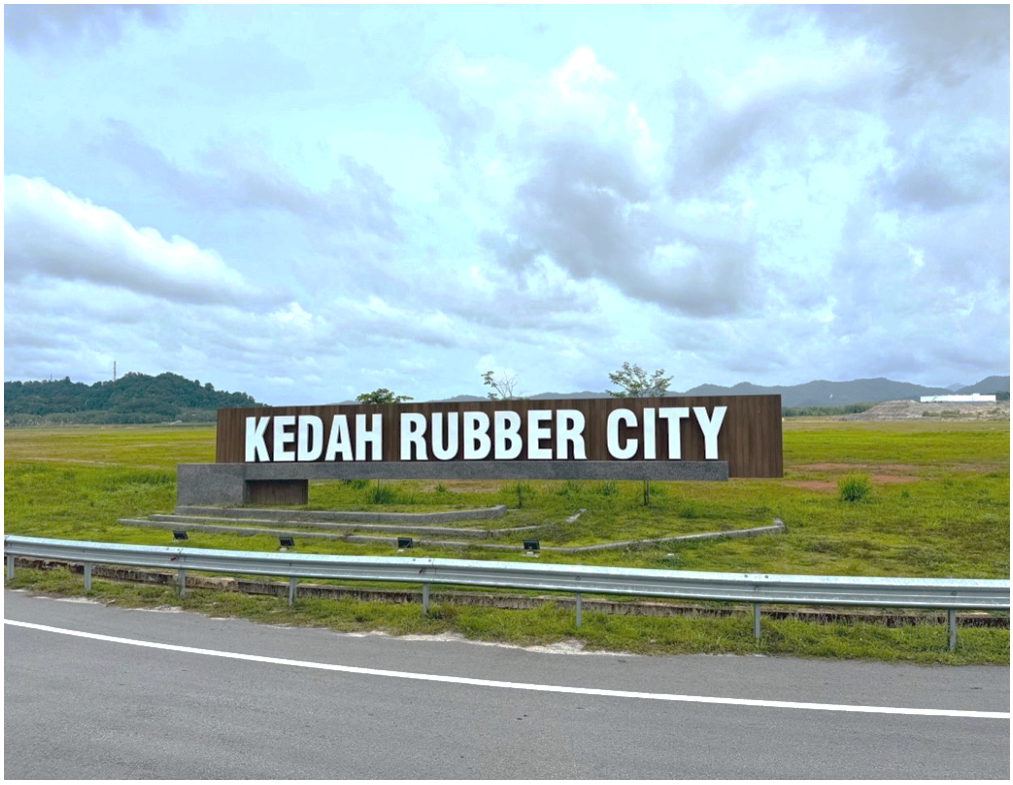
The literature on the hydrosocial cycle further strengthens this argument by refusing to treat water as a purely natural resource. Linton and Budds (2014) argue that water is continuously produced through relations among society, technology, law, infrastructure, capital and ecological processes. From this perspective, water does not simply flow from rivers to treatment plants and households. It is transformed through institutional arrangements, engineering decisions, political priorities and everyday social needs.

This approach is particularly relevant to industrial development because industrial water demand is not merely a question of volume. It is also a question of whose demand is recognised, whose supply is protected, which infrastructures are upgraded and which users are exposed to risk. In this sense, the hydrosocial approach allows this article to analyse Kedah Rubber City not only as an industrial park, but as a new intervention into Padang Terap's water relations.

Water security literature also provides a crucial foundation for this study. Cook and Bakker (2012) argue that water security has become an increasingly important but contested concept in both academic and policy debates. It includes not only the availability of water, but also questions of access, reliability, safety, governance, risk and resilience. This is important because domestic water security cannot be measured only by the physical presence of rivers, reservoirs or treatment plants. It also depends on whether treated-water systems have sufficient reserve margins, whether distribution networks can maintain pressure, whether non-revenue water is controlled and whether households remain protected during periods of drought, industrial expansion or infrastructure disruption. In the context of Kedah, the reported zero treated-water reserve margin makes this literature especially relevant because it shows that water security is not simply about present supply, but about the capacity of the system to absorb future shocks.

Figure 3

Entrance signage of Kedah Rubber City (KRC) in Padang Terap, Kedah



Entrance signage of Kedah Rubber City (KRC) in Padang Terap, Kedah, marking the district's transition from a rural agrarian landscape to an industrial development frontier. (Source: Author's photograph)

Studies on industrial ecology and eco-industrial parks provide another relevant body of scholarship. Eco-industrial park literature often emphasises the need for resource efficiency, industrial symbiosis, wastewater reuse, shared infrastructure and circular resource flows. Martin et al. (1996) demonstrated that

water cascading techniques in industrial parks can reduce freshwater use and pollutant discharge. More recent optimisation studies by O'Dwyer et al. (2020), Taheri (2021), and Aussel, Cao Van and Salas (2022) have developed models for water and wastewater networks in eco-industrial parks, showing that industrial water management requires careful planning across firms, technologies, locations and time periods. This literature is useful because it shows that industrial parks are not only sites of production. They are also sites of resource circulation and environmental risk. However, much of this literature remains technical and managerial, focusing on efficiency, optimisation and industrial symbiosis, while paying less attention to the politics of domestic water security beyond the park boundary.

This limitation is important for the Malaysian case. Kedah Rubber City is officially promoted as Malaysia's first dedicated rubber industrial park in Padang Terap, with industrial water requirements listed as part of its utility readiness. From an industrial planning perspective, the provision of water, electricity, gas and telecommunications signals investor readiness. However, from a political ecology perspective, the same utility profile raises a different question: how does an industrial park reshape water demand in an upstream district located within a state water system with limited treated-water reserve? Existing eco-industrial park literature tends to assume that water can be planned within the spatial boundary of the park. This article argues that such an assumption is insufficient because industrial water demand also has wider hydrological and social consequences beyond the investment site.

Critical infrastructure studies are also central to this article. Larkin (2013) argues that infrastructures organise social life, political authority and collective expectations. They are not simply built objects but systems that structure movement, access, imagination and dependency. Anand (2017), in his study of water infrastructure in Mumbai, shows how citizenship and urban belonging are shaped through everyday access to hydraulic systems. These insights are useful for analysing Padang Terap because the development of KRC does not merely introduce factories into a rural district. It reorganises the infrastructural meaning of the district itself. Padang Terap is no longer positioned only as an upstream rural hinterland, but as a strategic industrial water frontier. This shift has implications for how roads, pipes, treated water, electricity and public resources are planned and justified.

The concept of the resource frontier further helps to frame this transformation. As Bridge (2014) argues, frontiers are not simply empty, marginal or underdeveloped spaces awaiting investment, but are actively produced through state policy, infrastructure, capital and narratives of future growth. In this sense, Padang Terap can be understood as a new industrial frontier within Kedah's development geography. The district's value is being reimagined through its capacity to host rubber-based industrialisation and support regional economic restructuring. However, frontier development often obscures existing social and ecological relations. It tends to frame land, water and infrastructure as available inputs for growth, while local risks and long-term resource constraints receive less attention. This is why the concept of an industrial water frontier is useful for this article. It captures the way Padang Terap is being transformed from a rural water landscape into a site where water becomes a strategic input for industrial competitiveness.

At the same time, this article engages the literature on regional development and postcolonial infrastructure. In many postcolonial states, regional industrialisation is promoted as a way to overcome uneven development, create employment and attract foreign investment. However, development corridors and industrial parks often rely on centralised planning narratives that do not fully account for local ecological capacity. This problem becomes more serious when the region concerned already faces water-system fragility. In Kedah, industrial development is being pursued alongside wider infrastructure pressures, including non-revenue water, ageing distribution systems, treated-water reserve limitations and competing domestic, agricultural and industrial demands. The literature on postcolonial infrastructure is

therefore useful because it helps explain how states pursue modernisation through large projects while local water systems remain uneven, politically fragmented and technically vulnerable.

