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Technical Points of Water-Draw and Discharge Impact Analysis in Guidelines for Water Resource Assessment of Coastal Nuclear Power Plants

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Abstract: Nowadays, cleaner production is getting more and more attention, and nuclear power has been widely used due to its low energy consumption and lower pollution. Most nuclear power plants in China, including those under construction and constructed ones, are coastal. For a nuclear power plant, however, its large amount of water consumption and high guarantee rate of water quality will have impacts on the regional water-resource allocation in the site area. During the water-discharge process, low-level radioactive wastewater and warm water will be discharged, while medium or even highly radioactive wastewater will be generated in an accident, both of which will affect the environment of the receiving water. In 2016, the Chinese government began to work on the *Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*. The compilation work, led mainly by the Ministry of Water Resources, focused on analyzing key technical points of the impacts of water intake, wastewater discharge, and their reduction measures, as well as water-protection measures. In this study, the technical requirements for impact analysis of water-draw, wastewater discharge, and their remedial measures for coastal nuclear power construction projects in different periods were put forward. Lastly, the measures for water conservation, protection, and management were given. All the technical requirements and measures gave a research basis and technical support for the formulation of the guidelines.

Keywords: coastal nuclear plant projects; water-resource assessment; water-draw and discharge impacts; guideline; key points

Citation: Fan, G.; Hou, B.; Dong, X.; Ding, X. Technical Points of Water-Draw and Discharge Impact Analysis in Guidelines for Water Resource Assessment of Coastal Nuclear Power Plants. *Sustainability* **2021**, *13*, 6308. https://doi.org/10.3390/su13116308

Academic Editor: Alessio Siciliano

Received: 2 March 2021
Accepted: 24 April 2021
Published: 2 June 2021

1. Introduction

To cope with climate change and reduce CO_2 emission, many countries have begun to explore cleaner production and use clean energy to achieve these goals, and nuclear power is a kind of clear, economical, and efficient energy [1–4]. The large population of China makes the country's government pay more attention to clean energy utilization and clean production [5,6]. As of 2018, China had 12 nuclear power plants, all of which were coastal nuclear power plants (Table 1).

The locations of these plants are shown in Figure 1.

Some abbreviations used in this study are shown below.

A coastal nuclear power plant consumes a huge amount of freshwater during its operation period, which will affect the allocation of local water resources, as China is a country in which water resources are unevenly distributed in space and time [7–9].

Table 1. Details of the coastal nuclear power plants in China (as of April 2018).

No.	Coastal Nuclear Power Plant	Installed Capacity (GW)	Generated Power ($\times 10^6$ Wh/a)	Water Usage Volume ($\times 10^6$ m^3/a)
1	Yangjiang	5.40	48	4.42
2	Hongyanhe	4.47	45	3.40
3	Qinshan	4.40	35	4.34
4	Ningde	4.36	30	2.80
5	Lingao	4.15	29	4.04
6	Fuqing	2.18	16	4.25
7	Fangjiashan	2.16	15	3.01
8	Fangchenggang	2.16	15	1.56
9	Tianwan	2.12	14	2.25
10	Dayawan	1.97	15	2.25
11	Changjiang	1.30	9	1.10
12	Haiyang	8.7	17.5	5.01

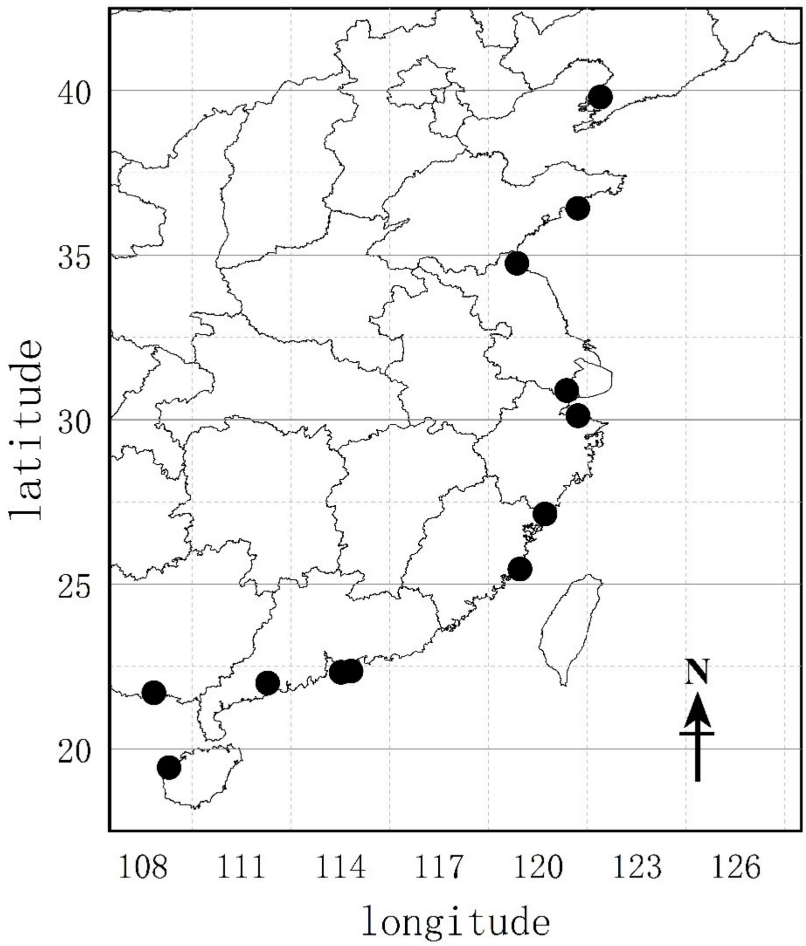

Figure 1. Locations of the coastal nuclear power plants in China (as of April 2018).