Despite these important contributions, the existing literature remains limited in three main ways. First, studies on industrial parks and eco-industrial development often focus on resource efficiency within industrial boundaries, but pay less attention to domestic water security outside the park. Second, water security studies frequently discuss scarcity, access and governance, but do not sufficiently analyse how new industrial parks transform upstream rural districts into water-dependent development frontiers. Third, political ecology and infrastructure studies have not yet adequately examined the specific condition of zero-reserve industrialisation, where resource-intensive industrial growth is pursued in a state water system that lacks sufficient treated-water reserve margins. This gap is significant for Malaysia because states such as Kedah are increasingly drawn into industrial and digital development strategies while their water infrastructure remains under stress.

This article addresses that gap by bringing the literature on political ecology, hydro social analysis, water security, eco-industrial parks and critical infrastructure studies into conversation with the empirical case of Padang Terap. It argues that Kedah Rubber City should not be analysed merely as a rubber industrial park or regional investment project. Rather, it should be understood as a water-dependent industrial infrastructure located within a state water system marked by limited reserve capacity. This framing allows the article to move beyond the descriptive question of whether KRC can attract investment and instead asks how industrial water demand is governed, justified and balanced against domestic water security. The article therefore contributes to the literature by introducing the concept of zero-reserve industrialisation.

Zero-reserve industrialisation refers to the pursuit of industrial development in a context where treated-water systems lack sufficient operational buffers to absorb new demand, climatic stress or infrastructure disruption (SPAN, 2024). This concept does not suggest that industrialisation should be rejected. Rather, it highlights the need to evaluate industrial growth through water-system resilience, domestic supply reliability and governance capacity. In the case of Padang Terap, KRC's industrial water requirement becomes significant not because it is exceptionally large in absolute terms, but because it enters a state water system where reserve margins have been reported as fragile. The concept therefore helps explain why industrial water demand cannot be treated as a neutral utility requirement. It is a political and ecological question involving priority, allocation, risk and responsibility.

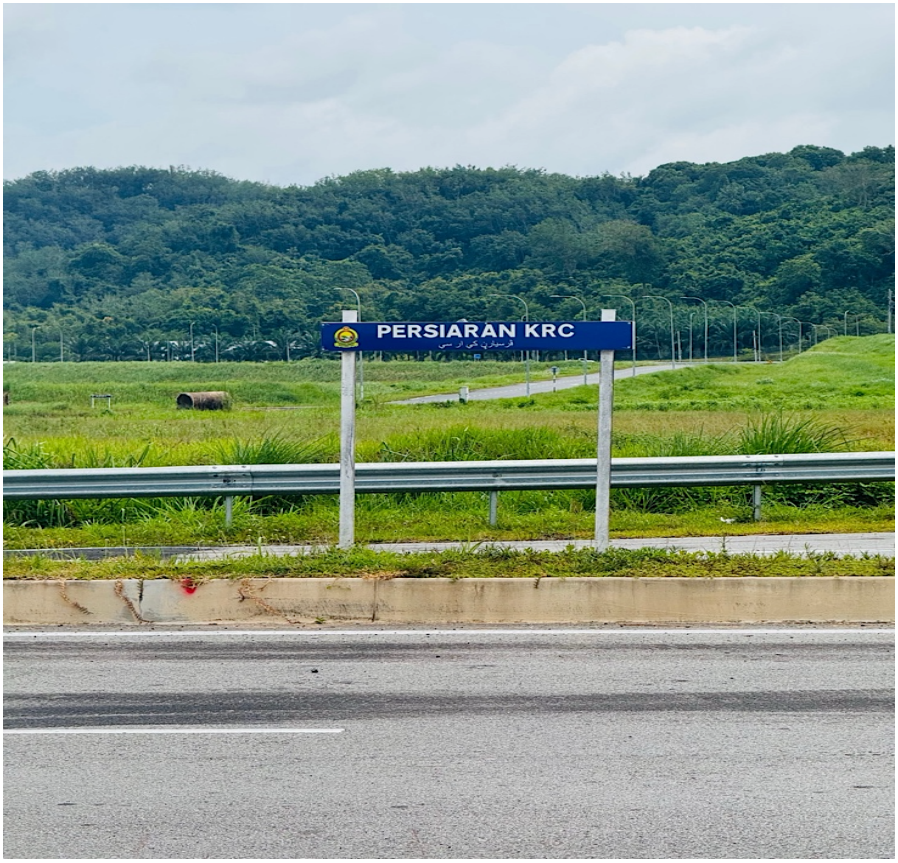
The article also contributes to wider debates on digital-industrial transformation. Although Padang Terap is not itself a data-centre site, its transformation must be situated within Kedah's broader development trajectory, where rubber-based industrialisation, border economic zones and AI-ready infrastructure are emerging in parallel. Existing debates on data centres and digital infrastructure often focus on the direct sites of computation. This article extends that discussion by showing that the effects of digital-industrial development may be distributed across wider water and infrastructure systems. Padang Terap is therefore important not because it hosts AI infrastructure, but because it reveals how peripheral and upstream districts are incorporated into wider circuits of industrial and digital growth through shared pressures on water, energy and infrastructure planning.

Taken together, these bodies of literature allow this article to make a clearer conceptual contribution. It argues that Kedah Rubber City should be understood as an industrial water frontier situated at the intersection of political ecology, hydrosocial relations, infrastructure studies, water security and regional development. The Malaysian case contributes to global debates by showing that industrialisation in water-fragile regions cannot be evaluated solely through investment value, employment creation or land availability. It must also be assessed through treated-water reserve margins, treatment capacity, distribution resilience, household protection and ecological sustainability. In doing so, this article moves beyond the

descriptive claim that industrial parks require water. It shows that in a zero-reserve context, industrial development produces a new governance problem: the struggle to reconcile regional industrial ambition with domestic water security.

Figure 4

Persiaran KRC in Kedah Rubber City, Padang Terap, Kedah



Persiaran KRC in Kedah Rubber City, Padang Terap, showing new road infrastructure embedded within the district's rural and forested landscape. (Source: Author's photograph)

RESEARCH METHODOLOGY

This study adopts a qualitative document-based research design to examine the relationship between Kedah Rubber City, industrial water demand, treated-water reserve capacity and domestic water security in Padang Terap, Kedah. The study is interpretative and critical in orientation because the issue cannot be adequately understood through technical indicators or investment data alone. It requires an integrated reading of policy documents, industrial planning materials, water-sector reports, infrastructure statements, academic literature and public development narratives. Methodologically, the study follows a structured document analysis protocol in which documents are treated not merely as factual repositories, but as institutional artefacts that reveal development priorities, regulatory assumptions, infrastructural dependencies and silences surrounding water security. This approach is consistent with qualitative document analysis, which enables researchers to systematically examine policy texts, institutional reports

and public documents as meaningful sources of social, political and environmental evidence (Bowen, 2009).

Data were gathered from four categories of sources. First, policy and institutional documents were selected from Malaysian government agencies and development institutions involved in regional planning, industrial investment, water governance and infrastructure provision, including NCER, NCIA, MIDA, SPAN, PAAB, *Syarikat Air Darul Aman* (SADA) and relevant Kedah state development materials. These documents were used to establish the official framing of Kedah Rubber City, its location in Padang Terap, its utility requirements and Kedah's broader water-sector condition. Second, peer-reviewed academic literature was selected to establish the conceptual basis for political ecology, hydrosocial analysis, water security, critical infrastructure studies, industrial water demand and resource-frontier development. Third, grey literature was included where it provided recent or otherwise unavailable information on Kedah's treated-water reserve margin, non-revenue water, industrial infrastructure, public utilities and regional development trajectories. Fourth, comparative international studies on industrial parks, eco-industrial development, water infrastructure and digital-industrial transformation were used to situate Padang Terap within wider global debates on resource-intensive development and domestic water security.

The selection process was guided by three criteria: relevance to Padang Terap, Kedah Rubber City, water infrastructure or industrial development; direct connection to Kedah, Malaysia, Southeast Asia or comparable industrial-water contexts; and evidential value, particularly where documents provided information on water demand, treated-water reserve, infrastructure capacity, institutional responsibility, planning priorities or sustainability claims. Documents that were purely promotional, lacked identifiable institutional authorship, or did not contain verifiable information on water, infrastructure, industrial demand or governance were excluded from the main empirical analysis. However, promotional investment materials were not rejected entirely where they provided official utility figures, project descriptions or institutional claims that could be cross read against other sources. Grey literature was not treated as equivalent to peer-reviewed scholarship but was used cautiously to capture fast-moving developments that have not yet appeared in academic publications. This is methodologically justified because grey literature can be valuable in policy and infrastructure studies where institutional and industry developments evolve more rapidly than peer-reviewed publication cycles, provided that the sources are selected and assessed systematically (Godin et al., 2015).