Compared to thermal power plants with the same productivity, coastal nuclear power plants (CNPP), using indirect cooling water systems, draw 20%–80% more water [10]. Moreover, most people use surface water as a drinking-water source in China, and its water environment carrying capacity is limited [11], so the requirements of a coastal nuclear power plant may change a region's original water-use plans. In addition, a CNPP will discharge low-level radioactive wastewater during its normal operation period, while medium and even high-level radioactive wastewater may be discharged under an accident condition, both of which will affect the water quality of receiving waterbodies and the ecological balance [12,13]. Furthermore, proposing targeted measures of water-draw and drainage is of great significance to regional water-resource utilization, water environmental protection, and sustainable development of the nuclear power industry [14,15]. In China, water-resource assessment of a construction project is a legal process that should be carried out in a feasibility study period to assure that water intake of the project is feasible and the impacts of drainage on the environment are acceptable. In addition, water-resource assessment of construction projects, including coastal nuclear power plants, relied on the *Guidelines for Water Resources Assessment of Construction Projects* (SL 322-2013) before the "*Guidelines for Water-Draw and Utilization Assessment on Coastal Nuclear Power Plants*" was proposed [14]. Accordingly, the guidelines for the assessment of water resources of coastal nuclear power plant construction projects began to be formulated by the Ministry of Water Resources in 2016, and the North China Electric Power University was invited to become one of the participating units of these guidelines.

Until now, some conclusions regarding water intake for nuclear power plants have been issued overseas. Firstly, in 2017, Mingquan and other partners concluded that water consumption by coal-fired power plants decreases, while that by natural gas and nuclear power plants increases, which may give some important insights for Chinese policymaking for water conservation [16]. Additionally, a series of useful papers related to such plants has been published. For example, in 2019, Muthulakshmi and others did some experiments near the Madras Nuclear Power Station and demonstrated that warm water discharged from the station had a negligible effect on the zooplankton population in an engineered canal near the Plutonium Recycle Project; they suggested that further investigation was required to estimate the impact zone at either side during different seasons [17]. In 2018, Turkish researchers measured the natural radioactive and heavy-metal concentrations and assessed the potential health risks in drinking water in Mersin, where a nuclear power plant would be established nearby in the near future [18]. Thirdly, not only the Chinese government but also local authorities have introduced some fundamental and specialized guidelines for nuclear power plant projection. For the whole country, National Nuclear Safety Administration has issued legal nuclear safety documents and provisions, including *Safety Operation of Nuclear Power Plants* [19], *Safety Regulations for Radioactive Waste Management in Nuclear Power Plants* [20], and so on. Apart from that, local authorities in some provinces (Guangdong, Tianjin, Zhejiang, etc.) have implemented a variety of regulations that are suitable for the local situation.

The objective of this research is to analyze the key technical points of water-draw, drainage and present suggestions of water protection measures, all of which provide technical support for the compilation of "*the Guidelines for water-draw and utilization assessment on coastal nuclear power plants*." Due to the large volume of water-draw and the high standard of water supply, the water intake technical points of coastal nuclear power plant projects were evaluated, including three specific parts. The analysis of water discharge technical points and recommendations of water protection measures also were divided into three parts and were proposed because the impacts of radioactive wastes dissolved in drainage cannot be ignored. Finally, with two conditions of nuclear power plants' operation, completed technical support for nuclear power plants were shown in conclusions. The purpose of this research is to provide technical support for the formulation of "*the Guidelines for water-draw and utilization assessment on coastal nuclear power plants*" in China. The Technology Roadmap of this research is shown in Figure 2, with which the WRA can be done easily, and technical points can be obtained clearly.