The analytical process involved four stages. First, all documents were classified according to source type, institutional origin, geographical focus and evidential function. This allowed the study to distinguish between official policy claims, investment-oriented narratives, technical water-sector data, media reporting and academic interpretation. Second, relevant data were extracted, including figures on KRC's industrial water requirement, Kedah's treated-water reserve margin, non-revenue water, infrastructure development, utility readiness, project location, and statements on domestic water security or industrial prioritisation. Third, the extracted materials were coded thematically using an iterative qualitative procedure. The main codes included industrial water demand, zero treated-water reserve, domestic water security, infrastructure readiness, upstream industrialisation, resource frontier, governance capacity, cumulative development pressure and water-allocation politics. Fourth, these themes were cross-examined across different source categories to identify convergence, contradiction and silence. For example, investment-oriented claims about KRC were compared with water-sector reports and public statements on Kedah's treated-water reserve condition to assess whether industrial development narratives sufficiently addressed domestic water-system resilience.

The study also applied triangulation to strengthen interpretative validity. Quantitative claims from official and media sources were not accepted in isolation, but were read against institutional documents, academic

literature and comparative studies on industrial water governance. For example, reports on Kedah's zero treated-water reserve margin were not treated as evidence of immediate domestic water collapse, but as indicators of limited operational buffer within the state water system. Thematic analysis was used not simply to summarise documents, but to identify patterns of meaning across institutional, ecological and political contexts. This follows established qualitative practice in which themes are developed through repeated reading, coding, comparison and refinement rather than imposed mechanically at the outset (Bowen, 2009). In addition, the cross-examination of policy texts, institutional statements and grey literature reflects the logic of structured document analysis in policy research, where documents are read not only for content but also for context, authorship, institutional purpose and political silence (Dalglish et al., 2020).

This article distinguishes between empirical evidence, reported figures, projections and author interpretation. Empirical evidence refers to data derived directly from policy documents, institutional reports, official project materials, peer-reviewed studies and government or regulatory statements. Reported figures refer to numerical claims appearing in official documents or reputable media sources, such as KRC's industrial water requirement or Kedah's treated-water reserve condition. Projections are treated as indicative future scenarios rather than confirmed outcomes, particularly where documents discuss expected industrial growth, employment creation, infrastructure completion or future reserve-margin targets. Author interpretation refers to the article's analytical reading of these materials through political ecology, hydrosocial analysis, critical infrastructure studies and water-security theory. This clarification prevents the conflation of measured data, reported data, future-oriented development claims and conceptual argument.

The study does not use primary interviews, household surveys or direct facility-level measurements of KRC's operational water use. It also does not claim to provide a hydraulic audit of Padang Terap's water distribution system or a technical assessment of SADA's daily operating capacity. This is acknowledged as a methodological limitation that restricts the empirical granularity of the study, particularly with regard to site-specific water withdrawal, treated-water allocation, pressure levels, seasonal variation and household experience of supply reliability. The article therefore does not claim that KRC has already reduced domestic water supply in Padang Terap. Instead, it analyses KRC as a water-dependent industrial infrastructure emerging within a state water system reported to have limited reserve capacity. In this sense, the absence of facility-level and household-level disclosure is treated cautiously as part of the evidential boundary of the study, rather than as a substitute for primary empirical data.

The contribution of the article lies in systematically synthesising available policy documents, institutional reports, water-sector data, peer-reviewed literature and verifiable grey literature to show how industrialisation in Padang Terap is being framed, justified and governed in relation to domestic water security. By reading KRC through the concept of zero-reserve industrialisation, the study moves beyond a descriptive account of industrial park development and asks how new industrial water demand enters a fragile treated-water system. This approach enables the article to connect local empirical realities in Kedah with wider global debates on political ecology, infrastructure, resource frontiers and the sustainability limits of investment-led development. The methodological strength of the study therefore lies not in producing a facility-level water audit, but in revealing the institutional, ecological and political conditions under which industrial growth becomes a domestic water-security question.

Figure 5

SADA Water-Supply Infrastructure Within Kedah Rubber City (KRC), Padang Terap

SADA water-supply infrastructure within Kedah Rubber City (KRC), Padang Terap, where industrial water readiness is projected at 20 MLD. (Source: Author's photograph)

FINDINGS AND DISCUSSION

Kedah's Zero Treated-Water Reserve and the Question of Domestic Water Security

To ensure conceptual and technical precision, this article distinguishes between raw-water availability, treated-water production and treated-water reserve margin. Raw-water availability refers to the presence of water in rivers, reservoirs, dams or groundwater sources before treatment. Treated-water production refers to the volume of water processed through water treatment plants and supplied into the distribution system. Treated-water reserve margin, however, refers to the surplus treated-water capacity available after existing demand has been met. This distinction is important because a state may have rivers, rainfall and raw-water sources, but still experience a treated-water reserve problem if treatment capacity, distribution networks, storage systems or pressure management are unable to keep pace with demand. In this article, million litres per day (MLD) is used where the discussion concerns water production, demand or system input volume, while percentage is used to refer to reserve margin and non-revenue water (NRW) (Alegre et al., 2006: SPAN, 2024).

Kedah provides a critical case for examining this distinction because the state's water problem is not simply one of natural water scarcity. Rather, it is a problem of treated-water capacity, infrastructure efficiency and domestic water security. According to SPAN's water-sector records, Kedah's treated-water reserve margin declined significantly over the late 2010s and early 2020s. The SPAN Water and Sewerage Fact Book

2021 show that Kedah's reserve margin fell from 8.3 per cent in 2017 and 2018 to 1.4 per cent in 2019, 0.5 per cent in 2020 and 0.0 per cent in 2021 (SPAN, 2021). The SPAN Water and Sewerage Fact Book 2022 similarly record Kedah's reserve margin at 0.0 per cent in 2022, confirming that the state had effectively reached a condition in which treated-water capacity no longer had a meaningful operational buffer (SPAN, 2022). However, the authors note a minor discrepancy between the 2021 and 2022 SPAN records, as Kedah's 2021 reserve margin is reported as 0.0 per cent in the 2021 Fact Book but 0.6 per cent in the 2022 Fact Book. This trend is significant because SPAN has generally treated a reserve margin of around 15 per cent as an important benchmark for system stability and future demand planning (New Straits Times, 2024).

Table 2

Kedah's Treated-Water Reserve Margin, 2017–2021, Declining From 8.3% In 2017–2018 To 1.4% In 2019, 0.5% In 2020 And 0.0% In 2021

Unit (%)	2017	2018	2019	2020	2021
Johor	15.4%	12.8%	7.8%	9.7%	14.3%
Kedah	8.3%	8.3%	1.4%	0.5%	0.0%
Kelantan	5.7%	5.0%	0.0%	0.0%	0.0%
F.T Labuan	30.1%	30.1%	24.6%	18.7%	17.1%
Melaka	19.7%	19.7%	15.8%	11.2%	7.5%
N.Sembilan	22.8%	23.0%	21.1%	20.0%	18.4%
Pulau Pinang	33.8%	33.8%	31.6%	30.7%	29.6%
Pahang	25.1%	25.1%	19.3%	14.2%	20.6%
Perak	28.8%	28.8%	28.1%	26.2%	26.7%
Perlis	2.1%	7.3%	1.9%	4.2%	0.0%
Selangor	0.0%	0.0%	0.0%	17.7%	17.4%
Terengganu	25.6%	27.1%	24.6%	23.6%	25.7%
Pen. Malaysia & F.T Labuan	13.9%	12.9%	11.0%	16.3%	16.8%

Source: Suruhanjaya Perkhidmatan Air Negara. (2021). Water and Sewerage Fact Book 2021. SPAN. https://www.span.gov.my/document/upload/wDC4eELu3ufaP3RCXb026ShRqJs4zjHO.pdf

Table 3

Kedah's Treated-Water Reserve Margin, 2018–2022, Declining From 8.3% In 2018 To 1.4% In 2019, 0.5% In 2020, 0.6% In 2021 And 0.0% In 2022.

Unit (%)	2018	2019	2020	2021	2022
Johor	12.8%	7.8%	9.7%	9.0%	11.5%
Kedah	8.3%	1.4%	0.5%	0.6%	0.0%
Kelantan	5.0%	0.0%	0.0%	0.0%	3.9%
F.T. Labuan	30.1%	24.6%	18.7%	19.5%	20.3%
Melaka	19.7%	15.8%	11.2%	7.5%	4.7%
N.Sembilan	23.0%	21.1%	20.0%	19.7%	19.1%
Pulau Pinang	33.8%	31.6%	30.7%	30.4%	26.4%
Pahang	25.1%	19.3%	14.2%	14.2%	17.3%
Perak	28.8%	28.1%	26.2%	26.1%	27.3%
Perlis	7.3%	1.9%	4.2%	1.5%	8.4%
Selangor	0.0%	0.0%	0.0%	17.4%	15.2%
Terengganu	27.1%	24.6%	23.6%	23.9%	31.8%
Pen. Malaysia & F.T. Labuan	12.9%	11.0%	16.3%	16.2%	15.7%

Source: Suruhanjaya Perkhidmatan Air Negara. (2022). Water and Sewerage Fact Book 2022. SPAN. https://www.span.gov.my/document/upload/Hb8Sv6cKhvUON85B2Lgde8ti7qAd6Pk0.pdf

A zero treated-water reserve margin does not mean that Kedah has no water at all. This point is crucial for avoiding analytical exaggeration. It means that the state's treated-water production and distribution capacity is operating very close to existing demand, leaving little room to absorb disruption, drought, pipe failure, treatment plant shutdown, industrial expansion or sudden demand increase. In other words, the issue is not the total absence of water, but the absence of spare treated-water capacity. This distinction was clearly reflected in the Kedah state government's own explanation in 2024, when it acknowledged that the state had zero treated-water reserve, while also stressing that Kedah still possessed water sources (The Edge, 2024). The problem, therefore, lies in the conversion of raw water into reliable, treated and distributable domestic supply.

This condition has direct implications for domestic water security. Water security cannot be reduced to the physical existence of rivers or reservoirs; it must also include reliability, accessibility, quality, pressure stability, resilience and institutional capacity to maintain household supply under stress (Cook & Bakker, 2012). When reserve margins are low, the water system becomes less resilient. Households may still receive water during normal conditions, but the system has limited capacity to withstand extraordinary stress. In such a setting, even a temporary disruption at a treatment plant, a pressure problem in the distribution network or a seasonal decline in raw-water availability can produce wider effects on users.

This is why Kedah's zero reserve margin must be understood not as a routine technical indicator, but as an early warning sign of domestic water vulnerability.

The seriousness of this condition is further reinforced by Kedah's high non-revenue water. NRW refers to treated water that has been produced and enters the supply system but is not billed to consumers because it is lost through leakage, pipe bursts, meter inaccuracies, illegal connections or other operational inefficiencies. The Edge Malaysia reported that Kedah had an NRW level of 51.5 per cent in 2022, meaning that more than half of the state's treated-water volume of 1,597 MLD was lost daily, while only 775 MLD was billed (The Edge, 2024). Another report in 2024 stated that Kedah's NRW was 57 per cent in 2023, including Langkawi, and that a 15-year NRW mitigation project had begun in January 2023 with the aim of reducing NRW by about two per cent annually (KLSE Screener, 2024). This is important because NRW weakens the relationship between production capacity and actual household benefit. A state may produce a large volume of treated water, but if half of it is lost before reaching paying users, domestic water security remains fragile.

This condition also complicates the meaning of new water infrastructure. The Kedah state government announced that treated-water reserves were expected to reach 15 per cent or more once five water treatment plant upgrading projects were completed. These projects include LRA Pelubang in Kubang Pasu, LRA Lubuk Buntar Lama in Bandar Baharu, LRA Sungai Limau in Baling, LRA Jenun Baru in Pendang and LRA Bukit Selambau in Kuala Muda (KLSE Screener, 2024). On the surface, these projects appear to offer a technical solution to the reserve problem. However, from a political ecology perspective, the issue is not merely whether more treatment capacity is built. The more important question is whether new capacity will be sufficient to overcome accumulated weaknesses in distribution, pressure management, NRW, financing, maintenance and future demand. If new capacity is immediately absorbed by existing losses or new industrial consumption, the domestic reserve problem may persist.

The Kedah case therefore reveals the limits of treating water reserve as a purely engineering issue. Reserve margin is also a political and developmental indicator. It reflects the ability of the state to plan ahead, finance infrastructure, regulate demand, reduce losses and prioritise household users. In 2025, Bernama reported that Kedah's water infrastructure problem had become politically contentious, especially in relation to delayed upgrading works at the Bukit Selambau Water Treatment Plant in Sungai Petani. The report noted that the project had entered a third extension of time and risked becoming a "white elephant", highlighting how treated-water infrastructure in Kedah has become a site of public concern, political scrutiny and development uncertainty (Bernama, 2025). This institutional arrangement shows that domestic water security in Kedah is shaped not only by hydrology, but also by federal–state relations, infrastructure funding, project delivery and regulatory oversight.

This is the context in which Padang Terap and Kedah Rubber City must be situated. Before discussing industrial water demand, it is necessary to recognise that Kedah is not entering a new phase of industrialisation from a position of abundant treated-water reserve. Instead, it is pursuing new development ambitions in a water system that has already been identified as having little or no operational buffer. This does not mean that every industrial project will automatically threaten domestic users. Such a claim would require site-level evidence. However, it does mean that additional water demand, especially from industrial parks, must be evaluated against the state's reserve margin, NRW, infrastructure readiness and household supply resilience.

Thus, Kedah's zero treated-water reserve is not merely background information. It is the central water-security condition that frames the politics of industrial development in Padang Terap. In a high-reserve system, industrial water demand can be treated as a manageable utility requirement. In a zero-reserve system, the same demand becomes a question of allocation, priority and risk. The issue is not only whether

Kedah has water, but whether it has sufficient treated, distributable and resilient water capacity to support both domestic users and new industrial ambitions. This is why the notion of zero-reserve industrialisation is analytically useful. It captures the condition in which industrial growth proceeds in a state water system that has not yet secured a stable domestic water buffer.

Figure 6

SADA Water-Supply Infrastructure Within Kedah Rubber City (KRC), Padang Terap, With Platform-Level Works in Progress at Sectional Completion.

Source: Northern Corridor Implementation Authority. (n.d.). Kedah Rubber City (KRC). Northern Corridor Economic Region. Northern Corridor Implementation Authority. https://www.ncer.com.my/invest-in-ncer/thematic-industrial-parks/kedah-rubber-city-krc

Padang Terap as an Upstream Industrial Water Frontier

To understand the significance of Kedah Rubber City, this article positions Padang Terap not merely as an administrative district, but as an emerging upstream industrial water frontier. The term "frontier" is used here not to describe an empty or undeveloped space, but to capture the process through which a rural and upstream district is reimagined as a strategic zone for industrial expansion. In conventional development narratives, frontiers are often presented as spaces of opportunity, land availability and future investment. However, from a political ecology perspective, frontiers are produced through state policy, infrastructure provision, investment promotion and the conversion of local resources into economic inputs (Bridge, 2014). In this sense, Padang Terap is not passively receiving development. It is being actively repositioned within Kedah's wider industrial geography through Kedah Rubber City.

Padang Terap has historically occupied a different place in Kedah's development imagination compared with urban-industrial districts such as Kulim, Kuala Muda or Kota Setar. It is commonly associated with rural settlements, upstream landscapes, forested areas, agricultural activity and its hinterland relationship to northern Kedah (Majlis Daerah Padang Terap, 2022: Muhammad Yusoff, Mohd Rosli & Hussain, 2022). The establishment of Kedah Rubber City changes this spatial meaning. Official investment materials

identify KRC as Malaysia's first dedicated rubber industrial park located in Padang Terap, Kedah, with a total area of approximately 1,243.70 acres, or about 503 hectares (MIDA, 2022). NCER's official profile similarly presents KRC as Malaysia's first dedicated Rubber Industrial Park and lists its readiness in terms of electricity, industrial water, gas and telecommunications (NCER, n.d.). These descriptions are important because they show that Padang Terap is no longer framed only as a rural district. It is being inserted into a national and regional industrial strategy.