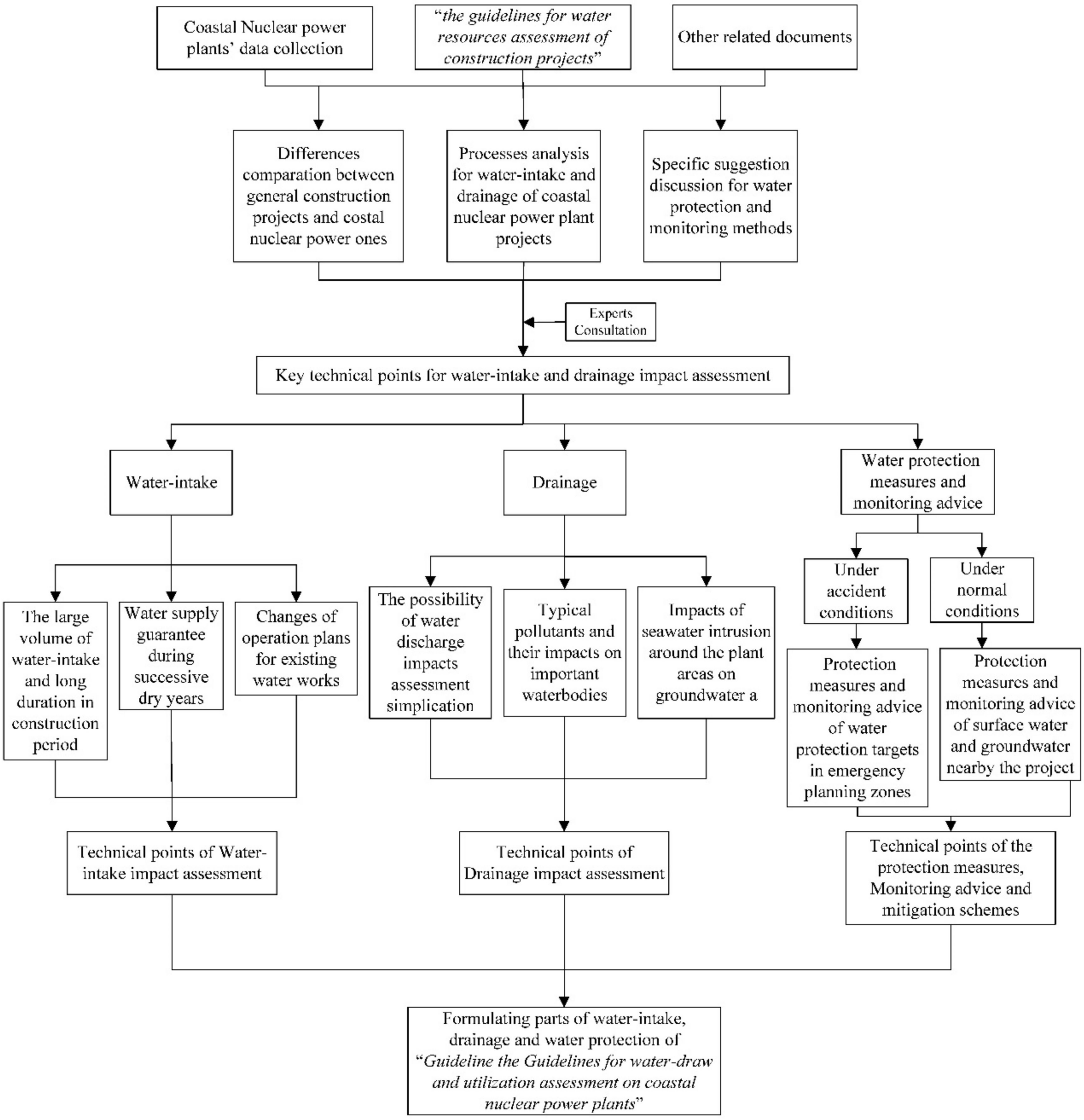

Figure 2. Technology roadmap of the nuclear power plant project's key points of water-draw and discharge impact analysis for water resources assessment.

For the whole roadmap, a variety of papers and statistics have been collected and analyzed to make relevant data more comprehensive and accurate. Moreover, a series of comparisons have been made to distinguish the traits of coastal nuclear power plants. Further, lots of expert consultations could integrate the specialized opinions and make the whole research more authoritative and authentic. When it comes to the water protection and monitoring suggestions, it was divided into two parts: normal and accident conditions, so that they can be considered in a comprehensive and differentiated manner. Finally, based on the traits of water-intake, water discharge, water protection measures, the technical points of water-intake impact assessment, drainage impact assessment, and the protection measures, monitoring advice and mitigation schemes have been proposed, thus providing technical support for the formulation of the relevant chapters of the guidelines. Through feasible procedures and reliable processes, scientific conclusions can be drawn.

Furthermore, it may also provide some directions for formulating water-related guidelines for coastal nuclear power plant projects in other countries.

2. Technical Points of Water-Draw Impact Assessment for "*the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*"

The water-draw impact assessment of a construction project is based on the "*the guidelines for water resources assessment of construction projects*" in China. Therefore, for a coastal nuclear power plant project (CNPPP), its water-draw impact assessment mainly bases on it. Considering that CNPPPs have certain characteristics, such as a long construction period and high-water quality requirement, there are several extra aspects that need to be considered.

2.1. Water-Draw Impact Assessment during Construction Period

Generally, a construction project includes the construction period and operation period at least. Nevertheless, the water-draw amount during the former is relatively less than that during the latter. Therefore, *"the guidelines for water resources assessment of construction projects"* is mainly focused on operation period water-draw impact assessment of a construction project. However, the construction period of a CNPPP is much longer than that of other construction projects. Take a second-generation two-gigawatt nuclear power plant of China as an example; its construction period almost takes 46 months, which indirectly increased the amount of water-draw and the inevitable impacts of long-term water-draw.