The industrial character of KRC is not limited to general manufacturing. It is specifically designed around the rubber value chain, including upstream, midstream and downstream rubber-based industries. This is significant because Malaysia has long occupied an important position in the global rubber economy, particularly in latex products, medical gloves, rubber goods and related manufacturing. KRC is therefore promoted not as an isolated district project, but as a high-impact strategic initiative intended to strengthen Malaysia's rubber industry and connect Kedah to wider regional production networks. The MIDA investment presentation describes KRC as a high-impact strategic national project and refers to it as Malaysia's first dedicated rubber eco-industrial park in Padang Terap (MIDA, 2022). This official framing gives Padang Terap a new economic identity: it becomes a site where rubber, land, labour, infrastructure and utilities are reorganised for industrial competitiveness.

However, the transformation of Padang Terap into an industrial frontier is also a transformation of its water relations. KRC's official utility profile lists industrial water at 20 MLD, while the MIDA presentation indicates 20 MLD per day for Phase 1 and a total of 40 MLD per day when the wider phasing is taken into account (NCER, n.d.: MIDA, 2022). This figure is important not because it automatically indicates crisis, but because it marks the entry of industrial-scale water demand into a district historically understood through rural and upstream functions. Water in Padang Terap is therefore no longer only connected to household consumption, small-scale settlement, agriculture or ecological flows. It is being recoded as a production input that supports industrial clustering, investor readiness and rubber-sector upgrading (Abdullah, 2019).

This recoding of water is central to the concept of an industrial water frontier. In an industrial frontier, water is not simply present as a natural resource. It is transformed into a planned utility through treatment plants, pipelines, reservoirs, pumping systems, industrial zoning and institutional coordination (Kaika, 2004). The political question is therefore not only whether Padang Terap has sufficient raw-water sources, but how those sources are converted into reliable treated water for industry, and how such conversion affects the wider ordering of local infrastructure. This issue was already visible in 2021, when the Kedah government reportedly established a task force to expedite power and water supply to KRC. The same report stated that the Menteri Besar had sought assistance from the Rural Development Ministry for a proposed new water treatment plant in Kuala Nerang to supply water to KRC and had asked the state Economic Planning Unit to discuss the matter with SADA (New Straits Times, 2021). Such a report is analytically significant because it shows that water was not a secondary issue. It was part of the basic infrastructural condition for making KRC possible.

The emphasis on utility readiness also reveals how industrial development reorganises institutional responsibility. KRC depends not only on land acquisition and investor attraction, but also on coordination among NCER, NCIA, MIDA, the Kedah state government, SADA, and potentially federal ministries or agencies involved in infrastructure funding. This multi-institutional arrangement is typical of frontier development. A rural district becomes investable only when its infrastructure is assembled through different layers of authority. In such a context, water infrastructure becomes part of the political machinery of industrialisation. It is used to signal readiness to investors, reduce perceived risk and accelerate industrial

occupation. At the same time, it raises questions about how local domestic needs, future district growth and environmental limits are incorporated into planning.

Figure 7

Tenaga Nasional Berhad (TNB)-Related Electricity Infrastructure Serving Kedah Rubber City (KRC), Padang Terap, Where Electricity Readiness Is Listed At 79 MVA.

Source: Northern Corridor Implementation Authority. (n.d.). Kedah Rubber City (KRC). Northern Corridor Economic Region. Northern Corridor Implementation Authority. https://www.ncer.com.my/invest-in-ncer/thematic-industrial-parks/kedah-rubber-city-krc

The economic narrative surrounding KRC reinforces this frontier logic. Bernama reported in 2026 that the development of KRC was expected to bring broad economic benefits to local residents in Padang Terap, including opportunities linked to employment, business activity and local economic spillover (Bernama, 2026). Earlier reports also stated that KRC had attracted committed investment and was expected to generate thousands of job opportunities (New Straits Times, 2022). These claims are important because they represent the promise through which industrial frontiers are legitimised. Development is framed as a means to reduce rural marginality, create employment and integrate peripheral districts into wider circuits of growth. However, such claims also need to be evaluated alongside the material conditions that make the promise possible, especially water, energy and infrastructure.

From the perspective of political ecology, this is where the tension emerges. The promise of industrial growth often foregrounds jobs, investment and regional upgrading, while the resource conditions of such growth remain less visible (Peet, Robbins & Watts, 2011). KRC's water requirement is listed as a utility figure, but a utility figure is not politically neutral. It signals that a specific volume of treated or industrial water must be secured, transported and maintained for productive use. Once this happens, Padang Terap's water landscape becomes part of an industrial calculation. The district is valued not only for its location or land, but for its capacity to support water-dependent manufacturing. This does not mean that KRC should be rejected as development. Rather, it means that the project should be analysed as an infrastructure-intensive transformation of an upstream district.

The term "upstream" is important in this analysis because upstream districts occupy a sensitive position within water governance. They are often treated as source regions, catchment spaces or peripheral development zones, but their ecological functions are rarely given the same policy visibility as downstream industrial or urban demand. When an upstream district such as Padang Terap becomes an industrial site, the boundary between source landscape and consumption landscape becomes blurred. The district is no longer only part of the background ecology that supports wider Kedah. It becomes a direct site of industrial water consumption. This is a major shift in the hydrosocial meaning of Padang Terap (Majlis Daerah Padang Terap, 2022: Bakker, 2010).

Therefore, Padang Terap's importance lies not simply in the presence of Kedah Rubber City, but in what KRC reveals about the changing geography of development in Kedah. The district is being repositioned from rural hinterland to industrial frontier, from upstream landscape to water-dependent production zone, and from peripheral district to strategic investment site. This transformation must be analysed beyond the language of investment readiness. It requires attention to the infrastructures that make industrialisation possible and the water relations that such infrastructures reorganise. In this sense, Padang Terap provides a crucial empirical lens for understanding how industrialisation enters upstream regions and converts domestic, ecological and rural water landscapes into strategic inputs for regional economic growth.

Kedah Rubber City and the Politics of Industrial Water Demand

To ensure analytical precision, this article treats industrial water demand not merely as a technical requirement, but as a political and institutional question. Industrial water demand refers to the volume of water required to support manufacturing processes, worker facilities, cooling, cleaning, sanitation, environmental compliance and the wider operation of an industrial ecosystem. In official investment documents, water is usually presented as part of utility readiness, alongside electricity, gas, roads and telecommunications. However, this language can obscure the fact that every allocation of industrial water involves a wider set of decisions about priority, infrastructure financing, distribution capacity and the protection of domestic users. In this sense, industrial water demand is not only about how much water is required. It is also about who secures water first, who pays for the infrastructure, who manages operational risks and how public water systems are reorganised to serve investment-led development (SPAN, 2025).

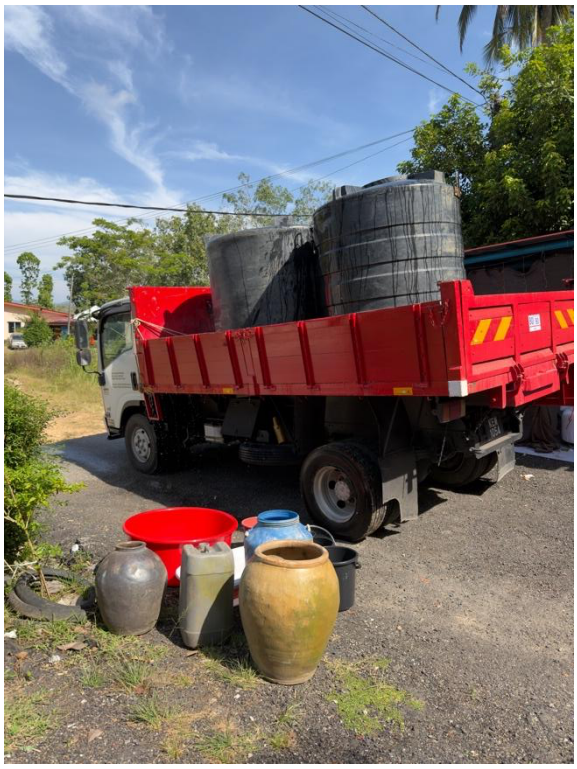
KRC provides an important case for examining this politics of industrial water demand. Official NCER materials list KRC's industrial water requirement at 20 MLD, while MIDA's investment presentation indicates 20 MLD per day for Phase 1 and up to 40 MLD per day when the wider phasing is considered (NCER, n.d.: MIDA, 2022). These figures should not be read simply as neutral engineering data. They are part of an investment narrative that signals to potential investors that KRC has, or is expected to have, sufficient utility capacity to support rubber-based industrial activities. From a development planning perspective, such figures demonstrate readiness. From a water-governance perspective, however, they raise the question of how industrial demand is translated into actual treated-water supply and how that supply is balanced against other users within Kedah's water system.