Further, the water-draw amount is also increased because of some special processes during that period such as equipment flushing, concrete pouring, sand washing, brick plastering, etc. In addition to the above factors, the design and construction scheme adopted, meteorological conditions, and the water usage of the auxiliary buildings during the construction period also increases the water-draw amount. For a CNPPP, the maximum water-draw amount during the construction period, about 300–360 days a year, is 4000–6000 m^3/d, so the annual water-draw volume of it is 1.2×10^6–1.3×10^6 m^3 according to the related statistics of CNPPs in China (Ding et al., 2013). In order to compare water intake and usage in combination with capacity directly, data about 12 coastal nuclear power plants are shown in Figure 2. Additionally, the data of installed capacity, generated power and water usage volume for the 12 CNPPs are shown in Figure 3.

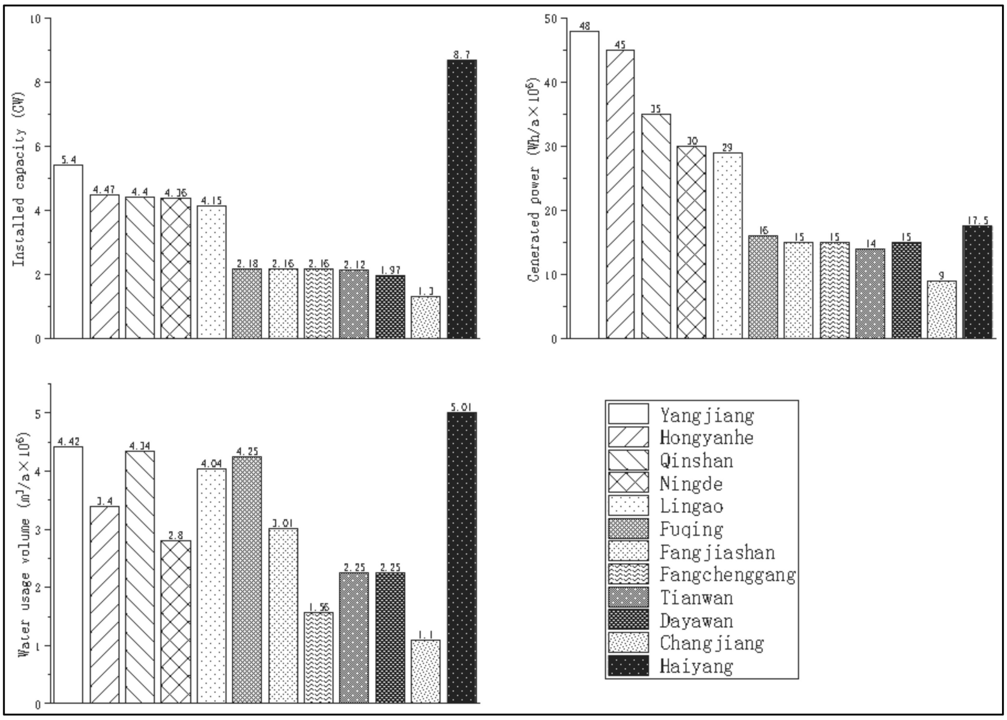

Figure 3. Data of 12 Coastal Nuclear Power Plants in China.

Due to technological innovation, the interannual water-draw amount of CNPPs also varies greatly. Take Qinshan phase III nuclear power as an example; the water-draw amount was 6000 m^3/d in 2000a while 3000 m^3/d in 1999a and before [21].

Hence, carrying out the water-draw impact assessment is also necessary during the construction period since its huge water-draw demands cannot be ignored.

2.2. Water-Draw Impact Assessment during Successive Dry Years

It is known that the site of a CNPPP is located in a coastal area, which often has a dense population, huge water demand, and scarce freshwater resources in China. Once the site of a CNPPP is at the successive dry years stage, the volume of water needed is hard to meet. Moreover, a CNPPP not only has a large amount of water-draw but also requires high water quality; thus, alternative water sources should be ensured for the successive dry years.

The water-draw amount requirement of a CNPPP can be guaranteed by multi-reservoir combined supply, construction of special reservoirs, modification of the original reservoir functions, and other methods during successive dry years. However, such methods will affect the regional water resource allocation and other water users. Therefore, aspects such as the water-draw impact on water resource allocation, the ecological environment within the assessment scope, and other water users should be considered when the long-series method is adopted to calculate the water-draw amount for successive dry years. The influence of such a period should be fully considered when typical years data is used to analyze the water-draw impact on determining boundary conditions.

Therefore, it is proposed that the water-draw impact on water resources allocation, ecological environment in affected scope, and other water users should be analyzed during successive dry years.

2.3. Impact Assessment of Water-Draw from Existing Water Works

Due to the huge water-draw and high-water quality requirements of a CNPPP, regional freshwater supply may not meet its demands. Therefore, several measures such as building special reservoirs, multi-reservoir combined supply, changing the original functions of reservoirs, or transferring water can be used to guarantee the regular water-draw demand. The methods of building a special reservoir or removing water from existing water works are generally adapted to solve this issue when water-draw requirements cannot be met by local water resources, and the latter is more economical than the former. However, the functions and scheduling schemes of existing water projects have been confirmed, and the diversion of water for a CNPPP might change the established functions or scheduling schemes of the existing water work because *"the guidelines for water resources assessment of construction projects"* is for general construction projects that scarcely involve changing the established functions or scheduling of existing water works. Nevertheless, considering its large amount of water-draw and high-water quality requirement, a CNPPP may cause such changes. These changes may reduce the water-draw amounts of related units or individuals and affect their regular production or living when the future water supply plans of existing units are adjusted and altered. Beyond that, the local ecological environment might also be affected.

Therefore, it is suggested that the impact on aspects such as water usage plans and the ecological environment should be analyzed when a CNPPP draws water from existing water work for their established functions or scheduling plans may be changed.

As mentioned above, the key points of water-draw impact assessment for CNPPPs are shown in Table 2.

Table 2. Key points of the Water-draw Impact Assessment for CNPPPs.

Key Points in Water-Draw Impact Assessment for "Guideline *the Guidelines for Water-Draw and Utilization Assessment on Coastal Nuclear Power Plants*"				
Assessment Factor	**General Guideline**	**New Guideline**	**Characteristics of CNPPPs**	**Main Points**
The period of Water-draw impact Assessment	Operation period	Operation and Construction period	CNPPPs have a longer construction period and larger water-draw amount than other normal projects	Not only the operation period but also the construction period should be analyzed, respectively
Impact of successive dry years	None	Selective analysis	Successive dry years may have an impact on region water amount and that on water-draw of a CNPPP	The impact of water-draw during successive dry years needs to be analyzed
Impact of change the established functions or scheduling schemes of existing water works	None	Selective analysis	Water drawn from the existing water works may change its established function or scheduling scheme and have adverse effects.	The impact of the functions or operation plans change of existing water works needs to be analyzed

3. Technical Points of Wastewater Discharge Impact Assessment for "*the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*"

The same as water-draw impacts assessment, water-discharge impact assessment of CNPPPs should firstly follow the "*the guidelines for water resources assessment of construction projects.*" Considering the characteristics of water discharge in CNPPPs, particular attention should be paid to the following aspects when assessing water-discharge impact.

3.1. Impact Assessment of Water-Discharge on the Marine Environment

CNPPPs are all located in coastal areas, which all wastewaters might be discharged into the nearby sea. Therefore, the water discharge impact of CNPPPs is mainly on the marine environment in this case. However, WRA mainly concerns the impacts on freshwater resources, and much more attention is paid to the water discharge impact on freshwater than seawater during the WRA period. Moreover, its influence on the freshwater system is relatively small, and that has been analyzed and assessed by Environmental Impact Assessment (EIA). Additionally, the drainage impacts of CNPPPs on freshwater bodies are the main objects of this paper instead of that on seawater.

Therefore, the process of water discharge impact assessment can be simplified when all the water is discharged into the sea.

3.2. Impact Assessment of Typical Pollutants Discharge

3.2.1. Liquid Radioactive Effluent

The estuary areas have a great significance for not only human society but also the ecosystem. Plus, rich nutrients carried by rivers and sedimented there make it become fertile fishing grounds.

During the operation period of a CNPP, its water discharge may impact the estuary areas where fresh and seawater will interact, and in these areas, the water-intake of human activities is frequent. Tidal limit water areas are water zones from the upper boundary of the tide level to the estuary. The water functional areas in china are kinds of areas with certain functions, and conservation areas are those that need to be protected.

Therefore, water discharge impacts other water users and several sensitive water areas such as estuaries, tidal limit water areas, water function areas, and conservation areas need to be emphasized when the drainage of a CNPP affects such areas. Apart from that, effective methods and measures should be taken to mitigate and eliminate the adverse influence of pollutants discharged into estuary areas. Specifically, appropriate remedial measures can limit the scope of the impact and prevent it from further deepening when the impact cannot be mitigated and eliminated. Further, compensation schemes need to be implemented to restore the ecological environment, and the losses of other water users also should be made up by suitable economic means. For a CNPP, liquid radioactive effluent is an important part of the drainage, which has a radioactive impact on the surrounding environment [22]. During the operation period of a CNPP, liquid radioactive effluent is discharged into receiving water, and radioactive substances also pose a threat to water quality and the water ecological environment.

When estuarine areas are affected by a CNPP's water discharge, impacts of radioactive liquid effluents on water users and sensitive water areas, such as estuarine and tidal limit water, water function areas, and protected areas, should be assessed. Further, it is necessary to evaluate some key aspects of radioactive liquid effluents such as nuclides and their half-life period, concentrations, annual productions, and discharge plans, which can protect sensitive water areas better and forward. Remedial measures and compensation schemes also need to be set in advance for kinds of water areas where are potentially affected by liquid radioactive effluents or have been inevitably contaminated or affected.