The political character of this demand becomes clearer when KRC is examined as a strategic national project rather than a local industrial site alone. The MIDA/NCER presentation frames KRC as a high-impact strategic national project designed to position Kedah as a regional high-value rubber industrial hub in ASEAN, with projected private investment of RM10 billion and job creation targets of around 14,500 by 2030 (MIDA, 2022). These figures show why water becomes politically sensitive. When an industrial project is framed as a national growth engine, the provision of water is no longer treated as ordinary public utility management. It becomes part of the state's obligation to make investment possible.

This is where the politics of industrial water demand emerges most clearly. KRC's water requirement is not an isolated request by a single factory. It represents a clustered industrial demand attached to national development goals, cross-border rubber value chains and regional competitiveness. The Invest Kedah profile describes KRC as a project that will form part of a "Rubber Corridor" linking major rubber producers in the Indonesia-Malaysia-Thailand Growth Triangle (IMT-GT) (Invest Kedah, n.d.). This means that water demand in Padang Terap is connected to a wider regional production strategy. Water is therefore transformed into an enabling condition for internationalised industrial integration. The local water system becomes tied to external investment expectations, export-oriented production and the politics of Malaysia's position in the rubber economy.

Figure 8

Domestic Water-Supply Vulnerability in Bukit Tembaga, Padang Terap, Kedah



Domestic water-supply vulnerability in Bukit Tembaga, Padang Terap, Kedah, situated within a district that continues to experience significant water-supply disruptions; in November 2024, about 5,000 consumer accounts in Padang Terap were affected following the temporary shutdown of water treatment plants.

Source: Author's photograph: Bernama. (2024). 5,000 akaun pengguna hadapi gangguan air akibat banjir. Bernama. https://bernama.com/bm/news.php?id=2369245

The 2021 reporting on KRC's utility readiness demonstrates that water supply was already understood as a critical bottleneck. Bernama reported that the Kedah government wanted utilities, including electricity and water, at the KRC site in Padang Terap to be ready within one year to meet investor needs (Bernama, 2021). New Straits Times similarly reported that the state government established a task force to expedite power and water supply to KRC, and that discussions involved state and federal agencies, including the possibility of a new water treatment plant in Kuala Nerang to supply the project (New Straits Times, 2021). These reports are important because they reveal the political urgency attached to industrial utility provision.

Water was not presented as a future environmental concern, but as an immediate condition for investor confidence and project implementation.

This urgency creates an important governance question. If water infrastructure is accelerated to meet industrial timelines, how are domestic timelines, rural service improvements and long-term system resilience incorporated into the same planning process? Industrial projects often operate according to compressed investment schedules, whereas water infrastructure requires long-term planning, land acquisition, financing, treatment capacity, distribution networks and maintenance. The difference between these timelines can generate governance tension. Investors require certainty and speed, but domestic water security requires caution, redundancy and resilience. In this sense, KRC illustrates a wider problem in development governance: industrial water demand often arrives as a promise of future growth, while the risks of infrastructure pressure are distributed through public systems (Bernama, 2024).

The politics of water demand is also visible in the language of development benefit. KRC is repeatedly described as a project that will generate employment, entrepreneurship opportunities and local economic spillovers for Padang Terap and the northern region (Bernama, 2026). These benefits should not be dismissed. For a district historically positioned outside Kedah's main industrial corridor, the promise of jobs and business opportunities is socially significant. However, a political ecology approach requires that these benefits be read together with their resource conditions. Industrial employment is not produced by land alone (Bridge, 2014). It depends on continuous flows of treated water, electricity, roads, waste systems and institutional support. The central analytical question is therefore whether the benefits of industrialisation are matched by transparent accounting of water demand, infrastructure cost and domestic supply safeguards.

This issue becomes especially important because water allocation is often less visible than land allocation or investment approval. When land is designated for industrial use, the decision is visible through planning maps, project launches and investment announcements. When water is allocated to industry, the decision is dispersed through treatment capacity, pipelines, pumping systems, operational agreements and daily distribution management. This makes industrial water politics harder to observe. The public may see the industrial park, but not necessarily the infrastructural adjustments required to sustain it. KRC's industrial water requirement should therefore be treated as an entry point for examining hidden water allocation, not merely as a utility specification.

Therefore, the politics of industrial water demand in KRC lies in the relationship between promise, priority and risk. The promise is regional industrial upgrading, employment and rubber-sector transformation. The priority is the provision of water and power to secure investor confidence. The risk is that water infrastructure may be evaluated mainly through industrial readiness rather than domestic resilience. This article does not argue that KRC has already displaced household water supply in Padang Terap. Such a claim would require facility-level and household-level evidence. Instead, it argues that KRC creates a new water-governance problem because its industrial water demand must be reconciled with the public responsibility to maintain reliable domestic supply. In this sense, KRC reveals that industrial water demand is never merely industrial. It is a political question about how development priorities are materially organised through water.

Cumulative Water Pressure in Kedah's Industrial-Digital Transformation

To ensure analytical precision, this article distinguishes between site-specific water demand and cumulative regional water pressure. Site-specific water demand refers to the volume of water required by

a particular project, facility or industrial park. Cumulative regional water pressure, however, refers to the broader stress created when multiple forms of development expand within the same state water system, even when they are located in different districts. This distinction is important because the hydrological effect of development is rarely confined to a single project boundary (Daly, 1992: International Finance Corporation, 2013). A rubber industrial park in Padang Terap, a data centre in Bukit Kayu Hitam, manufacturing activity in Kulim and new water-treatment infrastructure may appear as separate projects in policy documents. Yet, from the perspective of water governance, they are connected through shared treatment capacity, raw-water planning, distribution networks, electricity systems, financing arrangements and state-wide development priorities.

Figure 9

SMK Padang Terap, Kuala Nerang, Located Near KRC

SMK Padang Terap, Kuala Nerang, located near KRC, illustrating the proximity between local community institutions and the district's emerging industrial development frontier. (Source: Author's photograph)

Kedah's current transformation must therefore be understood as more than the development of Kedah Rubber City alone. The state is increasingly being repositioned as part of a northern industrial-digital corridor that combines traditional industrial strengths, border trade, high-technology infrastructure and digital connectivity. Open DC's D8-1 Data Centre in Bukit Kayu Hitam illustrates this shift. Its official profile identifies the facility as located in Kedah, with a total data centre size of 47,000 square feet in Phase 1, 40,000 square feet of available floor space, an 11kV power system of 5MW that is upgradable to 33kV and 20MW, a chilled water cooling system, and a target Power Usage Effectiveness below 1.5 (Open DC, n.d.). These specifications show that Kedah's development geography is no longer limited to agriculture, logistics or conventional manufacturing. It is moving into the domain of digital infrastructure, where electricity, cooling, telecommunications and reliable utility systems become central to regional competitiveness.

This digital turn is also explicitly connected to AI and power-intensive workloads. Open DC states that its next-generation data centre in Delapan SBEZ is designed to meet the increasing demands of artificial intelligence and power-intensive workloads. This statement is important because AI-ready infrastructure introduces a different form of resource pressure compared with ordinary commercial buildings. Data centres require continuous energy, redundant systems, thermal management, cooling technology and high reliability. Even where direct water-use figures are not publicly disclosed, the presence of chilled water systems indicates that cooling becomes a central infrastructure question. The point here is not to claim that the D8-1 Data Centre directly competes with Padang Terap for the same water source. Rather, it shows that Kedah is entering a development model in which utility-intensive projects become increasingly important across multiple districts (Open DC, n.d.: Open DC, 2024).

The emergence of Delapan SBEZ reinforces this cumulative logic. Delapan presents itself as a strategic border economic zone at the confluence of Malaysia and Thailand, designed to combine trade, connectivity, investment and modern innovation (Delapan, n.d.). Reports on Delapan describe it as a critical hub for cross-border trade and digital infrastructure in northern Malaysia (Delapan, 2024). This matters because border economic zones do not function only as land-development projects. They require roads, electricity, telecommunications, water supply, wastewater management, worker accommodation, logistics systems and supporting services. Once Kedah promotes Delapan as a digital and cross-border investment hub, the state's infrastructure system must accommodate not only existing domestic demand, but also new industrial and digital loads distributed across the northern corridor.

At the same time, Kedah's southeastern industrial geography continues to develop through Kulim and its surrounding districts. Kulim has long been associated with high-technology and manufacturing activity, and water-infrastructure planning in the district demonstrates how industrial growth requires large-scale utility support. SADA has listed the construction of the Sungai Karangan Water Treatment Plant Phase 1, with a capacity of 150 MLD, as a project for supply adequacy in the Kulim distribution area, scheduled from 2024 to 2029 (SADA, 2025). PAAB's project update similarly states that the Sungai Karangan WTP will have a capacity of 150 MLD and will include raw-water pipelines, treated-water pipelines to balancing reservoirs and 70 km of distribution pipelines serving Kulim Hi-Tech, Merbau Pulas, Padang Meha, Serdang and Padang Terap (PAAB, 2025). This is significant because it demonstrates that Kedah's water infrastructure is being planned through regional distribution systems rather than isolated district boundaries.

The inclusion of Padang Terap within such distribution language is analytically important. It shows that Padang Terap's future water security cannot be analysed only through local demand. It is increasingly connected to wider inter-district planning that includes industrial and growth areas elsewhere in Kedah. When a 150 MLD treatment plant is described as serving multiple areas, including industrial zones and Padang Terap, the water question becomes regional (PAAB, 2025). The central issue is not whether a single project alone will exhaust water capacity, but whether the combined demand from industrial parks, high-tech zones, data centres, border economic zones and domestic users can be accommodated without weakening resilience. This is the meaning of cumulative pressure.

This cumulative pressure is also temporal. Industrial and digital projects do not all reach full operation at the same time. Some require immediate utility readiness to attract investors; others are phased over several years. Water-treatment projects, meanwhile, may be scheduled for completion much later than investment announcements. This temporal mismatch creates planning risk. For example, if digital facilities, industrial parks and manufacturing clusters expand before new treatment and distribution systems are fully operational, the burden on existing infrastructure may increase. Conversely, if water infrastructure is completed but demand grows faster than projected, reserve capacity may again be absorbed. Therefore,

cumulative water pressure must be analysed not only spatially across districts, but also temporally across project phases, construction schedules and demand growth.

The Kedah case also illustrates how digital and industrial transformation can redistribute environmental pressures beyond the most visible project sites. Public debate often focuses on the immediate location of an industrial park or data centre. However, water, electricity and infrastructure networks operate across wider territories. A data centre in Bukit Kayu Hitam may shape utility priorities for the northern corridor. Industrial expansion in Kulim may justify new water-treatment investment. KRC may reposition Padang Terap as part of an industrial water landscape. Together, these developments create a state-wide pattern in which water becomes a shared enabling resource for multiple growth agendas. This is why Padang Terap remains relevant to Kedah's digital-industrial turn even though it is not itself a data-centre site (Open DC, n.d.: Open DC, 2024).

From a political ecology perspective, cumulative water pressure is important because it challenges project-by-project assessment. If each development is evaluated separately, its water demand may appear manageable. However, when multiple projects are placed within the same hydrological and infrastructural system, their combined effect becomes more significant (Bridge, 2014). This is especially true in regions where water infrastructure must serve households, industries, agriculture, commercial users and ecological functions simultaneously. The risk is that development planning may celebrate each project as evidence of investment success while underestimating the aggregate demand placed on public water systems. In such a situation, domestic users may not be directly displaced by any single project, but they may become more exposed to pressure loss, supply interruptions or reduced system flexibility when cumulative demand increases.

Therefore, the transformation of Kedah should be read as a multi-sited industrial-digital process. Padang Terap, Bukit Kayu Hitam, Kulim and other growth zones represent different but connected nodes in a state-wide development system. KRC illustrates rubber-based industrialisation; D8-1 represents AI-ready digital infrastructure; Kulim reflects high-technology and manufacturing concentration; and new treatment plants show the infrastructural response required to support growth. The analytical contribution of this article is to show that water pressure does not emerge only where a project is physically located. It emerges through networks, priorities and cumulative demand. In this sense, zero-reserve industrialisation is not only a Padang Terap issue. It is a broader governance condition in which Kedah's industrial and digital ambitions must be reconciled with the capacity, timing and resilience of its water infrastructure.

CONCLUSION

This article has argued that the development of Kedah Rubber City in Padang Terap should not be understood merely as a regional industrial project or a conventional investment initiative. Rather, it represents a critical case of zero-reserve industrialisation, where industrial expansion is pursued within a state water system already marked by limited treated-water reserve capacity. By foregrounding Padang Terap, the article demonstrates that the politics of water does not emerge only in large cities, downstream industrial corridors or visible sites of digital infrastructure. It can also take shape in upstream and peripheral districts when new industrial projects transform water from a domestic and rural resource into a strategic input for production, competitiveness and regional restructuring.

The central contribution of this article lies in showing that KRC's industrial water demand cannot be treated as a neutral utility requirement. In a high-reserve water system, a projected industrial requirement may be

absorbed through existing buffers, planned infrastructure and operational flexibility. In Kedah's case, however, the reported zero treated-water reserve margin changes the meaning of industrial water demand. It raises questions of priority, allocation, infrastructure timing, distribution resilience and domestic protection. The issue is therefore not whether industrialisation should be rejected, but whether industrial growth can be governed in a way that safeguards household water security while meeting legitimate economic development goals.

The article has also shown that Padang Terap's significance extends beyond its physical location. Although the district is not a data-centre site, it is increasingly implicated in Kedah's wider industrial-digital transformation. KRC in Padang Terap, AI-ready infrastructure in Delapan SBEZ, high-technology activity in Kulim and new water-treatment projects together reveal a broader pattern of cumulative development pressure. This demonstrates that water stress should not be analysed project by project alone. Instead, it must be examined through the regional systems that connect treatment capacity, pipelines, energy demand, investment timelines and inter-district infrastructure planning.

Conceptually, the article contributes to political ecology, water security and infrastructure studies by introducing zero-reserve industrialisation as an analytical framework. This concept explains how development ambitions become ecologically and politically sensitive when they enter water systems with little operational buffer. It also challenges investment-led narratives that assess industrial parks mainly through land availability, employment creation and capital inflow. In water-fragile regions, development must also be evaluated through treated-water reserve margins, non-revenue water, treatment capacity, distribution reliability and the protection of domestic users. Ultimately, the Padang Terap case demonstrates that the sustainability of industrialisation depends not only on attracting investors, but on the capacity of public water systems to absorb growth without transferring risk to households. For Malaysia and other postcolonial developing states, the lesson is clear: industrial and digital ambition must be reconciled with water sovereignty, infrastructural resilience and domestic water security.

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REFERENCES

Abdullah, M. F. (2019). *Pembangunan Bekalan Air Domestik di Negeri Kedah, 1957-1992*. Doctoral dissertation, Universiti Malaya.

Anand, N. (2017). *Hydraulic city: Water and the infrastructures of citizenship in Mumbai*. Duke University Press

Alegre, H., Hirner, W., Baptista, J. M., & Parena, R. (2006). *Performance indicators for water supply services (2nd ed.).* IWA Publishing.

Aussel, D., Cao Van, K., & Salas, D. (2022). *Optimal design of exchange water networks with control inputs in eco-industrial parks*. arXiv.

Bakker, K. (2010). *Privatizing water: Governance failure and the world's urban water crisis*. Cornell University Press.