3.2.2. Warm Drainage

Generally, the generated heat by a CNPP is carried away from the system through the third circuit during its operation phase. Whereafter the cooling water will be discharged into the receiving water and cause thermal pollution. Nevertheless, warm drainage will lead to water temperature rise, water quality and water ecology environment damages, and thermal pollution [23,24], especially in estuarine and tidal limit water areas. Specifically, the increasing temperature of water accelerates the biodegradation of organic matter and sediment as well as the cycling of nutrient elements; hence, the excessive growth and reproduction of algae will lead to eutrophication and red tide. Furthermore, the increased temperature of the water will also have some impacts on seaweed beds and fish spawning [25,26]. Plus, the biodegradation of organic matter increases the consumption of dissolved oxygen in water, affecting the distribution, growth and reproduction of aquatic organisms, and damaging the interests of fisheries near estuaries and other water users. Therefore, the impact assessment of CNPPs warm drainage on estuarine areas is a significant part of the environmental impact assessment of CNPPs.

When water discharge affects the estuarine area, the impacts of warm drainage on it and other areas such as tidal waters, water function areas, protected areas as well as other water users need to be analyzed according to the EIA and other Related thematic research. Similarly, for potential areas affected by warm drainage, remedial measures need to be assessed in advance. For those that have been contaminated or affected and cannot be mitigated or eliminated at present, compensation schemes should be evaluated and proposed.

3.2.3. Concentrated Brine from Desalination Facilities

As mentioned above, the site of CNPPPs is often located in such areas with dense populations, a large demand for production and domestic water as well as scarce freshwater resources [27]. If regional water resources cannot meet the needs of the construction and operation of a CNPPP, a certain scale of desalination facilities will be installed. In fact, the discharge of concentrated brine is an issue that should not be overlooked when desalinated facilities are operated. It will certainly impact the ecological environment of the estuary and water users who draw water for irrigation, drinking, or farming when chemical agents and corrosiveness products from the desalination process are discharged directly into the estuary or nearby sea areas. Therefore, remedial measures and compensation schemes are needed for the areas that will probably be affected by the concentrated brine as well as for those that have been contaminated or affected but cannot be mitigated or eliminated.

By and large, it is proposed that when the estuarine areas are affected by water discharge during the operation period, the influence of liquid radioactive effluents, warm drainage, and concentrated brine on estuary and tidal waters, water function areas, protection areas, and other water users should be mainly analyzed according to the research results of the sea areas use assessment and the marine environment impact assessment.

3.3. Impact Assessment of Seawater Intrusion on Groundwater around Sites

As mentioned above, the main object of WRA in China is freshwater. Groundwater, an important part of the freshwater resources on earth, should be protected carefully, considering that it plays an important role in the stability of the geological environment and the balance of the ecosystem [28,29]. The water level, however, is dropping sharply, and the hydrodynamic balance between seawater and freshwater is broken due to the overexploitation of groundwater in coastal areas, which leads to the movement of the brackish water boundary. As a consequence, the seawater may intrude at the site areas of CNPPPs. More precisely, seawater with liquid radioactive effluent generated by CNPPPs may intrude groundwater around the plant areas, enter the groundwater system, and cause radioactive pollution. Furthermore, seawater intrusion can have an impact on the function of groundwater and a radiative impact on drinking water sources. In addition, water users who draw groundwater from the sites for drinking, irrigation, and other purposes may also be affected.

Therefore, according to the regional groundwater function zoning and drinking water requirements, impacts of liquid radioactive effluent on groundwater in seawater intrusion zones should be assessed based on an environmental impact assessment and other related research when groundwater around the CNPPP areas involve seawater intrusion. In addition, the degree and change of groundwater pollution can be known by monitoring the groundwater around the plant. Specifically, the changes of radionuclides and their concentration can be mastered over time through long-term monitoring of groundwater around the plant, and the abrupt changes of groundwater radiation environment can be detected in time. Through the monitoring of multiple spots of the areas, the migration of radioactive materials can be revealed, and the spread of radioactive contamination can be prevented or slowed down. Therefore, it is necessary to put forward monitoring requirements for groundwater around CNPPPs.

Remedial measures can prevent further intensification of the effect in the seawater intrusion zone. Additionally, compensation schemes could compensate for economic and natural environmental losses in the affected areas. Therefore, remedial measures and compensation schemes should be clearly put forwarded when liquid radioactive effluent has a significant impact on the groundwater of seawater invasion areas.

Therefore, the analysis of liquid radioactive effluent impacts on the groundwater of seawater intrusion zones needs to be completed, and the monitoring requirements for groundwater around the plant areas will also be determined by guidelines established in advance. Remedial measures and compensation schemes should be clearly proposed when liquid radioactive effluent of CNPPPs has a significant impact on the groundwater of the seawater invasion areas. In conclusion, the key points of water-discharge impact assessment for CNPPPs are shown in Table 3.

Table 3. Key points of the Water-discharge Impact Assessment for CNPPPs.