Bernama. (2021). State hopes supply of electricity and water in Kedah Rubber City can be ready in one year. *Bernama.* https://www.bernama.com/en//news.php?id=2010614

Bernama. (2024). 5,000 akaun pengguna hadapi gangguan air akibat banjir. *Bernama.* https://bernama.com/bm/news.php?id=2369245

Bernama. (2025). Bukit Selambau water project risks becoming "white elephant" – Bau Wong. *Bernama.* https://www.bernama.com/en/general/news.php?id=2489490

Bernama. (2026). Kedah Rubber City to bring broad economic benefits to local residents – Mahdzir. *Bernama.* https://www.bernama.com/en/general/news.php?id=2522467

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27–40.

Bridge, G. (2014). Resource geographies II: The resource-state nexus. *Progress in Human Geography, 38*(1), 118–130.

Carse, A. (2012). Nature as infrastructure: Making and managing the Panama Canal watershed. *Social Studies of Science, 42*(4), 539–563.

Cook, C., & Bakker, K. (2012). Water security: Debating an emerging paradigm. *Global Environmental Change, 22*(1), 94–102.

Daly, M. E. (1992). *Industrial development and Irish national identity, 1922-1939*. Syracuse University Press.

Dalglish, S. L., Khalid, H., & McMahon, S. A. (2020). Document analysis in health policy research: The READ approach. *Health Policy and Planning, 35*(10), 1424–1431.

Delapan. (n.d.). Delapan Special Border Economic Zone. *Delapan.* https://delapan.my/

Delapan. (2024). Delapan: Transforming Northern Malaysia into a strategic economic hub. *Delapan.* https://delapan.my/delapan-transforming-northern-malaysia-into-a-strategic-economic-hub/

International Finance Corporation. (2013). *Good practice handbook: Cumulative impact assessment* and management: Guidance for the private sector in emerging markets. *World Bank Group.* https://www.ifc.org/content/dam/ifc/doc/mgrt/ifc-goodpracticehandbook-cumulativeimpactassessment.pdf

Invest Kedah. (n.d.). *Kedah Rubber City*. *Invest Kedah.* https://www.investkedah.com/kedah-rubber-city/

Kaika, M. (2004). *City of flows: Modernity, nature, and the city*. Routledge.

KLSE Screener. (2024). Kedah treated water reserves to reach 15% by 2026, says exco member. *KLSE Screener.* https://www.klsescreener.com/v2/news/view/1290281/kedah-treated-water-reserves-to-reach-15-by-2026-says-exco-member

Kollar, J., & Stokols, A. (2026). Geopolitical ecologies of cloud capitalism: Territorial restructuring and the making of national computing power in the US and China. *Environment and Planning A: Economy and Space*, *58*(1), 38-58.

Larkin, B. (2013). The politics and poetics of infrastructure. *Annual Review of Anthropology, 42*, 327–343.

Li, B., Yang, Z., & Xu, X. (2019). Examining China's water pressure from industrialization driven by consumption and export during 2002–2015. *Journal of Cleaner Production*, *229*, 818-827.

Linton, J., & Budds, J. (2014). The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum*, 57, 170–180.

Majlis Daerah Padang Terap. (2022). Profil daerah Padang Terap. *Portal Rasmi Pejabat Daerah dan Tanah Negeri Kedah. Kerajaan Negeri Kedah.* https://webpdt.kedah.gov.my/profil-5/

Malaysian Investment Development Authority. (2022). *Kedah Invest Series: Unfolding State Business Potential — Northern Corridor Economic Region / Kedah Rubber City*. *MIDA*. https://www.mida.gov.my/wp-content/uploads/2022/09/FINAL_Kedah-Invest-Series-Unfolding-State-Business-Potential_220922_NCER-DECK.pdf

Malaysian Investment Development Authority. (2025, January 4). *Riding the data centre wave*. *Malaysian Investment Development Authority.* https://www.mida.gov.my/mida-news/riding-the-data-centre-wave-2/

Martin, S. A., Weitz, K. A., Cushman, R. A., Sharma, A., Lindrooth, R. C., & Moran, S. R. (1996). *Eco-industrial parks: A case study and analysis of economic, environmental, technical, and regulatory issues*. Research Triangle Institute.

Muhammad Yusoff, N. H., Mohd Rosli, M. K. A. & Hussain. (2022). Perkembangan Pengeluaran Getah di Negeri Kedah, 1970-1990. *SEJARAH: Journal of the Department of History, 31*(2), 142-162.

Northern Corridor Implementation Authority. (n.d.). *Kedah Rubber City (KRC)*. Northern Corridor Economic Region. *Northern Corridor Implementation Authority*. https://www.ncer.com.my/invest-in-ncer/thematic-industrial-parks/kedah-rubber-city-krc

Northern Corridor Economic Region. (n.d.). *Thematic industrial parks: Kedah Rubber City (KRC)*. NCER Malaysia. https://www.ncer.com.my/invest-in-ncer/thematic-industrial-parks/kedah-rubber-city-krc

New Straits Times. (2021). Task force to expedite power and water supply to Kedah Rubber City. *New Straits Times*. https://www.nst.com.my/news/nation/2021/10/733844/task-force-expedite-power-and-water-supply-kedah-rubber-city

New Straits Times. (2022). Kedah Rubber City to create 15,000 jobs by 2025, says PM Ismail Sabri. *New Straits Times*. https://www.nst.com.my/news/nation/2022/02/769396/kedah-rubber-city-create-15000-jobs-2025-says-pm-ismail-sabri

New Straits Times. (2024). Zero water reserve margin in Kedah. *New Straits Times*. https://www.nst.com.my/news/nation/2024/01/1002279/zero-water-reserve-margin-kedah

O'Dwyer, E., Chen, K., Wang, H., Wang, A., Shah, N., & Guo, M. (2020). *Optimisation of wastewater treatment strategies in eco-industrial parks: Technology, location and transport*. *arXiv*. https://arxiv.org/abs/2005.09987

Open DC. (n.d.). *D8-1 Data Centre*. *Open DC.* https://www.opendc.my/data-centre/d8-1/

Open DC. (2024, September 2). *AI and sustainability at core of Open DC's next-gen data centre in Delapan SBEZ. Open DC.* https://www.opendc.my/ai-and-sustainability-at-core-of-open-dcs-next-gen-data-centre-in-delapan-sbez/

Peet, R., Robbins, P., & Watts, M. (Eds.). (2011). *Global political ecology*. Routledge

Pengurusan Aset Air Berhad. (2025). PAAB–SADA LRA Sungai Karangan project update. *PAAB.* https://www.linkedin.com/posts/pengurusan-aset-air-berhad-paab_paab-sada-lra-activity7351153748037001216-d_eH/

RimbaWatch. (2025, August 8). *Climate impacts of Malaysia's data centre expansion* (Analysis). RimbaWatch.

Suruhanjaya Perkhidmatan Air Negara. (2021). Water and Sewerage Fact Book 2021. *SPAN.* https://www.span.gov.my/document/upload/wDC4eELu3ufaP3RCXb026ShRqJs4zjHO.pdf

Suruhanjaya Perkhidmatan Air Negara. (2022). Water and Sewerage Fact Book 2022. *SPAN.* https://www.span.gov.my/document/upload/Hb8Sv6cKhvUON85B2Lgde8ti7qAd6Pk0.pdf

Suruhanjaya Perkhidmatan Air Negara. (2024). Water and Sewerage Fact Book 2024. *SPAN*. https://www.span.gov.my/document/upload/KASixe2qy0sqnqNLWvBFVxgffGbQBDyR.pdf

Swyngedouw, E. (2004). *Social power and the urbanization of water: Flows of power*. Oxford University Press.

Syarikat Air Darul Aman. (2025). Komitmen SADA: Cadangan Projek Bekalan Air. *SADA.* https://www.sada.com.my/komitmen

Taheri, S. (2021). *A multi-period water network planning for industrial parks: Impact of design periods on park's flexibility*. arXiv.

The Edge Malaysia. (2024). The State of the Nation: Water supply imbalance among states an obstacle to development. *The Edge Malaysia.* https://theedgemalaysia.com/node/718285

Robbins, P. (2012). *Political ecology: A critical introduction* (2nd ed.). Wiley-Blackwell.