Key Points of Water-Discharge Impact Assessment for "*the Guidelines for Water-Draw and Utilization Assessment on Coastal Nuclear Power Plants*"				
Assessment Factor	**General Guideline**	**New Guideline**	**Characteristics**	**Main Points**
Impact of total water discharged into sea	None of these assessment factors were previously considered in the General Guidelines. We suggest that each of these should have simplified analyses applied to them for water-draw and utilization assessment of CNPPP.		The impact of total water-discharge into the sea in a freshwater system is relatively small and has been analyzed by EIA.	The water-discharge impact assessment can be simplified when all the water is discharged into the sea environment.
Liquid radioactive effluent Warm drainage Concentrated brine from desalination facilities			Radioactive substances in liquid radioactive effluent and the concentrated brine from desalination processes have an impact on water quality and water ecology. The rising water temperature caused by warm drainage may do harm to the water quality and water ecological environment and produce thermal pollution.	The impact of liquid radioactive effluent, warm drainage, and concentrated brine on major zones such as estuaries, tidal waters, etc., should be evaluated.
Impact of seawater intrusion zones around CNPPPs			The radioactive pollutions from CNPPPs may enter the groundwater system by seawater intrusion and cause radioactive pollution.	The impact of liquid radioactive effluent and the monitoring requirements should be assessed and proposed.

4. Water Resources Protection Measures for "*the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*"

The water resources protection measures of CNPPPs are mainly divided into two aspects: water resources protection measures under normal working conditions and water resources protection measures under accident working conditions.

4.1. Water Resources Protection Measures under Normal Conditions

As mentioned above, low-level radioactive wastewater produced by CNPPs and discharged into the surface receiving water will cause several detrimental impacts. Therefore, it is inevitable to do radiation monitoring, which can detect the changes in radiation values within the assessment scope of surface water and groundwater. Hence, "*Regulation for environmental radiation protection of nuclear power plant*" (GB6249-2011) was issued by the Chinese government to stipulate the requirements of radiation environment monitoring of CNPPs in the early and normal operation period. Additionally, other aspects should be assessed and proposed, such as recommendations of the accuracy and validity of monitoring data, scientific application and implementation of monitoring methods. Therefore, it is concluded that suggestions on the monitoring and management of radiation environment for surface water and groundwater within the scope of assessment need to be put forward.

In addition, freshwater resources in coastal areas are relatively scarce, while the discharge water from the CNPP may discharge into such waterbodies, which may have impacts on it by radioactive effusions, warm drainage, as well as concentrated brine from desalination facilities. More precisely, seawater intrusion with liquid radioactive effluent may exist around the CNPP, which has a negative impact on groundwater quality in the seawater invasion zone. Furthermore, not only management opinions should be recommended, but also radiation monitoring programs should be formulated based on the practical situation during the assessment period when the assessment involves the above.

Because of the large amount of water-draw and the pollution substances generated by CNPPs, it is suggested that flexible water management measures and appropriate suggestions should be put forward during the assessment period. These measures and suggestions can avoid wasting and help to improve the efficiency of water usage, mitigate the adverse effects of liquid radioactive effusions, warm drainage, concentrated brine and seawater intrusion on groundwater. Therefore, it is proposed that a radiation monitoring program for freshwater within the scope of assessment should be developed, and feasible water resources management measures or suggestions are also indispensable under the following two conditions that water-discharge has adverse impact on freshwater bodies:

1. Water discharge during the operation period affecting estuary areas as well as liquid radioactive effluent discharge, warm drainage and concentrated brine discharged from seawater desalination facilities adversely affecting estuary, tidal limit water, functional areas, as well as other water users.
2. The site areas of the plant involving seawater intruded into groundwater, and the discharge of liquid radioactive effluent has an impact on the groundwater quality in the seawater-intruded areas.

4.2. Water Resources Protection Measures under Accident Conditions

In the planning period of a CNPPP, a series of emergency planning zones should be divided into two types: smoke plume emergency planning areas and ingestion emergency planning areas. Specifically, smoke plume emergency planning areas are the places where direct external irradiation is generated by the radioactive plume, while internal irradiation is produced by the inhalation of radionuclides from the radioactive plume. Ingestion emergency planning areas are the regions where the major irradiation is internal irradiation caused by the intake of contaminative food and water by radioactive materials. Additionally, there may probably have some significant water conservation targets in the smoke plume and ingestion emergency planning areas. The released radioactive stive will scatter in the smoke plume and ingestion emergency planning areas, and the radioactive material will also fell into both emergency planning areas when critical accidents occurred in a CNPP.

Therefore, significant water conservation targets in the smoke plume and ingestion emergency planning areas should be listed. More comprehensive and frequent monitoring should be proposed under accident conditions since the monitoring of atmospheric radiation is helpful for emergency response departments to determine the migration direction of radioactive stive. Further, radiation monitoring of water resources can help to understand the contaminative range and radioactive concentration of water in both emergency planning areas. Appropriate measures are conducive to mitigate the impacts of accidents and control radioactive pollutants in the atmosphere and water, such as locking down the reactors with concrete or keeping the radioactive water away from the water supply system, etc.

Therefore, it is proposed that significant water conservation targets in the nuclear power plant smoke plume emergency planning areas and the ingestion emergency planning areas should be listed, and recommendations for radiation monitoring as well as control in the event of an accident should also be presented.

Above all, the key points of water resources protection measures for CNPPPs are shown in Table 4.

Table 4. Key points of the water resources protection measures for CNPPPs.

Key Points Water Resources Protection Measures for "*the Guidelines for Water-Draw and Utilization Assessment on Coastal Nuclear Power Plants*"				
Assessment Factor	**General Guideline**	**New Guideline**	**Characteristics**	**Main Points**
Normal conditions water protection measures	No radiation monitoring was involved	Radiation monitoring management is added	Radioactive wastewater will be discharged into the surface receiving waterbody and groundwater	Suggestions on the monitoring and management of radiation environment for surface water and groundwater within the scope of assessment should be proposed
Accident conditions water protection measures	Put forward the emergency treatment and control plan for water pollution	Monitoring advice of significant water conservation targets in emergency planning areas are added	Significant water conservation targets may in smoke plume and ingestion emergency planning areas	Suggestions for the monitoring of significant water conservation targets in smoke plume and ingestion emergency planning areas should be put forward

5. Conclusions

To cope with climate change and reduce CO_2 emission, clean production has attracted much more attention from countries, including China, and nuclear power, as a kind of clean energy, is used by many nations. 12 coastal nuclear power plants have been constructed in China for social and sustainable development.

The life circle of a coastal nuclear power plant is closely related to water resources due to its huge water consumption as well as the discharge of low-radioactive water during regular operation periods and even medium or high-radioactive water in case of accidents. In China, water resources assessment of a construction project is a legal process that should be carried out in a feasible study period to assure that water intake of the project is feasible and the impacts of drainage on the environment are acceptable. Therefore, carrying out that before the construction of a coastal nuclear power plant is significant for the water protection and the sustainability of the nuclear industry in China. Considering the water-related particularities of coastal nuclear power plant projects, the Chinese government has issued "*the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*". Accordingly, key technical points of water resources assessment for coastal nuclear power plant projects, including water intake, drainage, and water resources protection, were proposed firstly. The relevant conclusions are as follows.

Compared with the water intake impacts of general construction projects, three extra aspects need to be considered for those of coastal nuclear power plant projects. Firstly, the water intake impact analysis should be evaluated not only during the operation period but also during the construction period, as the water intake of a nuclear power plant is relatively large in the construction period. Secondly, continuous-dry-year may lead the regional water supply capacity to decline; thus, the impact of water intake during such period on affected areas, including that on water allocation, water users, and the eco-environment, should be analyzed. Thirdly, the huge water intake of a coastal nuclear power plant may lead to adjustments in the existing water works functions or operation plans, and the impacts of these adjustments also need to be assessed.

Apart from the general provisions of the big guidelines for the water discharge from construction projects, three extra aspects are suggested to consider:

1. The impacts caused by pollutants (liquid radioactive effluent, warm drainage, etc.) on estuaries, tidal limit water areas, water functional and protective areas as well as relevant water users,
2. The impacts caused by intruded seawater with liquid radioactive effluent on groundwater around plant areas,

3. The monitoring requirements of groundwater around plant areas.

In terms of water resources protection measures, the following three supplements were put forward for the "*the Guidelines for water-draw and utilization assessment on coastal nuclear power plants*" guidelines. First of all, recommendations for water resources protection targets radioactivity monitoring and control should be put forward since they may exist in smoke plume and ingestion emergency planning areas. In addition, suggestions for the radioactivity monitoring and management of freshwater and groundwater within the scope of assessment need to be valued due to the particularity of groundwater and the scarcity of freshwater resources. Last but not least, proper water resources management recommendations should be proposed for drainage from coast nuclear power plants that may harm freshwater.

Author Contributions: Methodology, X.D. (Xiaowen Ding); validation, X.D. (Xiaowen Ding), G.F., and B.H.; formal analysis, G.F. and X.D. (Xiaowen Ding); investigation, G.F. and X.D. (Xinsheng Dong); resources, X.D. (Xinsheng Dong) and B.H.; data curation, X.D. (Xinsheng Dong) and G.F.; writing—original draft preparation, G.F.; writing—review and editing, G.F. and X.D. (Xiaowen Ding); supervision, X.D. (Xiaowen Ding); project administration, X.D. (Xinsheng Dong); All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Key R&D Program of China CERC-WET Project (2018YFE0196000).

Institutional Review Board Statement: This study did not involve humans or animals.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors gratefully acknowledge the financial support of the program and agencies.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

CNPP	coastal nuclear power plant
CNPPP	coastal nuclear power plant project
NPPP	nuclear power plant project
MWR	Ministry of Water Resources
EIA	environmental impact assessment
WRA	water resources assessment
GFRTP	glass-fiber-reinforced thermosetting polymer plastic

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